2021 PANHANDLE WATER PLAN

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NOVEMBER 2020

Prepared for:

PANHANDLE WATER PLANNING GROUP

10/30/2020

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
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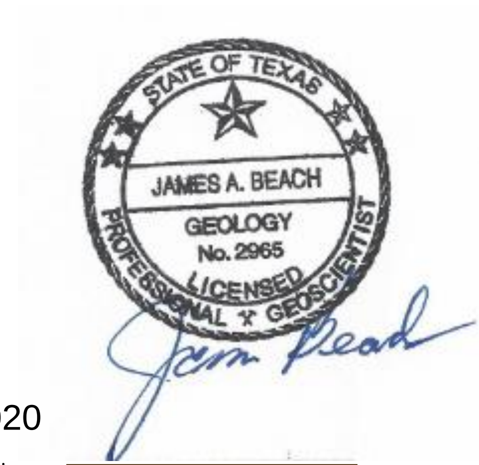
F-2144



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Preface

In 1997, the 75th Texas Legislature passed Senate Bill One, legislation designed to address Texas water issues. Senate Bill One put in place a grass-roots regional process to plan for the future water needs of all Texans. To implement this process, the Texas Water Development Board created 16 regional water planning groups across the state and established regulations governing regional planning efforts. This plan presents the results of this process for the Panhandle Water Planning Area that represents 21 counties in the Texas Panhandle.

In accordance with the State planning guidelines, the regional water plan includes eleven specific chapters. In addition to the eleven required sections, this report also includes appendices providing more detailed information on the planning efforts. The elements contained in this plan meet Texas Water Development Board regional planning requirements and guidelines.

The *2021 Panhandle Water Plan* represents the culmination of five years of working together with the PWPG, regional and local water providers, and the public. As you read this water plan, the PWPG would like you to keep in mind the following points:

- The *2021 Panhandle Water Plan* presents a comprehensive overview of the water supply issues in the region. It does not predict or forecast future water droughts or floods.
- This plan is a living document that will change as new data become available that better represent the demands on our water resources, available supplies from these resources, and the water supply projects that are being pursued.
- The report presents planning level analyses of the recommended water management strategies. Additional engineering studies and design will be needed prior to the implementation of the strategies.
- The specific surpluses and needs shown in the plan should be treated with caution because their development requires certain assumptions that may or may not come to fruition.
- The PWPG has no authority to regulate water supplies or implement water management strategies. The identified water management strategies are assumed to be implemented by the respective water user.

2021 Panhandle Water Plan Chapters

1. Planning Area Description
2. Current and Projected Population and Water Demand
3. Evaluation of Regional Water Supplies
4. Identification of Water Needs
5. Water Management Strategies
6. Impacts of the Regional Water Plan
7. Drought Response Information, Activities and Recommendations
8. Regulatory, Administrative and Legislative Recommendations
9. Water Infrastructure Funding Recommendations
10. Plan Adoption and Public Participation
11. Implementation and Comparison to Previous Regional Water Plan

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2021 PANHANDLE WATER PLAN. VOLUME II. APPENDICES.

LIST OF ACRONYMS

Acronym	Name	Meaning
ASR	Aquifer Storage and Recovery	A type of water management strategy that stores water underground for future extraction and use
CRMWA	Canadian River Municipal Water Authority	Water authority that operates Lake Meredith and a well field in Roberts County.
DFC	Desired Future Condition	Criteria for which is used to define the amount of available groundwater from an aquifer.
GAM	Groundwater Availability Model	Numerical groundwater flow model. GAMs are used to determine the aquifer response to pumping scenarios. These are the preferred models to assess groundwater availability.
GCD	Groundwater Conservation District	Generic term for all or individual state recognized Districts that oversee the groundwater resources within a specified political boundary.
GMA	Groundwater Management Area	Sixteen GMAs in Texas. Tasked by the Legislature to define the desired future conditions for major and minor aquifers within the GMA.
MAG	Modeled Available Groundwater	The MAG is determined by the TWDB based on the DFC approved by the GMA. Once the MAG is established, this value must be used as the available groundwater in regional water planning.
MWP	Major Water Provider	A WUG or WWP of particular significance to the region's water supply as determined by the regional water planning group.
PDWD	Palo Duro Water District	Water district that operates Palo Duro Reservoir in Hansford County.
PGMA	Priority Groundwater Management Area	Area designated by TCEQ for purposes of protecting the groundwater resources within the area.
PWPA	Panhandle Water Planning Area	The 21-county area in the Texas Panhandle that comprises the regional water planning area for this plan. Also referred to as Region A.
PWPG	Panhandle Water Planning Group	Regional planning group comprised of representatives from diverse interest groups. Responsible for development of five year regional water plans in the Texas Panhandle.

Acronym	Name	Meaning
RWPG	Regional Water Planning Group	The generic term for the planning groups that oversee the regional water plan development in each respective region in the State of Texas
SB1	Senate Bill One	Legislation passed by the 75th Texas Legislature that is the basis for the current regional water planning process.
SB2	Senate Bill 2	Legislation passed by the 77th Texas Legislature that built on policies created in SB1.
TCEQ	Texas Commission on Environmental Quality	Texas Agency charged with oversight of Texas surface water rights and WAM program.
TWDB	Texas Water Development Board	Texas Agency charged with oversight of regional water plan development and oversight of GCDs
WAM	Water Availability Model	Computer model of a river watershed that evaluates surface water availability based on Texas water rights.
WMS	Water Management Strategy	Strategies available to RWPG to meet water needs identified in the regional water plan.
WUG	Water User Group	A group that uses water. Six major types of WUGs: municipal, manufacturing, mining, steam electric power, irrigation and livestock.
WWP	Wholesale Water Provider	Entity that has or is expected to have contracts to sell wholesale water.

EXECUTIVE SUMMARY

Introduction

> **Executive Summary Related Documents**
>
> - Attachment ES 1: Water Management Strategy and Project Reports
> - Attachment ES 2: County Summaries
> - Appendix J: TWDB Data Tables

In 1997, Senate Bill 1 (SB1) began a comprehensive water planning and management effort using a "bottom up" approach to ensure that the water needs of all Texans are met as we entered the 21st Century. Regional water plans map out how to conserve water supplies, meet future water supply needs and respond to future droughts in the planning areas. The Panhandle Water Planning Group (PWPG) was formed to develop a 50-year regional water plan for the Panhandle Water Planning Area (PWPA). Since the initiation of this process, the PWPG has overseen the development of four regional water plans. This plan is the fifth regional water plan, which is an update of the 2016 Regional Water Plan for the PWPA.

Associated data necessary in developing the plan is included in several chapter attachments and appendices. The plan's required database reports are in Appendix J.

Planning Area Description

The PWPA consists of a 21-county area that includes Armstrong, Carson, Childress, Collingsworth, Dallam, Donley, Gray, Hall, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Potter, Randall, Roberts, Sherman, and Wheeler Counties (see Figure ES-1).

The economy and water use in the PWPA are heavily driven by agriculture and supporting agribusiness and manufacturing. The petroleum industry and tourism continue to contribute to the regional economy. As such the major water uses include irrigation, agricultural production, petroleum refining, food processing and kindred, chemical and allied products, and electric power generation.

Non-agricultural water use is generally provided through cities, wholesale water providers or developed directly from underlying aquifers.

Population and Water Demand Projections

In 2016, the region accounted for 1.5 percent of the State's total population and approximately 15 percent of the State's annual water demand. Projections show total water use for the region will decline over the 2020-2070 period, primarily due to an expected reduction in agricultural irrigation water requirements. Irrigation water use is expected to decline because of projected insufficient quantities of groundwater to meet future irrigation water demands, implementation of conservation practices, advances in plant breeding, implementation of new crop varieties, and the use of more efficient irrigation technology.

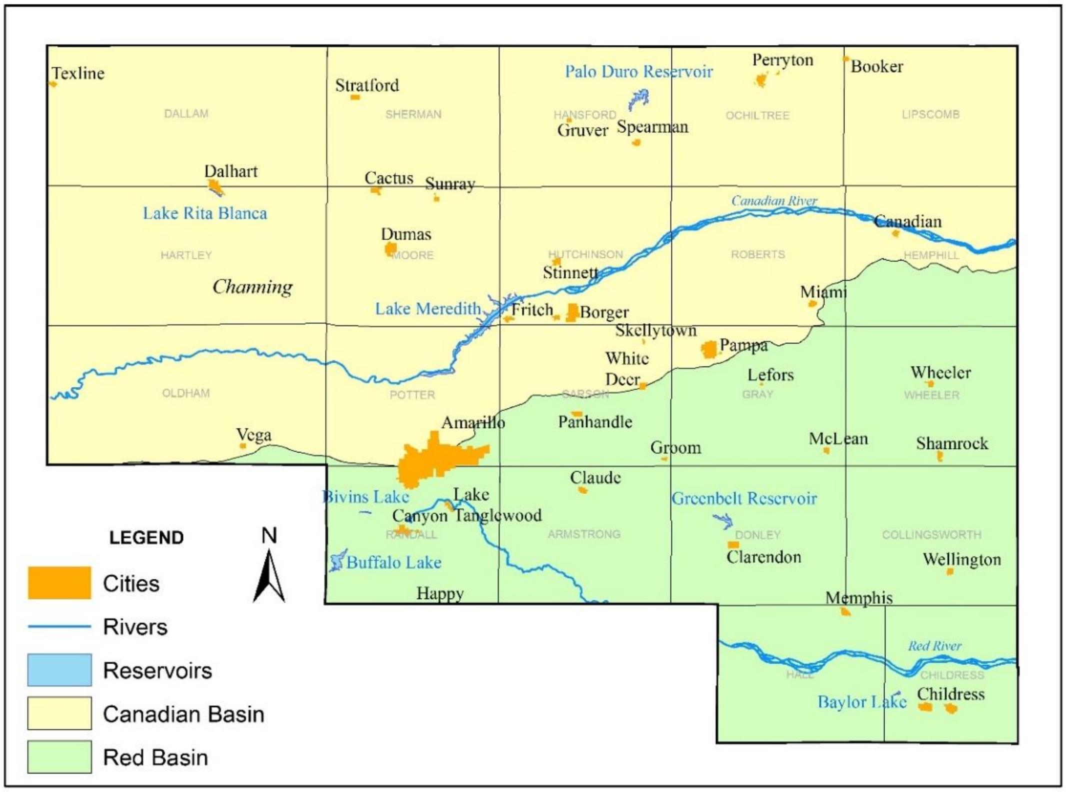


Figure ES-1: Cities in the PWPA

PWPA Major Water Providers

- City of Amarillo
- Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA)
- Canadian River Municipal Water Authority (CRMWA)
- City of Borger
- City of Cactus

Regional population is expected to grow from 418,345 in 2020 to 637,412 in 2070. Much of this growth is located in larger cities and surrounding rural areas. Projections for water demand indicate that total annual water usage in the PWPA will decrease from 2,130,529 acre-feet in 2020 to 1,598,115 acre-feet in 2070. Hartley County has the highest projected water use of 415,197 acre-feet per year in 2020 decreasing to 238,315 acre-feet per year by 2070. Dallam County and Sherman County demands are slightly less but similar in demand levels. For all three of these counties, irrigation use accounts for approximately 98 percent of the demand. Only Randall and Potter Counties have substantial projected increases in demand during the planning period. This is due to the projected increases in municipal demand associated with Amarillo and surrounding areas. The remaining 19 counties are projected to have flat or decreased projected water demand during the planning period, which is mostly attributed to declining irrigation demands.

Table ES-1: Projected Population and Water Demands in PWPA

	2020	2030	2040	2050	2060	2070
Population	418,345	460,448	502,685	545,895	590,781	637,412
Water User Group	**Water Demands (ac ft/yr)**					
Irrigation	1,919,070	1,914,141	1,763,959	1,549,038	1,335,673	1,335,673
Livestock	39,759	43,437	45,731	48,196	50,847	53,700
Manufacturing	49,370	52,834	52,834	52,834	52,834	52,834
Mining	11,330	9,909	7,223	4,465	2,996	2,968
Municipal	92,446	99,608	107,097	115,454	124,680	134,386
Steam Electric Power	18,554	18,554	18,554	18,554	18,554	18,554
Total	**2,130,529**	**2,138,483**	**1,995,398**	**1,788,541**	**1,585,584**	**1,598,115**

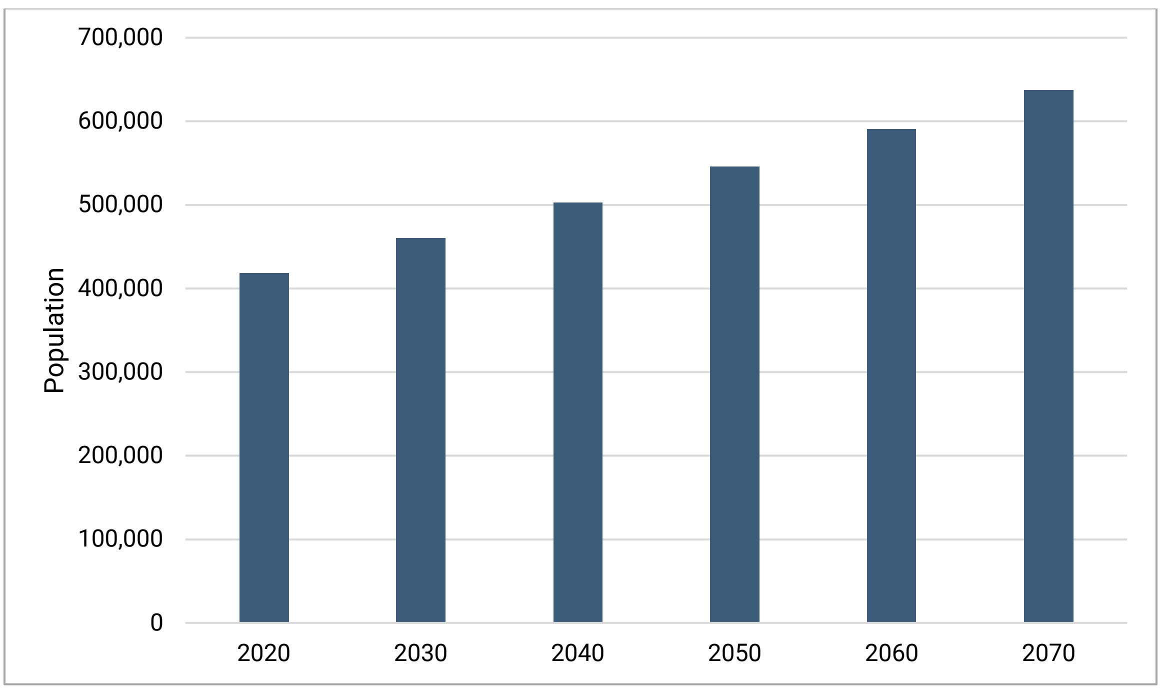


Figure ES-2: PWPA Population

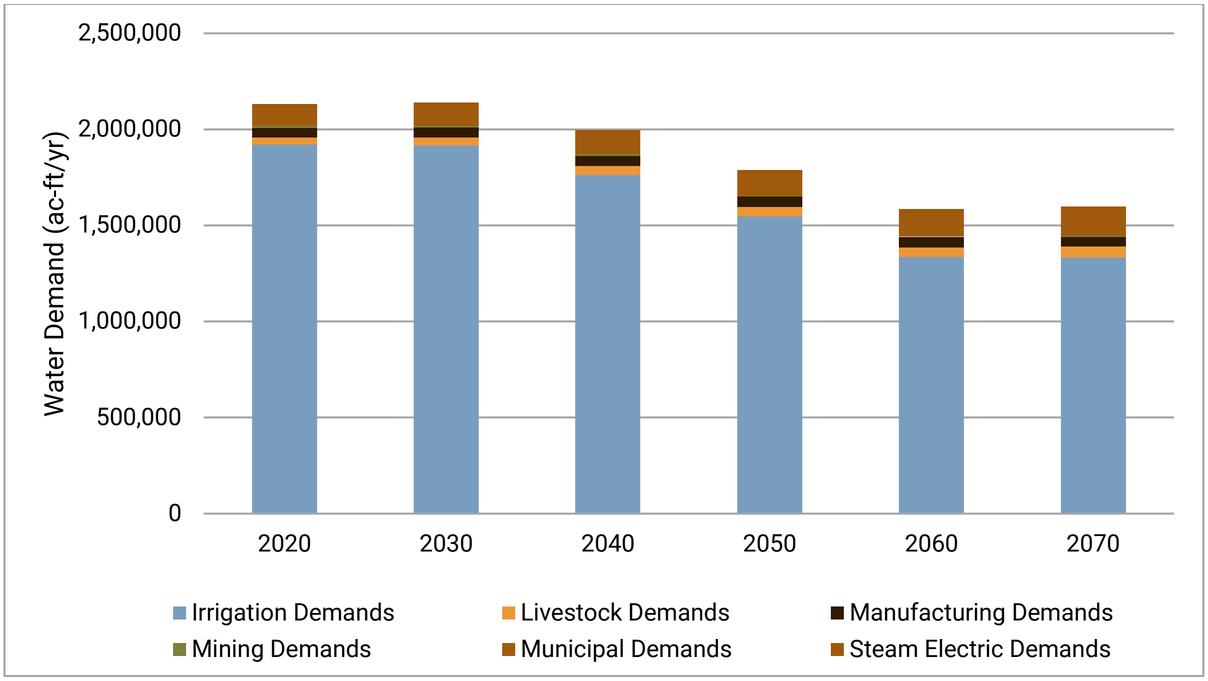


Figure ES-3: Projected Demands in the PWPA

Water Supply Analysis

The PWPA is located within portions of the Canadian River Basin and Red River Basin. In 2016, only one percent of the total water use in the PWPA came from surface water sources. There are three major reservoirs in the PWPA: Lake Meredith, Palo Duro Reservoir, and Greenbelt Reservoir. According to the TCEQ's State of Texas Water Quality Inventory, the principal water quality problems in the Canadian and Red River Basins are elevated dissolved solids, nutrients, nitrates and dissolved metals.

Surface water supplies in the region were determined through water availability models (WAM) and other hydrologic modeling of the Red and Canadian Basins. The challenge with determining reliable surface water supply in the PWPA is that the region is in critical drought conditions.

Water Supply in PWPA

- 2 River Basins: Red River, Canadian River
- 2 Major aquifers: Ogallala & Seymour
- 3 Minor aquifers: Dockum, Blaine & Rita Blanca
- 4 Million acre feet per year of supply

Record low inflows in the Canadian and upper Red River Basins have severely impacted water availability in the region. For planning purposes, estimates of reliable supply from Lake Meredith and Greenbelt Reservoir were assessed based on extended hydrology through 2017 and 2016, respectively. For Palo Duro Reservoir, the yield as determined from the Canadian

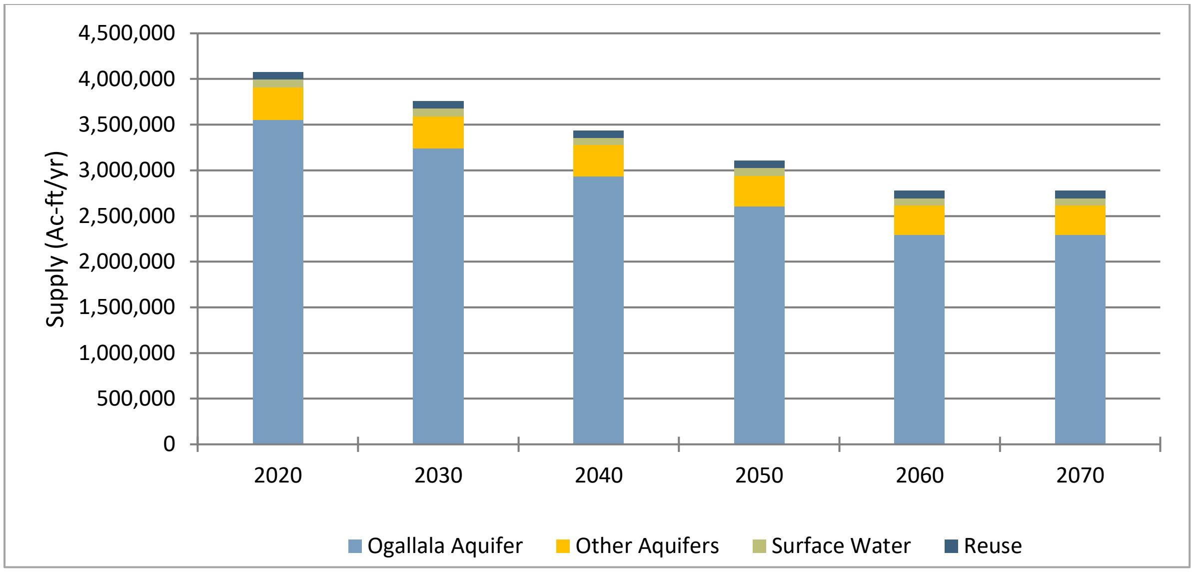


Figure ES-4: Total Available Supplies in the PWPA[11]

WAM was reported. This resulted in changes to available surface water supplies in the region (see Table ES-2). Lake Meredith is shown to have greater reliability than in the 2016 Plan, and the reliable supply of Greenbelt Reservoir was reduced by over 20 to 35 percent as compared to the 2016 Plan. For both Lake Meredith and Greenbelt Reservoir, the 2021 Plan uses the one-year safe yield for supply availability, which is defined as the amount of water that can be diverted annually, leaving a minimum of a one-year supply in reserve during the critical period. While the firm yield of Palo Duro Reservoir is reported to be slightly less than 4,000 acre-feet per year, the yield will need to be reassessed prior to using this source for water supply. Currently, the reservoir is only 5 percent full.

