Texas Produced Water Consortium

Water Market Trends in the Permian Basin

August 8, 2024

WestWater Research LLC

Table of Contents

1. Executive Summary
2. Project Purpose & Approach
3. Overview of the Permian Basin
4. Fresh Water Assets Characteristics
5. Existing Water Market Characteristics
6. Water Valuation Approaches
7. Agricultural Water Valuation
8. Municipal Water Valuation
9. Valuation Results Summary

Executive Summary

Executive Summary: Purpose

The Texas Produced Water Consortium (TPWC) was created by the Texas Legislature in 2021 to bring together informational resources to study the economics of and technology related to, and the environmental and public health considerations for, beneficial uses of fluid oil and gas waste, or produced water.

To evaluate the potential beneficial use of produced water outside of the oil & gas industry, TPWC contracted with WestWater Research, LLC (WestWater) to develop a water market overview of the Permian Basin including an economic analysis of market value of freshwater for both present day and forecasted to 2050.

WestWater is an economic consulting company specializing in water markets and water valuation with extensive experience working across the western U.S., including Texas, on projects similar in scope to the requested project.

Executive Summary: Water use Overview

FRESH WATER ASSETS

Groundwater

- Groundwater in Texas is managed by rule of capture and further managed at a local level by Groundwater Conservation Districts (GCD). Groundwater use from areas without a GCD or exempt uses of groundwater have few barriers withdrawal and use. Nonexempt uses within a GCD may be more difficult, however permits continue to be authorized throughout the Permian Basin.
- Considering Modeled Available Groundwater (MAG), a metric which combines policy and science, and Total Recoverable Storage, a physical estimate of total groundwater storage, there remains groundwater development potential in most counties in the Permian Basin. However, development potential may be lower in those counties that have higher population and/or irrigation water use.

Surface Water

- Surface water diversion permits are issued by the Texas Commission on Environmental Quality (TCEQ) and have limited reliability due to high variability in the Upper Colorado River. Surface water supply is projected to decline over time and has low water supply development potential

EXISTING AND PROJECTED WATER USE

Existing Water use

- The Permian Basin covers a 24-county region in west Texas where land use primarily consists of irrigation, oil and gas production, and a few urban centers.
- Water use trends closely follow land use. Average agricultural water use comprises 75% of total use in the Permian Basin with the remaining water use split between the municipal and industrial sectors.
- Municipal and Industrial use has grown over time, while agricultural use has remained generally constant. However, use and growth in each sector is concentrated in specific counties, with most other counties seeing steady or even decreased water use.
- Municipal use is supplied by both groundwater and surface water through by multiple suppliers including the Colorado River Municipal Water District. While industrial and agricultural use is primarily supplied by groundwater. Mining in the region also has a significant amount of reuse.

Projected Water Use

- On an aggregate level, water supply shortages are projected in every sector. Potentially feasible water supply strategies are projected to make up for the shortage in the municipal sector. However, potentially feasible strategies are not projected to be sufficient to prevent a shortage in the agricultural sector. Like historical water use in the agricultural sector, projected shortages are concentrated in specific counties, with most counties of the Permian Basin not expected to face a shortage.

Executive Summary: Methods

Following WestWater's evaluation of available data and end use sectors, five approaches were considered to value current and future freshwater in the Permian Basin for the agricultural and municipal sectors.

CURRENT VALUATION METHODS

Agricultural

- *Pumping Cost:* Estimates the current cost producers are paying to pump water with existing crops, irrigation systems, and wells. Current pumping costs represents the *price floor* for ag. water value.
- *Crop Budgets*: Income approach to estimate irrigation water's contribution to net revenue from agricultural production. Models the differential between irrigated and dryland farms to estimate the amount that producers are willing to pay (WTP) for irrigation water and still remain profitable – the *price ceiling* for ag. water value.

Municipal

- *Wholesale Maximum WTP:* Estimates the retail level WTP (less transmission and distribution costs), assuming an affordability threshold of 2.5% of median income for household water expense and current per capita water consumption estimates.
- *Replacement Cost*: Uses a list of potential water management strategies in the Permian Basin and levelized cost of water method to estimate the least cost alternative to develop new water supplies.
- *Shortage Avoidance WTP:* Estimates the WTP to avoid a supply shortage under multiple scenarios by applying a price elasticity to a constant elasticity demand function (adjusted to municipalities in the Permian Basin) based on 2030 shortage estimates.

FORECASTED VALUATION METHODS

Agricultural

- Future water level declines through 2050 were estimated based on historical trends from observation well data for 1990-2023.
- *Future pumping costs* were estimated using forecasted future water level declines.
- *Future willingness to pay* is held constant (i.e., consistent with current value).

Municipal

- *Wholesale Maximum WTP:* Estimates the retail level WTP (less transmission and distribution costs), assuming an affordability threshold of 2.5% of median income for household water expense and household per capita water consumption estimates through 2050.
- *Replacement Cost*: Estimated replacement costs were categorized accounting to when they are expected to come online. Annualized cost of water management strategies expected online in the future are used as a forecasted replacement cost.
- *Shortage Avoidance WTP*: Estimates the WTP to avoid a shortage of supplies under multiple shortage scenarios by applying a price elasticity to a constant elasticity demand function (adjusted to municipalities in the Permian Basin) based on 2040-2050 shortage estimates.

Executive Summary: Current and Forecasted Market Values

Water Sector	Valuation Approach	Water Value Estimates: Average by Demand Class (2024 price level)					
		Large		Medium		Small	
		$/AF	$/bbl	$/AF	$/bbl	$/AF	$/bbl
Current Value (stated in 2024$)							
Agriculture	Pumping Costs *Willingness to Pay (WTP)*	$18 *$227*	$0.002 *$0.022*	$30 *$343*	$0.003 *$0.033*	$28 *$347*	$0.003 *$0.034*
Municipal	Replacement Costs *WTP – EPA Threshold* *WTP – Shortage Avoidance***	$1,350 *$3,325* *$3,341*	$0.131 *$0.321* *$0.323*	$831* *$1,912* *$3,341*	$0.80* *$0.185* *$0.323*	-- *$2,953* *$3,341*	-- *$0.285* *$0.323*
Future Value (forecasted to year 2050, stated in 2024$)							
Agriculture	Pumping Costs *Willingness to Pay*	$20 *$227*	$0.002 *$0.022*	$32 *$345*	$0.003 *$0.033*	$31 *$347*	$0.003 *$0.034*
Municipal	Replacement Costs*** *WTP – EPA Threshold* *WTP – Shortage Avoidance***	$2,508 *$3,485* *$4,344*	$0.242 *$0.337* *$0.420*	$2,508 *$1,975* *$4,344*	$0.242 *$0.191* *$0.420*	$2,508 *$3,091* *$4,344*	$0.242 *$0.299* *$0.420*

*Median value due to significant upward skewness of mean. All other values presented are mean.
**Average across Permian Basin – inadequate data to estimate by demand class. Current: 2030 basin-wide average shortage of 9.4%; Future: 2050 basin-wide average shortage of 13.7%.
***Average municipal project costs **up to 2040** across Permian Basin – inadequate data to estimate by demand class.

Project Purpose & Approach

Project Objectives & Analysis Approach

What are the water uses and needs in the Permian Basin?	
Demographic and Land Use Trends	Water Use Trends

What are the characteristics of freshwater assets of the Basin?
Transferability, Reliability, Water Development Potential, Water Quality, Existing Market Activity

What are the market dynamics in various sectors?			
Residential	Manufacturing/ Industrial	Agricultural	Power Gen. and Energy Production

What is the current value of freshwater assets in various sectors?			
Willingness to Pay	Observed Sales	Income	Current Cost

What is the forecasted values for freshwater assets?		
Change in Demand	Water Supply Development Costs	Trends

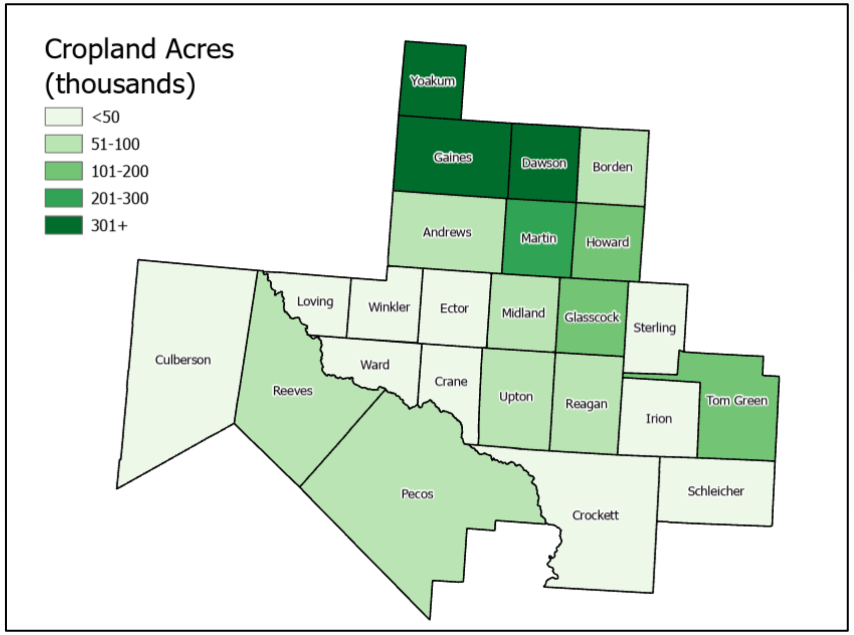
Key Data Sources

- USDA Census of Agriculture
- Texas Water Development Board (TWDB) Planning Data, State Water Plan, and Regional Water Planning Resources
- U.S. Census Bureau
- United States Geological Survey Datasets
- Texas A&M Extension Offices
- Texas Railroad Commission Datasets
- WestWater's *Waterlitix™* Transactions Data

Overview of the Permian Basin

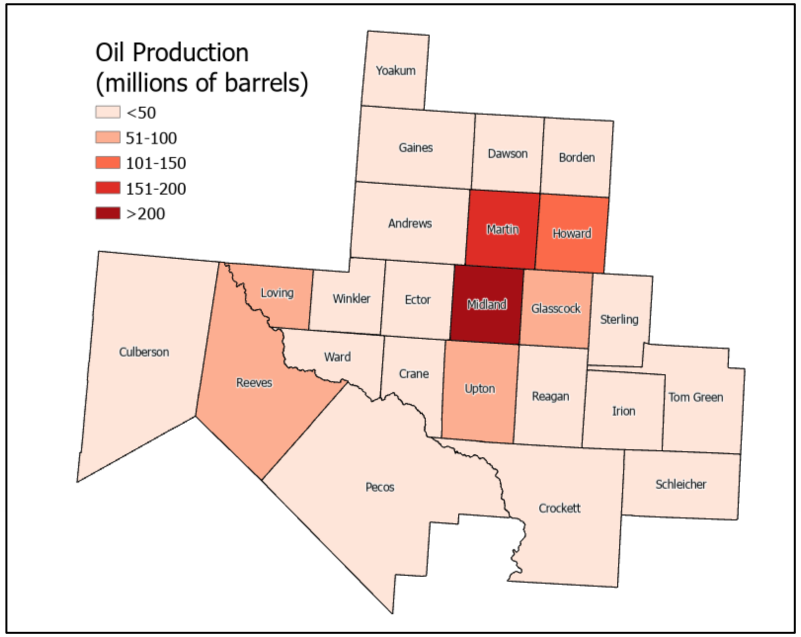
Demographic and Land Use Overview

AGRICULTURAL



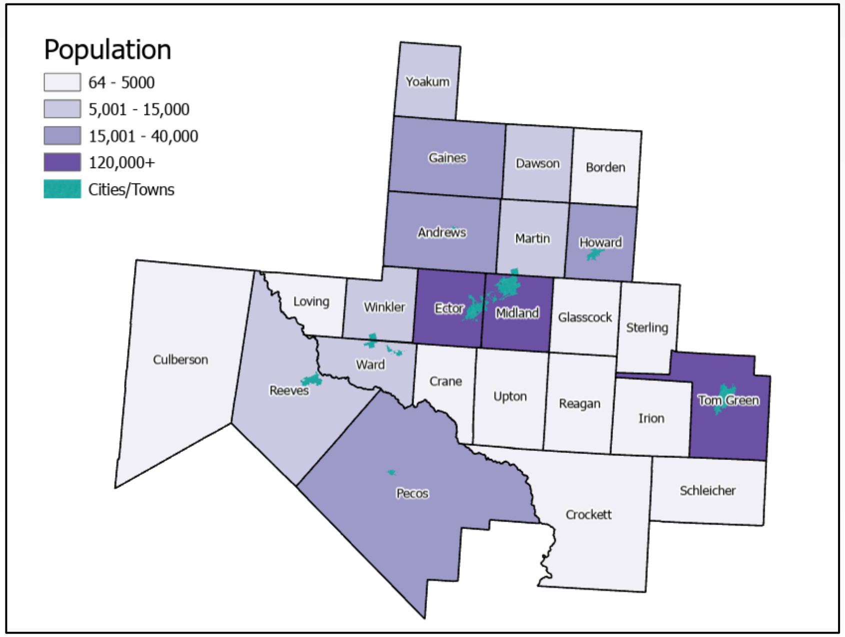
Source: United States National Agricultural Statistics Service (2017) Census of Agriculture, http://www.agcensus.usda.gov/

OIL & GAS PRODUCTION



Source: Railroad Commission (2022). Oil and Gas Production Data https://www.rrc.texas.gov/oil-and-gas/research-and-statistics/production-data/

MUNICIPAL

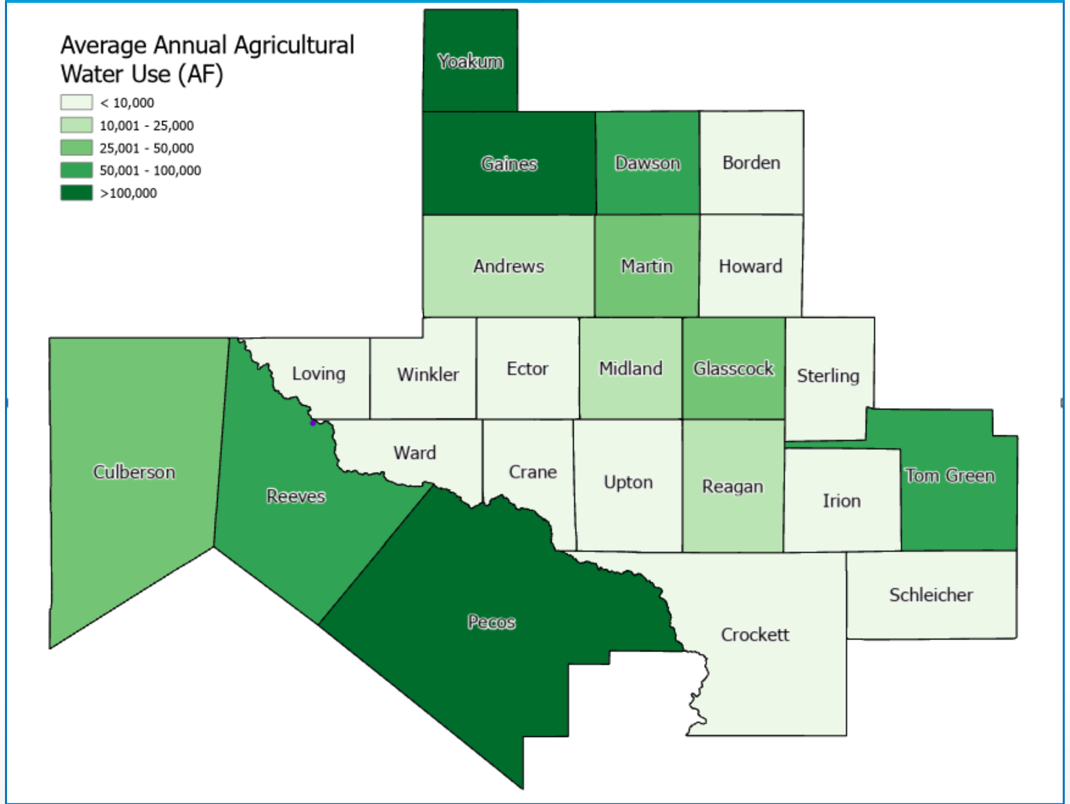


Source: United States Census Bureau (2020) 2020 Census Results https://www.census.gov/programs-surveys/decennial-census/decade/2020

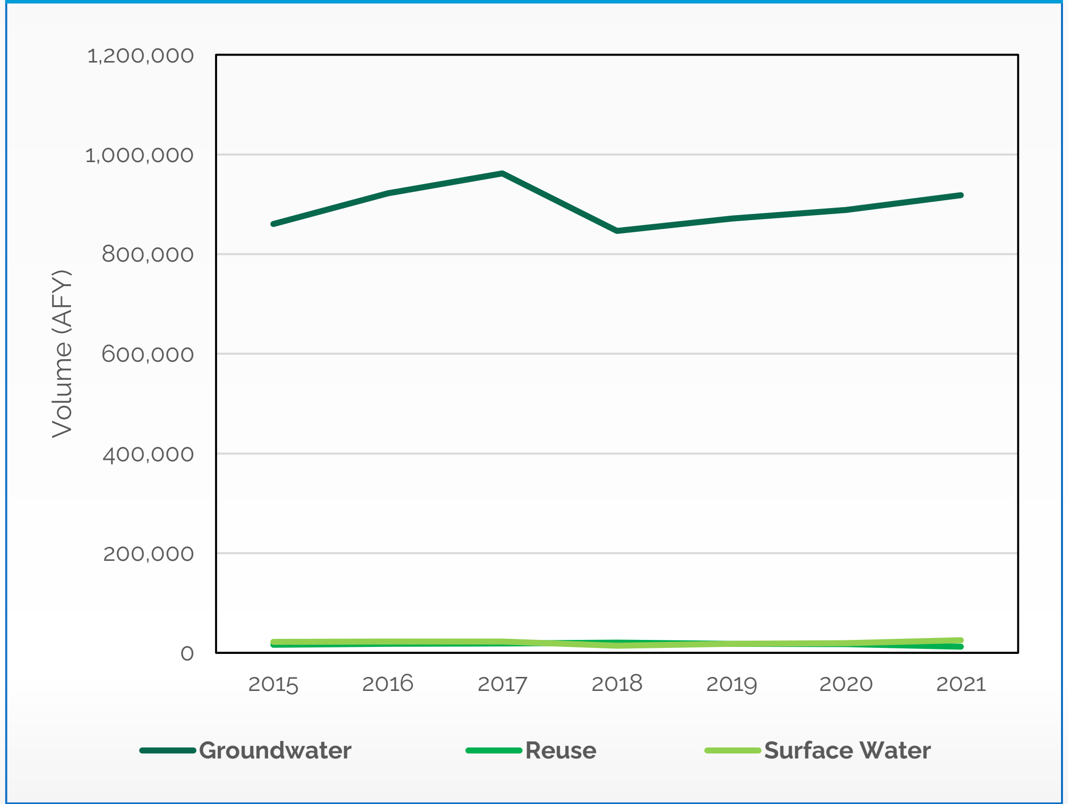
- The Permian Basin consists largely of rural land. Dominant land uses include grass/shrubland, irrigation, oil and gas production, and several urban centers.
- **Agricultural:** Cropland is concentrated in the northwest corner of the Permian Basin. Total cropland in the Permian Basin has remained steady in recent decades. An increase in cropland in Yoakum, Gaines, Martin have been balanced with slight decreases in most other counties in the Permian Basin.
- **Oil and Gas:** Concentrated in Martin and Midland Counties, comprising 40% of production. Total production has increased in the Permian Basin by over 250 MMbbl from 2018 to 2022.
- **Municipal:** Over 70% of the population and its associated land use is concentrated in Ector, Midland and Tom Green Counites, where the three largest cities in the Permian Basin are located. Since 2010, Midland and Ector have grown over 20%, while Tom Green has increased population by 10%. Andrew and Gaines counties have also increased by approximately 25% since 2010. A majority of the counties have less than 8,000 residents, and population in these more rural counties has experienced some decline. The remaining mid-sized counties have generally maintained their population levels.