Groundwater sources in the PWPA include two major and three minor aquifers. These include the Ogallala, Seymour, Blaine, Dockum, and Rita Blanca aquifers. The Rita Blanca aquifer underlies the Ogallala aquifer in the northwestern part of the region, and it was analyzed as part of the Ogallala aquifer. Groundwater availability in the PWPA is based on desired future conditions as adopted through the joint planning process. These desired future conditions were modeled using available groundwater models to determine the annual availability from these sources. In total, the PWPA has over 3.9 million acre-feet per year of groundwater in 2020. The Ogallala aquifer constitutes 90 percent of the total groundwater availability in the PWPA. This is consistent with the use of these resources. However, in the southern and southwestern part of the region the Ogallala is either not present or only partially present, which necessitates the reliance on other groundwater sources.

[1] The total available supply is the reliable supply from sources in the PWPA. This differs from the developed water that is currently available to water users in the PWPA. Developed water considers infrastructure and availability to deliver the water to the end user.

Table ES-2: Available Water Supplies in the PWPA

Source	Supply (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Lake Meredith[1]	24,669	24,635	24,602	24,568	24,534	24,501
Greenbelt Lake[1]	3,112	2,941	2,770	2,599	2,428	2,256
Palo Duro Reservoir[2]	3,917	3,875	3,833	3,792	3,750	3,708
Canadian Run-of-River	298	298	298	298	298	298
Red Run-of-River	2,240	2,240	2,240	2,240	2,240	2,240
Total Surface Water	**34,236**	**33,989**	**33,743**	**33,497**	**33,250**	**33,003**
Ogallala Aquifer	3,553,323	3,240,141	2,930,987	2,606,560	2,293,573	2,293,573
Seymour Aquifer	59,752	51,489	51,640	53,334	51,573	50,661
Blaine Aquifer	33,241	33,154	33,241	33,154	33,241	33,154
Dockum Aquifer	261,079	265,547	256,307	244,788	232,128	232,128
Other Aquifers	2,753	2,753	2,753	2,753	2,753	2,753
Total Groundwater	**3,910,148**	**3,593,084**	**3,274,928**	**2,940,589**	**2,613,268**	**2,612,269**
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	28,478	30,591	32,598	34,754	37,222	39,830
Total Supply in PWPA	**3,989,645**	**3,674,447**	**3,358,052**	**3,025,623**	**2,700,523**	**2,701,885**

[1]One-year safe yield is shown for Lake Meredith and Greenbelt Reservoir. These supply values were used for planning purposes.
[2]No Current Infrastructure

Table ES-3: Developed Water Supplies in the PWPA

Water User Group	Existing Supplies (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Irrigation	1,776,392	1,536,167	1,382,492	1,201,096	1,029,554	1,028,811
Livestock	41,177	44,432	46,596	48,933	51,465	54,209
Manufacturing	48,707	50,274	48,844	45,927	43,487	43,175
Mining	11,330	9,909	7,223	4,465	2,996	2,968
Municipal	103,923	96,526	90,677	83,988	78,654	79,525
Steam Electric Power	18,554	18,554	18,554	18,554	18,554	18,554
Total	**2,000,083**	**1,755,862**	**1,594,386**	**1,402,963**	**1,224,710**	**1,227,242**

Water Supply Needs and Strategies

To assess the water supplies needs in the PWPA, water was allocated to the users considering geographical availabilities, infrastructure constraints and contractual limits, as appropriate. With these considerations, the projected developed supplies total nearly 2 million acre-feet per year in 2020, which is about 50 percent of the total available supply. This indicates that there is plenty of water available to users in the PWPA that simply has not been developed (Table ES-4). However, for some users the available water cannot be economically produced for the intended use. This is the case for irrigation users that rely on locally developed supplies and cannot use water that is located many miles away.

Considering the developed supplies, water demands exceed the supplies on a regional basis by 130,000 acre-feet per year in 2020, increasing to 373,000 acre-feet per year by 2070. Typically, the counties with the largest needs are those with large irrigation demands. There are 15 counties with 36 water user groups with projected water needs during the planning period.

Figure ES-5 shows the projected net water needs by county (this includes both needs and surplus supplies). Table ES-5 summarizes only the needs by use type (no surpluses are considered).

Table ES-4: Unallocated (Undeveloped) Water Supplies in the PWPA

Source	Supply (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Lake Meredith	0	0	0	0	0	0
Greenbelt Lake	712	436	165	36	0	0
Palo Duro Reservoir[2]	3,917	3,875	3,833	3,792	3,750	3,708
Total Surface Water	**4,629**	**4,311**	**3,998**	**3,828**	**3,750**	**3,708**
Ogallala Aquifer	1,680,158	1,604,971	1,460,198	1,330,038	1,196,497	1,193,312
Seymour Aquifer	5,820	4,403	3,608	3,907	4,039	3,705
Blaine Aquifer	17,291	17,103	17,173	17,058	17,100	16,955
Dockum Aquifer	232,449	237,750	228,875	217,439	204,679	204,751
Other Aquifers	436	436	436	436	436	436
Total Groundwater	**1,936,154**	**1,864,663**	**1,710,290**	**1,568,878**	**1,422,751**	**1,419,159**
Other Supplies	0	0	0	0	0	0
Total Supply	**1,940,783**	**1,868,974**	**1,714,288**	**1,572,706**	**1,426,501**	**1,422,867**

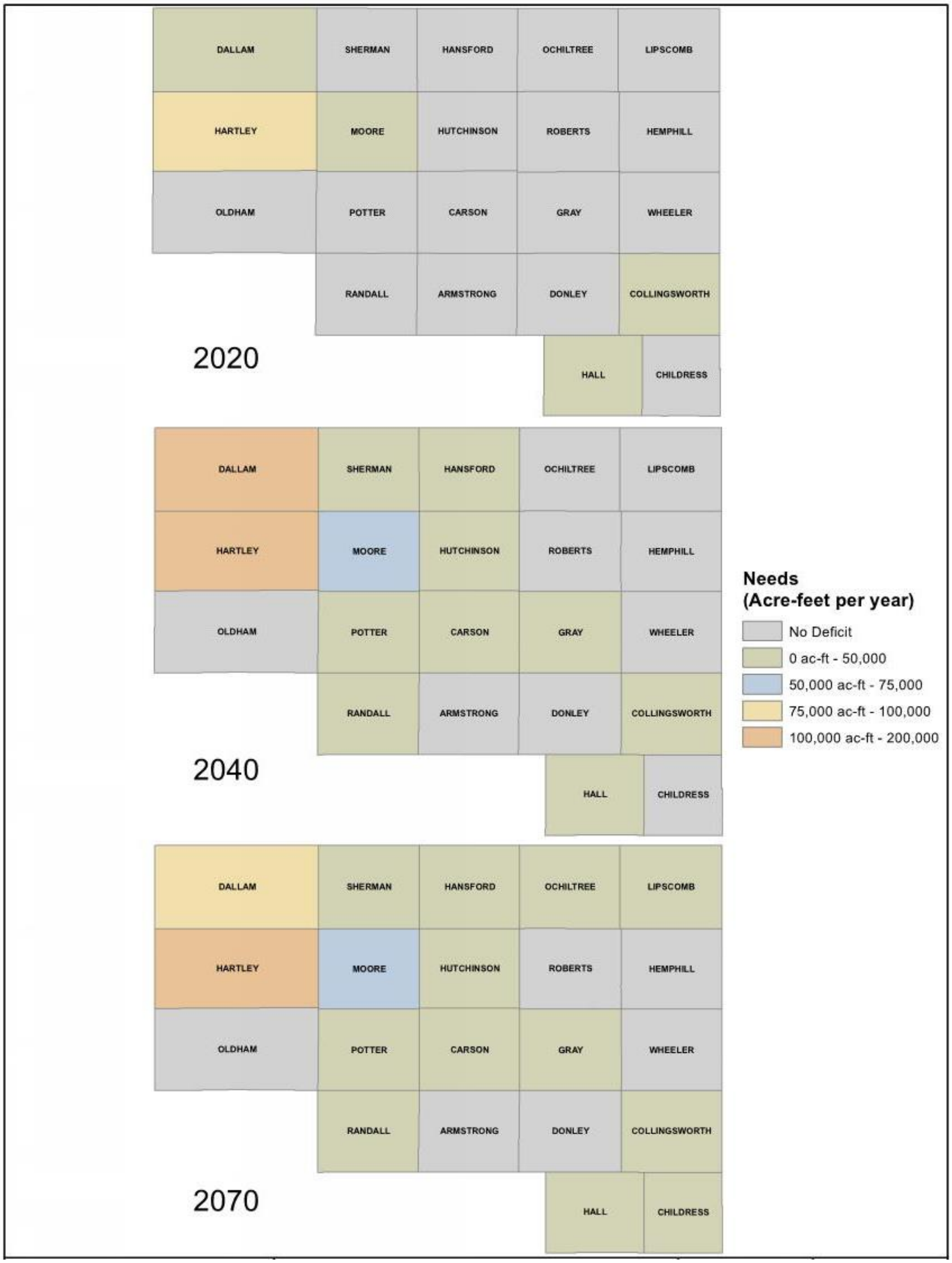


Figure ES-5: Needs in PWPA for Planning Period Year 2020 – Year 2070

Table ES-5: Projected Water Needs in the PWPA

Water User Group	Water Needs (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Municipal	1,387	9,961	21,873	35,686	49,380	58,136
Irrigation	146,064	381,558	385,042	351,667	309,729	310,547
Livestock	-	-	-	-	-	-
Manufacturing	1,008	2,585	4,015	6,932	9,371	9,684
Mining	-	-	-	-	-	-
Steam Electric Power	-	-	-	-	-	-
Total	**148,459**	**394,104**	**410,930**	**394,285**	**368,480**	**378,367**

Evaluation of Potentially Feasible Strategies

All potentially feasible strategies were evaluated with respect to:

- Quantity, reliability, and cost
- Environmental factors
- Impacts on water resources and other water management strategies
- Impacts on agriculture and natural resources
- Other relevant factors such as: key water quality, regulatory requirements, political and local issues, implementation time, recreational impacts and socioeconomic benefits or impacts

Conservation and demand management are important strategies to meet the projected needs and offset dependence on expanding supply development. The PWPA considers conservation a priority and crucial in maintaining future supplies. Water infrastructure strategies were developed to meet the needs that could not be met through conservation.

Strategies were developed for water user groups in the context of their current supply sources, previous supply studies and available supply within the PWPA. Each water need considered conservation as a first strategy to offset the water need for that user. To help ensure supplies for the future in the PWPA, conservation is a recommended strategy for all municipalities and irrigation water use, whether the user had a need or not.

Most of the water supply in the PWPA is from groundwater, and for many of the identified needs, potentially feasible strategies include development of new groundwater supplies or further developing an existing well field. A total of 99 strategies (66 strategies are conservation) are recommended to meet the water needs in the PWPA. These strategies are listed in Table ES-6. There are four alternate strategies recommended, which are listed in Table ES-7. Summaries of each recommended and alternate strategy are included in Attachment ES-1.

Table ES-6: Recommended Strategies

Water User Group	Water Management Strategy	Plan Chapter
Municipal Water Users	Municipal Conservation	5B
Irrigation Water Users	Irrigation Conservation	5B
Amarillo	Advanced Metering Infrastructure	5B
Amarillo	Aquifer Storage and Recovery	5C
Amarillo	Direct Potable Reuse	5C
Amarillo	Develop Potter/Carson County Well Field	5C
Amarillo	Develop Roberts County Well Field	5C
Booker	Develop Ogallala Aquifer Supplies	5D
Cactus	Develop Ogallala Aquifer Supplies	5C
CRMWA	Aquifer Storage and Recovery	5C
CRMWA	Replace Well Capacity	5C
CRMWA	Expand Capacity for CRMWA II	5C
CRMWA	Brush Control	5C
Canyon	Develop Dockum/Ogallala Aquifer Supplies	5D
Dalhart	Develop Ogallala Aquifer Supplies	5D
Dumas	Develop Ogallala Aquifer Supplies	5D
Greenbelt MIWA	Develop Ogallala Aquifer in Donley County	5C
Gruver	Develop Ogallala Aquifer Supplies	5D
McLean	Develop Ogallala Aquifer Supplies	5D
Memphis	Develop Ogallala Aquifer Supplies	5D
Moore County Manufacturing	Develop Dockum/Ogallala Aquifer Supplies	5D
Pampa	Aquifer Storage and Recovery	5D
Pampa	Develop Ogallala Aquifer Supplies	5D
Panhandle	Develop Ogallala Aquifer Supplies	5D
Perryton	Develop Ogallala Aquifer Supplies	5D
Potter County Manufacturing	Develop Ogallala Aquifer Supplies	5D
Randall County Manufacturing	Develop Ogallala Aquifer Supplies	5D
Spearman	Develop Ogallala Aquifer Supplies	5D
Stinnett	Develop Ogallala Aquifer Supplies	5D
Sunray	Develop Ogallala Aquifer Supplies	5D
TCW Supply	Develop Ogallala Aquifer Supplies	5D
Texline	Develop Ogallala Aquifer Supplies	5D
Turkey	Develop Ogallala Aquifer Supplies	5D
Wellington	Nitrate Treatment	5D
Wellington	Develop Seymour Aquifer Supplies	5D
Wheeler	Develop Ogallala Aquifer Supplies	5D

Table ES-7: Alternate Strategies

Water User Group	Water Management Strategy	Plan Chapter
Hall County-Other (Lakeview)	Advanced Treatment	5D
Palo Duro Water District	Develop PDWD Transmission System	5C, 5D
Hall County-Other (Brice-Lesly)	Develop Seymour Aquifer Supplies	5D
Hall County-Other (Estelline)	Develop Seymour Aquifer Supplies	5D

Collectively, conservation is expected to provide approximately 570,000 acre-feet per year of water savings to users in the PWPA by 2070 as shown in Figure ES-6. New groundwater development is recommended to provide approximately 9,300 acre-feet per year in 2020, increasing to approximately 78,000 acre-feet per year by 2070, with additional new groundwater supplies provided to users outside of the PWPA. These two strategy types account for 98 percent of the supplies from the recommended water management strategies to water user groups. Other strategies include aquifer storage and recovery, direct potable reuse, brush control and water quality improvements. Supplies developed by the major water providers that are not assigned to a water user group are not included in these totals. This includes additional groundwater developed by CRMWA and Greenbelt MIWA.

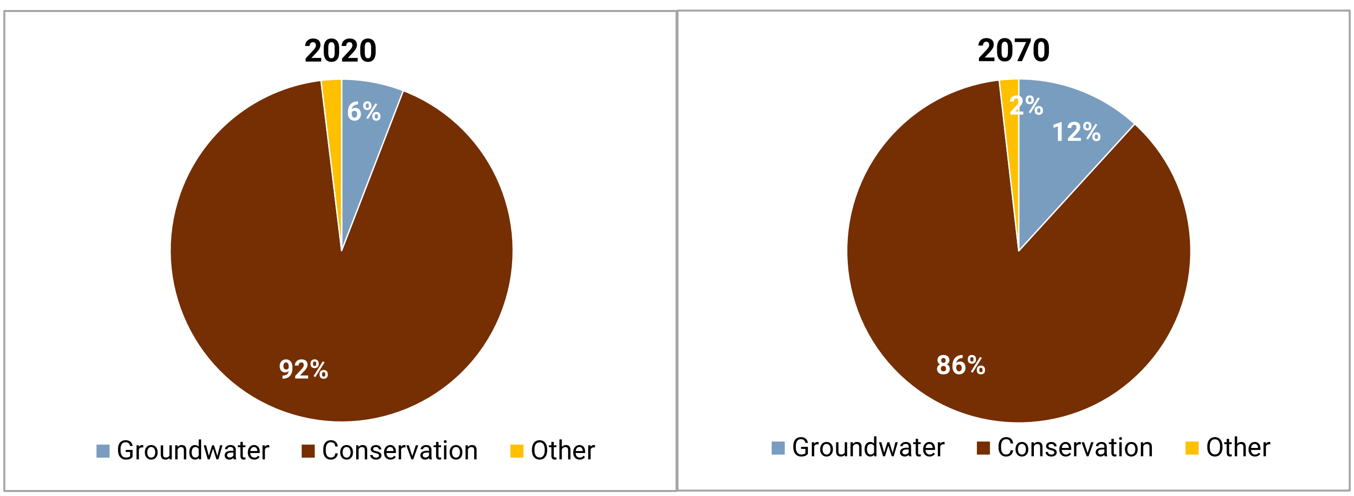


Figure ES-6: Percentage by Water Management Strategy Type, by Volume

Table ES-8: Unmet Water Needs in the PWPA, ac-ft/yr

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(81,419)	(235,828)	(123,363)	(65,504)	(48,048)	(42,031)

Key Findings and Recommendations

- Increased availability of surface water, particularly from Lake Meredith, has resulted in reduced municipal water needs in the PWPA. With the development of additional groundwater in Roberts County, CRMWA can better manage their sources conjunctively to continue to utilize Lake Meredith.
- Increased irrigation demand has resulted in greater irrigation needs, although most of those needs are satisfied by conservation by the end of the planning period.
- Large irrigation needs are concentrated in two counties: Dallam and Hartley. Most of these needs are due to limited groundwater supply for irrigated agriculture. The recommended strategies are conservation.
- Limited ground water supplies in the southeast part of the region provide few options for new supply development.
- Four major water providers are projected to have needs over the planning period. The recommended strategies for each provider are to develop additional groundwater, along with other strategies for Amarillo and CRMWA.
- Conservation is critical strategy to the region, as it can be used to reduce water needs as well as preserve limited water sources for future generations.

County Summary Pages

Detailed descriptions of water resource planning issues for each county within the PWPA are included in Attachment ES-2.

ATTACHMENT ES-1

RECOMMENDED AND ALTERNATE WATER MANAGEMENT STRATEGIES FOR PWPA

Summary of Recommended Water Management Strategies in the PWPA

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/af/y)	Total Supply 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/af/y)
Advanced Metering Infrastructure											
Amarillo	Potter/Randall	2020	$31,000,000	$1,062	1,485	1,655	1,831	2,008	2,198	2,398	$0
Aquifer Storage and Recovery											
Amarillo	Potter/Randall	2030	$11,472,000	$260	0	5,000	6,500	6,500	6,500	6,500	$419
CRMWA	Multiple	2030	$27,815,000	$355	0	12,000	11,500	11,500	11,500	11,500	$159
Pampa	Gray	2030	$2,183,000	$340	0	0	500	500	500	500	$32
Brush Control											
CRMWA	Multiple	2020	N/A	$60	2,500	2,500	2,500	2,500	2,500	2,500	$60
Develop Dockum/Ogallala Aquifer Supplies											
Canyon	Randall	2030	$9,565,000	$270	0	1,500	1,500	1,500	3,000	3,000	$354
Moore County Manufacturing	Moore	2050	$3,620,000	$145	0	0	0	3,000	3,000	3,000	$60
Develop Ogallala Aquifer in Donley County											
Greenbelt MIWA	Multiple	2030	$17,879,000	$743	0	2,000	2,000	2,000	2,000	2,000	$114
Develop Ogallala Aquifer Supplies											
Booker	Lipscomb/ Ochiltree	2040	$1,796,000	$1,268	0	0	400	400	400	400	$953
Cactus	Randall	2020	$16,598,000	$363	5,000	5,000	5,000	5,000	5,000	5,000	$129
Dalhart	Hartley/Dallam	2020	$7,279,000	$507	3,140	3,140	3,140	3,140	3,140	3,140	$113
Dumas	Moore	2030	$5,560,000	$134	0	5,000	5,000	5,000	5,000	5,000	$56
Gruver	Hansford	2030	$891,000	$286	0	280	280	280	280	280	$61
McLean	Gray	2030	$414,000	$213	0	150	150	150	150	150	$20
Memphis	Hall	2020	$1,128,000	$1,107	0	150	150	150	150	150	$580
Pampa	Gray	2040	$4,091,000	$354	0	0	1,100	1,100	1,100	1,100	$92
Panhandle	Carson	2030	$1,814,000	$390	0	600	600	600	600	600	$177
Perryton	Ochiltree	2050	$9,097,000	$955	0	0	0	820	820	820	$174

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/af/y)	Total Supply 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/af/y)
Develop Ogallala Aquifer Supplies											
Potter County Manufacturing	Potter	2040	$324,000	$253	0	0	150	150	150	150	$100
Randall County Manufacturing	Randall	2030	$386,000	$400	0	100	100	100	100	100	$130
Spearman	Hansford	2050	$2,604,000	$467	0	0	0	520	520	520	$115
Stinnett	Hutchinson	2050	$848,000	$1,320	0	0	0	50	50	50	$120
Sunray	Moore	2030	$4,465,000	$756	0	500	500	500	500	500	$128
TCW Supply	Hutchinson	2030	$3,945,000	$868	0	400	400	400	400	400	$173
Texline	Dallam	2050	$495,000	$390	0	0	0	100	100	100	$40
Turkey	Hall	2030	$1,597,000	$1,280	0	100	100	100	100	100	$160
Wheeler	Wheeler	2050	$2,776,000	$1,463	0	0	0	160	160	160	$244
Develop Potter/Carson County Well Field											
Amarillo	Potter/Randall	2030	$59,200,000	$319	0	10,000	10,000	20,000	20,000	20,000	$111
Develop Roberts County Well Field											
Amarillo	Potter/Randall	2065	$113,082,000	$1,425	0	0	0	0	0	11,210	$1,425
Develop Seymour Aquifer Supplies											
Wellington		2030	$1,563,000	$1,250	0	100	100	100	100	100	$150
Direct Potable Reuse[1]											
Amarillo	Potter/Randall	2040	$51,270,000	$2,259	0	0	2,000	2,000	2,000	2,000	$1,228
Expand Groundwater and Delivery Capacity for CRMWA II											
CRMWA	Multiple	2030	$468,523,000	$758	0	65,000	65,000	65,000	60,674	55,476	$299
Irrigation Conservation											
Armstrong County Irrigation	Armstrong	2020	$206,924	$66	290	542	1,014	1,200	1,314	1,415	$66
Carson County Irrigation	Carson	2020	$2,501,489	$66	7,290	12,416	24,597	28,628	30,535	32,317	$66
Childress County Irrigation	Childress	2020	$453,203	$66	655	1,095	2,194	2,547	2,704	2,854	$66

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/af/y)	Total Supply 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/af/y)
Irrigation Conservation											
Collingsworth County Irrigation	Collingsworth	2020	$1,271,751	$66	2,610	3,966	7,955	9,658	9,419	9,757	$66
Dallam County Irrigation	Dallam	2020	$8,083,969	$66	24,329	43,270	80,019	87,678	80,502	83,654	$66
Donley County Irrigation	Donley	2020	$870,018	$66	1,115	1,888	3,636	4,301	4,681	5,054	$66
Gray County Irrigation	Gray	2020	$987,478	$66	2,222	3,766	7,320	8,612	9,308	9,981	$66
Hall County Irrigation	Hall	2020	$816,256	$66	1,898	3,025	6,317	7,232	7,518	7,796	$66
Hansford County Irrigation	Hansford	2020	$4,742,867	$66	14,572	25,101	49,532	57,670	61,580	65,189	$66
Hartley County Irrigation	Hartley	2020	$9,018,439	$66	27,160	48,052	89,129	99,463	94,245	99,380	$66
Hemphill County Irrigation	Hemphill	2020	$335,683	$66	97	194	294	387	478	569	$66
Hutchinson County Irrigation	Hutchinson	2020	$1,152,269	$66	4,432	7,624	15,285	17,656	18,663	19,562	$66
Lipscomb County Irrigation	Lipscomb	2020	$1,121,165	$66	2,167	3,768	7,135	8,478	9,291	10,074	$66
Moore County Irrigation	Moore	2020	$4,675,364	$66	16,630	29,092	57,177	64,138	59,240	60,841	$66
Ochiltree County Irrigation	Ochiltree	2020	$2,341,044	$66	7,080	12,160	23,955	27,927	29,865	31,668	$66
Oldham County Irrigation	Oldham	2020	$141,967	$66	255	495	916	1,085	1,191	1,284	$66
Potter County Irrigation	Potter	2020	$44,158	$66	120	272	505	585	631	661	$66
Randall County Irrigation	Randall	2020	$500,354	$66	1,003	2,027	3,820	4,454	4,810	5,089	$66
Roberts County Irrigation	Roberts	2020	$222,399	$66	683	1,158	2,283	2,666	2,855	3,034	$66
Sherman County Irrigation	Sherman	2020	$7,394,465	$66	25,895	45,383	88,429	103,368	104,313	111,300	$66
Wheeler County Irrigation	Wheeler	2020	$420,824	$66	895	1,505	3,008	3,493	3,712	3,918	$66

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/af/y)	Total Supply 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/af/y)
Municipal Conservation											
Amarillo	Potter/Randall	2020	N/A	$425	976	1,087	1,202	1,319	1,444	1,575	$417
Booker	Lipscomb/Ochiltree	2020	N/A	$1,358	5	6	6	7	7	8	$1,218
Borger	Hutchinson	2020	N/A	$422	41	43	43	43	43	43	$404
Cactus	Moore	2020	N/A	$1,089	13	15	17	19	21	23	$766
Canadian	Hemphill	2020	N/A	$1,154	10	11	12	13	14	15	$1,067
Canyon	Randall	2020	N/A	$385	45	51	56	89	98	107	$592
Childress	Childress	2020	N/A	$905	19	20	21	21	22	22	$779
Clarendon	Donley	2020	N/A	$1,293	6	6	6	6	6	6	$1,293
Claude	Armstrong	2020	N/A	$1,570	4	4	4	4	4	4	$1,570
Dalhart	Hartley/Dallam	2020	N/A	$648	27	30	32	35	37	40	$443
Darrouzett	Lipscomb	2020	N/A	$2,799	1	1	1	2	2	2	$2,430
Dumas	Moore	2020	N/A	$333	53	60	98	110	122	134	$554
Follett	Lipscomb	2020	N/A	$2,813	1	1	1	2	2	2	$2,442
Fritch	Hutchinson	2020	N/A	$1,169	9	9	10	10	10	10	$1,157
Groom	Carson	2020	N/A	$2,330	2	2	2	2	2	2	$2,330
Gruver	Hansford	2020	N/A	$1,447	5	5	5	6	6	7	$1,280
Hartley	Hartley	2020	N/A	$2,146	2	2	2	2	2	2	$1,958
Higgins	Lipscomb	2020	N/A	$2,777	1	1	1	2	2	2	$2,413
Lake Tanglewood	Randall	2020	N/A	$1,618	3	3	3	3	3	3	$1,618
McLean	Gray	2020	N/A	$1,835	3	3	3	4	4	4	$1,459
Memphis	Hall	2020	N/A	$1,245	7	7	7	7	7	7	$1,235
Miami	Roberts	2020	N/A	$2,216	2	2	2	2	2	2	$2,193
Moore County-Other	Moore	2020	N/A	$1,272	7	8	9	10	11	12	$1,110
Pampa	Gray	2020	N/A	$294	59	95	106	121	132	144	$664
Panhandle	Carson	2020	N/A	$1,221	8	8	8	8	8	8	$1,203

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/af/y)	Total Supply 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/af/y)
Municipal Conservation											
Perryton	Ochiltree	2020	N/A	$616	28	31	33	35	38	41	$430
Red River Authority	Multiple	2020	N/A	$1,184	9	9	10	11	11	12	$124
Shamrock	Wheeler	2020	N/A	$1,309	6	6	7	7	7	7	$1,239
Spearman	Hansford	2020	N/A	$1,129	11	11	12	12	12	13	$1,094
Stinnett	Hutchinson	2020	N/A	$1,306	6	6	6	6	6	6	$1,288
Stratford	Sherman	2020	N/A	$1,248	7	8	8	8	9	9	$1,184
Sunray	Moore	2020	N/A	$1,307	6	6	6	7	7	7	$1,251
TCW Supply	Hutchinson	2020	N/A	$1,298	6	6	6	6	6	6	$1,281
Texhoma	Sherman	2020	N/A	$3,244	1	1	1	1	1	1	$2,817
Texline	Dallam	2020	N/A	$2,335	2	2	2	2	2	2	$1,913
Turkey	Hall	2020	N/A	$2,893	1	1	1	1	1	1	$2,845
Vega	Oldham	2020	N/A	$1,682	3	3	3	3	3	3	$1,682
Wellington	Collingsworth	2020	N/A	$1,248	7	7	8	8	8	8	$1,192
Wheeler	Wheeler	2020	N/A	$1,406	5	5	5	5	6	6	$1,319
White Deer	Carson	2020	N/A	$1,574	4	4	4	4	4	4	$1,538
Nitrate Treatment											
Wellington	Collingsworth	2020	$8,262,000	$2,116	560	560	560	560	560	560	$1,079
Replace Well Capacity											
CRMWA	Multiple	2040	$30,900,000	$159	0	0	4,326	9,524	19,493	24,691	$123
Water Audit and Leak Repair											
Amarillo	Potter/Randall	2020	$170,849,900	$1,570	2,077	2,268	2,472	2,692	2,943	3,209	$1,488
Canyon	Randall	2020	$11,725,000	$878	174	191	208	227	249	271	$886
Dumas	Moore	2020	$14,179,600	$1,536	115	128	142	158	175	192	$1,566
Higgins	Lipscomb	2020	$594,500	$1,113	8	9	9	10	10	10	$1,027
Turkey	Hall	2020	$549,800	$2,365	4	4	4	4	4	4	$2,411

1. Amarillo will develop 3,500 acre-feet per year of potable reuse. Of this amount, 1,500 acre-feet per year is shown with the ASR project.

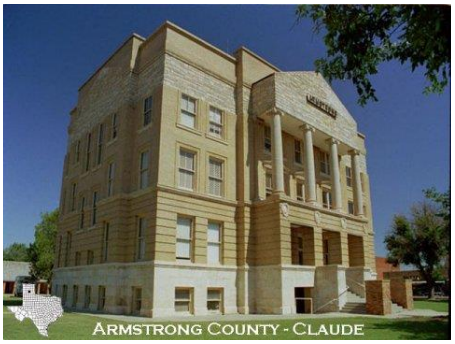
Summary of Alternate Water Management Strategies in PWPA

Entity	County Used	Expected Online	Capital Cost	First Decade Unit Cost ($/ac ft/yr)	Total Yield 2020	2030	2040	2050	2060	2070	Last Decade Unit Cost ($/ac ft/yr)
Advanced Treatment											
Hall County-Other (Lakeview)	Hall	2030	$2,592,000	$6,200	0	50	50	50	50	50	$2,560
Develop Palo Duro Water District Transmission System											
Cactus	Moore	2030	$122,561,000	$6,476	0	1,744	1,744	1,744	1,744	1,744	$1,531
Dumas	Moore	2030	$85,139,000	$5,884	0	1,356	1,356	1,356	1,356	1,356	$1,467
Gruver	Hansford	2030	$8,909,000	$6,791	0	116	116	116	116	116	$1,398
Spearman	Hansford	2030	$9,095,000	$2,799	0	271	271	271	271	271	$440
Stinnett	Hutchinson	2030	$12,126,000	$9,006	0	116	116	116	116	116	$1,666
Sunray	Moore	2030	$17,108,000	$5,924	0	271	271	271	271	271	$1,486
Develop Seymour Aquifer Supplies											
Hall County-Other (Brice-Lesley)	Hall	2030	$398,000	$60	0	50	50	50	50	50	$60
Hall County-Other (Estelline)	Hall	2030	$209,000	$60	0	50	50	50	50	50	$20

ATTACHMENT ES-2

COUNTY SUMMARIES

ARMSTRONG COUNTY SUMMARY PAGE



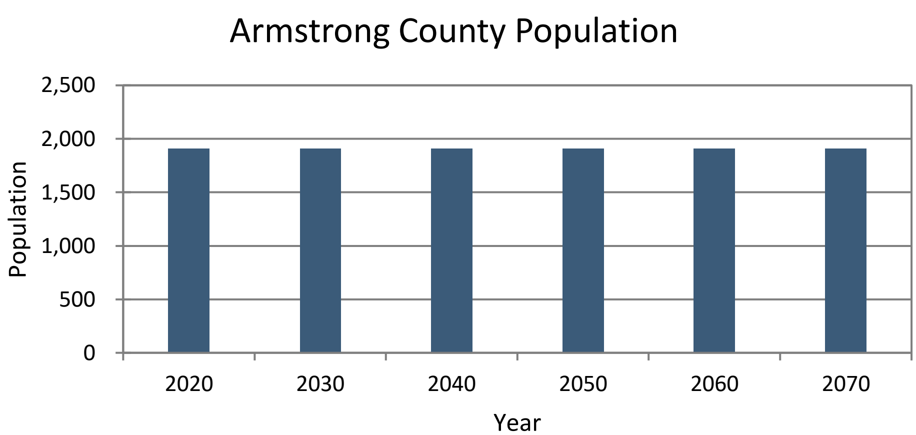
Who are my representatives?

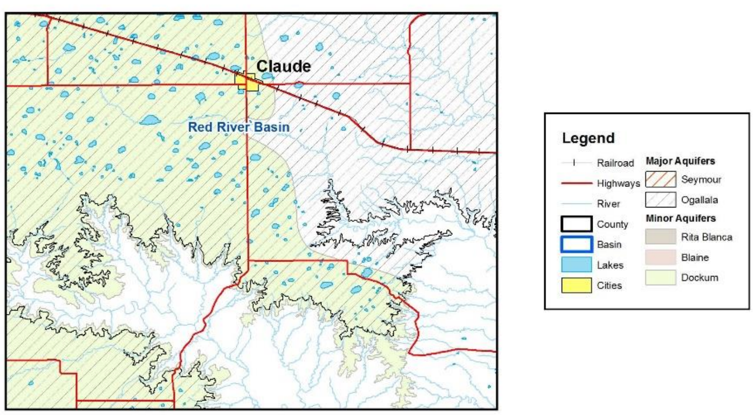
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

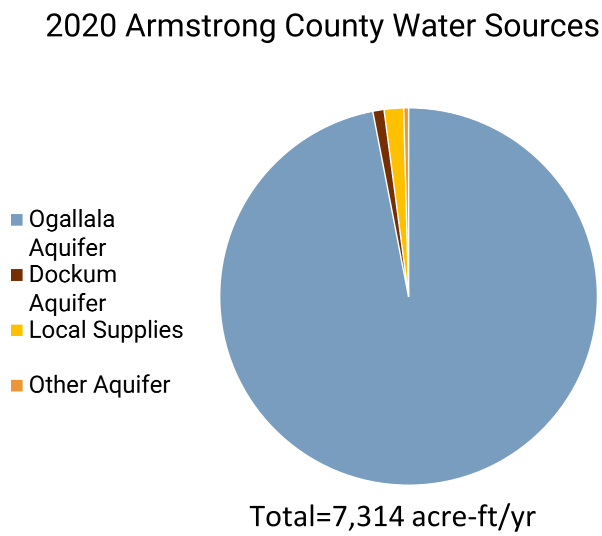
County Seat: City of Claude

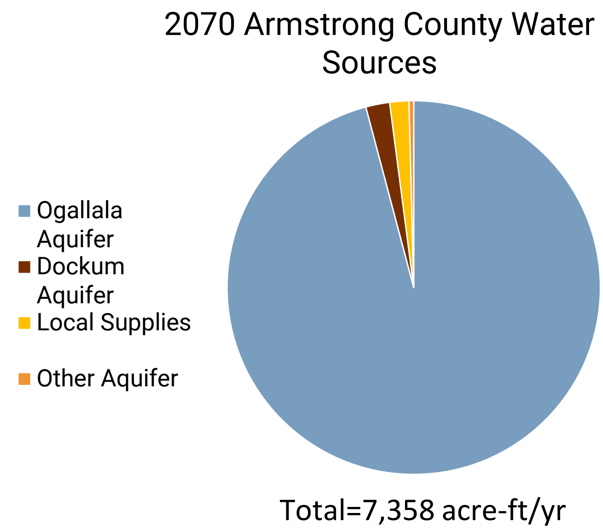
Economy: Agribusiness, Tourism

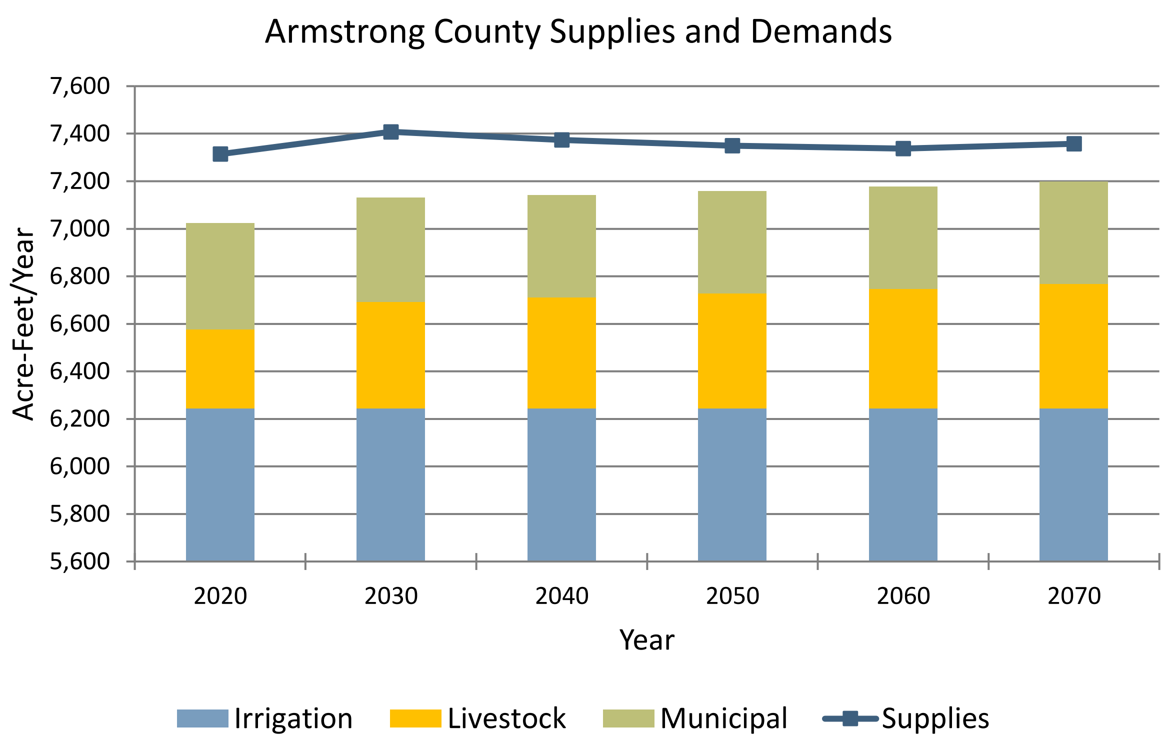
What is the source of my water? Ogallala, Dockum Aquifers