Water Use Trends: Agricultural

Permian Basin Average Municipal Water Use by County, 2015-2021 (AF)[1]



Permian Basin Municipal Water Use by Type, 2015-2021 (AF)

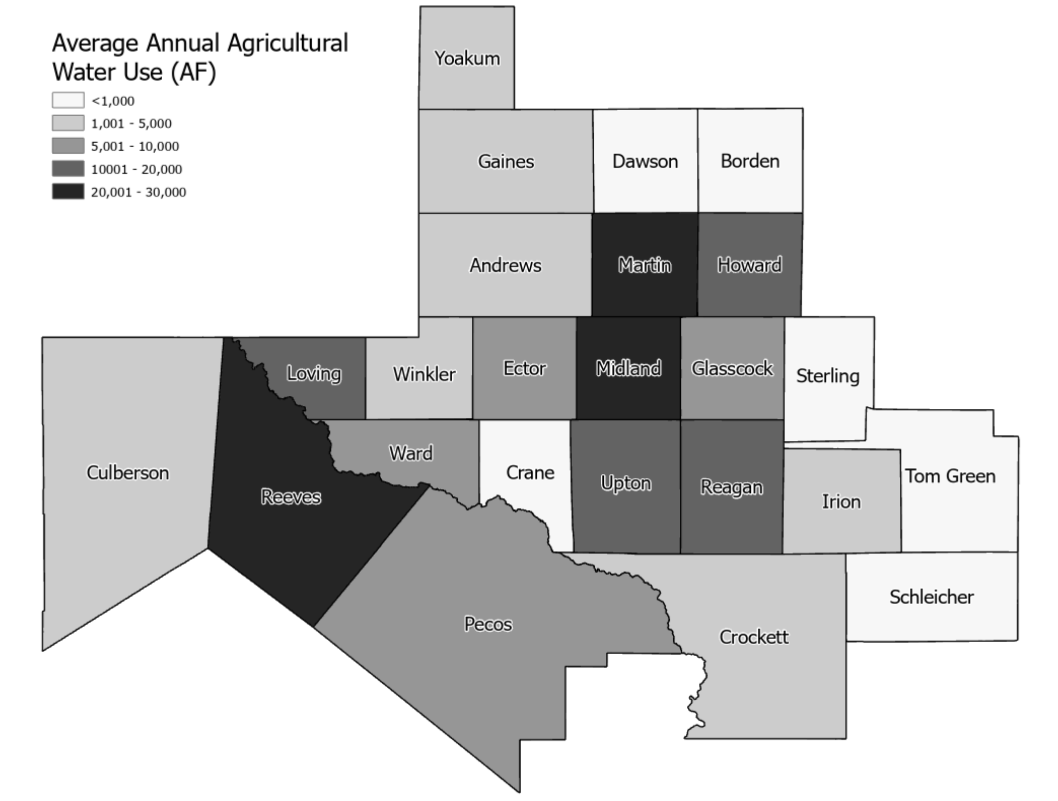


- Overall, Agriculture is the dominant water use in the Permian Basin, averaging 75% of total annual water use
- Water use has stayed generally constant over time and is primarily supplied by groundwater
- Surface water and reuse consists of less than 5% of agricultural water use
  - Surface water use is concentrated in Reeves County from the Pecos River
  - Reuse is highest in Midland County

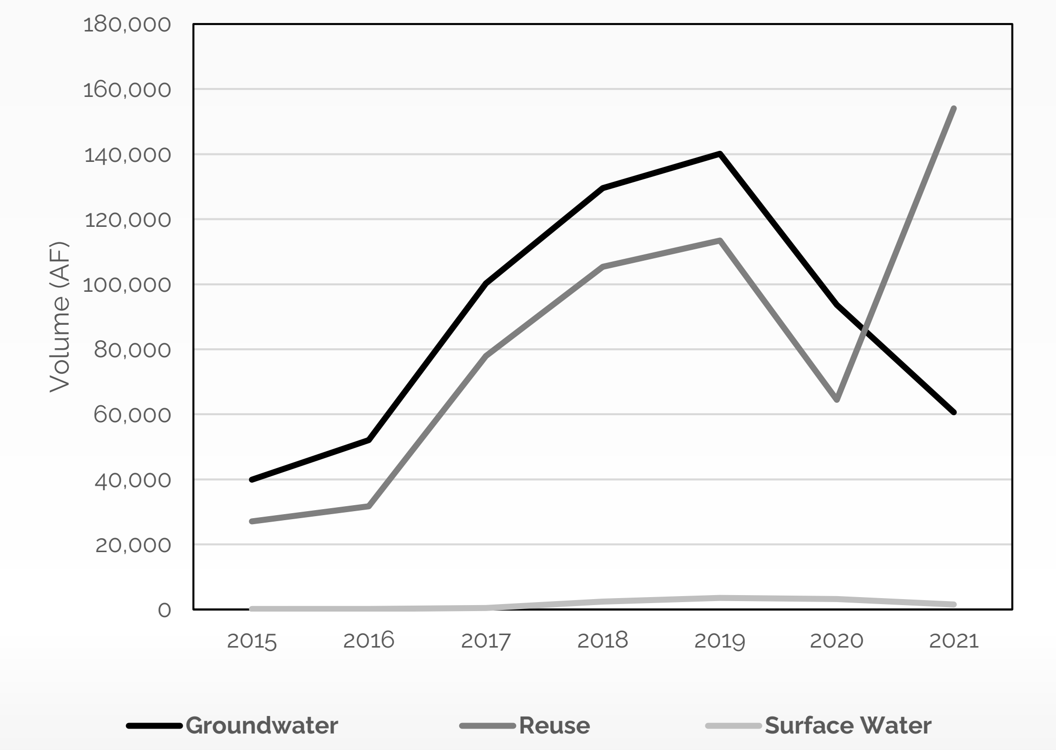
[1]**Source:** Texas Water Development Board (2015-2021) Water use Survey Historical Summary Estimates by County. https://www3.twdb.texas.gov/apps/reports/WU_REP/SumFinal_CountyReportWithReuse

Water Use Trends: Industrial

Permian Basin Average Municipal Water Use by County, 2015-2021 (AF)



Permian Basin Industrial Water Use by Type, 2015-2021 (AF)[1]

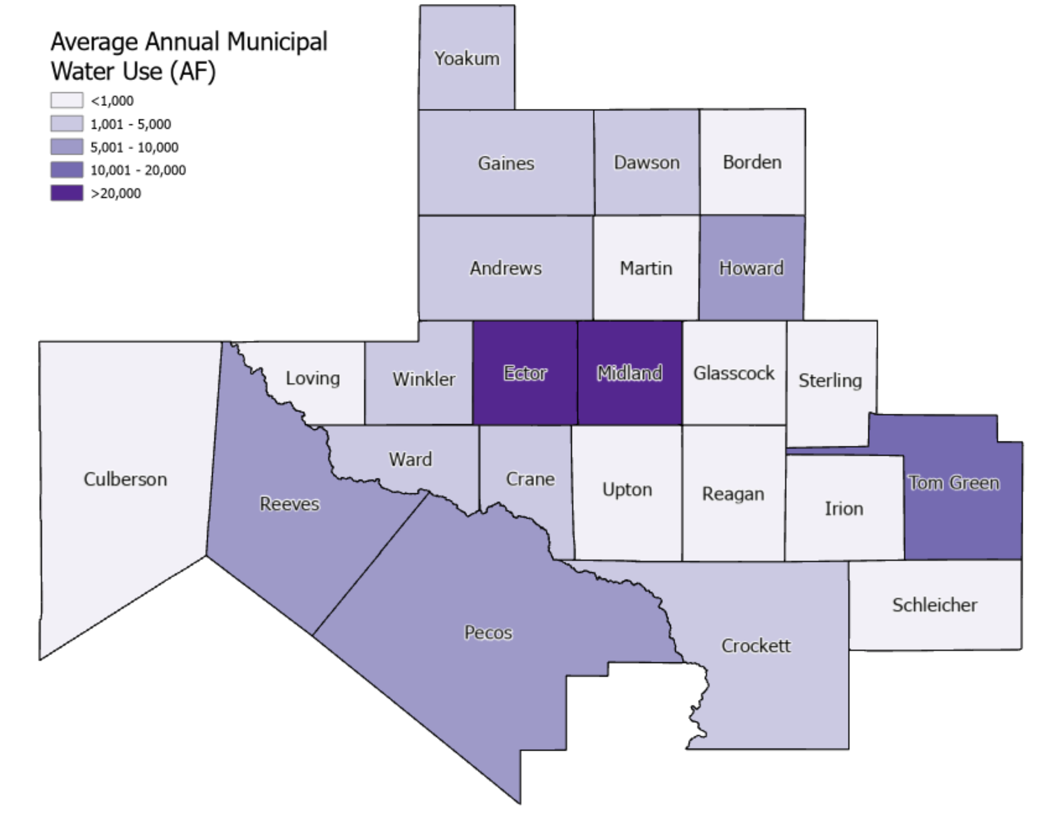


- The industrial water demand subsectors consists of power generation, mining, and manufacturing, with the mining industrial representing more than 91% of the total water use from 2015 to 2020. Since 2015, there has been large variation in the types of water sources used by the industrial sector, however, overall use has increased from 2015-2021.
- Groundwater, including brackish groundwater use, is the dominant source of supply, with reuse supply increasing in recent years
  - Reuse is highest in Midland, Martin, Howard, and Reeves counties, primarily in the mining sector

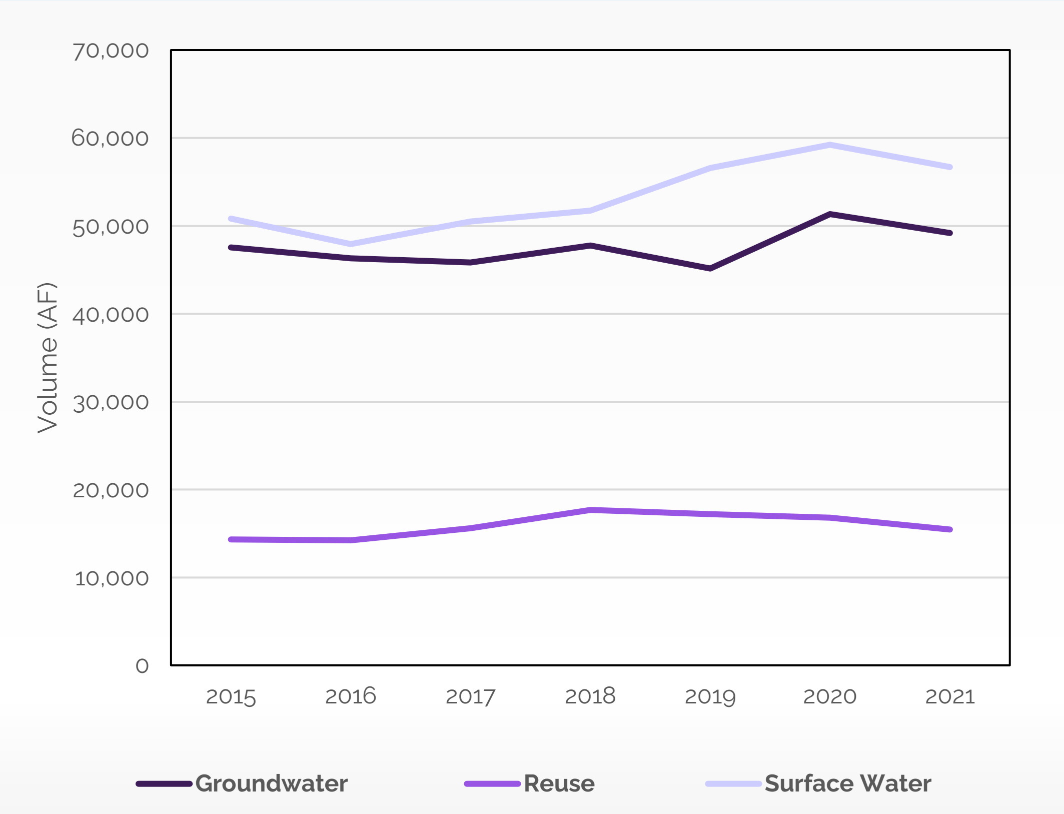
[1]**Source:** Texas Water Development Board (2015-2021) Water use Survey Historical Summary Estimates by County. https://www3.twdb.texas.gov/apps/reports/WU_REP/SumFinal_CountyReportWithReuse

Water Use Trends: Municipal

Permian Basin Average Municipal Water Use by County, 2015-2021 (AF)



Permian Basin Municipal Water Use by Type, 2015-2021 (AF)



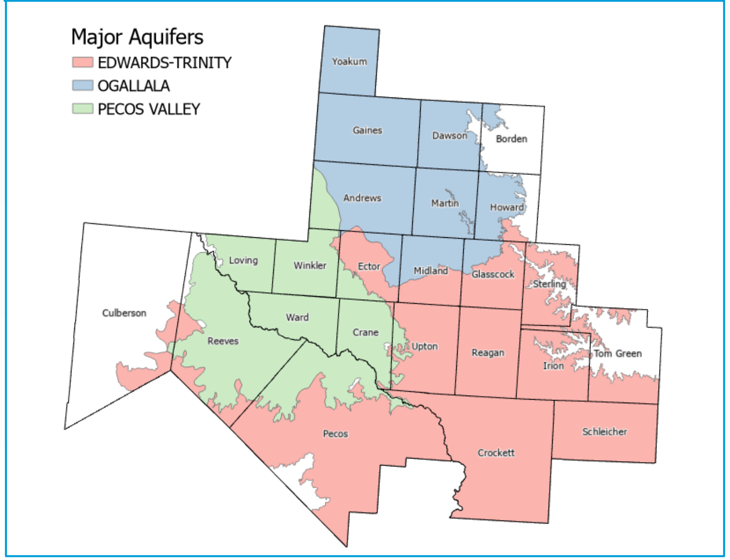
- Overall water use has increased for the municipal sector from 2015-2021
- Half of the Permian Basin municipal supply consists of deliveries from the Colorado River Municipal Water District, which is primarily surface water from the Colorado River. Groundwater and reuse make up the remaining water supplies.
  - Surface water is a municipal supply source of Howard, Midland, Ector, Dawson, and Tom Green counties, who are all customers or members of Colorado River Municipal Water District or the Canadian River Municipal Water Authority
  - Reuse is concentrated in Midland consisting of 70% of municipal reuse
  - The remaining counties municipal water use is primarily groundwater

[1]**Source:** Texas Water Development Board (2015-2021) Water use Survey Historical Summary Estimates by County. https://www3.twdb.texas.gov/apps/reports/WU_REP/SumFinal_CountyReportWithReuse

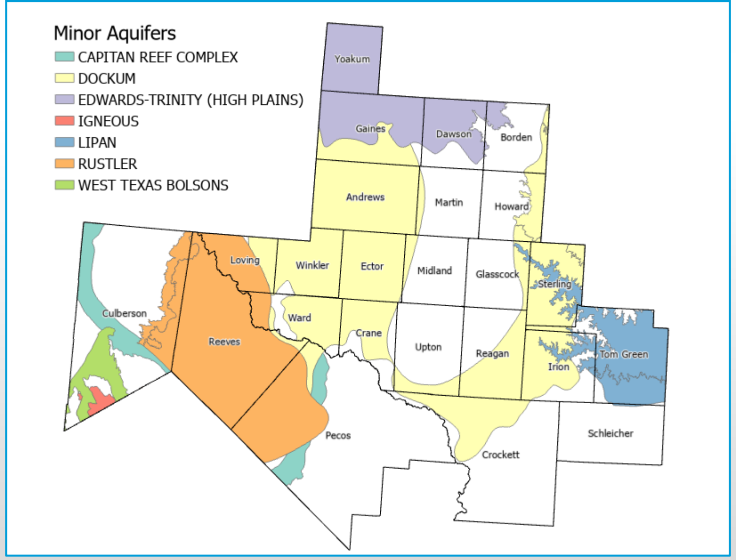
Fresh Water Assets Characteristics

Groundwater Characteristics

Major Aquifers, Permian Basin



Minor Aquifers, Permian Basin



There are 3 major and 7 minor aquifers underlying the Permian Basin. A 2016 TWDB Aquifer Study estimated the total recoverable groundwater storage across the aquifers in Texas.[1]

Total recoverable storage represents a static snapshot of the quantity of groundwater that is in storage in each aquifer. However, the amount that is physically recoverable given available technology ranges between 25% to 75% of the total. This range might be further reduced to account for how policy, law, economics, and/or hydrologic influences might change recoverable groundwater over time.

Although the total volumes may not be withdrawn from the aquifer given the constraints discussed above, these volumes provide an indication of the total amount of groundwater potentially recoverable from storage.

Estimated Recoverable Groundwater in Storage (Acre-Feet)[1]

Aquifer Type	Aquifer	Total	75% of Storage	25% of Storage	25% Storage Annual (2024-2050)
Major*	Edwards Trinity	26,934,137	20,200,603	6,733,534	269,341
Major*	Ogallala	32,151,493	24,113,620	8,037,873	321,515
Major*	Pecos Valley	317,346,551	238,009,914	79,336,638	3,173,466
Minor	Captain Reef Complex	50,730,000	38,047,500	12,682,500	507,300
Minor	Dockum	791,100,000	593,325,000	197,775,000	7,911,000
Minor	Edwards Trinity (High Plains)	8,200,000	6,150,000	2,050,000	82,000
Minor	Igneous	814,350	610,763	203,588	8,144
Minor	Lipan	3,054,500	2,290,875	763,625	30,545
Minor	Rustler	36,180,000	27,135,000	9,045,000	361,800
Minor	West Texas Bolsons	5,400,000	4,050,000	1,350,000	54,000
Total		**1,403,976,750**	**1,271,911,032**	**953,933,274**	**12,719,110**

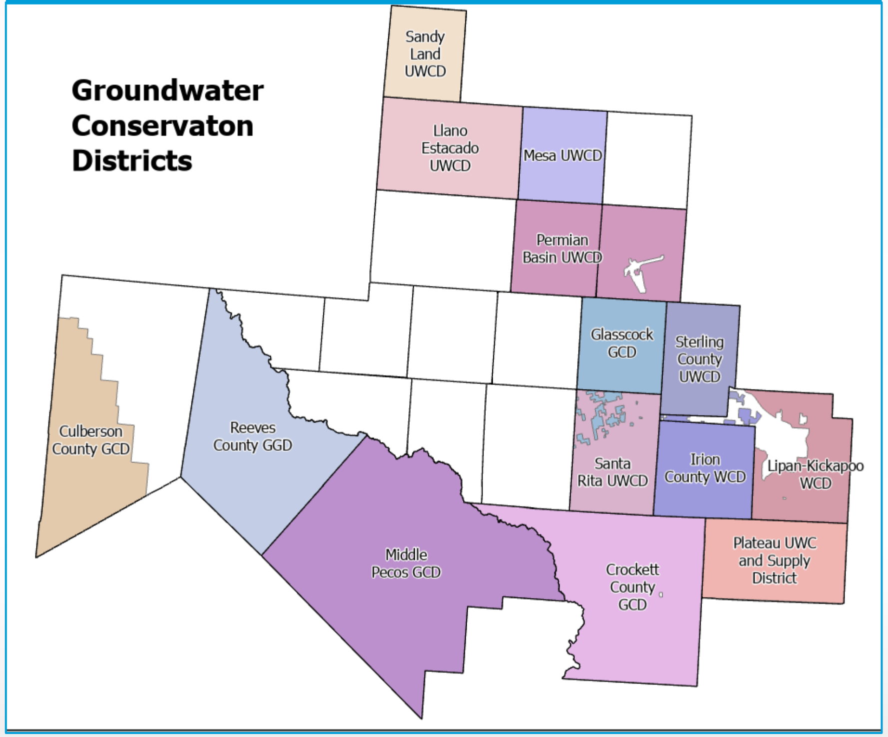
** The major aquifers include published data by groundwater management areas 2, 4, and 7. As the GMAs include counties outside of the Permian Basin, this data has been proportioned based on the 2020 groundwater use by county,[2] which may not be an exact representation of what is physically available to the counties in the Permian Basin.*

[1]**Source:** Braun,B, et al. (2016) Texas Aquifers Study: Groundwater Quality, Flow, and Contributions Surface Water https://www.twdb.texas.gov/groundwater/docs/studies/TexasAquifersStudy_2016.pdf

[2]**Source:** Texas Water Development Board (2020), Historical Water Use by County. https://www3.twdb.texas.gov/apps/reports/WU_REP/SumFinal_RegionReportWithReuse

Groundwater Characteristics: Transferability

GCDs, Permian Basin



All Groundwater in Texas is governed by "Rule of Capture,"[1] which allows the right to pump groundwater if your own or have legal access to the surface above it.