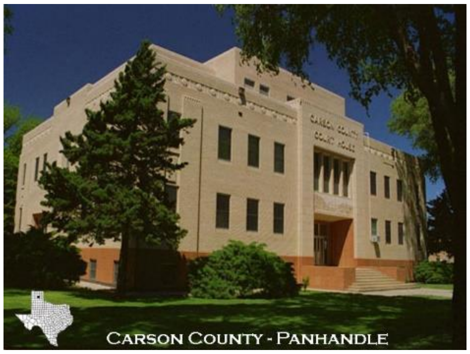






WATER USER GROUP	STRATEGY
Claude	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Demands in this Category
Steam Electric Power	No Demands in this Category

CARSON COUNTY SUMMARY PAGE



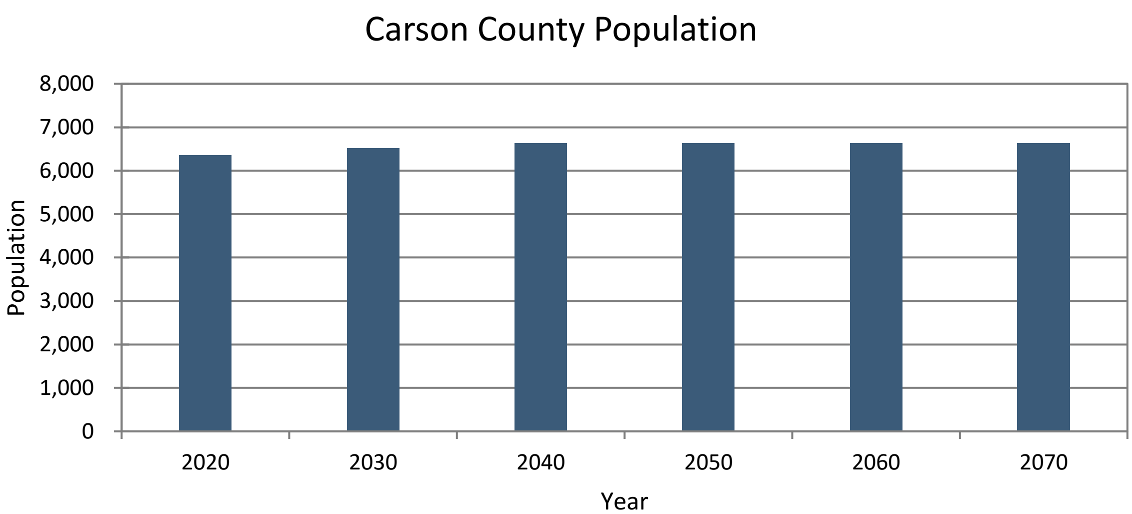
Who are my representatives?

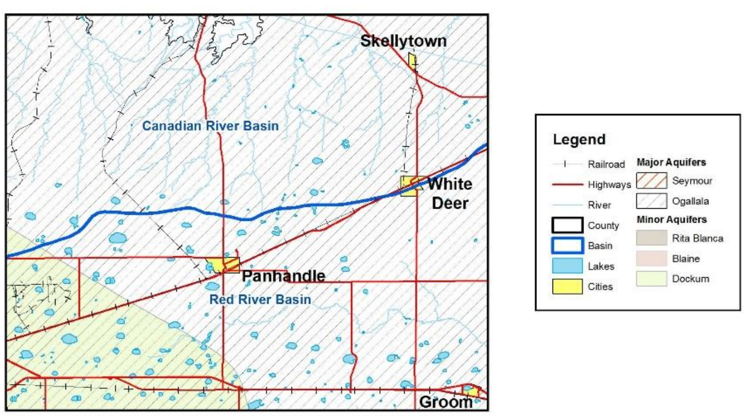
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

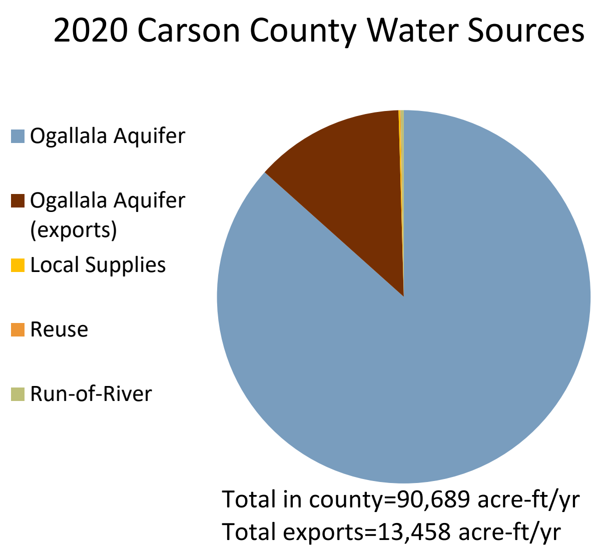
County Seat: City of Panhandle

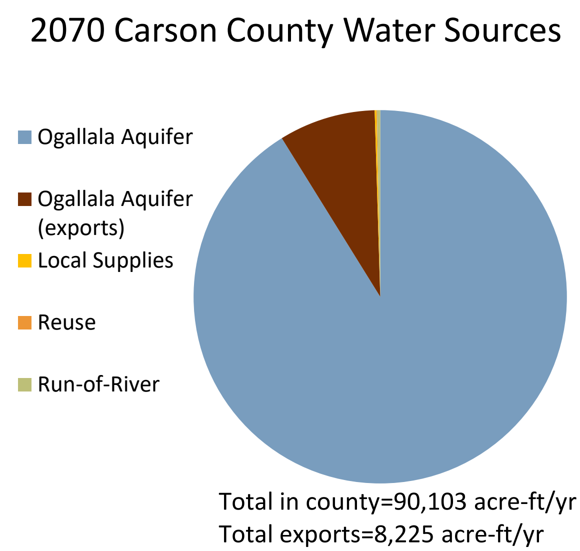
Economy: Agribusiness, Petroleum

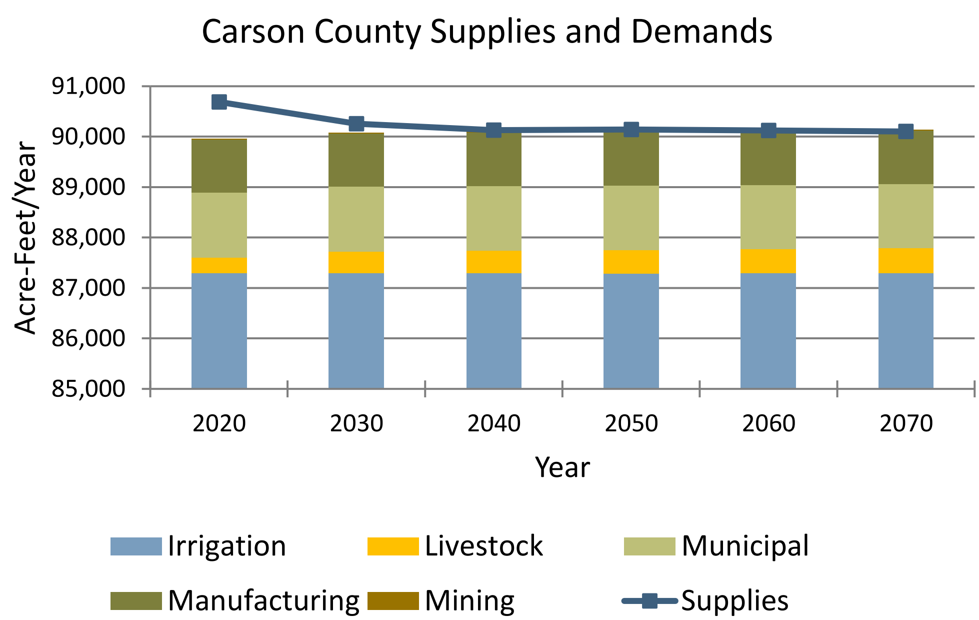
What is the source of my water? Ogallala Aquifer





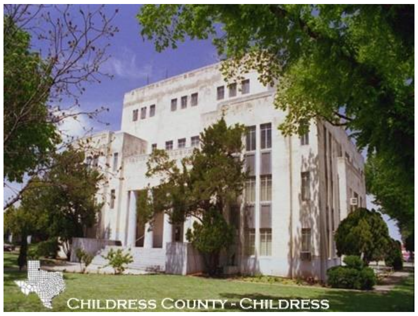






WATER USER GROUP	STRATEGY
Groom	Conservation
Panhandle	Conservation, New Well(s)
White Deer	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

CHILDRESS COUNTY SUMMARY PAGE



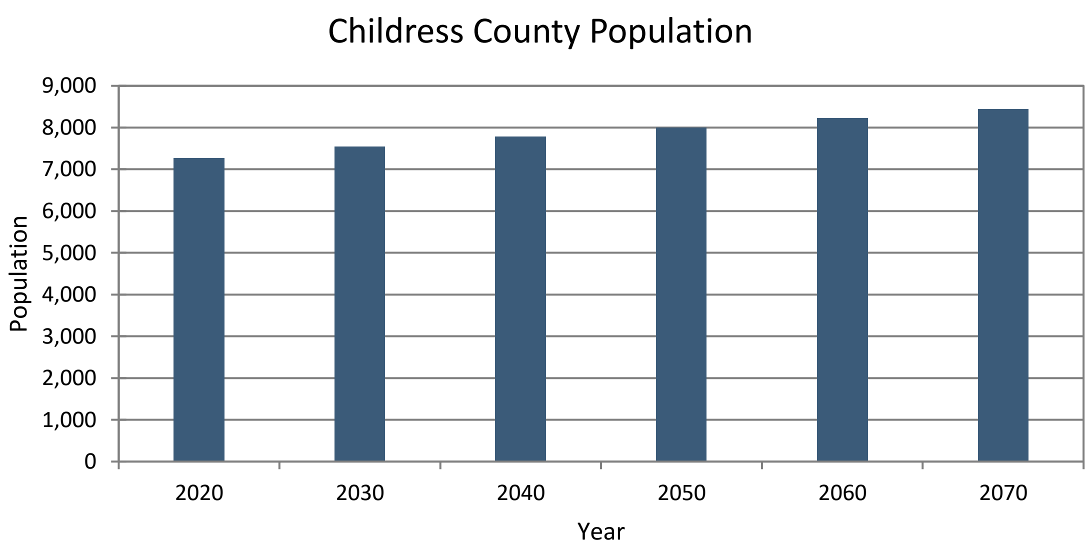
Who are my representatives?

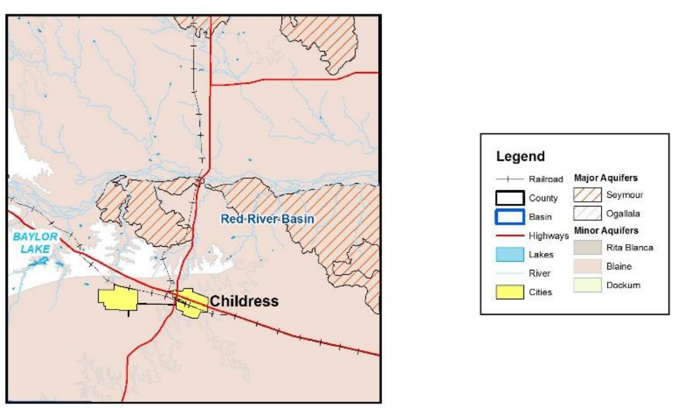
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Bobbie Kidd	- Greenbelt MIWA
Lynn Smith	- GMA #6

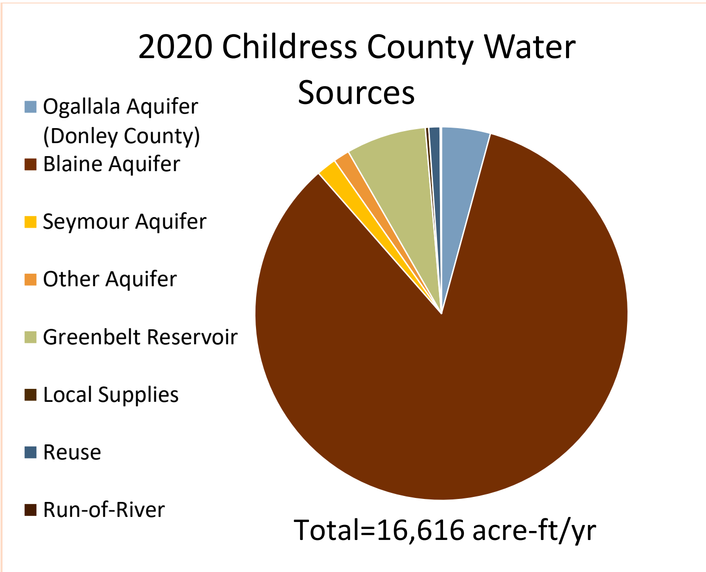
County Seat: City of Childress

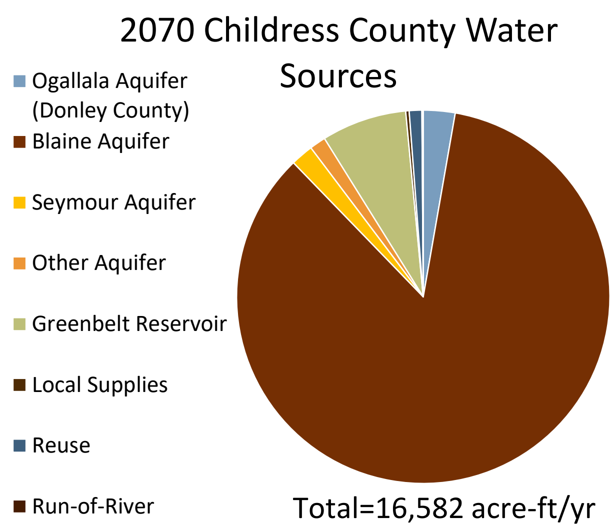
Economy: Agribusiness, Tourism

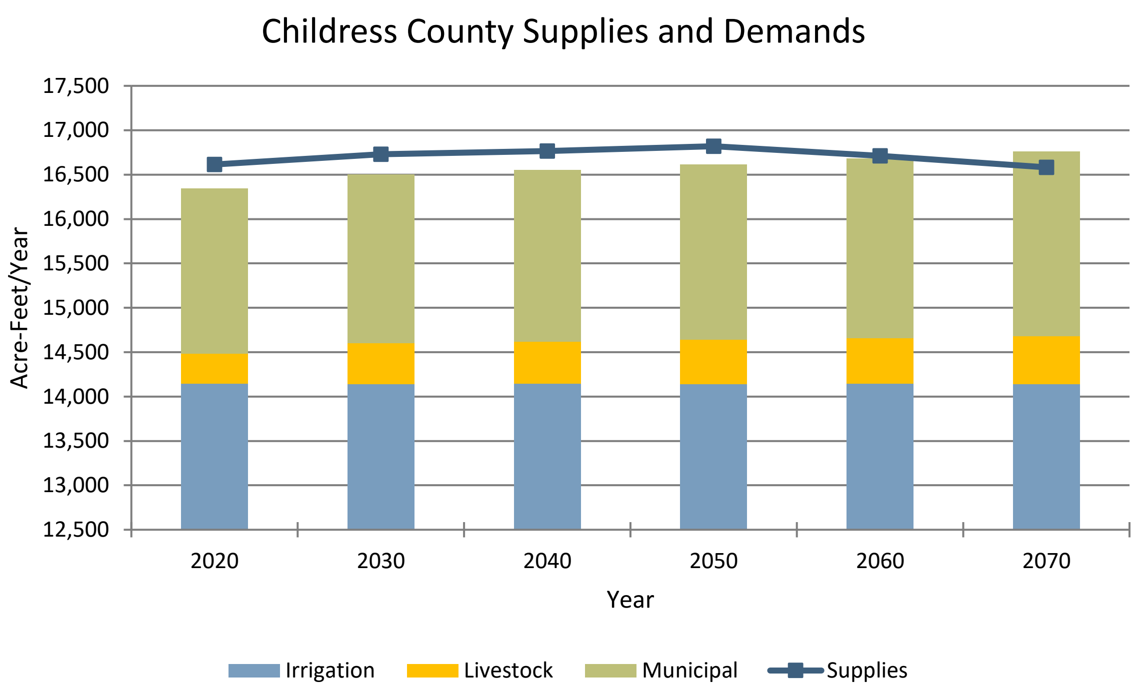
What is the source of my water? Ogallala, Seymour, Blaine Aquifers, Greenbelt Reservoir











WATER USER GROUP	STRATEGY
Childress	Conservation
Red River Authority of Texas	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

COLLINGSWORTH COUNTY SUMMARY PAGE

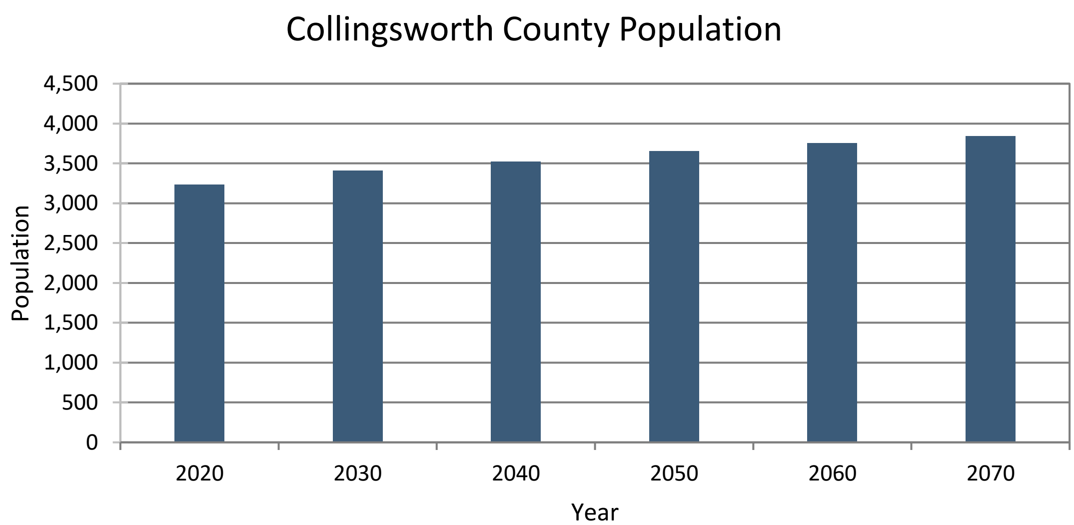
Who are my representatives?

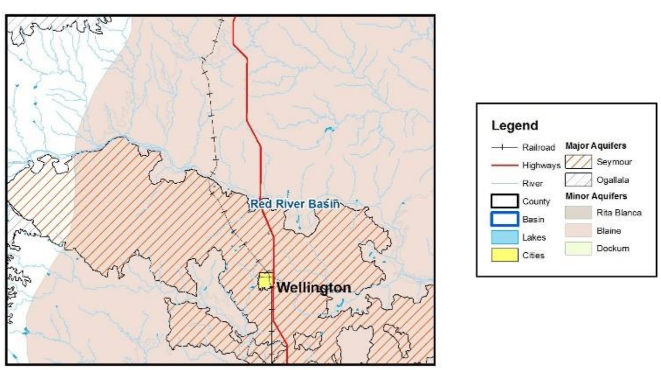
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Bobbie Kidd	- Greenbelt MIWA
Joe Baumgardner	- Farmer
Lynn Smith	- GMA #6

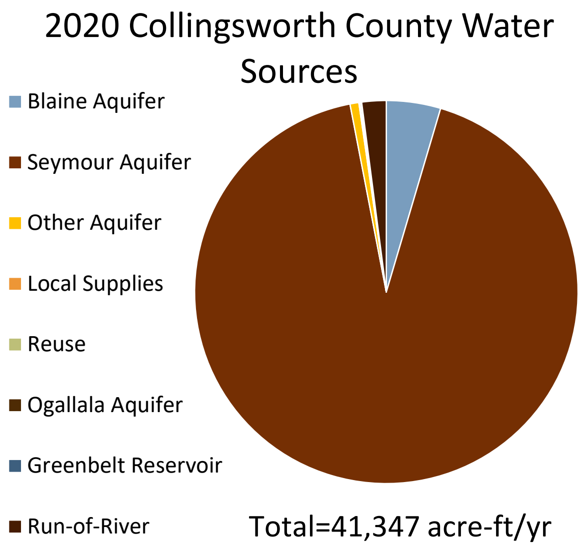
County Seat: City of Wellington

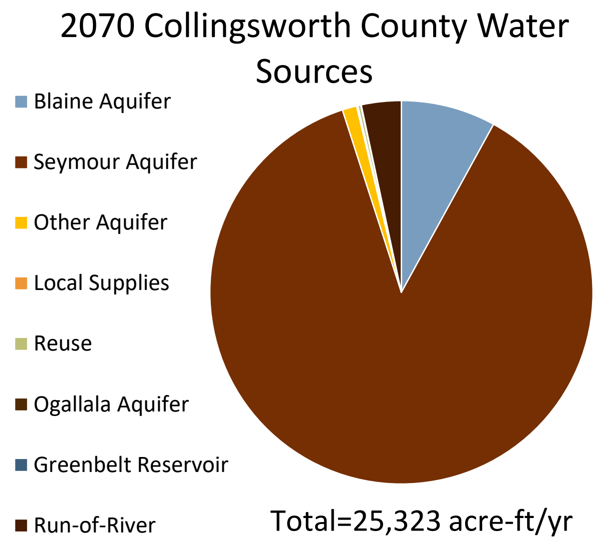
Economy: Agribusiness

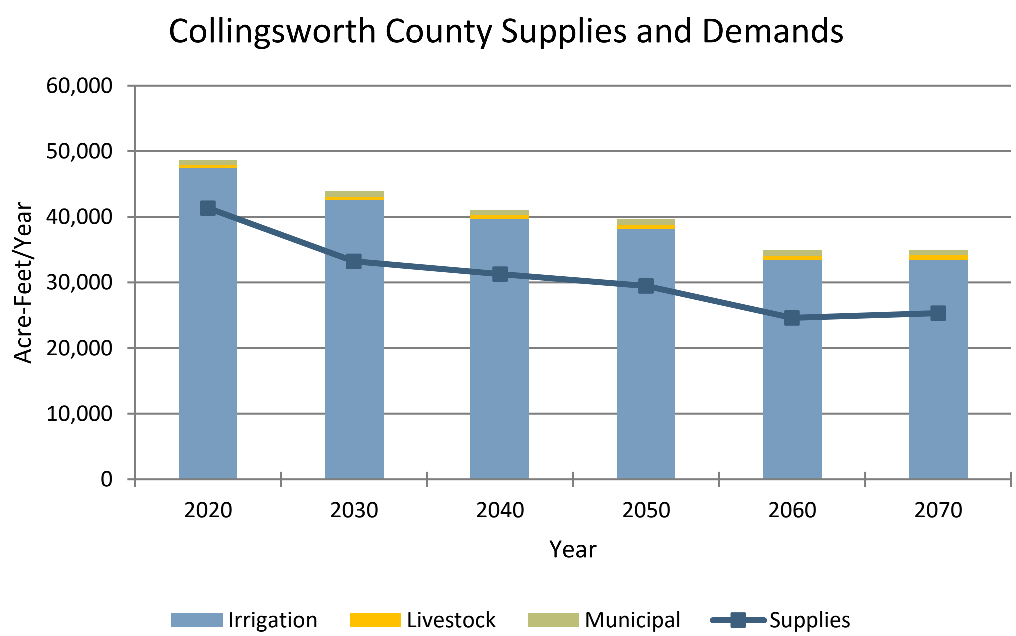
What is the source of my water? Seymour, Blaine Aquifers











WATER USER GROUP	STRATEGY
Wellington	Conservation, New Well(s), Water Quality Improvements
Red River Authority of Texas	No Water Need Identified
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Demands in this Category
Steam Electric Power	No Demands in this Category

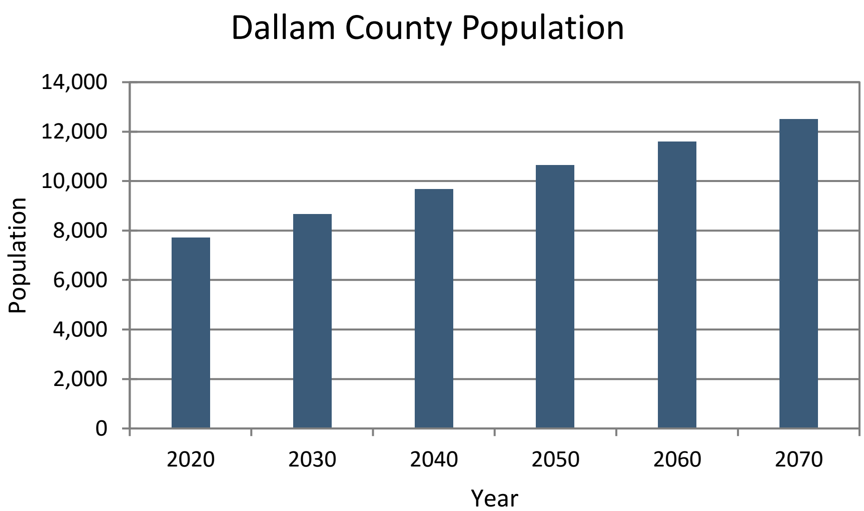
DALLAM COUNTY SUMMARY PAGE

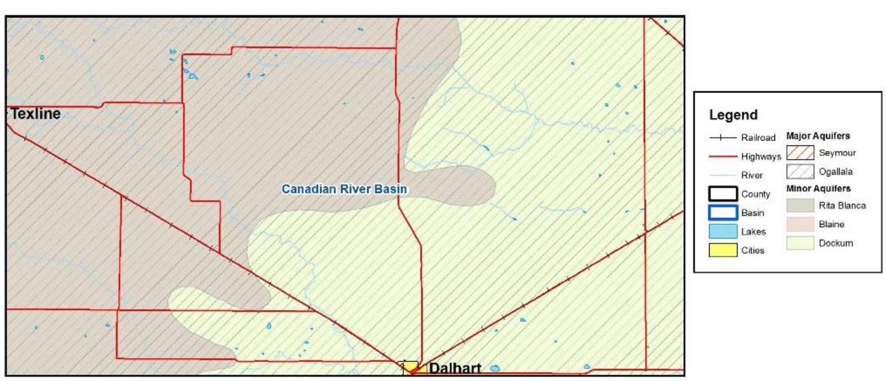
Who are my representatives?

Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Steve Walthour - North Plains GCD
Rusty Gilmore - Water Well Driller
Danny Krienke - GMA #1
County Seat: City of Dalhart

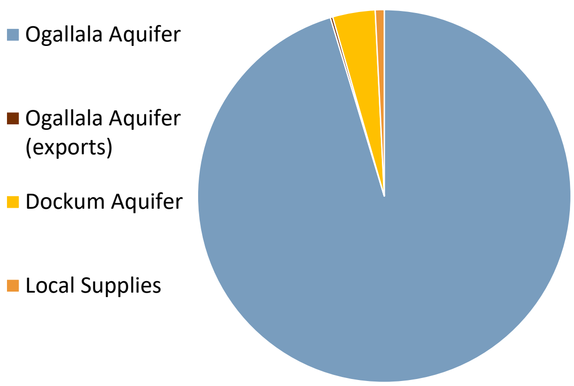
Economy: Agribusiness, Manufacturing, Tourism

What is the source of my water? Ogallala, Dockum Aquifers



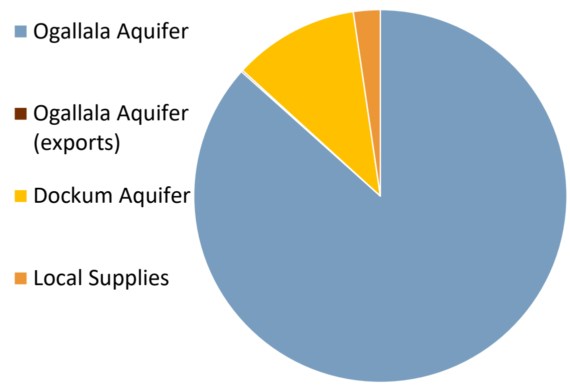


2020 Dallam County Water Sources



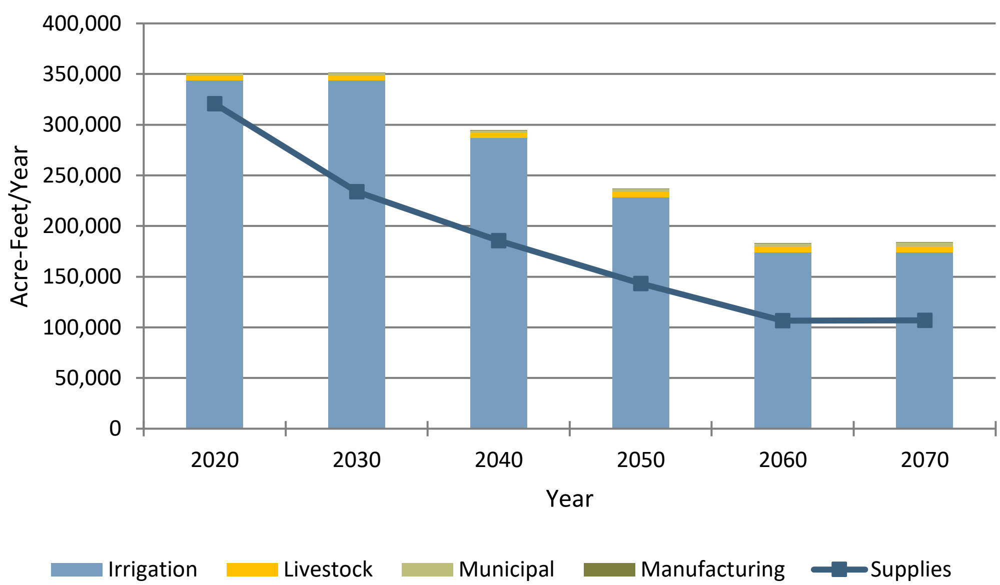
Total in county=320,620 acre-ft/yr
Total exports=675 acre-ft/yr

2070 Dallam County Water Sources



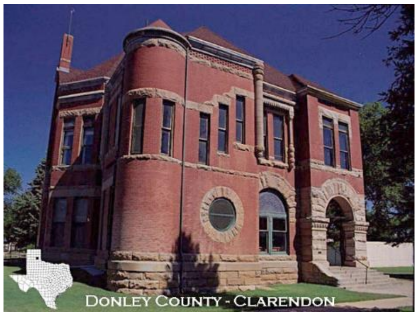
Total in county=106,957 acre-ft/yr
Total exports=155 acre-ft/yr

Dallam County Supplies and Demands



WATER USER GROUP	STRATEGY
Dalhart	Conservation, New Well(s)
Texline	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Demands in this Category
Steam Electric Power	No Demands in this Category

DONLEY COUNTY SUMMARY PAGE

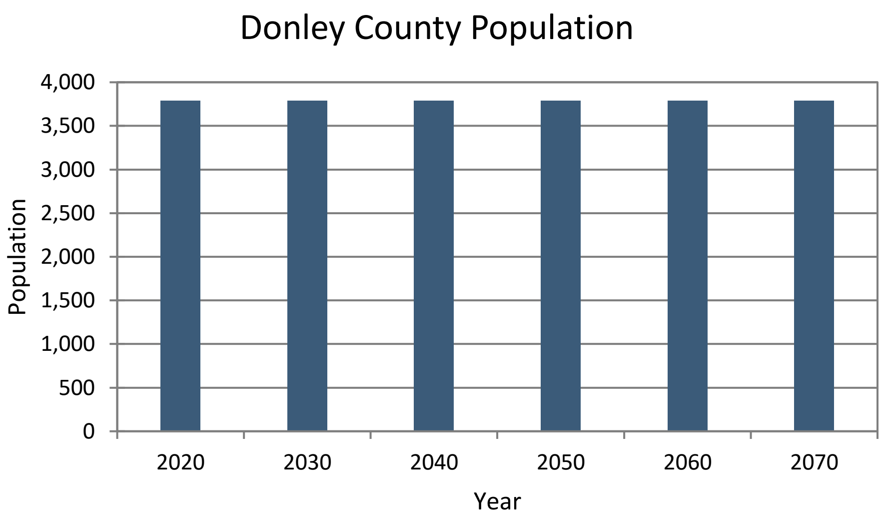


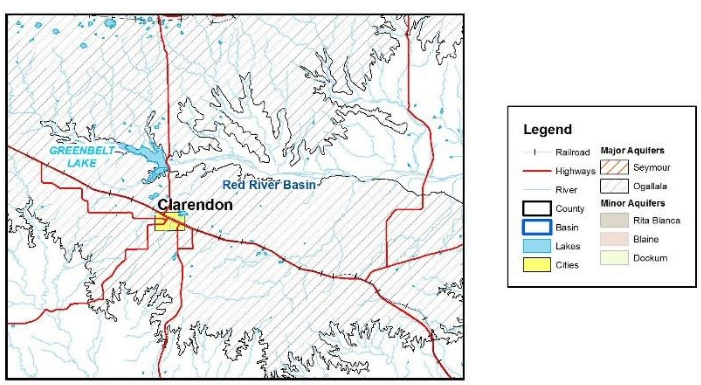
Who are my representatives?

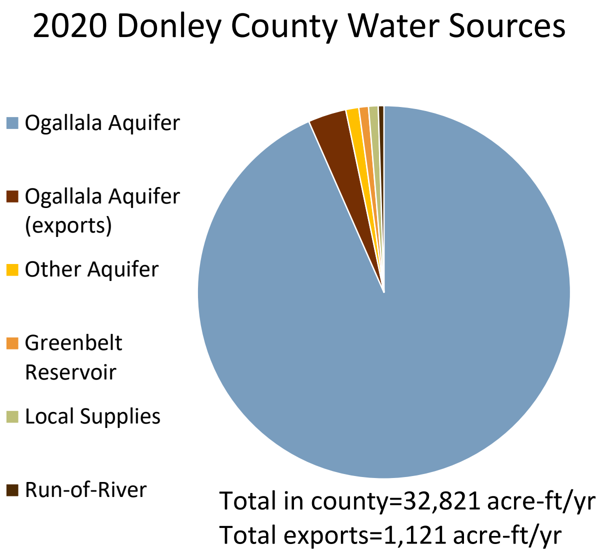
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Bobbie Kidd - Greenbelt MIWA
C.E. Williams - Panhandle GCD
Danny Krienke - GMA #1
County Seat: City of Clarendon

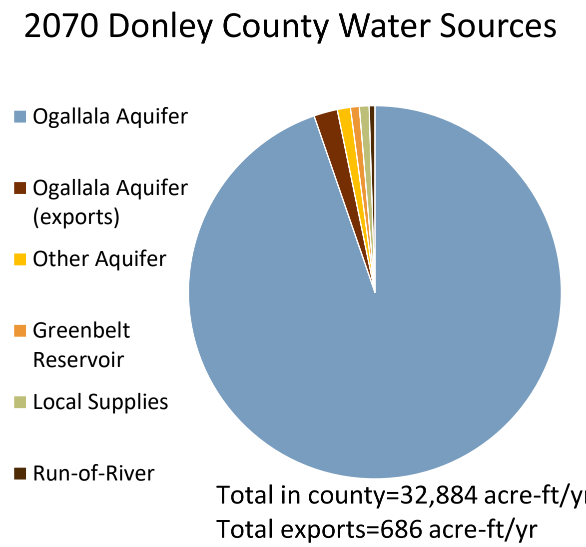
Economy: Agribusiness, Tourism

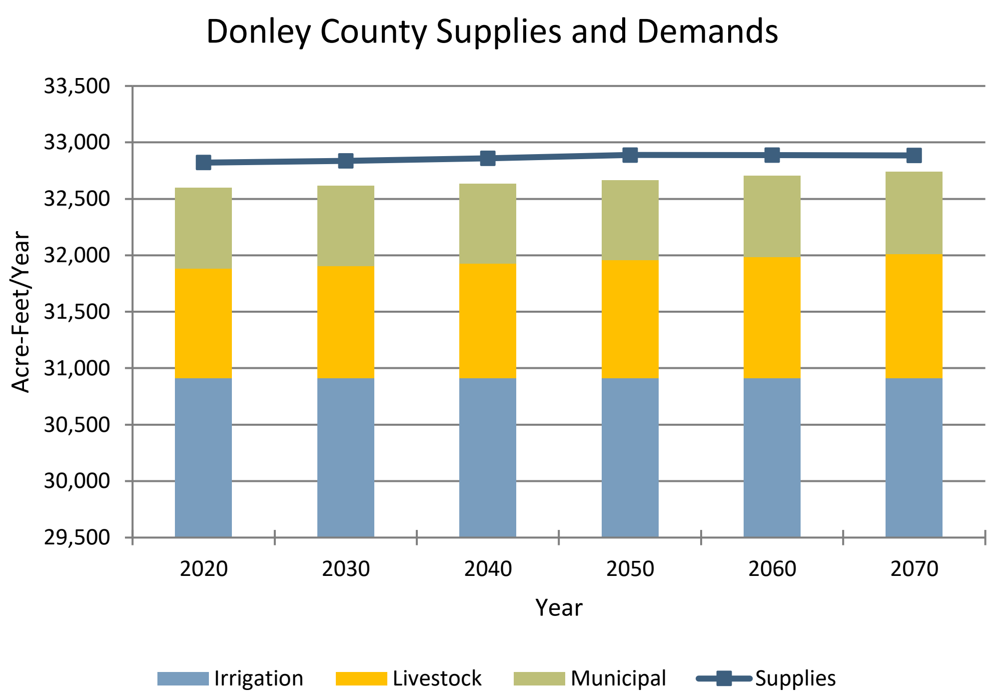
What is the source of my water? Ogallala Aquifer, Greenbelt Reservoir











WATER USER GROUP	STRATEGY
Clarendon	Conservation
Red River Authority of Texas	No Water Need Identified
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

GRAY COUNTY SUMMARY PAGE

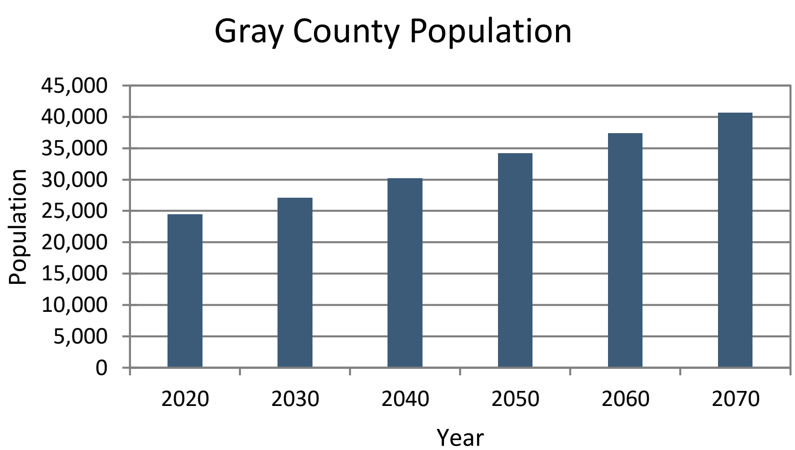
Who are my representatives?