- Groundwater is further managed by Groundwater Conservation Districts (GCD) or Underground Water Conservation Districts (UWCD), which are the state of Texas' preferred method of groundwater management[2].
- There are 3 types of groundwater use that are considered when determining transferability:
  - Withdrawn from areas without a GCD or UWCD or "White Zones"
  - Exempt withdrawals of groundwater in areas regulated by a GCD/UWCD. Exempt withdrawals are typically those that withdrawal at a high rate.
  - Non-Exempt withdrawals of groundwater in areas regulated by a GCD/UWCD. Non-Exempt Withdrawals are typically those that withdrawal at a low rate, including domestic wells.
- Groundwater withdrawn from White Zones and Exempt withdrawals of groundwater have few barriers to withdrawal and use. Legal groundwater withdrawal access typically occur through a transfer of land and are subject to Rule of Capture.
- Non-exempt uses of groundwater within a GCD/UWCD face more hurdles to withdrawal as they must be permitted by a GCDs/UWCD. Permitting criteria differs by GCD/UWCD, however in general groundwater permits have and continue to be authorized by GCD/UWCDs across the Permian Basin

[1] **Source:** Houston Texas Central Railroad Company V. W.A. East 98 Tex. 146, 81 S.W. 279, Texas Supreme Court, 1904
[2] **Source:** Texas Water Code, Chapter 36, Title 2: Groundwater Conservation Districts.
https://statutes.capitol.texas.gov/Docs/WA/pdf/WA.36.pdf?d=7300.199999988079

Groundwater Characteristics: Reliability

There are two ways to approach the reliability of groundwater: (1) Modeled Available Groundwater; and (2) Total Recoverable Storage.

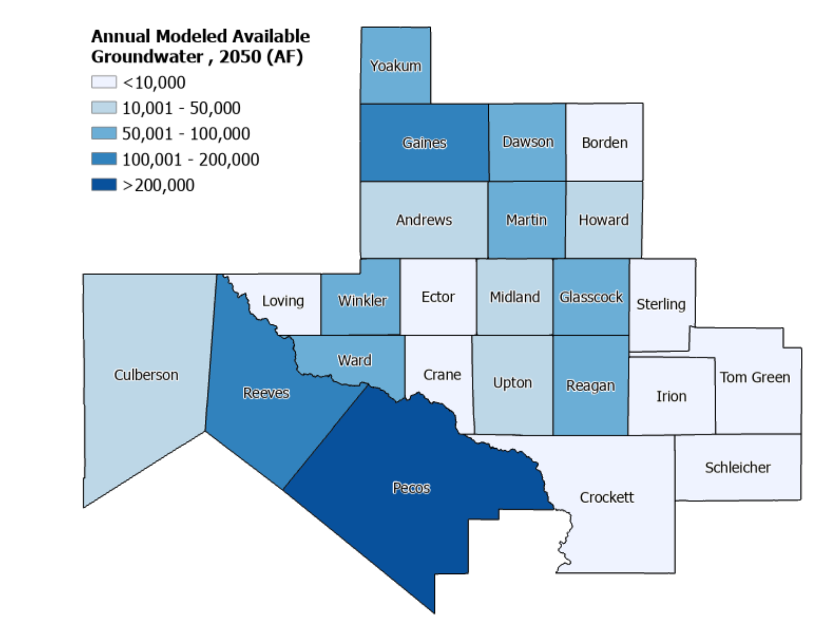
Modeled Available Groundwater (MAG): the average annual volume of groundwater withdrawals that will achieve a desired future condition (DFC).

- MAGs are a metric that combine the regulatory and physical availability of groundwater.
- DFCs are determined during the regional planning process every 5 years and are the desired, quantified condition of groundwater resources at a specified future time. In the Permian Basin these are typically set by the decade
- DFCs and therefore MAGs are limited as a way to determine availability in several ways
  - A new metric that has only been in place since 2012
  - Not all districts have firm methods of determining compliance with DFCs
  - Can change during the regional planning process
  - Are not the only criteria used, if at all, to authorized groundwater withdrawal permits
  - Aquifers can be exempt from having a DFC and therefore MAG.
- As MAGs are limited, Total Recoverable storage may be another metric to look at availability of groundwater in the Permian Basin

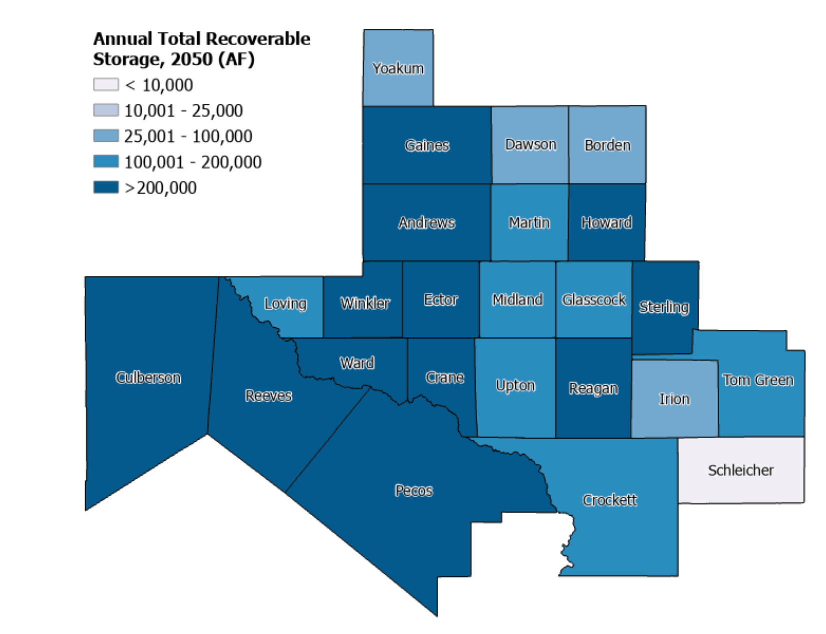
Total Recoverable Storage (TRS): the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25% and 75%.

- TRS are a physical estimate of groundwater and is estimated pursuant to Texas Water Code, §36.001 (24)
- The 75% and 25% scenarios are intended to account for the what may be technically feasible to recover. This volume does not account for the limitations that may result from policy, quality, or economics
- May represent the upper end of the volume of groundwater that is physically available

Annual Modeled Available Groundwater (AF) 2050

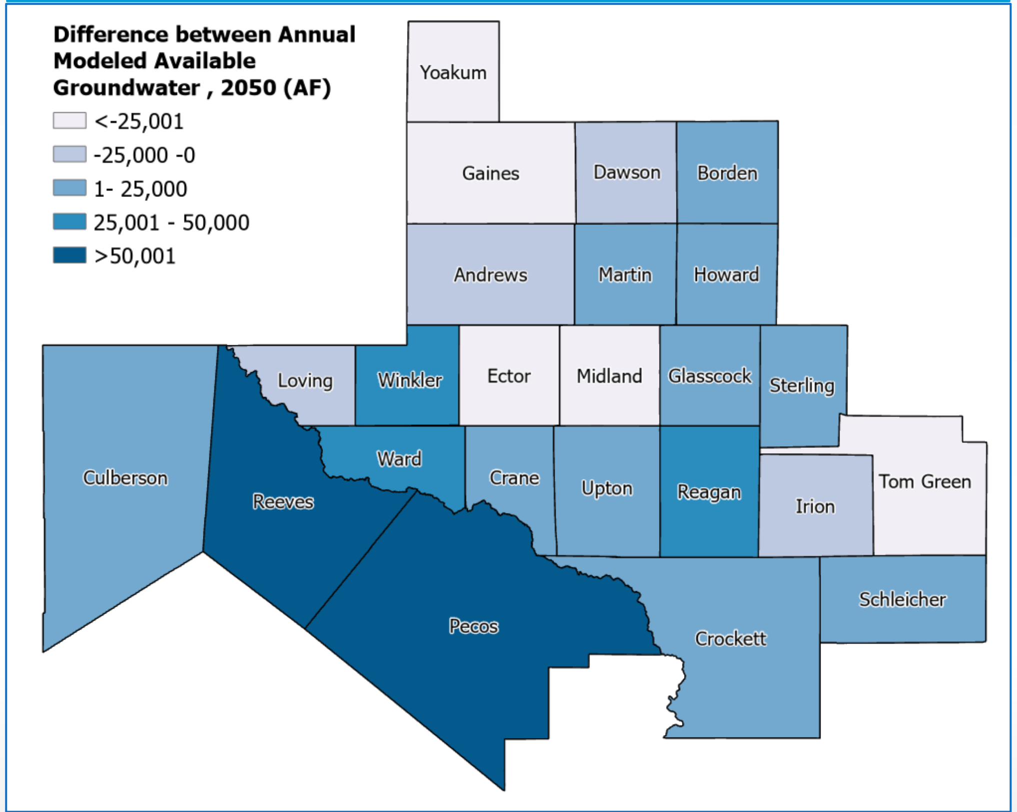


Annual Total Recoverable Storage (AF) 2050

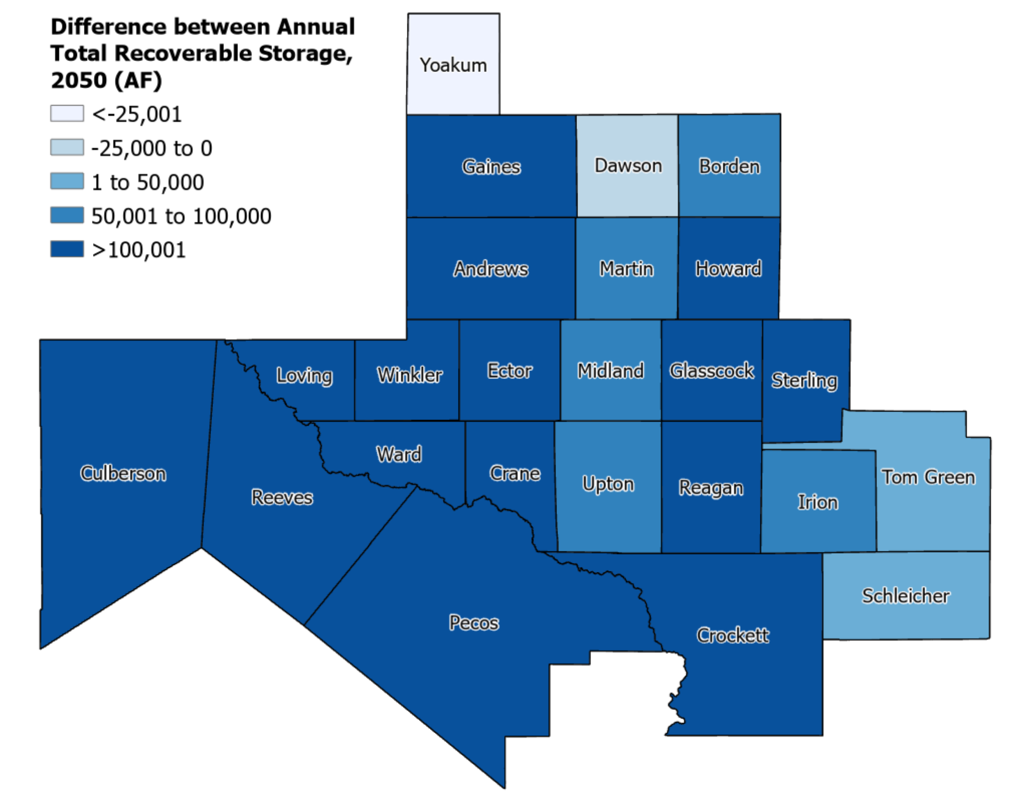


Groundwater Characteristics: Water Supply Development Potential

Annual Difference between MAG and Demand, 2050 (AF)



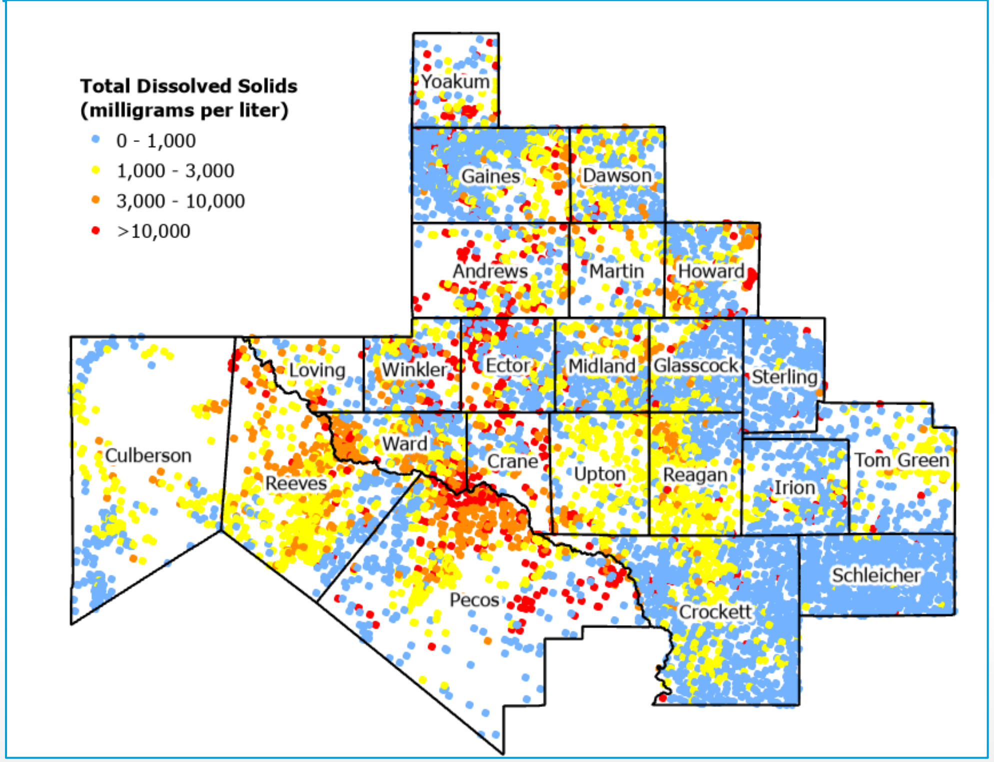
Annual Difference between TRS and Demand, 2050 (AF)



- To determine potential water supply development potential, MAG and TRS was compared with projected demand in 2050
- Both analyses show groundwater development potential in most counites in the Permian Basin.
  - The MAG analysis showed lower development potential in 9 counties, including those that have high population and/or high irrigation water use,
  - The TRS analysis showed water supply development potential in all but 2 counties in the Permian Basin.

Groundwater Characteristics: Quality & Markets

Total Dissolved Solids (mg/liter), 2017[1]



Water Quality[2]

- Water quality in the Permian Basin is variable by aquifer and location.
- However, compared to many other areas in the of the state the, water is more saline in the Permian Basin.
- In general, the southeast areas, above the Pecos Valley aquifer are slightly-to-moderately saline, particularly Reeves, Loving, Ward, and most of Pecos counties. Water here is affected by recharge from the Pecos river, oil and gas field brine, and agricultural runoff. The water here is also hard with high chlorides and sulfates.
- The Ogallala is generally of good quality as it approaches the Permian and becomes more saline across the basin. The southern extent of the Ogallala—underlying the Permian—is also higher in elements that make it unpotable, including arsenic, fluoride, and selenium nitrate. High nitrates are found in agricultural areas, including the northern reach of the basin in Yoakum, Gaines, and Dawson counties, and to the east in Tom Green County.
- A majority of the Trinity Aquifer has low total dissolved solids (TDS), but as you move to the east into the Permian Basin, the groundwater becomes more saline.
- Most areas of the minor aquifers are slightly to moderately saline, with some pockets of lower TDS water. Waters of the Dockum Aquifer, which has a large MAG, is of poor quality with a high presence of minerals, making it unsuitable for drinking.