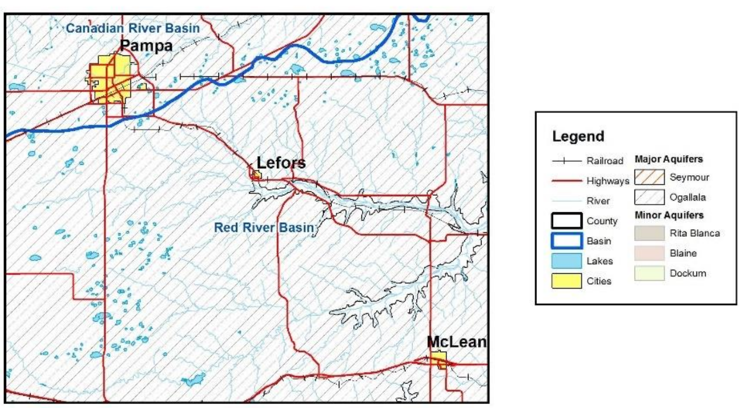
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Kent Satterwhite	- Canadian River MWA
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

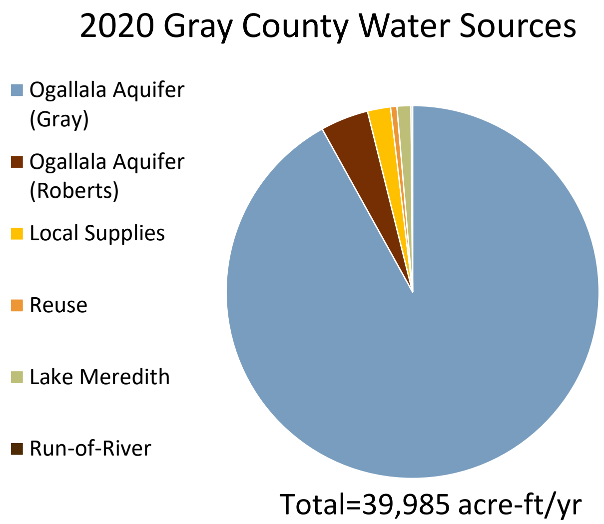
County Seat: City of Pampa

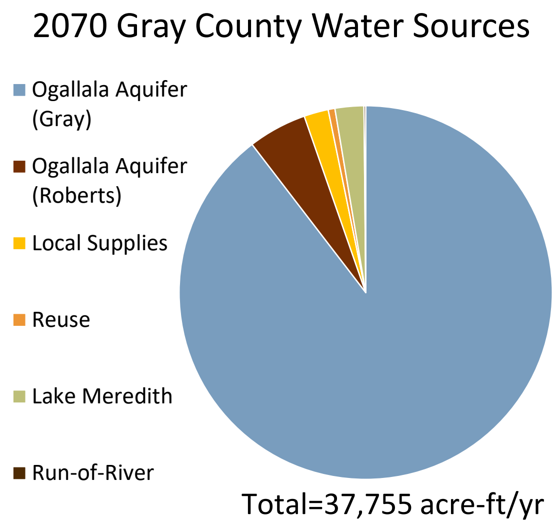
Economy: Agribusiness, Manufacturing, Tourism

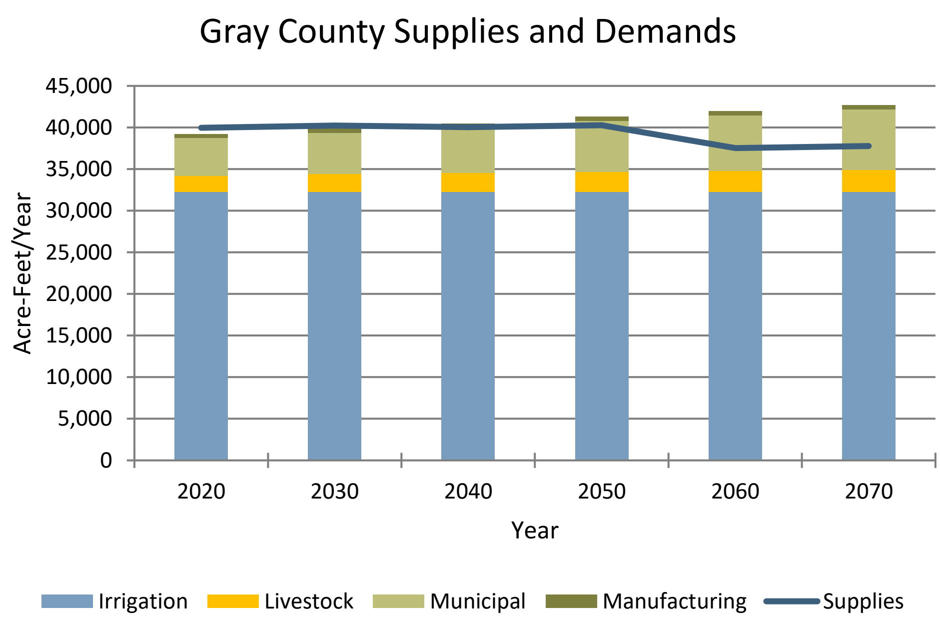
What is the source of my water? Ogallala Aquifer, Lake Meredith











WATER USER GROUP	STRATEGY
McLean	Conservation, New Well(s)
Pampa	Conservation, New Well(s), Contractual Supply From CRMWA
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

HALL COUNTY SUMMARY PAGE

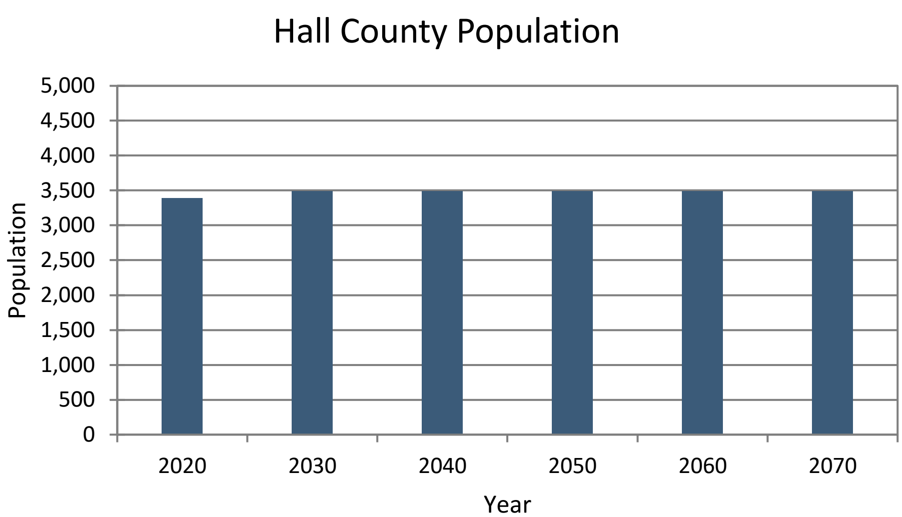
Who are my representatives?

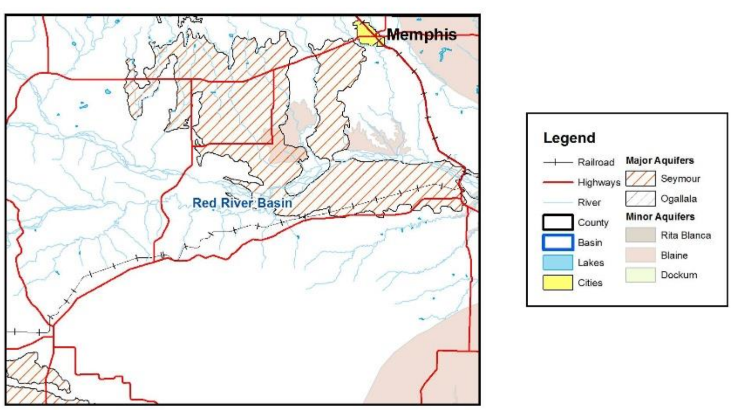
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Bobbie Kidd - Greenbelt MIWA
Lynn Smith - GMA #6

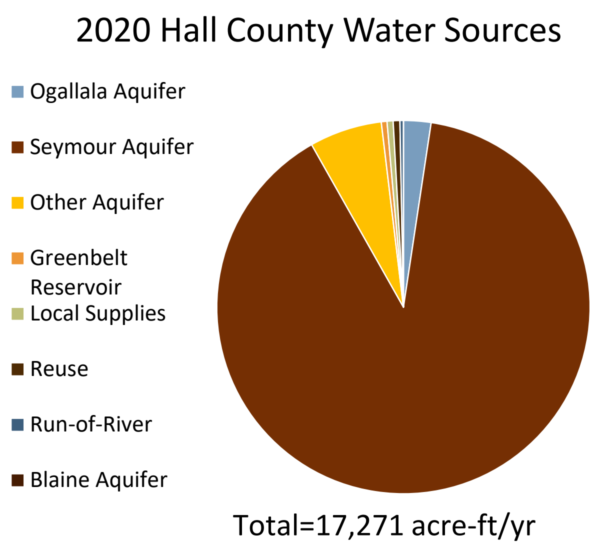
County Seat: City of Memphis

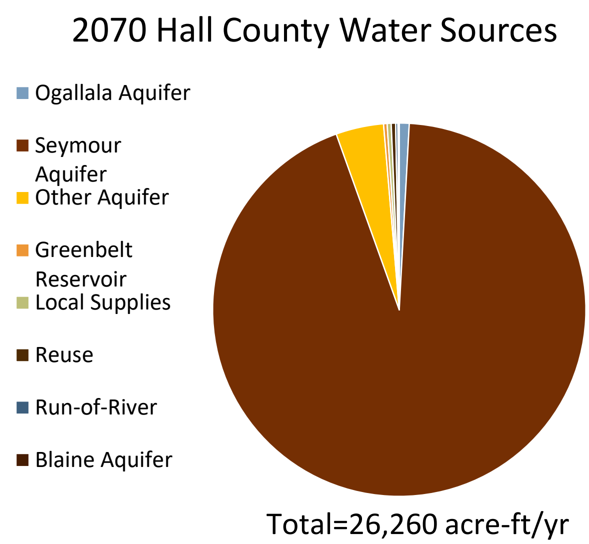
Economy: Agribusiness

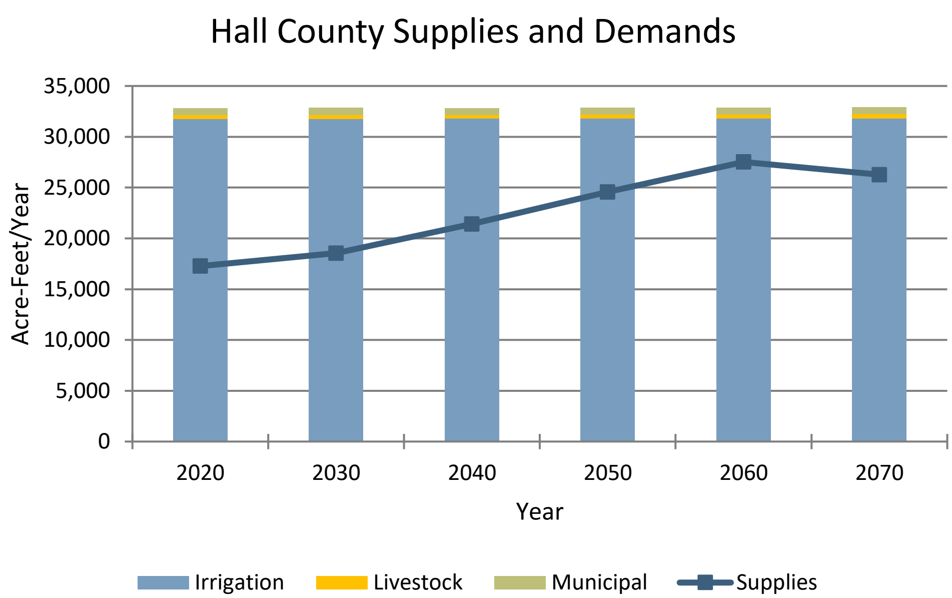
What is the source of my water? Ogallala, Seymour Aquifers, Greenbelt Reservoir











WATER USER GROUP	STRATEGY
Memphis	Conservation, New Well(s)
Red River Authority of Texas	No Water Need Identified
Turkey	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

HANSFORD COUNTY SUMMARY PAGE

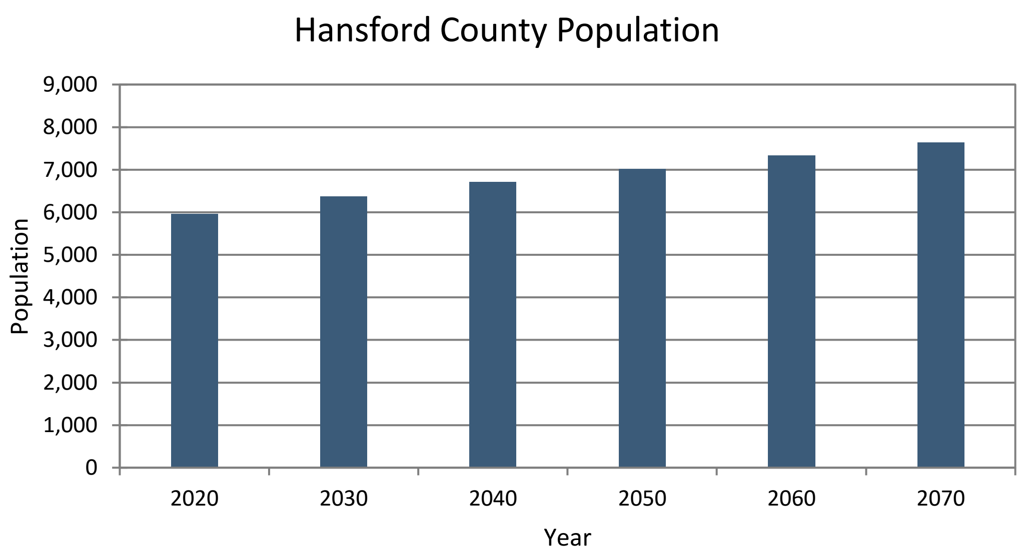
Who are my representatives?

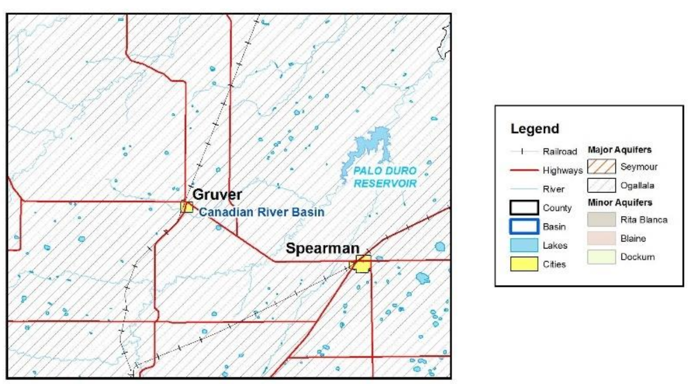
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

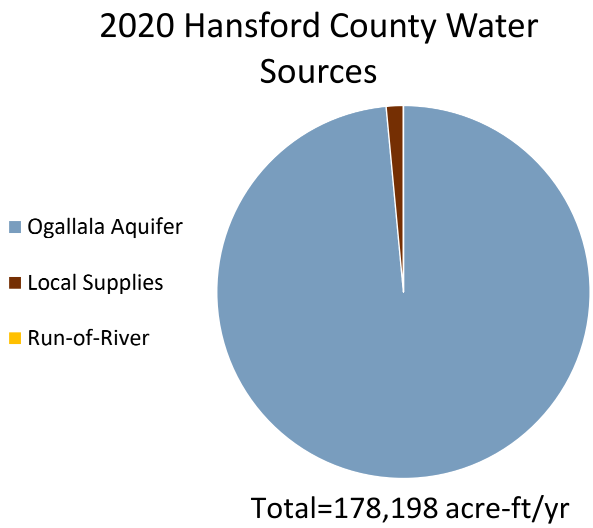
County Seat: City of Spearman

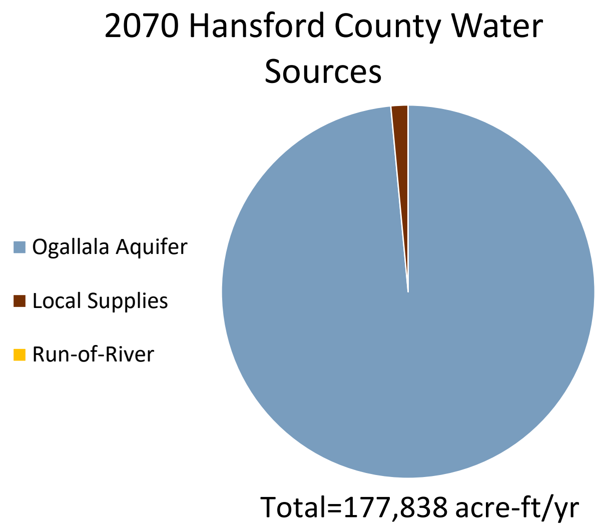
Economy: Agribusiness, Petroleum

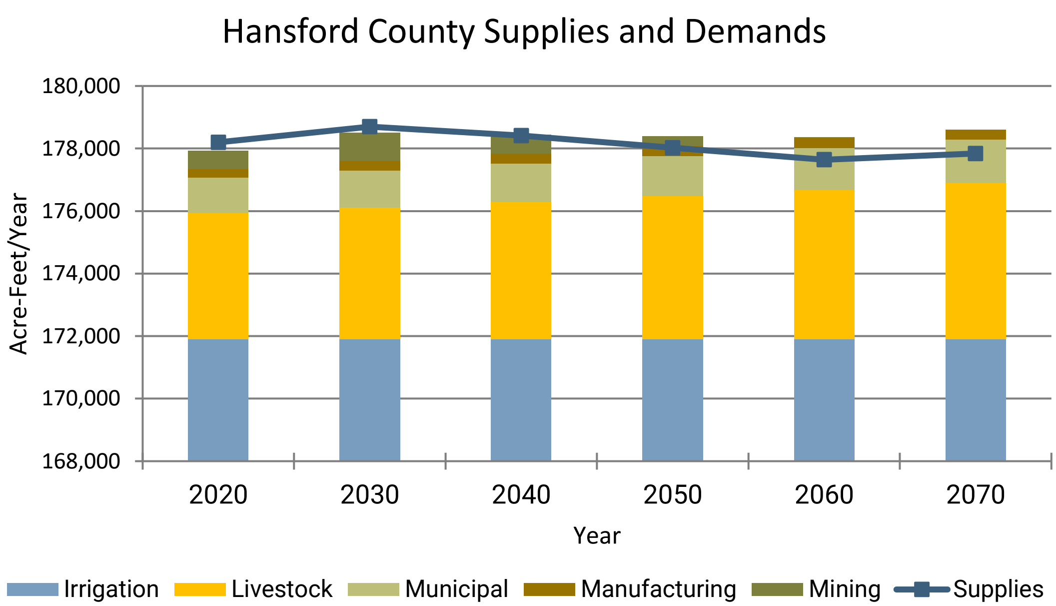
What is the source of my water? Ogallala Aquifer





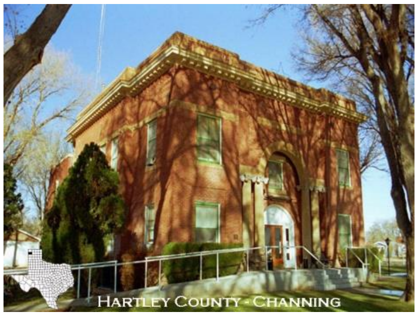






WATER USER GROUP	STRATEGY
Gruver	Conservation, New Well(s)
Spearman	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

HARTLEY COUNTY SUMMARY PAGE



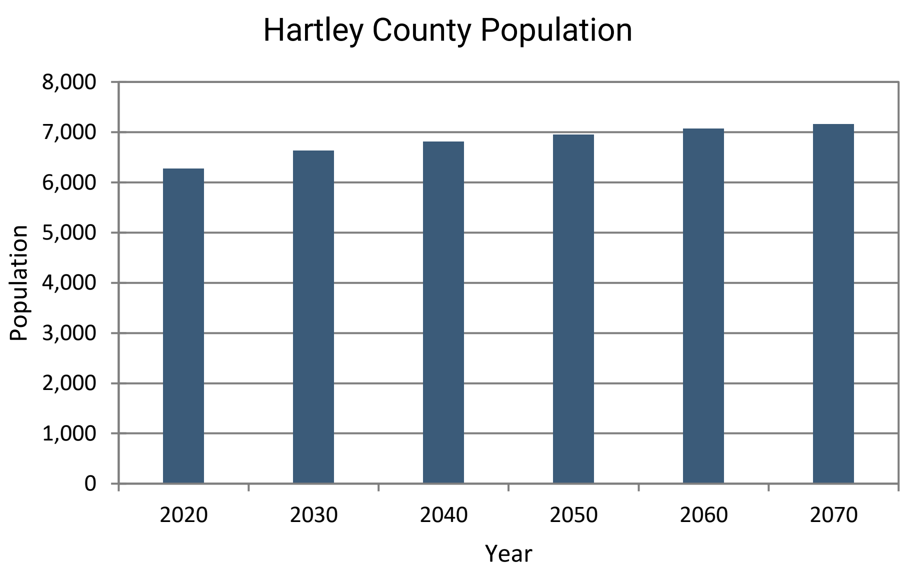
Who are my representatives?