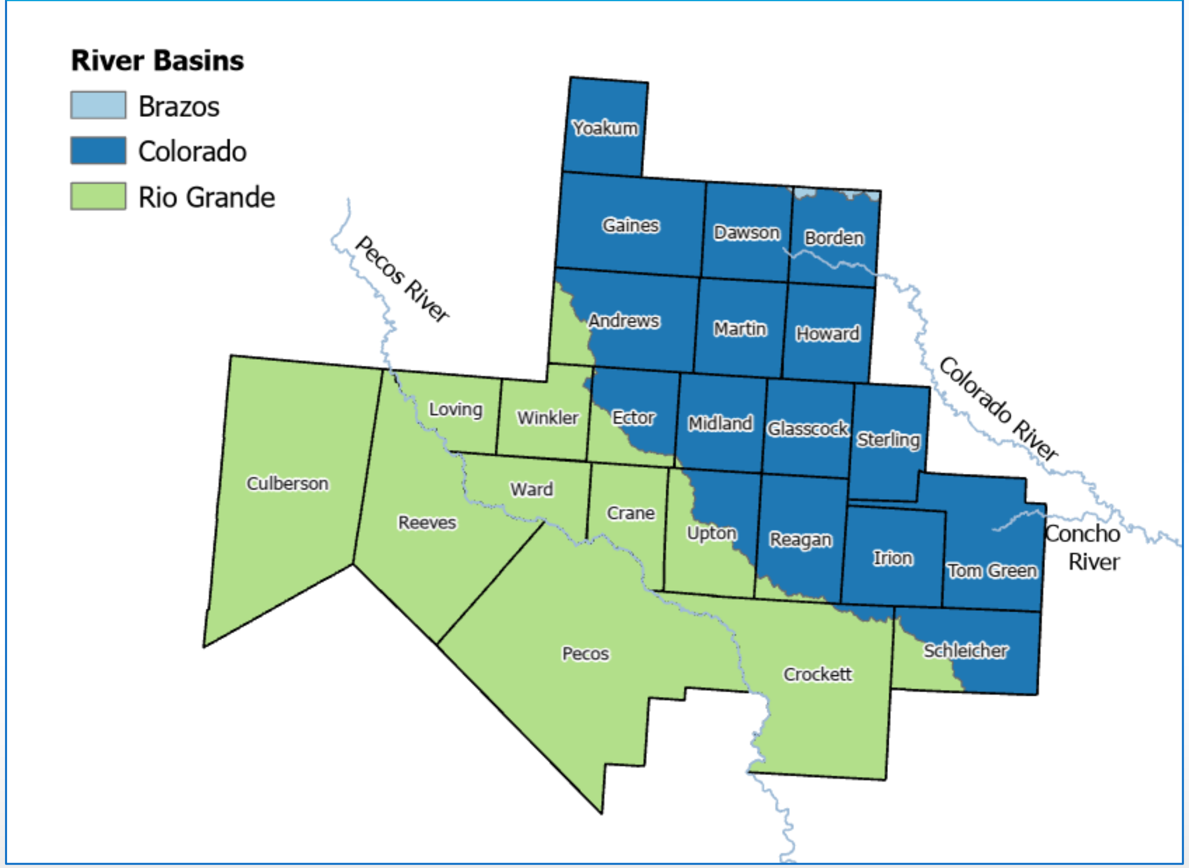
Current Market Activity

- Due to the availability of groundwater, transactions in the Permian Basin for municipal and agricultural uses are uncommon.
- Groundwater is typically traded with property, and it is often difficult to separate groundwater from land transfers.
- In recent years, one notable groundwater agreement was made by the West Texas Water Partnership (2020) and will transfer 28,400 AF of groundwater from the Fort Stockton area to the City of Midland.[3]

[1]**Source:** Qi, S.L., and Harris, A.C. (2017) Geochemical Database for the Brackish Groundwater Assessment of the United States: U.S. Geological Survey data release, https://doi.org/10.5066/F72F7KK1.
[2]**Source:** Braun, B, et al. (2016) Texas Aquifers Study: Groundwater Quality, Flow, and Contributions Surface Water https://www.twdb.texas.gov/groundwater/docs/studies/TexasAquifersStudy_2016.pdf
[3]**Source:** ,City of San Angelo (2020). West Texas Water Partnership https://www.cosatx.us/departments-services/water-utilities/west-texas-water-partnership

Surface Water Characteristics

River Basins, Permian Basin

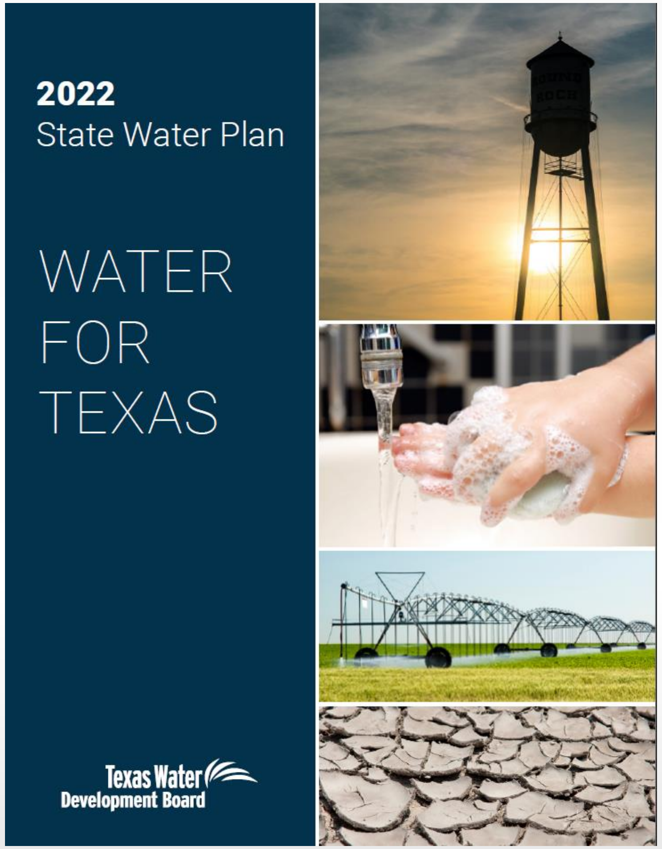


Characteristics	Surface Water
Transferability	• Surface water diversion permits are issued by the Texas Commission on Environmental Quality (TCEQ). TCEQ administers surface water rights by priority doctrine and may appoint a Watermaster. Within the CRB, the Concho River Subbasin is the only region under Watermaster jurisdiction.[1]
Reliability	• Safe yield for each river basin determined using Water Availability Models (WAM). The Rio Grande and Colorado River Basin WAMs estimate a limited loss of capacity in major surface water reservoir due to sedimentation.[2] • Permitted diversion of major reservoirs is 5.85x higher than recent use. • High variability in Upper Colorado river basin during dry years. In general, Upper Colorado water rights entitlements are junior to entitlements in the Lower Colorado and are at risk of priority calls enforcements from TCEQ.
Water Supply Development Potential	• Limited Development Potential: Colorado River & Pecos River's WAM indicate a reduction of surface water supply over time.
Water Quality	• High levels of TDS, due to both natural and human factors, are present in rivers and reservoirs.[2] • High salinity is a common issue, which requires advanced treatment technology such as reverse osmosis
Current Market Activity	• Limited number of surface water asset transfers in the region • CRMWD is main wholesaler of surface water to municipalities and is the main holder of surface water reservoir diversion permits.[3]

[1] **Source:** Angelia Sanders, Concho River Watermaster Program, Watermaster
[2] **Source:** 2021 Region F Water Plan, Texas Water Development Board, from: http://www.twdb.texas.gov/waterplanning/rwp/plans/2021/index.asp
[3] **Source:** Colorado River Municipal Water District Profile and Water Conservation Plan, 2019

Existing Water Market Characteristics

Supply and Demand Conditions



Regional water supply and demand conditions indicate marketability

Data Review

- Surface and groundwater supplies
- Regulatory management of surface and groundwater
- Existing water rights
- Regional water demand & supply projections

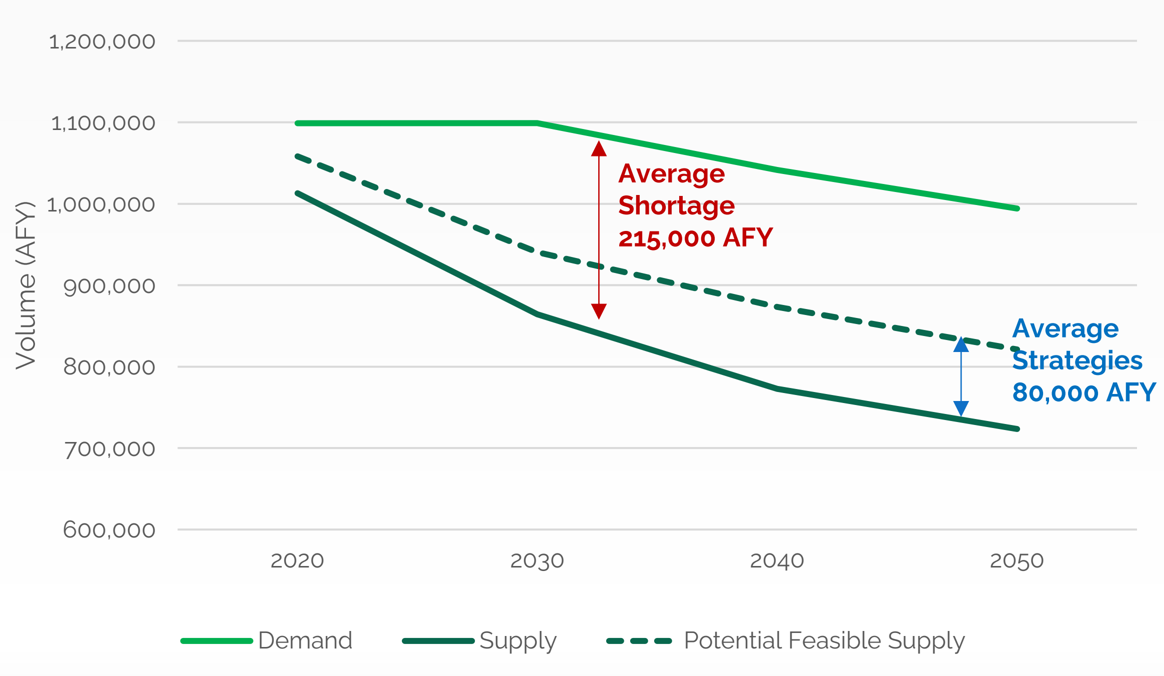
Considerations

- Is there demonstrated demand in the transferable region?
- Is there unallocated water available in the region?
- How does demand compare with size/character of available fresh water?

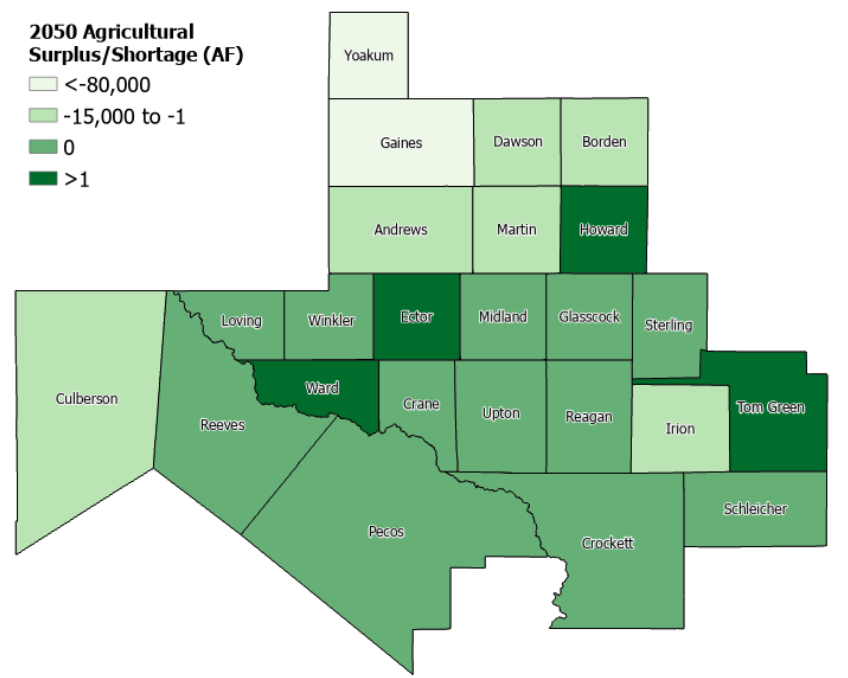
- To evaluate the market for freshwater resources for various end uses, a review of regulation water supply and demand conditions was done using the 2022 Texas State water Plan.
- Supply and demand data is reported by decade for each county in the Permian Basin.
- In addition to existing and projected supplies and demands, the plan also includes potentially feasible water management strategies that will help to avoid shortages.

Supply and Demand Conditions: Agricultural

Projected Agricultural Supplies, Demand, and Potential Strategies, 2020-2050 (AF)



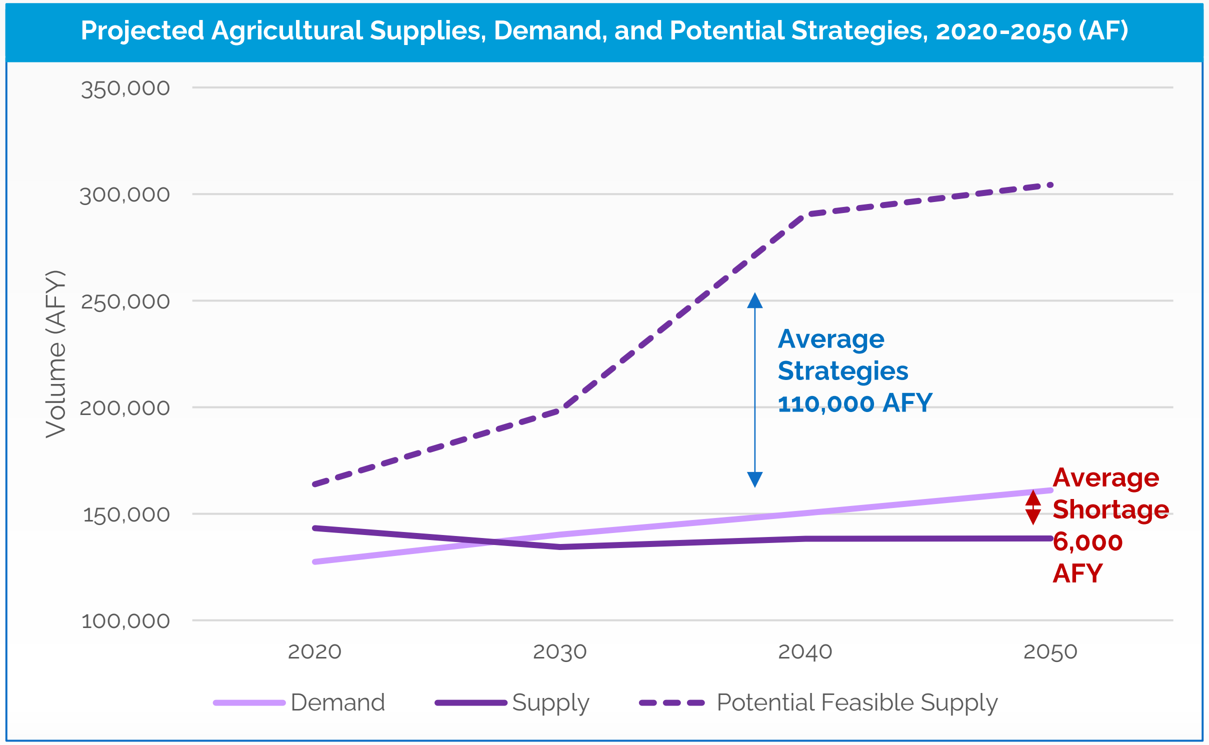
Annual Agricultural Water Supply Shortage/Surplus, 2050 (AF)

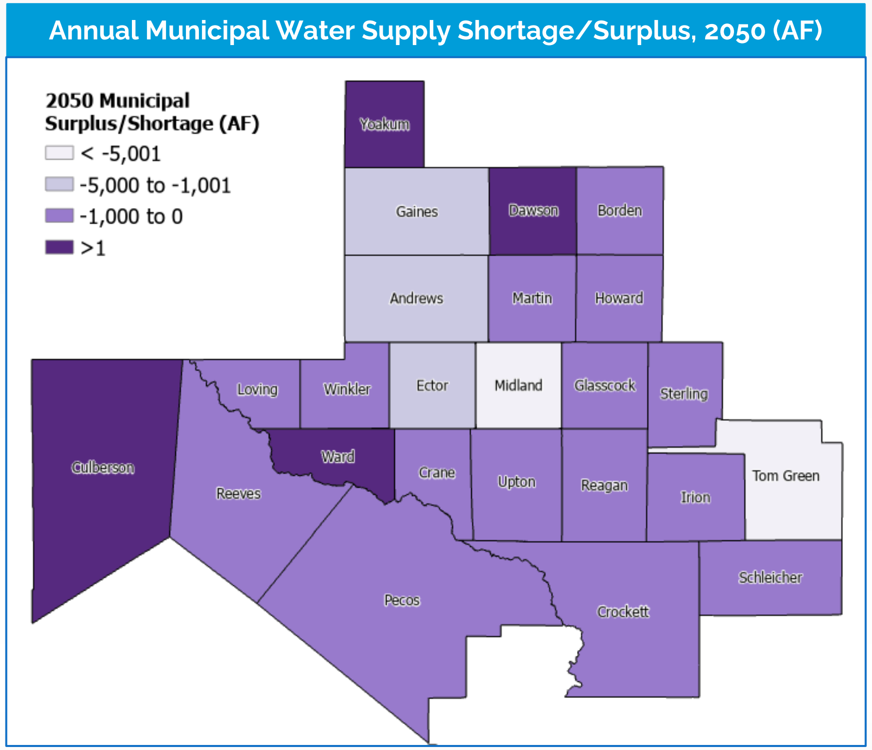


- In aggregate, there is a shortage projected for every year through 2050, ranging from -86,000 AF to -271,000 AF, with an average of 215,000 AF.
- The potentially feasible strategies for the agricultural sector consist of groundwater well development, surface water subordination, weather modification, and conservation. Conservation averages over 90% of strategy supplies.
- Despite the 40,000 AF to 90,000 AF of strategies supplies, there is still a projected shortage in the agricultural sector from 2020-2050.
- The projected shortage is concentrated in the areas where there is higher agricultural use, particularity Yoakum and Gaines counties. Over half of the Permian Basin counties are not anticipated to face a shortage in supplies for the agricultural sector.

Source: Texas Water Development Board (2022): State Water Plan: Water for Texas. https://www.twdb.texas.gov/waterplanning/swp/index.asp

Supply and Demand Conditions: Municipal

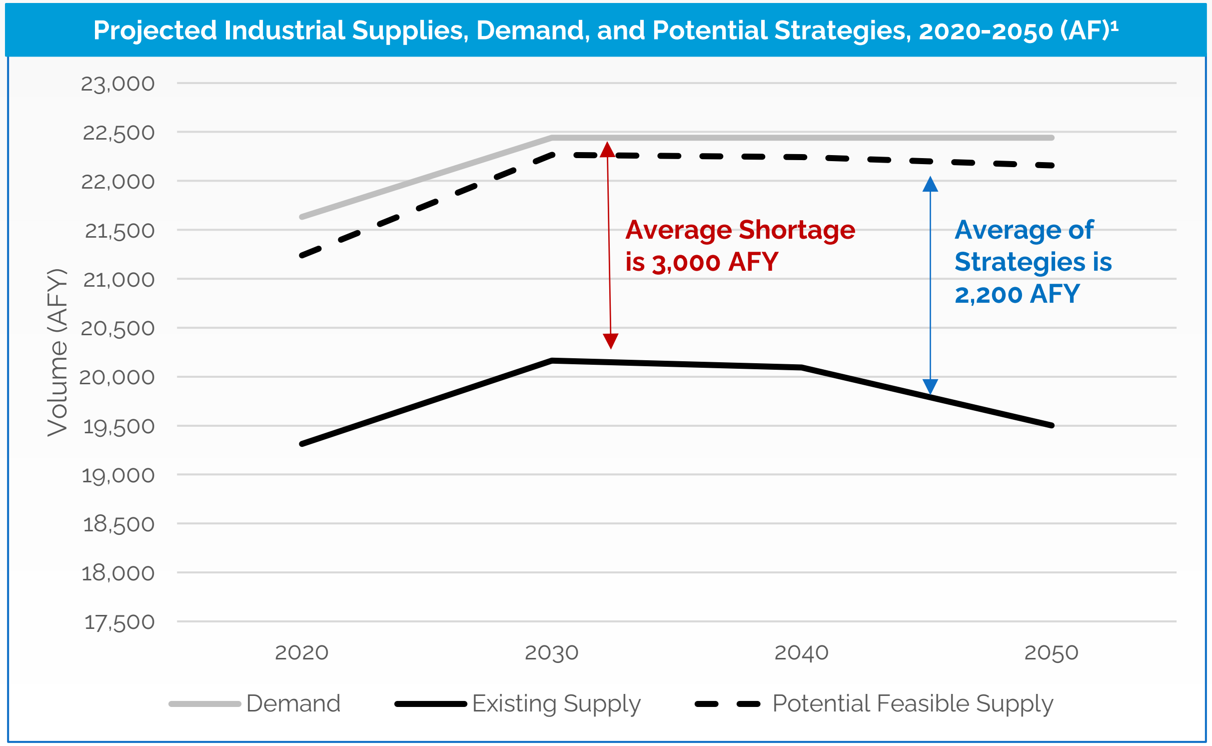


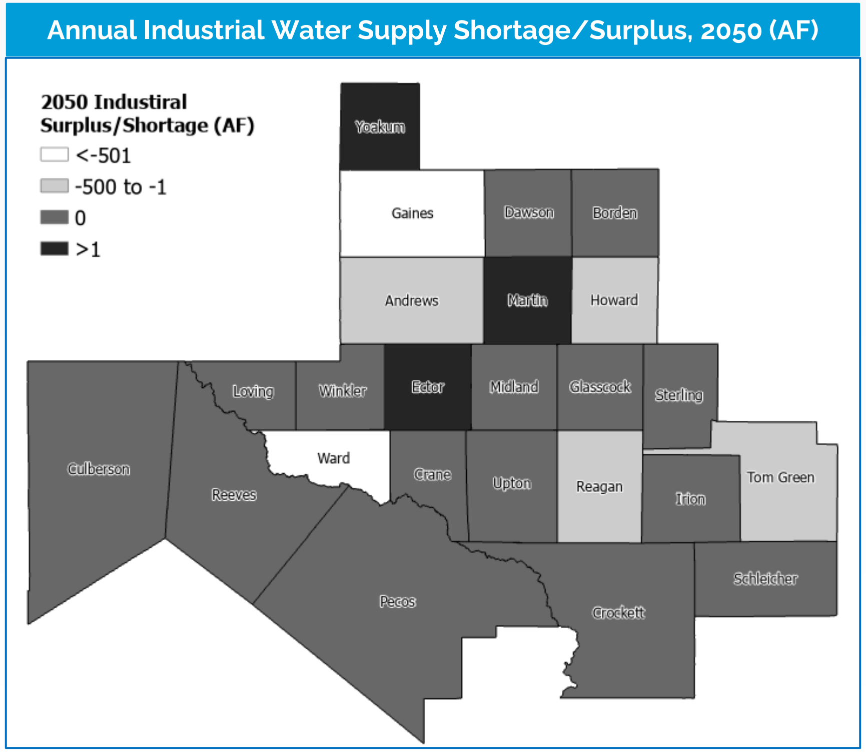


- There is projected shortage in the municipal sector beginning in 2030 and through 2050, ranging from 5,800 to 22,000 AF.
- The shortage is generally concentrated in counties with the highest population, including Ector, Midland, and Tom Green, or those expected to experience significant growth, including Gaines and Andrews counties.
- The potentially feasible strategies are projected to make up for the shortage and result in surplus of supplies in every county. The volume of strategies ranges from 26,000 AF in 2020 to 170,000 AF in 2050.
- The strategies include groundwater well development, surface water yield enhancement, conservation, reuse, and desalination. New groundwater well development is projected to provide the largest volume, averaging 60% of potentially feasible strategies.

Source: Texas Water Development Board (2022): State Water Plan: Water for Texas. https://www.twdb.texas.gov/waterplanning/swp/index.asp

Supply and Demand Conditions: Industrial





- As the purpose of this analysis is the valuation of freshwater assets in the Permian Basin exclusive of the oil and gas industry, the mining sector was not included in the supply and demand analysis, nor was it valued. As a result, the industrial sector water demand is small, with shortages ranging from 2,000 to 4,500 AF through 2050.
- Demand for Manufacturing is concentrated near municipal centers in Ector, Howard, and Tom Green counties. Manufacturing mostly consists of sand and gravel processing operations and is expected to remain constant over the next 25 years.[1] Power generation demand mainly consists of cooling water for condensing process steam, with cooling requirements varying by production process.[2] The TWDB plan projects limited increases in water demand for power production, with potential future projects focused on solar power generation.[3]
- Overall, projected shortages are highest in Gaines and Ward counties, with most of the Permian Basin not projecting a shortage in industrial supplies.
- Potentially feasible strategies include groundwater well development, surface water yield enhancement, and reuse, averaging 2,200 AF.

Due to the limited size of the demand and shortage, and the existing locations of manufacturing operations near municipalities, WestWater determined that the industrial sector has similar dynamics as the Municipal Sector and it is therefore not independently valued.

[1] **Source:** Texas Water Development Board (2022): State Water Plan: Water for Texas. https://www.twdb.texas.gov/waterplanning/swp/index.asp
[2] **Source:** Water Demand Projections for Power Generation in Texas, Texas Water Development Board, 2008
[3] **Source:** 2022 Long-Term Reliability Assessment, North American Electric Reliability Corporation, December 2022

Water Valuation Approaches

Valuation Approaches

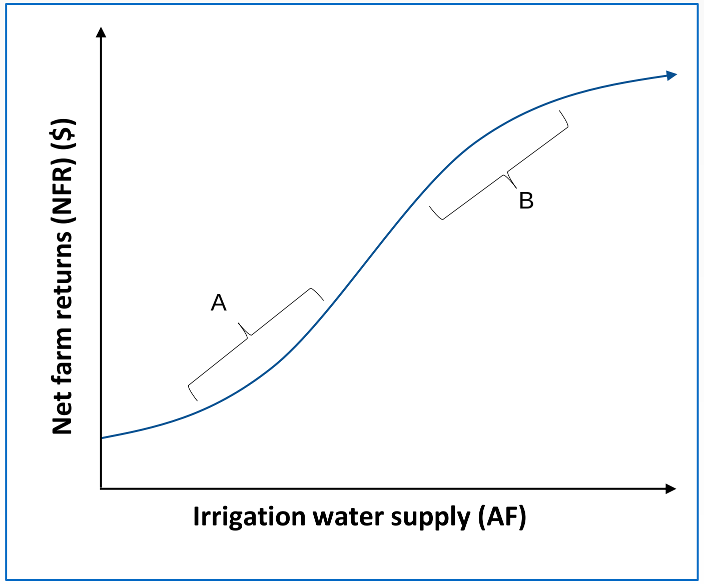
Approaches used

Approach	Description	Best Practice Enablers & Assumptions
Sales Comparison	Comparison of subject water resource to similar supplies that have been sold in the past	• Active market for water resources separate from land • Prior transactions of similar (fungible) water resources
Income Basis	*Capitalization*: Water's contribution to net revenue, as an input to current operations *Affordability Threshold*: An entity's ability to pay for water supply	• Water is a critical input to economic production (e.g., agriculture) • Can provide an indication of maximum willingness to pay (WTP) for water
Replacement Cost	Least-cost alternative to develop new water supplies comparable to the asset of interest	• Generally feasible alternative for water resource replacement • Replacement provides substantially similar benefit to ongoing operations
Land Price Differential	Net value contributed to a property as a result of access to associated water resources	• Active market for both irrigated and non-irrigated land

Agricultural Water Valuation

Income Approach—Estimating Max WTP

1



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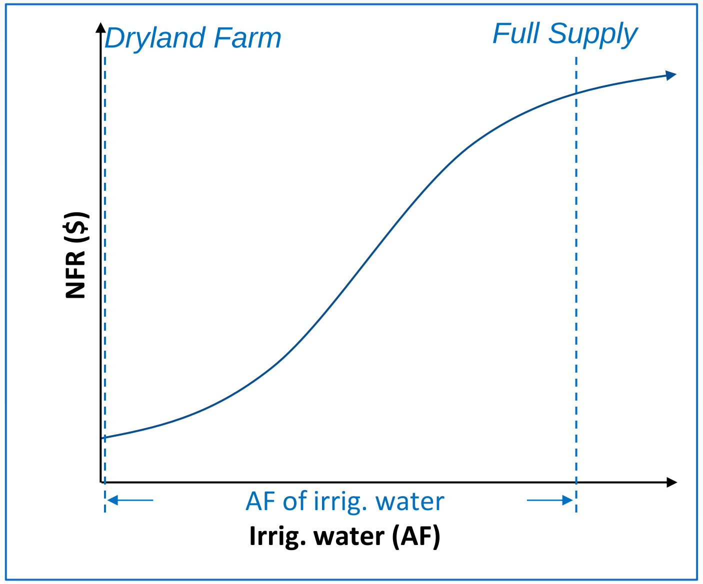

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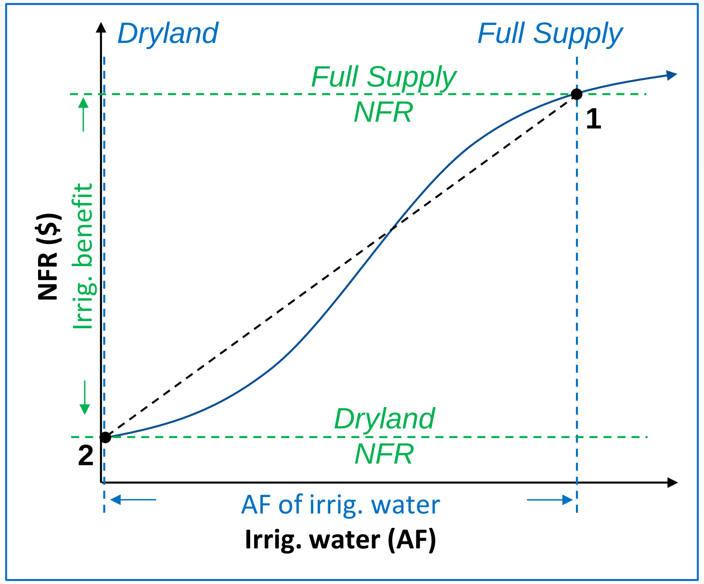
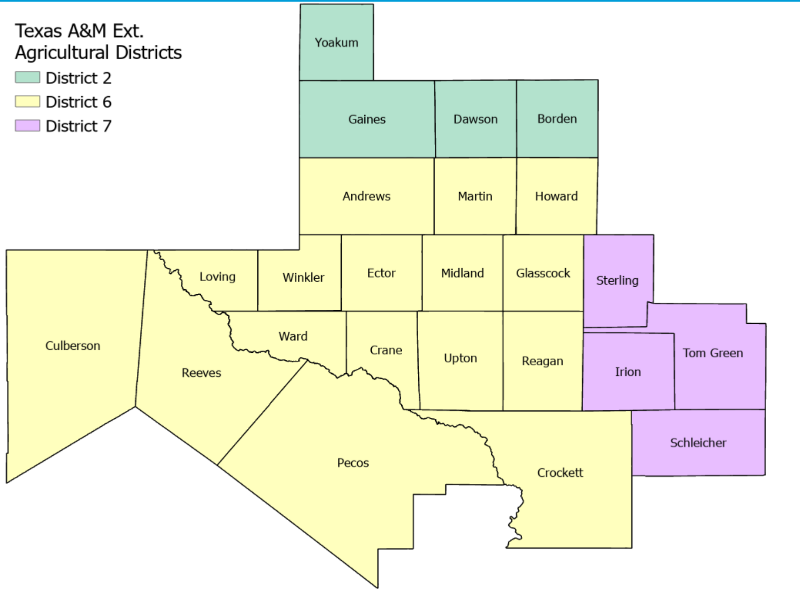


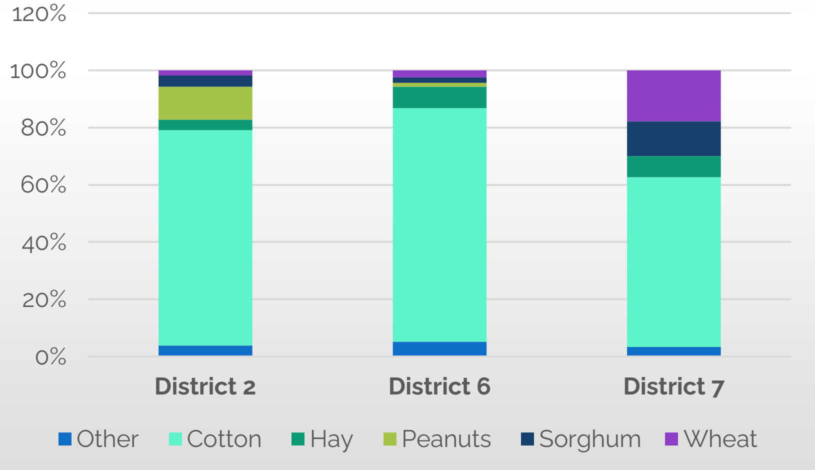
- In general, an increase in irrigation water supply = increase in net farm returns (NFR)
- Bracket A (convex): increasing marginal returns (yield increases, cropping pattern shifts to more valuable commodities, etc.).
- Bracket B (concave): diminishing marginal returns upon approaching a full irrigation supply
- When irrigation water is scarce, each additional unit is increasingly valuable; when plentiful, each additional unit is decreasingly valuable.
- Irrigation Benefit = difference in Dryland and Full Supply conditions.
- Marginal benefit of irrigation water is dependent on which length of the curve is being solved (often not possible)
- Rather, two solvable points along the curve are estimated. The slope of the linear curve approximates the marginal benefit of 1 additional AF.
- The benefit provided by the irrigation water represents the maximum willingness to pay (WTP). If water cost exceeds this, dryland farming is economically preferred.

Agricultural Value: Current Condition Methods

Texas A&M Extension Districts in the Permian Basin



Percentage of Cropland Acres by District, 2017



Source: United States National Agricultural Statistics Service (2017) Census of Agriculture, http://www.agcensus.usda.gov/

Two methods were used estimate the current value of irrigation water in the Permian Basin. Texas A&M Extension districts were used to develop regional pumping costs and WTP estimates for Permian Basin irrigation water

Pumping Costs

- The cost to pump irrigation water was estimated to determine the current cost that producers *actually* pay for water in the Permian Basin
- The results of this analysis represents the low end of the current value of irrigation water
- Pumping costs were estimated for multiple districts and crops using information on:
    - Average Well Depth
    - Average Farm Size
    - Application rate of water by most irrigated crops
    - Pressurization requirements (PSI) and application efficiency
    - Cost of electricity (base rates, demand charges, and meter fees)
    - Irrigation season length

Crop Budgets

- Allows for estimation of the agricultural value of water in its current use by assessing irrigation water's contribution to net revenue from agricultural production
- The estimates derived from a crop budget analysis provide a measure of the level of compensation that would be required to ensure equivalent farm income with and without the water, or the minimum price that the producer might be willing to accept to stop irrigating
- The results of this analysis will serve as the maximum amount the producer is willing to pay and still remain profitable
- Crop budgets were developed for multiple districts and crops using 2023 Texas A&M District Crop Budgets as a foundation

Agricultural Value Current Condition : Data

Modeled Crops*			Farm Size (Acres)	Applied Water (AF/ac)	Irrigation System	Pumping Lift (ft)	Counties
District	Irrigated	Dryland					
2	Cotton/Wheat	Cotton/Wheat	160	0.94	Center Pivot	134	All District 2 Counties
	Cotton/Sorghum	Cotton/Sorghum	160	0.80	Center Pivot	134	All District 2 Counties
	Peanuts	Cotton/Wheat	122	1.83	Center Pivot	134	Gaines, Yoakum
6	Cotton/Wheat	Cotton/Wheat	350	1.94	Center Pivot	152	All District 6 Counties
	Cotton/Sorghum	Cotton/Sorghum	350	1.60	Center Pivot	152	All District 6 Counties
	Pecans	Cotton/Sorghum	50	1.17	Furrow	152	Crane, Ector, Pecos, Reeves, Ward
7	Cotton/Wheat	Cotton/Wheat	400	1.44	Center Pivot	77	All District 7 Counties
	Cotton/Sorghum	Cotton/Sorghum	400	1.10	Center Pivot	77	All District 7 Counties

*Rotations modeled as 2 years cotton, 1 year wheat/sorghum. Applied water and all outputs were weighted accordingly.

Sample crop budgets from Texas A&M Extension were used as a foundation for the crop budgets developed for the Permian Basin.

Additional data to complement A&M assumptions, such as price and yield data, agricultural practices, farm size, irrigation system and applied water, were obtained from relevant literature and conversations with A&M Extension agents, as listed in the appendix.

District	Crop	Commodity 1				Commodity 2			
		Product	Units	Units/ac	$/Unit	Product	Units	Units/ac	$/Unit
2	Cotton	Lint	Pound	1,000	$0.85	Seed	Ton	0.71	$250.00
	Wheat	Grain	Bushel	60.0	$8.00	Grazing	Pound	136	$0.55
	Sorghum	Grain	CWT	45.0	$10.20				
	Peanuts	Peanuts	Ton	2.2	$510.00				
6	Cotton	Lint	Pound	1,500	$0.90	Seed	Ton	1.4	$300.00
	Wheat	Grain	Bushel	50.0	$8.25				
	Sorghum	Hay	Ton	5.0	$214.50				
	Pecans	Pecans	Pound	1,364	$2.00				
7	Cotton	Lint	Pound	1,326	$0.90	Seed	Ton	0.96	$360.00
	Wheat	Wheat	Bushel	50.0	$8.25				
	Sorghum	Hay	Ton	5.0	$214.50				

Agriculture Value: Current Condition Pumping Costs & WTP Results

	Price Paid (Pumping Cost, $/AF)					Max Willingness to Pay (Net Farm Returns Differential, $/AF)				
	Minimum Price Paid		Maximum Price Paid		Average Price Paid	Low-end WTP		High-end WTP		Average WTP
District	$/AF	Crop	$/AF	Crop	$/AF	$/AF	Crop	$/AF	Crop	$/AF
2	$12.17	Peanuts	$13.94	Cotton/Sorghum	$13.17	$108.48	Peanuts	$158.58	Cotton/Sorghum	$141.63
2	$13.40	Cotton/Wheat	$13.94	Cotton/Sorghum	$13.67	$157.84	Cotton/Wheat	$158.58	Cotton/Sorghum	$158.21
6	$29.89	Cotton/Wheat	$34.29	Pecans	$31.60	$274.28	Cotton/Wheat	$710.89	Pecans	$457.23
6	$29.89	Cotton/Wheat	$30.62	Cotton/Sorghum	$30.25	$274.28	Cotton/Wheat	$386.52	Cotton/Sorghum	$330.40
7	$25.40	Cotton/Wheat	$25.95	Cotton/Sorghum	$25.67	$234.06	Cotton/Wheat	$404.66	Cotton/Sorghum	$319.36

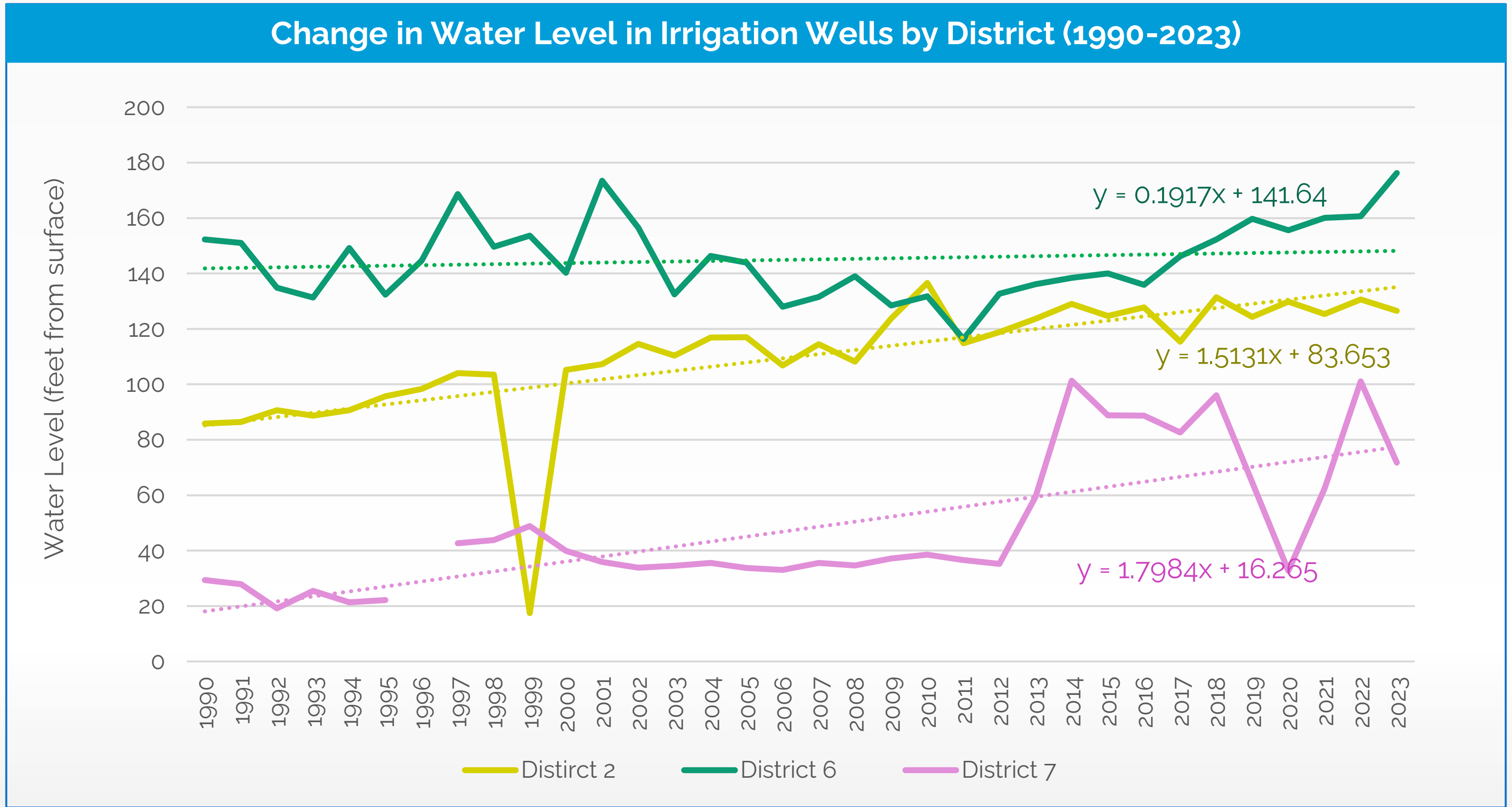
Pumping costs represent ***actual price paid*** for irrigation water

- Lowest pumping cost: District 2, where wells are typically shallower.
- Highest pumping cost: District 6, where wells are generally deeper.
- Pumping cost ranges from $12/AF to $34/AF

Difference in NFR between a fully-irrigated crop and a dryland crop on the same acre indicates the farmer's ***maximum willingness to pay*** (WTP) for irrigation water.