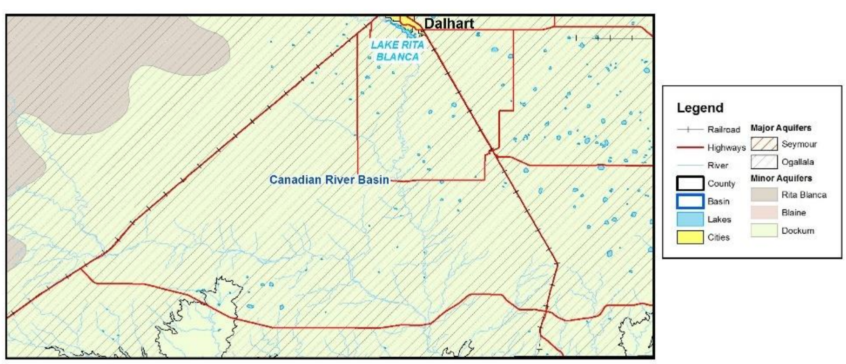
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Steve Walthour - North Plains GCD
Danny Krienke - GMA #1

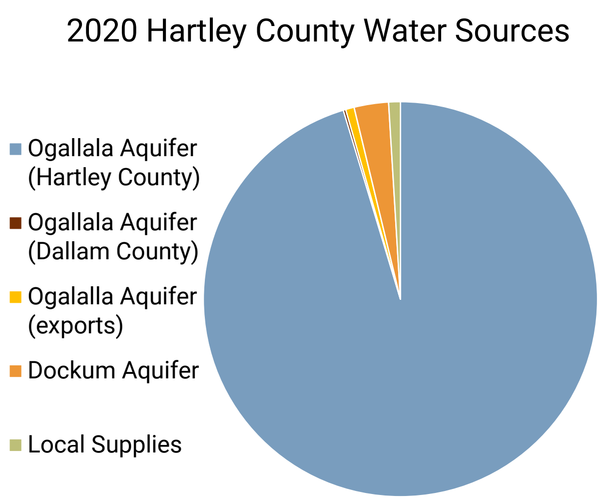
County Seat: City of Channing

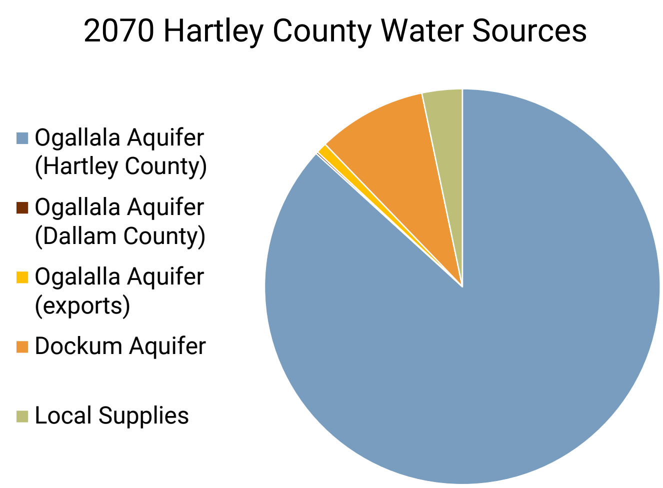
Economy: Agribusiness, Manufacturing, Petroleum

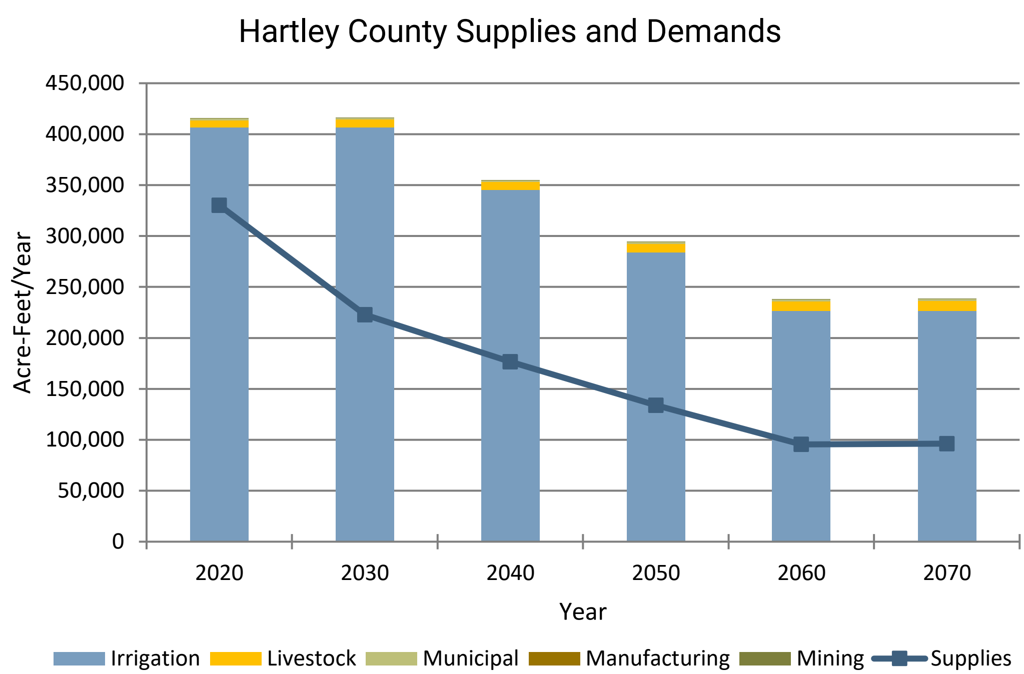
What is the source of my water? Ogallala, Dockum Aquifers





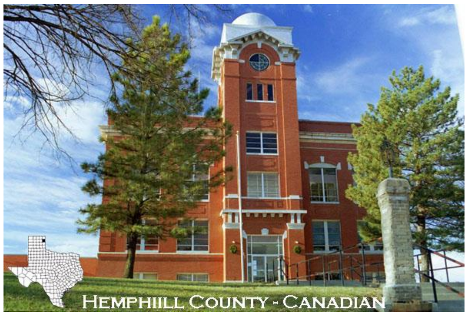






WATER USER GROUP	STRATEGY
Dalhart	Conservation, New Well(s)
Hartley	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

HEMPHILL COUNTY SUMMARY PAGE



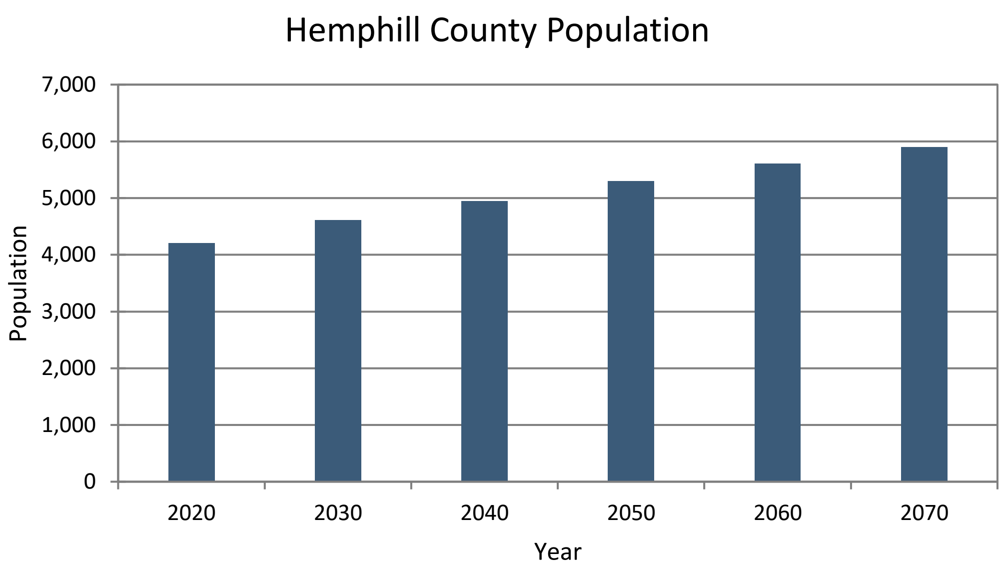
Who are my representatives?

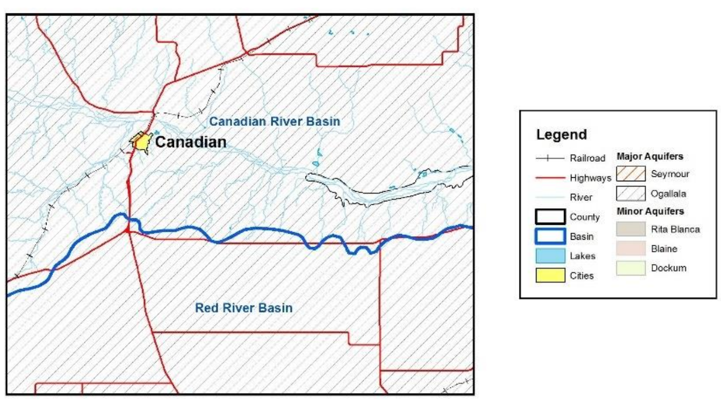
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Janet Guthrie	- Hemphill UGCD
Danny Krienke	- GMA #1

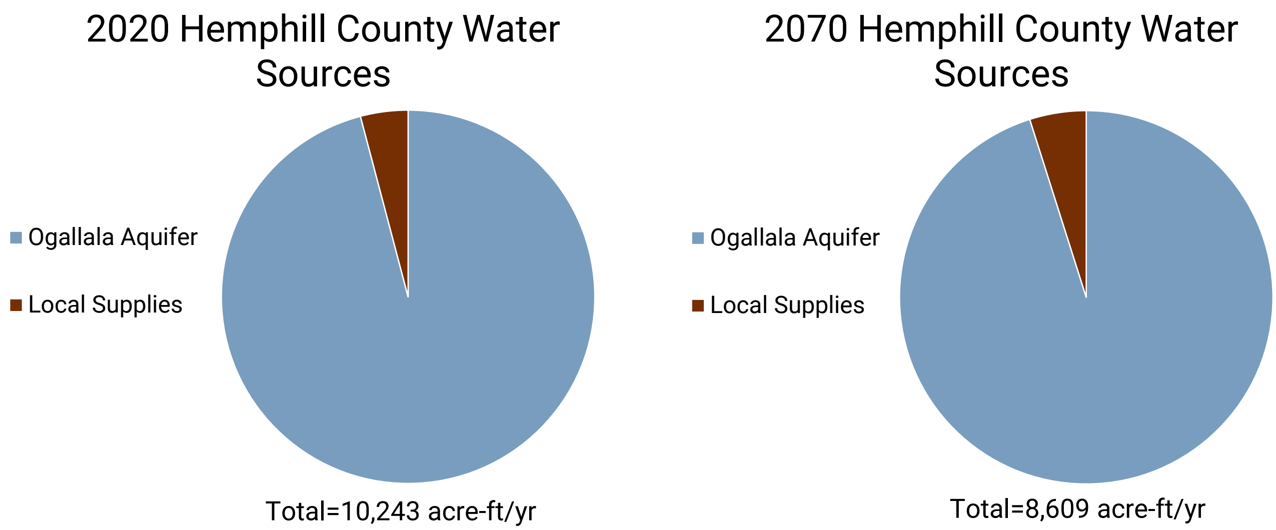
County Seat: City of Canadian

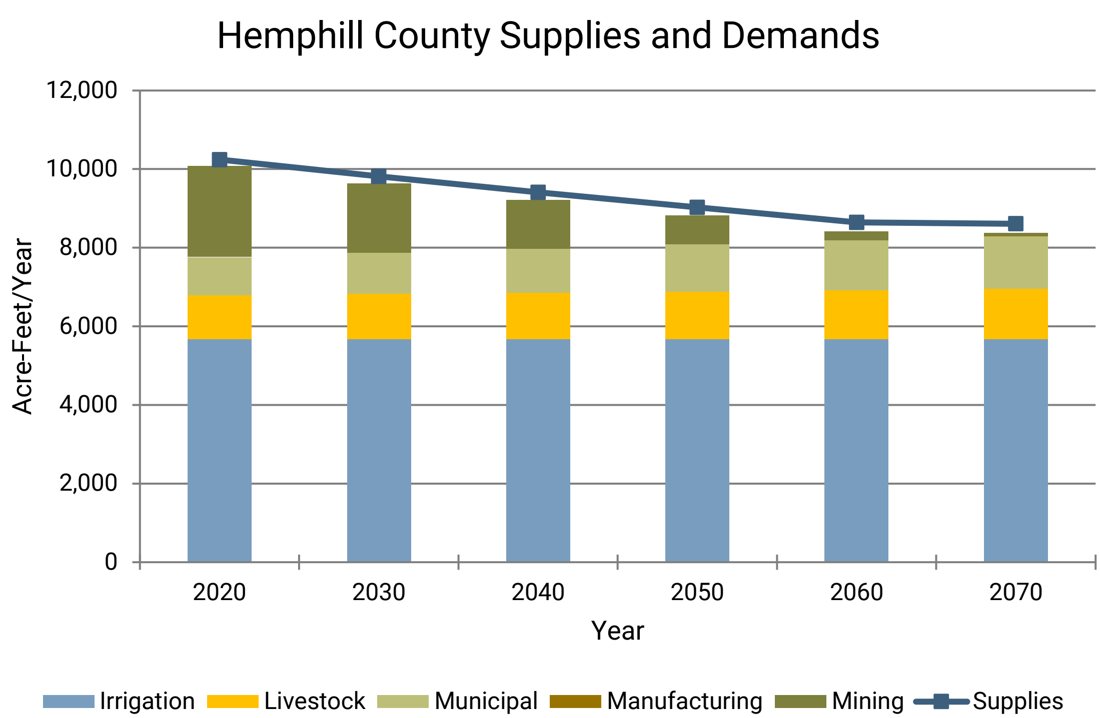
Economy: Agribusiness, Petroleum

What is the source of my water? Ogallala Aquifer









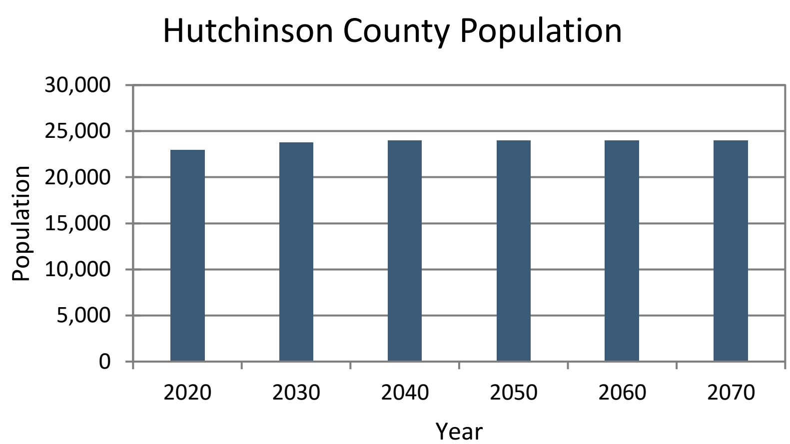
WATER USER GROUP	STRATEGY
Canadian	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

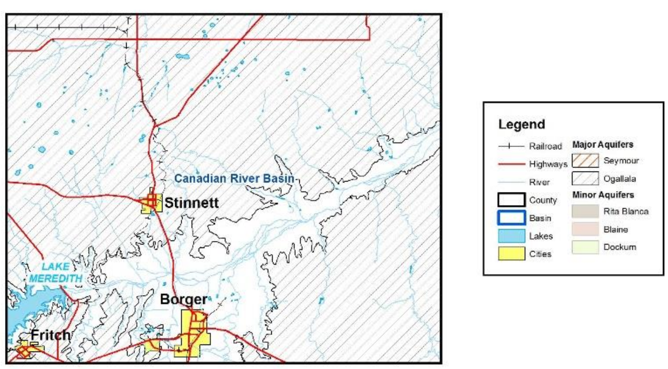
HUTCHINSON COUNTY SUMMARY PAGE

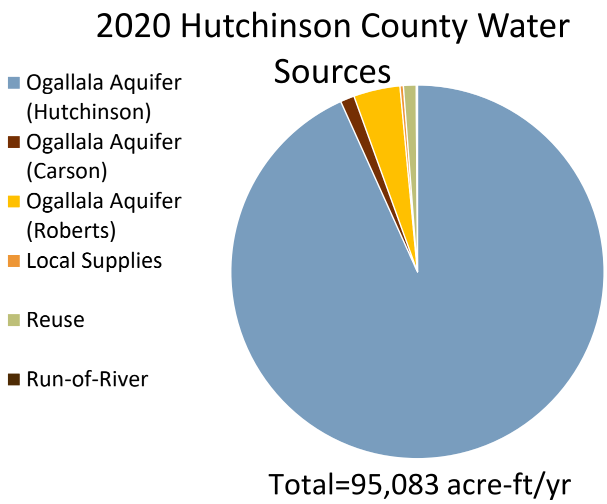
Who are my representatives?