- Lowest WTP: District 2 where dryland farming is more common
- Highest WTP: District 6. Pecans, only allocated to District 6, are the most valuable crop modeled.
- Willingness to pay ranges from $108/AF to $711/AF

Agriculture Value Forecast: Water Level Decline by District



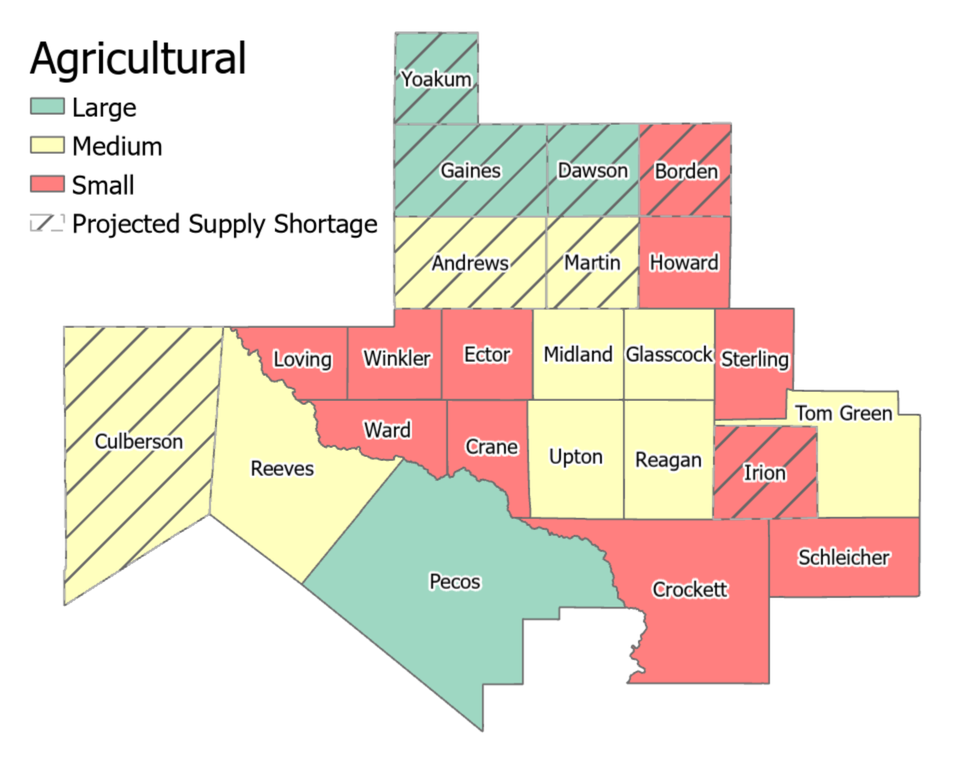
District 2 Aquifers	District 6 Aquifers		District 7 Aquifers
Ogallala	Ogallala	Dockum	Edwards-Trinity
Edwards-Trinity (High Plains)	Pecos Valley	Rustler	Lipan
Dockum	Edwards-Trinity	Captain Reef	Dockum

- Water level data for each district's underlying aquifers was used to estimate future declines. A future decline in water level is assumed to increase pumping depth by the same amount.
- Based on irrigation well observations from 1990-2023, water level trends indicate:
  - ***District 2 is seeing a decline of 1.5 ft/yr***
  - ***District 6 is seeing a decline of 0.2 ft/yr***
  - ***District 7 is seeing a decline of 1.8 ft/yr***
- Extrapolating these trends into future decades accommodates the estimation of future pumping costs.
- When groundwater supplies are plentiful, pumping costs represent the cost for water supply.
- Increased pumping costs due to water level decline had a negligible impact on NFR estimates in the crop budgets. Future maximum WTP is therefore held constant with current WTP.

Source: *Texas Water Development Board (1990-2023) Water levels by County.* *https://www3.twdb.texas.gov/apps/reports/GWDB/WaterLevelsByCounty*

Agriculture Value Forecast: Methods

Permian Basin Agricultural Demand Classes



Large (>100,000 AF)	Medium (10,000–100,000AF)	Small (<10,000 AF)

- Projected changes in pumping depths were used to adjust pumping costs to determine forecasted agricultural water prices paid.
- Forecasted water level declines are modeled for 2050
- As agricultural water use differs significantly throughout the Permian Basin, with most demand concentrated in a few counties, the forecasted value of irrigation water results was aggregated by magnitude of water demand into three demand classes, rather than A&M agricultural district:
  - Large demand class counties agricultural demand: > 100,000 AF
  - Medium demand class counties agricultural demand: 10,000–100,000 AF
  - Small demand class counties agricultural demand: < 10,000 AF
- The future market potential will likely be in the large demand class, especially those with a projected supply shortage.

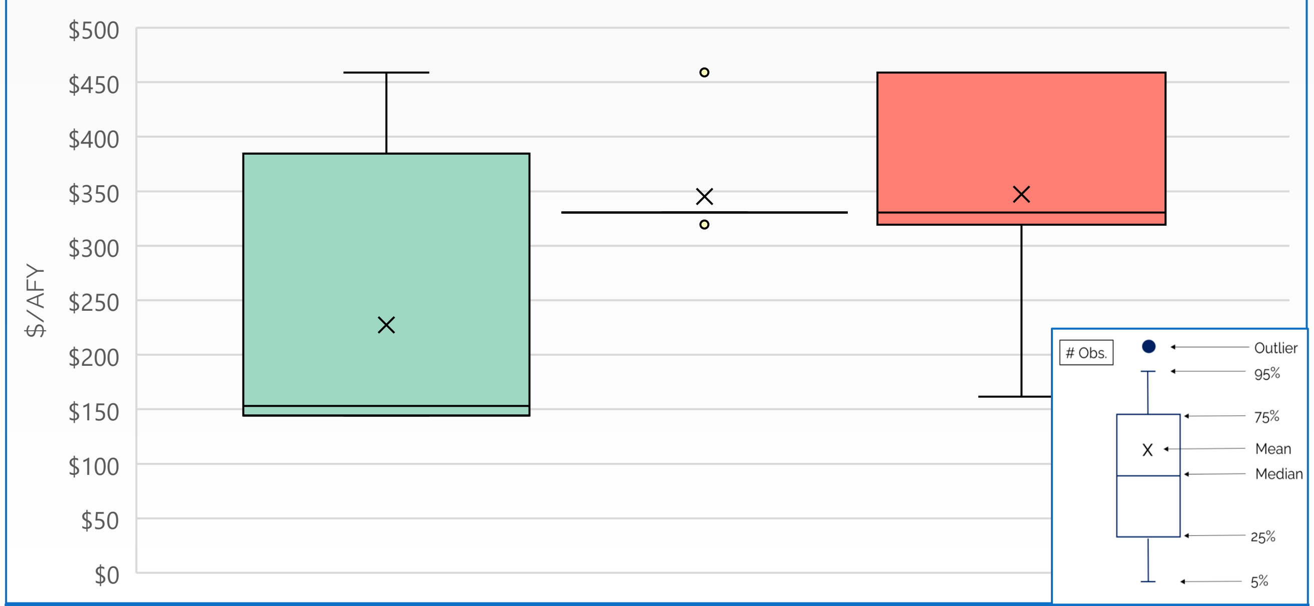
Agriculture Value Forecast: Results

Average Pumping Costs by Demand Class, 2020-2050 ($/AF)*									
Cost	Large (>100,000 AF)			Med. (10,000-100,000 AF)			Small (<10,000 AF)		
	2020	2050	Annual Growth Rate	2020	2050	Annual Growth Rate	2020	2050	Annual Growth Rate
Minimum	$13	$15	0.49%	$26	$31	0.63%	$14	$16	0.47%
Maximum	$32	$32	0.08%	$32	$35	0.36%	$32	$35	0.36%
Average	**$18**	**$20**	**0.31%**	**$30**	**$32**	**0.19%**	**$28**	**$31**	**0.37%**

**Values in 2024$/AF*

- Pumping costs do not change significantly when water levels decline.
- In the absence of a shortage, pumping costs represent the water price the market will bear ($13-$35/AF).
- Farmers in counties facing a projected shortage might *approach* WTP but would not exceed it.
- Pumping cost increases had a negligible impact on NFR and therefore future maximum WTP is set to current WTP.
- Maximum willingness to pay is highest for the counties in the small demand class. However, the large demand class is more likely the future market for additional water supply.

Agricultural Maximum Willingness to Pay by Demand Class, 2020-2050 ($/AF)



Large (>100,000 AF) [$/AFY]	Medium (10,000–100,000AF) [$/AFY]		Small (<10,000 AF) [$/AFY]	
Dawson: [$162]*	Andrews: [$330]*	Reagan: [$330]	Borden: [$162]*	Irion: [$319]*
Gaines: [$144]*	Culberson: [$330]*	Reeves: [$459]	Crane: [$459]	Loving: [$330]
Pecos: [$459]	Glasscock: [$330]	Tom Green: [$319]	Crockett: [$330]	Schleicher: [$319]
Yoakum: [$144]*	Martin: [$330]*	Upton: [$330]	Ector: [$459]	Sterling: [$319]
	Midland: [$330]		Howard: [$330]	Ward: [$459]
				Winkler: [$330]
Avg. for Large: $227/AF	**Avg. for Medium**	**$343/AF**	**Avg. for Small:**	**$347/AF**

*Counties with a projected shortage by 2050.

Municipal Water Valuation

Municipal Max WTP Estimate: EPA Criteria

- Using the Environmental Protection Agency's (EPA) affordability threshold of 2.5% of median income for household water expense,[1] a maximum WTP for municipal water was estimated for each county.
- As this method represents the retail level maximum WTP, the results were modified to a wholesale level by removing transmission and distribution costs using the following data and methodology:

Wholesale-level Max WTP = Retail-level Max WTP less Transmission & Distribution Costs

- Retail-level Max WTP = Median Household Income x Affordability Threshold (2.5%)
- Household income data by county is obtained from 2022 Census for all PB counties
- 26.5% of retail water costs are attributable to Trans. & Dist. Costs[2]
- 73.5% of Retail-level Max WTP is assignable as the Wholesale-level Max WTP for treated water

Final Model Specification

$$\boldsymbol{WTP_{Whole,i} = WTP_{Retail,i} \times WF} \quad \text{and} \quad \boldsymbol{WTP_{Retail,i} = HHI_i \times AT/HHC_i}$$

Where:

$WTP_{Whole,i}$ = Wholesale-level Max WTP for county *i* in $/AF

$WTP_{Retail,i}$ = Retail-level Max WTP for county *i* in $/AF

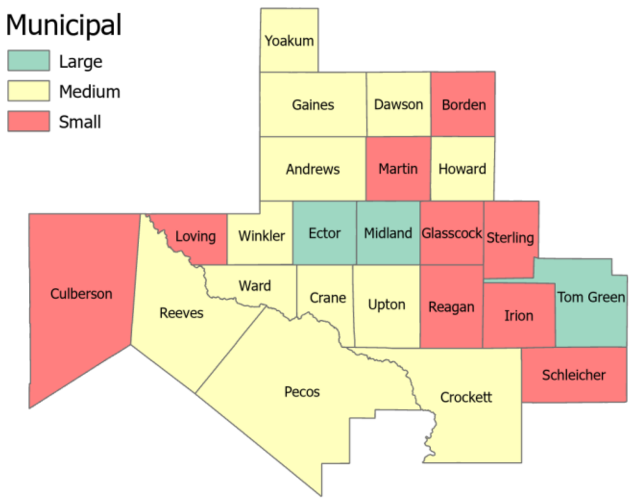
WF = Wholesale factor of 73.5%; portion of Retail-level Max WTP assignable for wholesale treated water

HHI_i = Median household income for county *i* per 2022 Census data

HHC_i = AF of household water consumption for county *i* (Average for 2017–21)

AT = EPA's household water Affordability Threshold of 2.5% of median HH income

Permian Basin Municipal Demand Classes

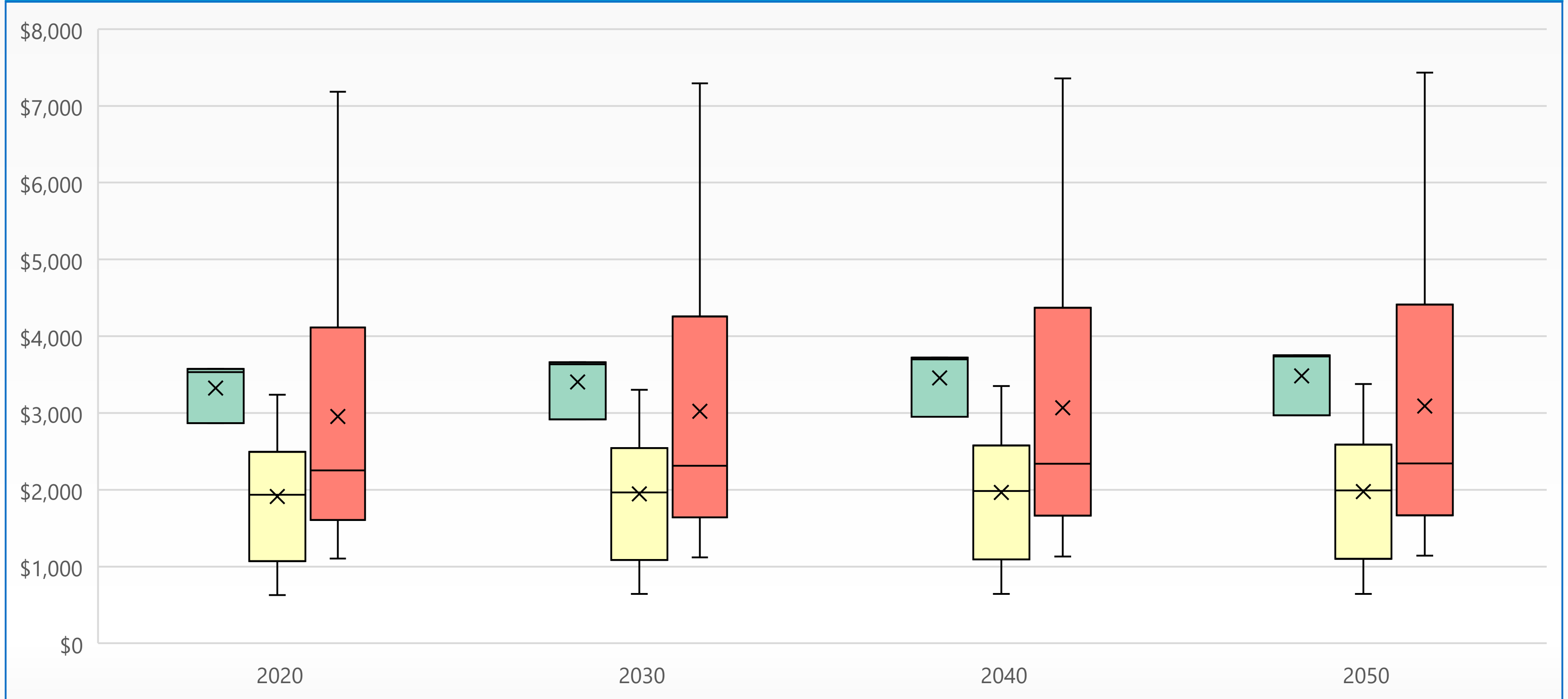


- **County-level results** were aggregated by demand class (large, medium, small):
  - **Large** demand class counties municipal demand > 10,000 AF
  - **Medium** demand class counties municipal demand of 1,000–10,000 AF
  - **Small** demand class counties municipal demand < 1,000 AF
- The large demand class is the most likely future market for additional supply, particularly if the counties are expected to see a growth in water use.

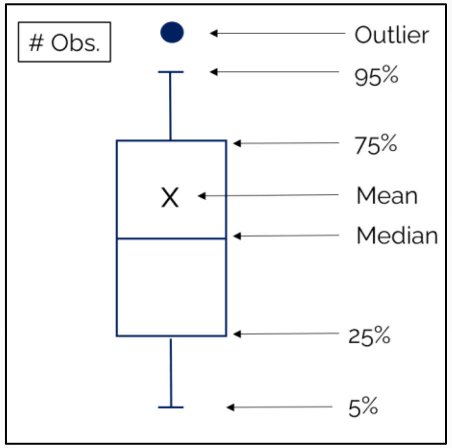
[1] **Source:** US EPA (2003). *Recommendations of the National Drinking Water Advisory Council to U.S. EPA on Its National Small Systems Affordability Criteria* (link).
[2] Inclusive of the portion of depreciation, payments to general and reserve funds, debt service, and capital improvements attributable to transmission and distribution system and 25% of "Other Routine Operating Expenses." [US EPA (2009). *2006 Community Water System Survey - Volume II: Detailed Tables and Survey Methodology* (link).

Municipal Max WTP Estimate: EPA Criteria

Maximum Municipal Willingness to Pay by Demand Class, 2020-2050 ($/AF)*



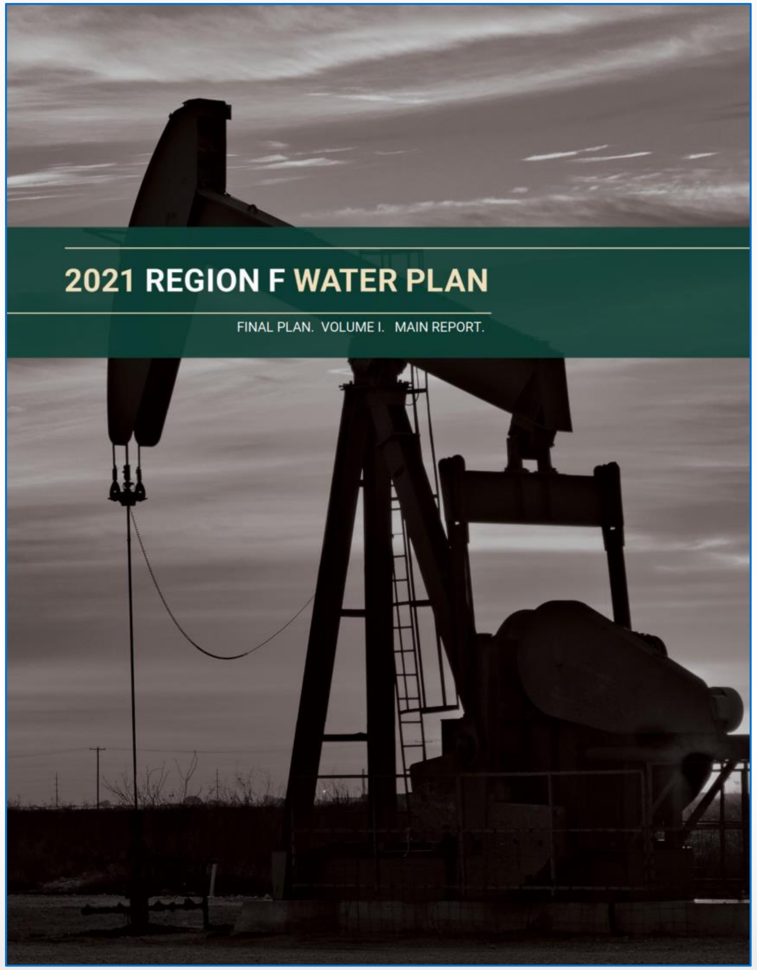
Large (>10,000 AF)				Medium (1,000–10,000 AF)				Small (<1,000 AF)			
Ector*				Andrews*	Gaines*	Upton		Borden		Loving	
Midland*				Crane	Howard	Ward		Culberson		Martin	
Tom Green*				Crockett	Pecos*	Winkler		Glasscock		Schleicher	
				Dawson	Reeves	Yoakum		Irion		Sterling	
Average $/AF by decade				**Average $/AF by decade**				**Average $/AF by decade**			
2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
$3,325	**$3,403**	**$3,457**	**$3,485**	**$1,912**	**$1,945**	**$1,966**	**$1,975**	**$2,953**	**$3,021**	**$3,068**	**$3,091**



- Projected per capita consumption through 2050 applied to 2017-2021 average household water use to forecast future decades' WTP/AF.
- HH consumption is projected to slightly decrease while median HH income is held constant.
- Therefore, WTP shows a slight increase for future decades.
- The maximum WTP is highest in the large demand class.

* *Counties with growing water demand through 2050*

Municipal: Replacement Cost Analysis



Valuation Goal

Estimating the least-cost alternative to develop a water supply for the water use sector under consideration or determining the costs of capital improvements necessary to maintain water supply at the level require to meet current and future demand of water.

Regional Water Plans Water Management Strategies

- As part of the regional planning process, each water management regions must provide a list of potential water managements strategies (WMS) to address current and/or future shortages of water for various water sectors.
- WestWater compiled the WMS located in all the Permian Basin counties, which included strategies from both planning Regions F and O.
- In total, 289 WMS and their costs were reviewed by WestWater to estimate applicable Replacement Costs. Each project falls under 1 of the 6 strategy categories listed below.
- Projects were filtered for specific attributes: recommended (vs alternative), infrastructure, and municipal sector as end use.
- Annualized unit cost calculated as the *levelized cost of water* for each infrastructure project for time-equivalent comparison.

Project Categories

Conservation/ Subordination	Reuse
Expanded Use of Existing Supply	Regional Management
Groundwater Development	Desalination

Analysis Filters

- Municipal End Use
- Infrastructure Projects
- MAG Dependent
- Recommended (vs Alternative)

Levelized Cost of Water (LCOW) Calculation*

- LCOW is the minimum unit price of water that when charged over the infrastructure service life ensures full cost recovery and calculated as:

$$LCOW_i = \frac{\sum_{t=0}^{T} C_{i,t}/(1+d)^t}{\sum_{t=0}^{T} Q_{i,t}/(1+d)^t}$$

Where:

$C_{i,t}$ is total costs for infrastructure project i in year t

$Q_{i,t}$ is total water yielded by infrastructure project i in year t

d is the discount rate

T is the total service life of infrastructure project i

For all evaluated infrastructure projects:

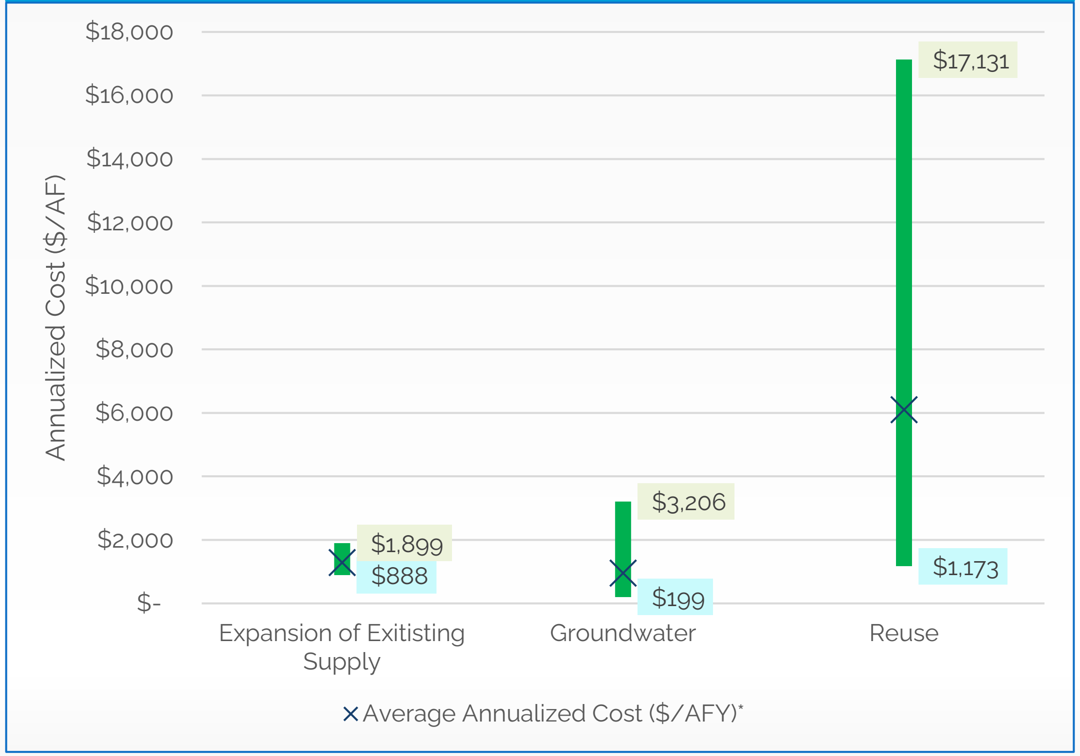
- Service life is set to 50 years—typical of large industrial well and water recycling plant expected service life.
- First year of cost analysis (i.e., $t = 0$) is 2024, even if this precedes the "project online" date, to maintain a consistent price level.
- Discount rate is 4.5%—the average bond yield for the longest termed bonds across a selection of large and medium Permian Basin municipalities.

*Annualized unit cost calculation based on the LCOW uses the WMS planning-level costs, reported as two components:

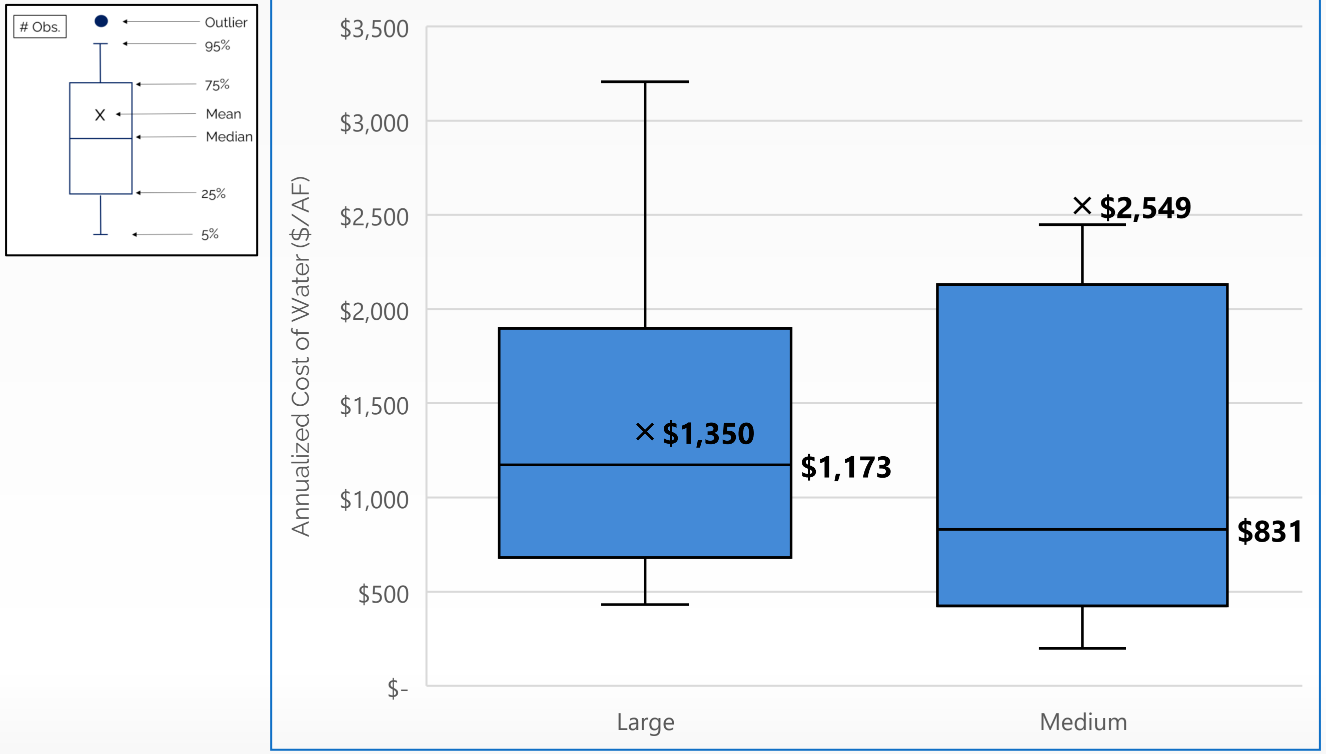
a. *Initial Capital Costs:* Including total construction cost of facilities, engineering & legal contingencies, environmental & archaeology studies & mitigation, land acquisition & surveying, and interest during construction (3% rate less a 0.5% rate of return on investment of unspent funds).

b. *Average Annual Costs:* Including annual operation & maintenance costs, pumping energy costs, purchase of water and debt service.

Municipal Value: Current Replacement Costs



Note: Recommended municipal infrastructure WMS only.

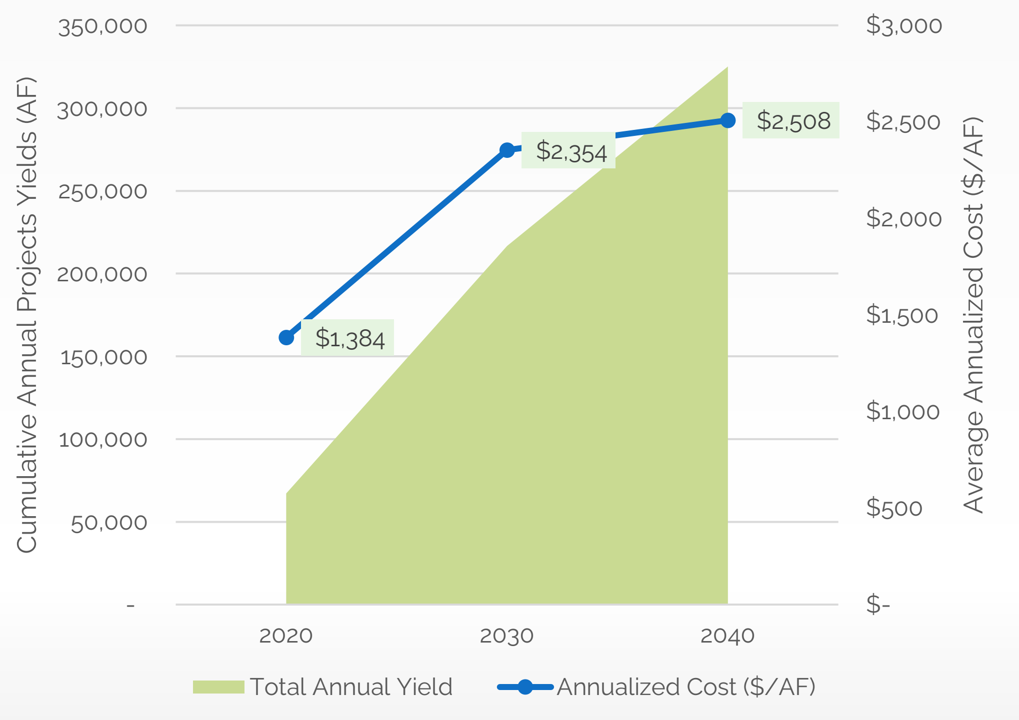


Note: Recommended municipal infrastructure WMS LWC only. Dawson County in Region O includes one groundwater recharge project with an annualized cost of $17,131/AF, which is an outlier not shown on the graph.

- For the municipal water use sector, annualized costs for recommended projects vary across strategy types and demand sizes.
- Among recommended municipal WMS, **projects intended to develop groundwater supplies had the lowest average annual cost at $951/AF.** Projects designed to expand existing supplies, such as municipal water treatment plant capacity expansion, averaged $1,285/AF per year, and reuse project costs varied significantly, bringing the average annualized cost to $6,096/AF.
- Recommended municipal WMS were only reported for counties in the Large and Medium water demand classes, with **larger municipal centers having a higher average strategy cost per AF than medium municipalities,** all strategy types combined.

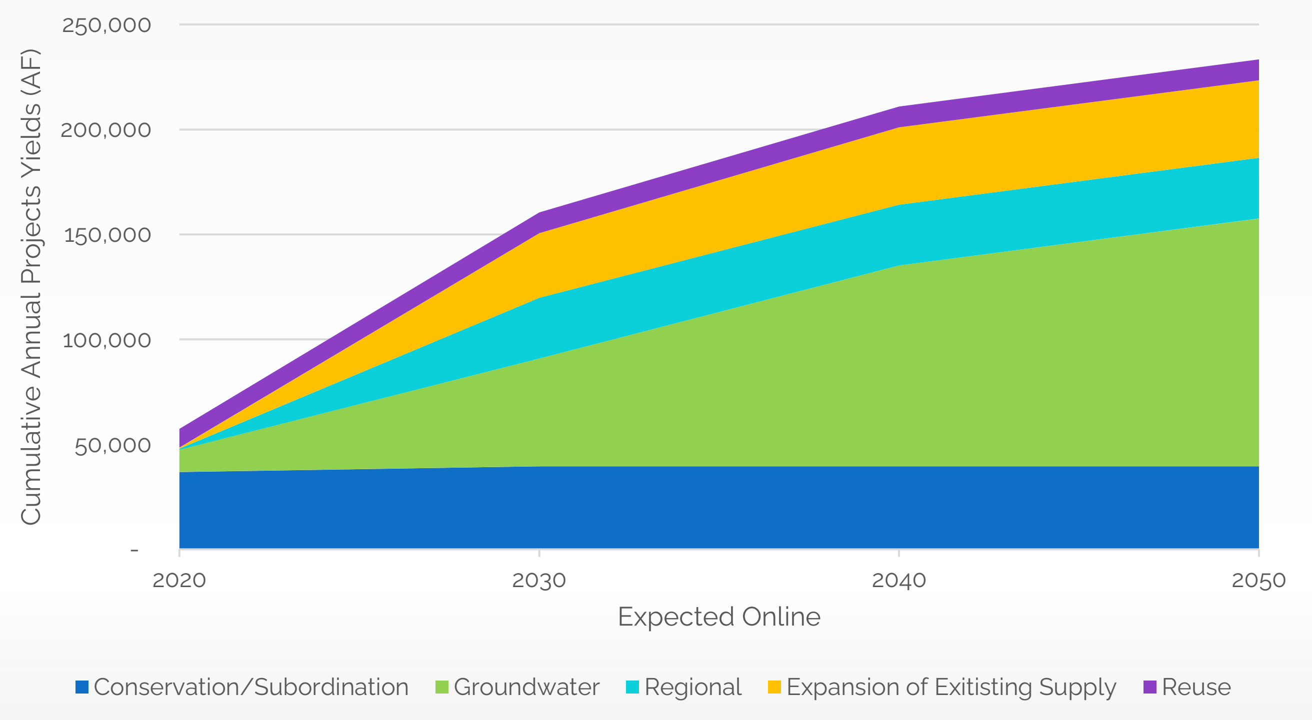
Municipal Value: Forecasted Replacement Costs

Municipal Projects Annualized Cost, Per Expected Online



Note: All municipal WMS.

Permian Basin Water Supply Strategies, Cumulative Yield per Project Type

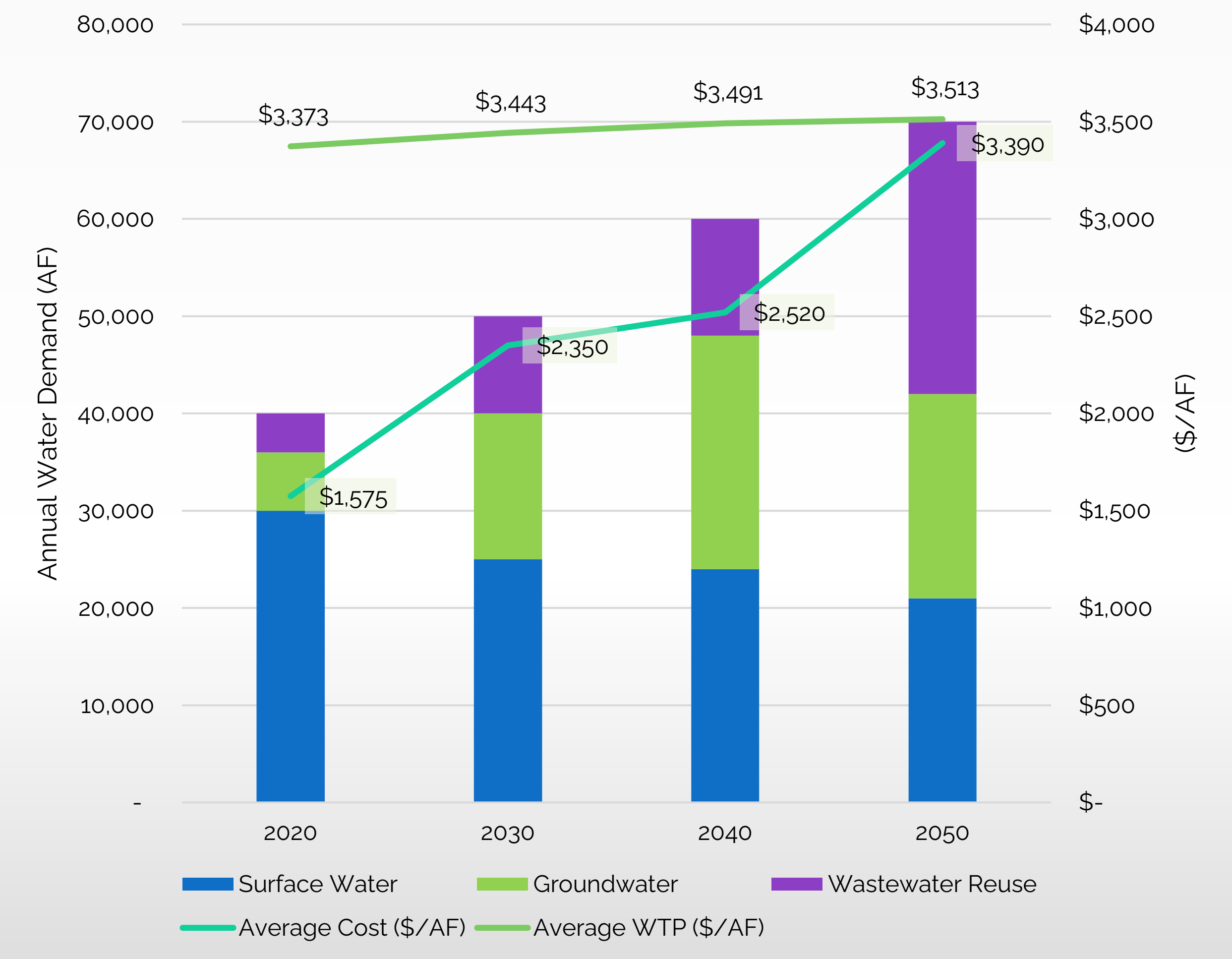


Note: Recommended municipal WMS only.

- Regional water management plans also include when the WMS are expected to be implemented, or “Expected Online.” As shown above, annualized costs of the WMS increase over time (in 2024$). The cost of a marginal new source of water supply increases due to the type of strategy implemented, with the lower cost strategies, such as groundwater development and conservation, implemented first, followed by more expansion strategies with the most complex and costly projects.
- **In 2040, a marginal increase of water is estimated to cost an annualized cost of $2,508/AF, an 180% increase from 2020 project costs. This value is representative of the future least cost alternative to develop new water supplies in the Permian Basin.**

Municipal Value: Portfolio Analysis

Example of Average Cost of a Municipal Water Supply Portfolio vs Willingness to Pay



- Municipalities often have a portfolio of water supply sources, which can have different annualized costs. When evaluating a new potential water supply, a municipality will evaluate the blended cost of their portfolio to determine if the new water management strategy is feasible.
- In the example illustrated in the figure, a municipality may be willing to invest in a more expensive source of future supply, as long as the blended cost of water does not exceed the willingness to pay of its consumers.

Supply Source	Supply Cost ($/AF)	Annual Demand (AF)			
		2020	2030	2040	2050
Surface Water	800	30,000	25,000	24,000	21,000
Groundwater	2,500	6,000	15,000	24,000	21,000
Wastewater Reuse	6,000	4,000	10,000	12,000	28,000
Annual Demand		40,000	50,000	60,000	70,000
Average Cost ($/AF)		1,575	2,350	2,520	3,390
Average WTP ($/AF)		3,373	3,443	3,491	3,513

Municipal Max WTP: Shortage Avoidance

- An indication of the value ceiling for municipal water supply is estimated as the willingness to pay to avoid a shortage.
- This analysis applies a price elasticity of-0.3 to a constant elasticity of demand function calibrated to price and demand information from a selection of municipalities in the Permian Basin.
- The willingness to pay for 1 AF of water is calculated under multiple shortage assumptions from 2030-2050

$$Value_x = k_x \frac{\eta}{1+\eta}\left[(D_x - Q_R)^{\left\{\frac{\eta}{1+\eta}\right\}} - (D_x + 1 + Q_R)^{\left\{\frac{\eta}{1+\eta}\right\}}\right]$$

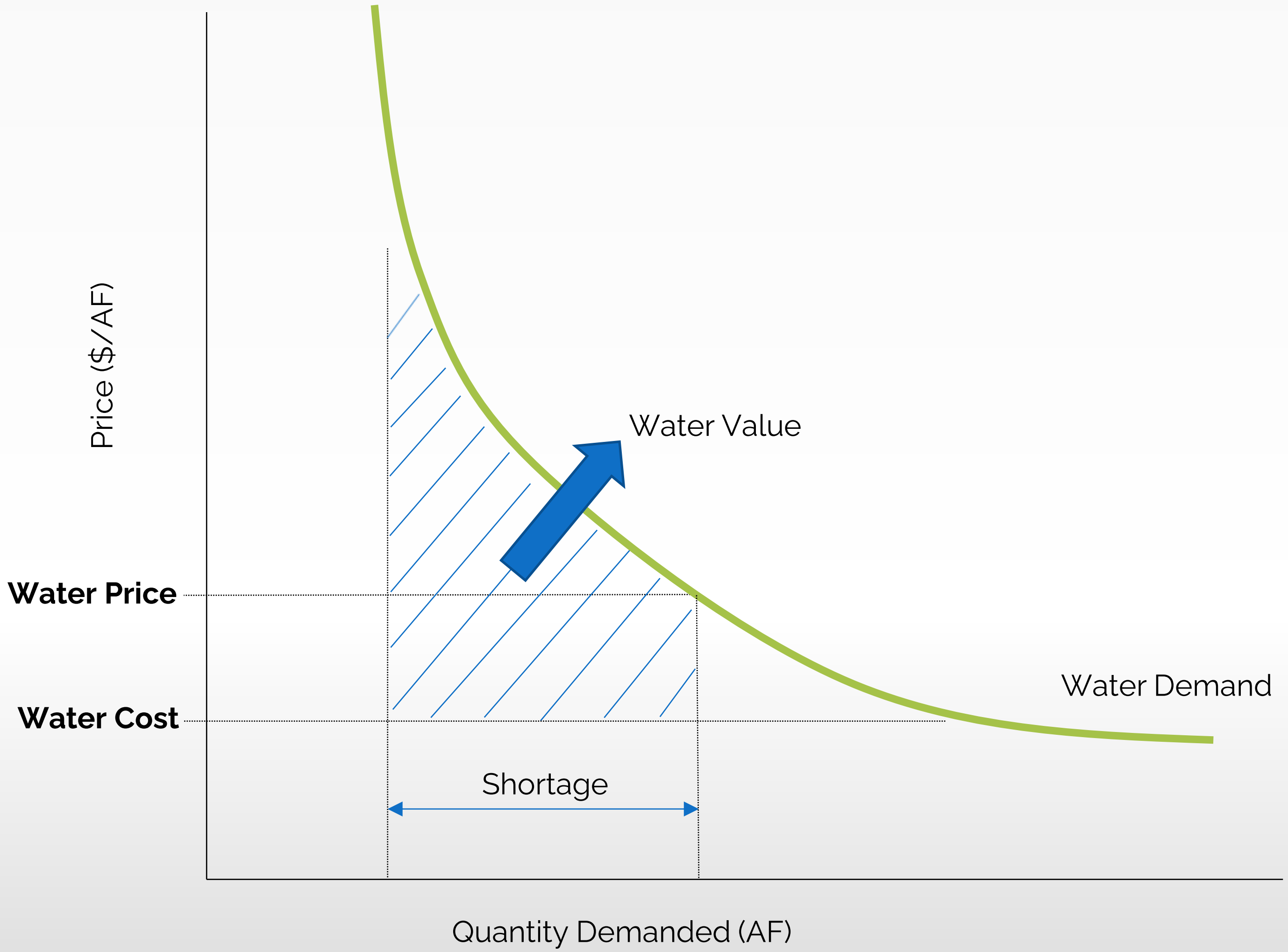
Where:

k_x = *integration constant based on existing water price and demand*

D_x = *projected demand in year x*

Q_R = *projected shortage of supplies*

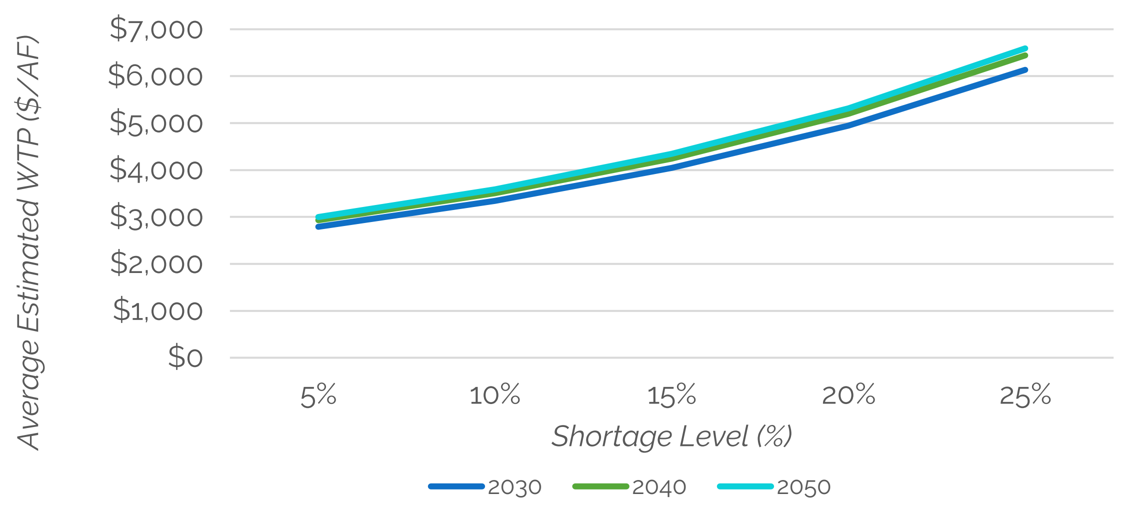
η = *the long-run price elasticity of demand*



Municipal Shortage Avoidance: Results

City	2023 Retail Price[1] ($/AF)	2023 Demand[3] (AF)
Odessa	$2,513	22,482
Pecos City	$2,186	2,990
Andrews	$1,825	4,270
Seminole	$1,792	2,348
Monahans	$1,592	2,518
Kermit	$1,010	1,774
Denver City	$1,382	1,423
Crane	$2,085	1,262
Big Lake	$1,916	731
Stanton	$2,914	539
Seagraves	$3,519	419
Van Horn	$1,466	662
McCamey	$1,209	776
Plains	$2,607	432
Wink	$1,215	360
Coahoma	$3,969	183
O'Donnell	$4,049	123
Mertzon	$2,835	102

Estimated WTP under Multiple Shortage Scenarios (2030-2050), ($/AF



Estimated WTP under Multiple Shortage Scenarios (2030-2050), ($/AF

Shortage Level	Year		
	2030	2040	2050
5%	$2,790	$2,931	$2,999
10%	**$3,341***	$3,509	$3,591
15%	$4,043	$4,246	**$4,344****
20%	$4,948	$5,196	$5,317
25%	$6,135	$6,443	$6,593

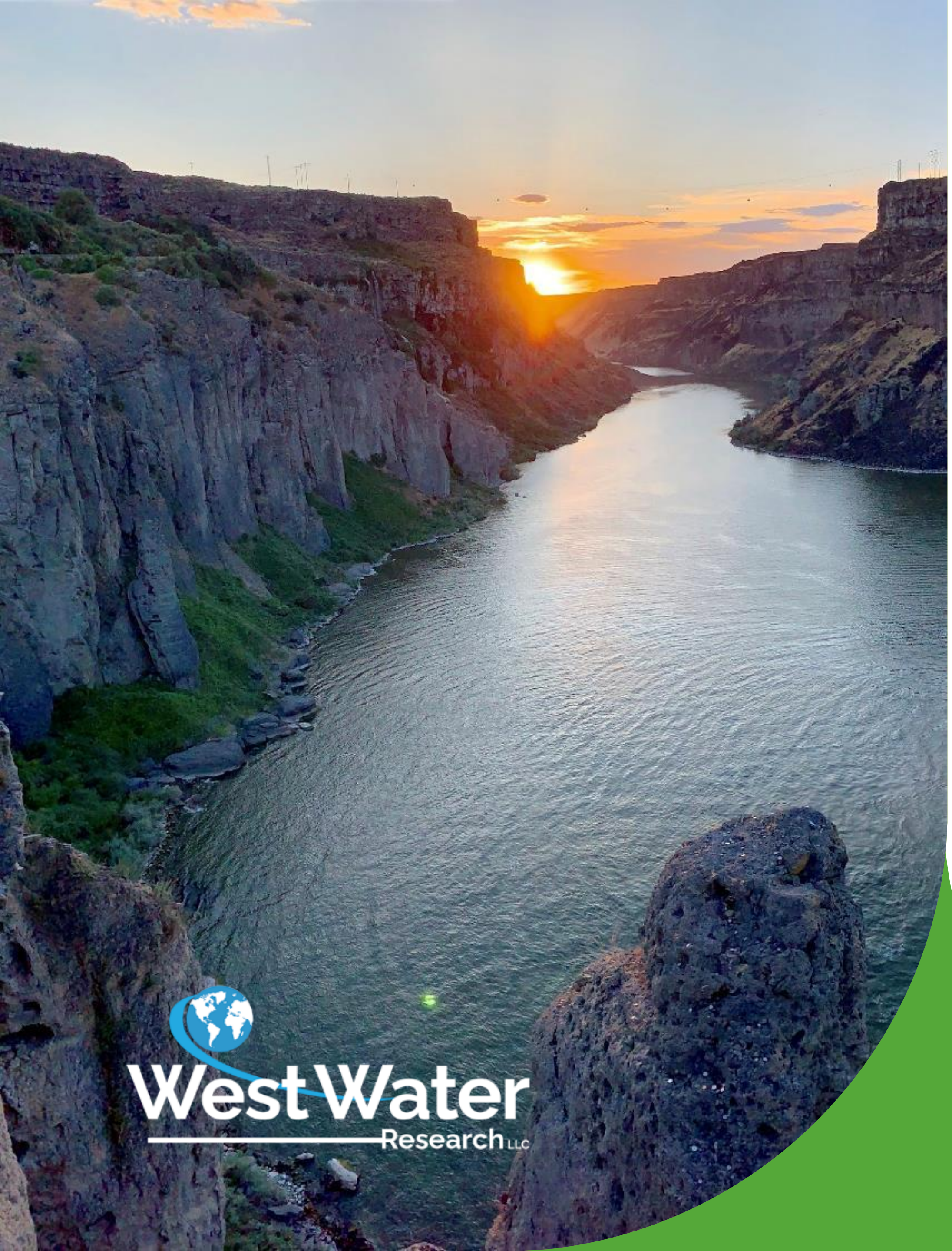
*Average projected shortage across the Permian Basin in 2030 is 9.4%.
**Average projected shortage across the Permian Basin in 2050 is 13.7%.

Source[1] Texas Municipal League (2023). *2023 Water and Wastewater Survey.* https://www.tml.org/229/Water-Wastewater-Survey-Results
Source[2] Texas Water Development Board (2016). *2016 Regional Water Plan - Population Projections for 2020-2070 City Summary.* https://www3.twdb.texas.gov/apps/reports/Projections/pop_City
Source[3] Texas Water Development Board (2016). 2016 *Regional Water Plan - Municipal Water Demand Projections for 2020-2070 City Summary.* https://www3.twdb.texas.gov/apps/reports/Projections/pop_City

Valuation Results: Current and Forecasted Market Values

Water Sector	Valuation Approach	Water Value Estimates: Average by Demand Class (2024 price level)					
		Large		Medium		Small	
		$/AF	$/bbl	$/AF	$/bbl	$/AF	$/bbl
Current Value (stated in 2024$)							
Agriculture	Pumping Costs *Willingness to Pay (WTP)*	$18 *$227*	$0.002 *$0.022*	$30 *$343*	$0.003 *$0.033*	$28 *$347*	$0.003 *$0.034*
Municipal	Replacement Costs *WTP – EPA Threshold* *WTP – Shortage Avoidance*****	$1,350 *$3,325* *$3,341*	$0.131 *$0.321* *$0.323*	$831* *$1,912* *$3,341*	$0.80* *$0.185* *$0.323*	-- *$2,953* *$3,341*	-- *$0.285* *$0.323*
Future Value (forecasted to year 2050, stated in 2024$)							
Agriculture	Pumping Costs *Willingness to Pay*	$20 *$227*	$0.002 *$0.033*	$32 *$345*	$0.003 *$0.033*	$31 *$347*	$0.003 *$0.034*
Municipal	Replacement Costs*** *WTP – EPA Threshold* *WTP – Shortage Avoidance*****	$2,508 *$3,485* *$4,344*	$0.242 *$0.337* *$0.420*	$2,508 *$1,975* *$4,344*	$0.242 *$0.191* *$0.420*	$2,508 *$3,091* *$4,344*	$0.242 *$0.299* *$0.420*

*Median value due to significant upward skewness of mean. All other values presented are mean.
**Average across Permian Basin – inadequate data to estimate by demand class. Current: 2030 basin-wide average shortage of 9.4%; Future: 2050 basin-wide average shortage of 13.7%.
***Average municipal project costs **up to 2040** across Permian Basin – inadequate data to estimate by demand class.



Thank You

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Appendix A

Appendix A
Agricultural Valuation Data Sources

Data Variable	Source
Average Well Depth	• Texas Water Development Board (2024). *Groundwater Database (GWDB) Record of Wells Report.* *https://www3.twdb.texas.gov/apps/reports/GWDB/RecordOfWellsByCounty* • Personal with Communication with Texas A&M Extension District Offices
Average Farm Size	• USDA, National Agricultural Statistics Service (2017). *Farms, Land in Farms, Value of Land and Buildings, and Land Use.* https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/st48_2_0008_0008.pdf • Personal with Communication with Texas A&M Extension District Offices
Application rate of water by irrigated crops	• Texas A&M Extension (2023). *Texas Crop and Livestock Budgets.* *https://agecoext.tamu.edu/resources/crop-livestock-budgets/budgets-by-extension-district/district-6-far-west/2023-district-6-texas-crop-and-livestock-budgets/* • Borrelli, J. et al (1998). *Mean Crop Consumptive Use and Free-Water Evaporation for Texas.* *https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/95483137.pdf* • Personal with Communication with Texas A&M Extension District Offices
Pressurization requirements (PSI) and application efficiency	• Amosson, S. et al (2011). *Economics of Irrigation Systems.* *https://amarillo.tamu.edu/files/2011/10/Irrigation-Bulletin-FINAL-B6113.pdf* • Personal with Communication with Texas A&M Extension District Offices
Cost of electricity (base rate and monthly charges)	• Concho Valley Electric Cooperative (2022). *Rate Schedule I: Irrigation Service.* *https://cvec.coop/services/electric/rates* • Xcel Energy (2022). *Electric Tariff.* *https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/IV-173,%20Rev%2011%20-%20Primary%20General%20Service%20%20(3-1-22).pdf*
Price and Yield Data	• Texas A&M Extension (2023). *Texas Crop and Livestock Budgets.* *https://agecoext.tamu.edu/resources/crop-livestock-budgets/budgets-by-extension-district/district-6-far-west/2023-district-6-texas-crop-and-livestock-budgets/* • USDA, National Agricultural Statistics Service (2022). *Crop Yields.* *https://quickstats.nass.usda.gov/* • Personal with Communication with Texas A&M Extension District Offices