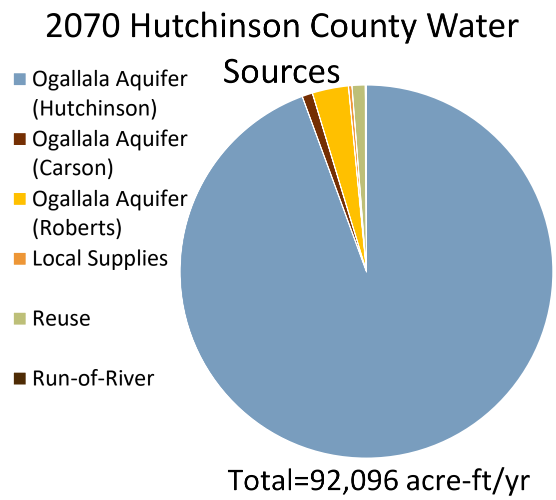
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Dean Cooke - TCW Supply
Kent Satterwhite - Canadian River MWA
Steve Walthour - North Plains GCD
C.E. Williams - Panhandle GCD
Beverly Stephens - Phillips 66
Danny Krienke - GMA #1

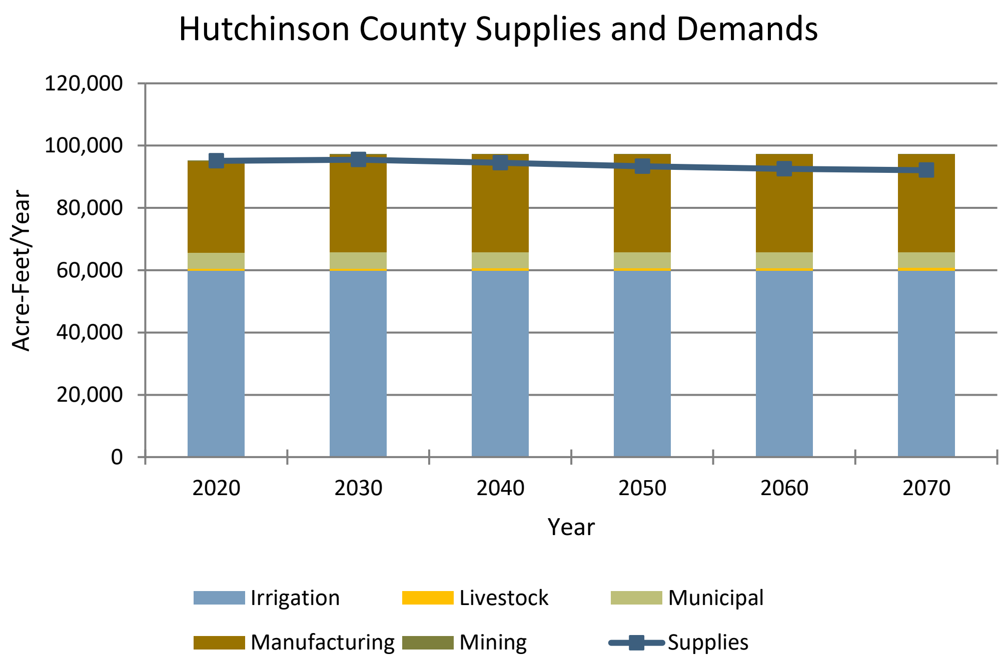
County Seat: City of Stinnett
Economy: Agribusiness, Manufacturing, Petroleum, Tourism
What is the source of my water? Ogallala Aquifer, Reuse











WATER USER GROUP	STRATEGY
Borger	Conservation, Contractual supplies from CRMWA
Fritch	Conservation
Stinnett	Conservation, New Well(s)
TCW Water Supply Inc.	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	Contractual Supply from Borger
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

LIPSCOMB COUNTY SUMMARY PAGE

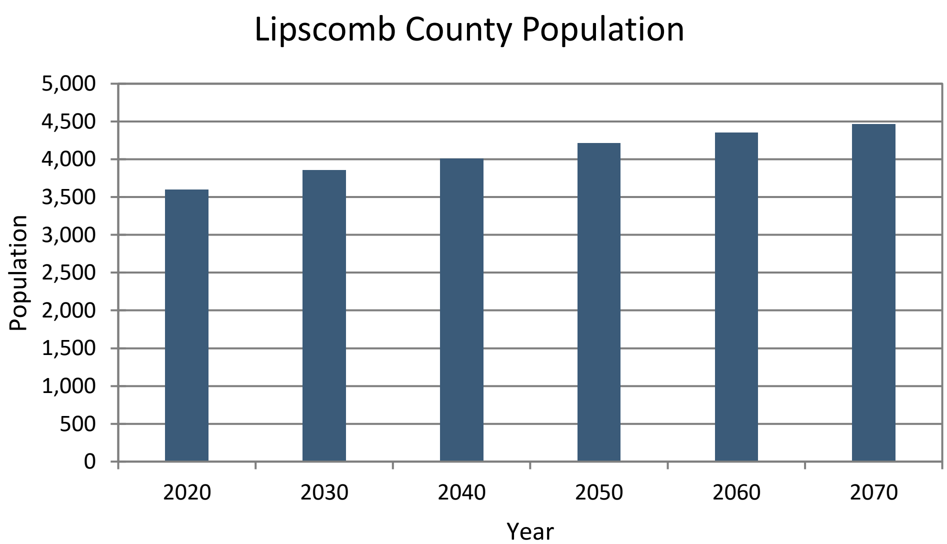
Who are my representatives?

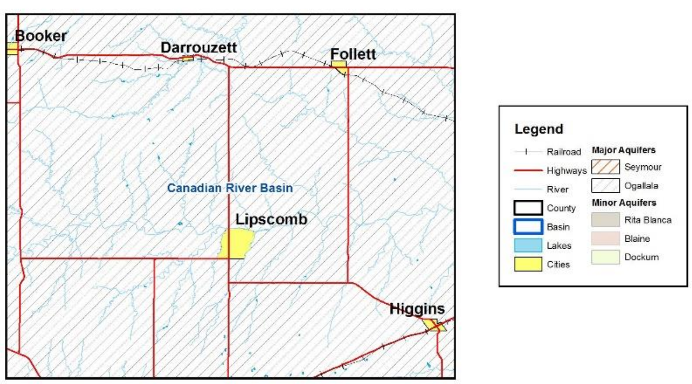
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Janet Tregellas - Farm/Ranch
Steve Walthour - North Plains GCD
Danny Krienke - GMA #1

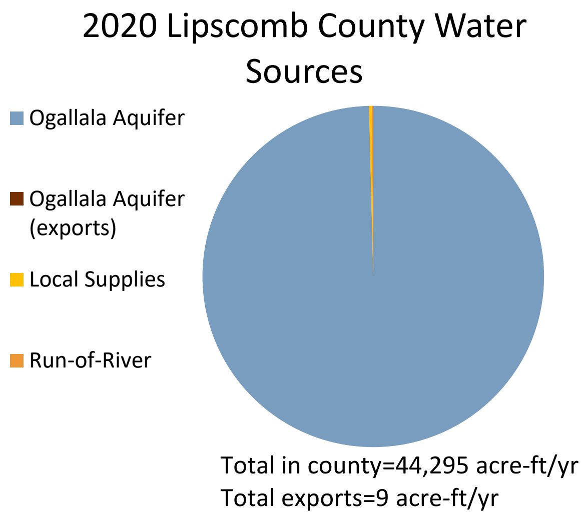
County Seat: City of Lipscomb

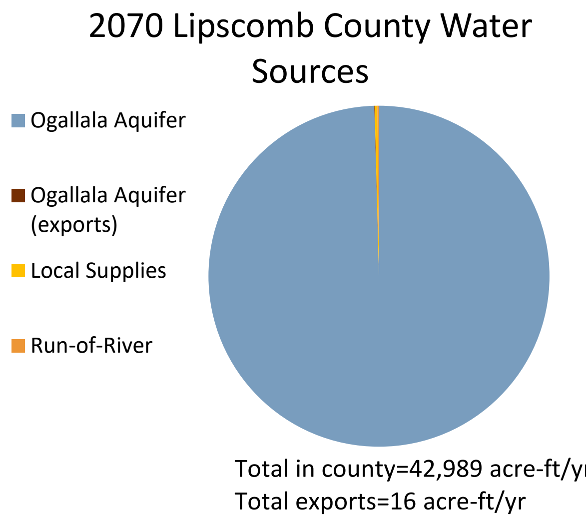
Economy: Agribusiness, Petroleum

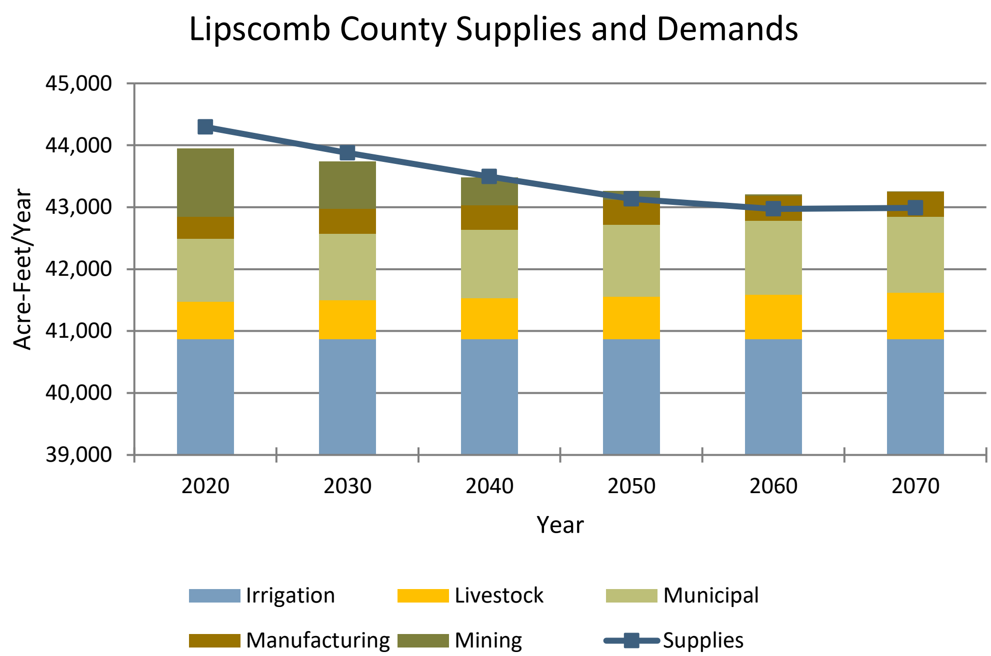
What is the source of my water? Ogallala Aquifer





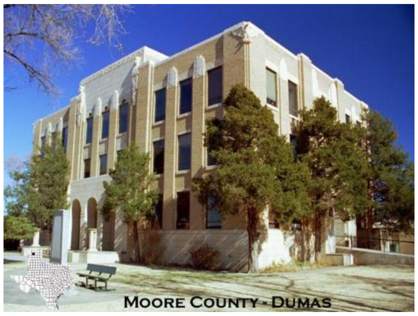






WATER USER GROUP	STRATEGY
Booker	Conservation, New Well(s)
Darrouzett	Conservation
Follett	Conservation
Higgins	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	Contractual Supply from Booker
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

MOORE COUNTY SUMMARY PAGE



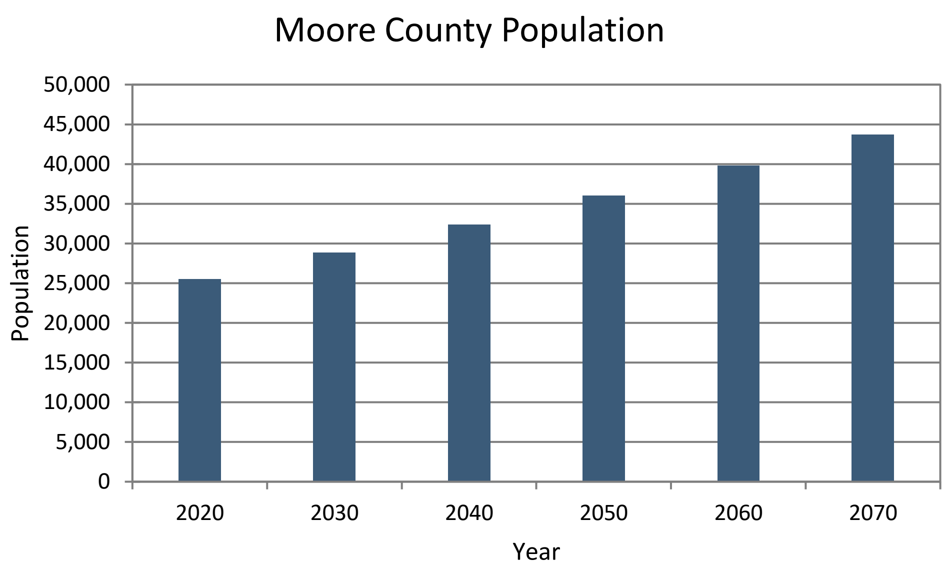
Who are my representatives?

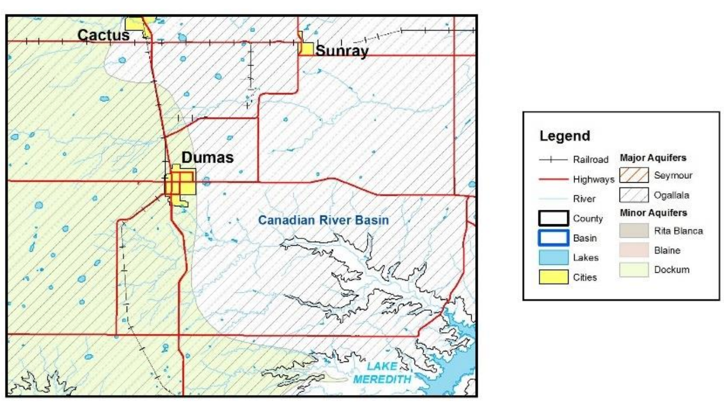
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Steve Walthour - North Plains GCD
Danny Krienke - GMA #1

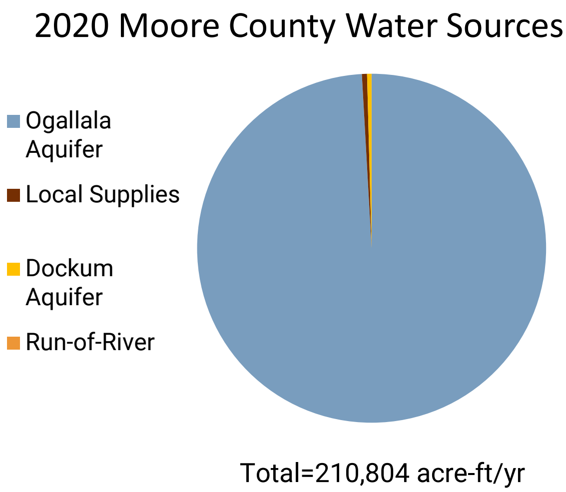
County Seat: City of Dumas

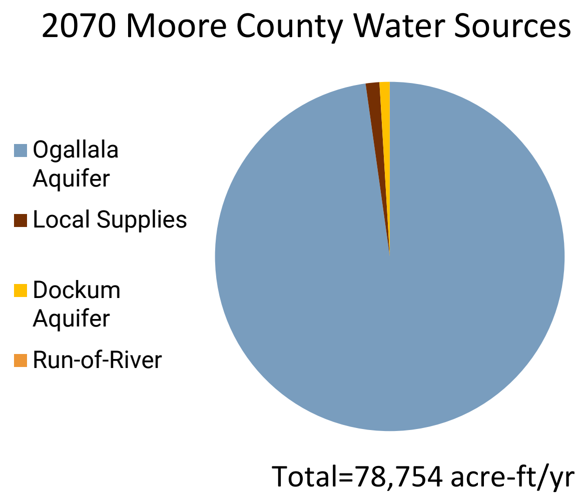
Economy: Agribusiness, Petroleum

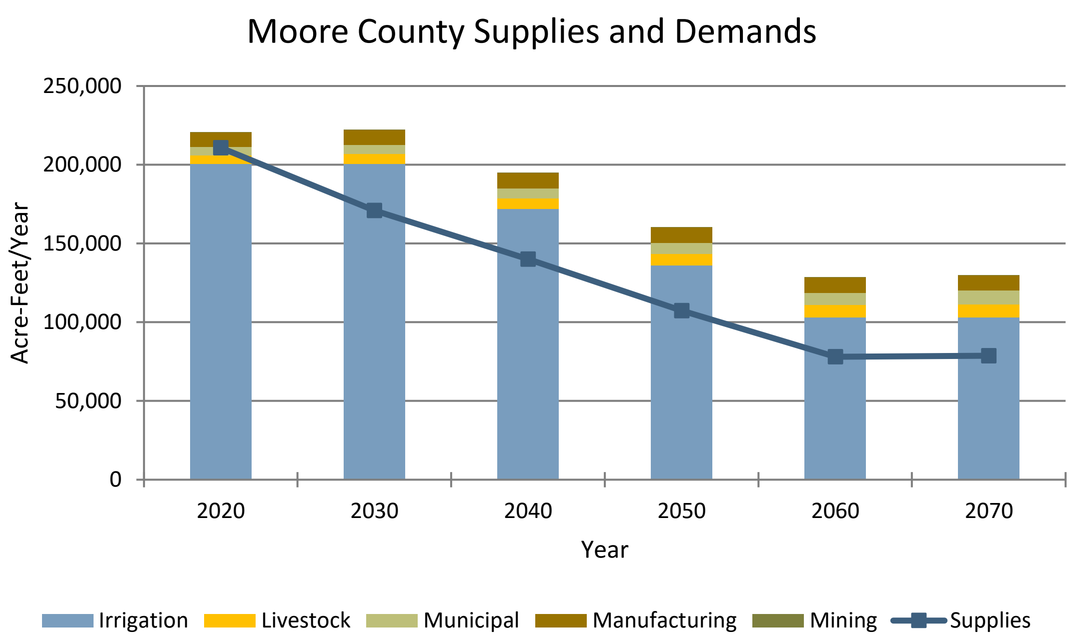
What is the source of my water? Ogallala Aquifer











WATER USER GROUP	STRATEGY
Cactus	Conservation, New Well(s)
Dumas	Conservation, New Well(s)
Fritch	Conservation
Sunray	Conservation, New Well(s)
County-Other	Conservation, Purchase Supply from Dumas
Irrigation	Conservation
Manufacturing	Purchase Supply from Cactus, New Well(s)
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

OCHILTREE COUNTY SUMMARY PAGE

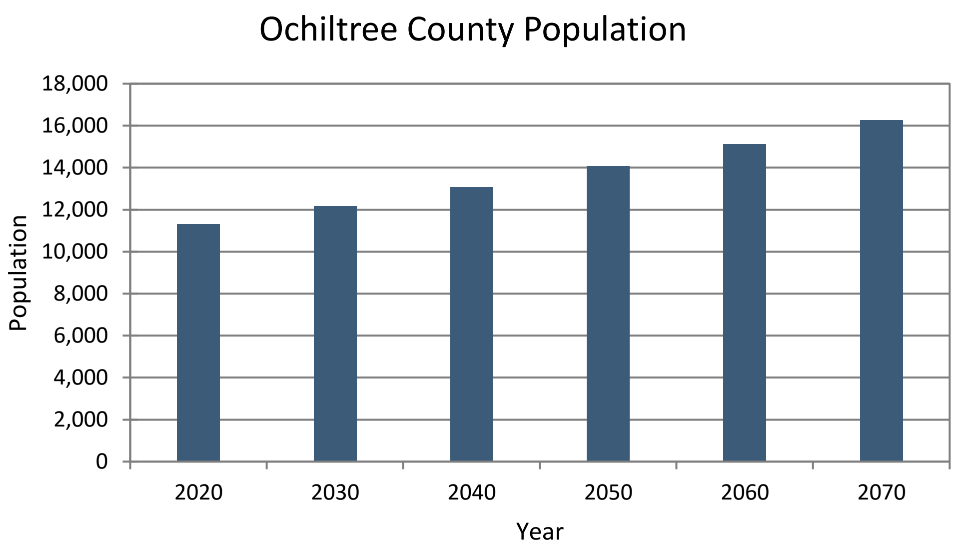
Who are my representatives?

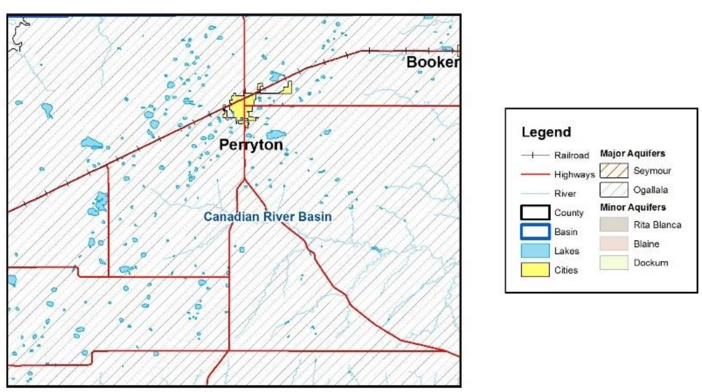
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
David Landis - City of Perryton
Steve Walthour - North Plains GCD
Danny Krienke - GMA #1

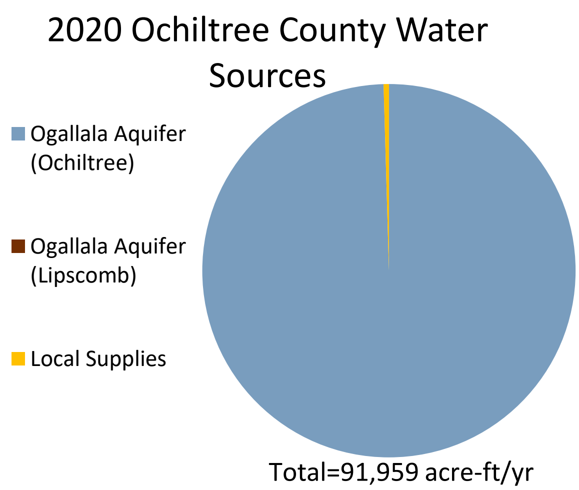
County Seat: City of Perryton

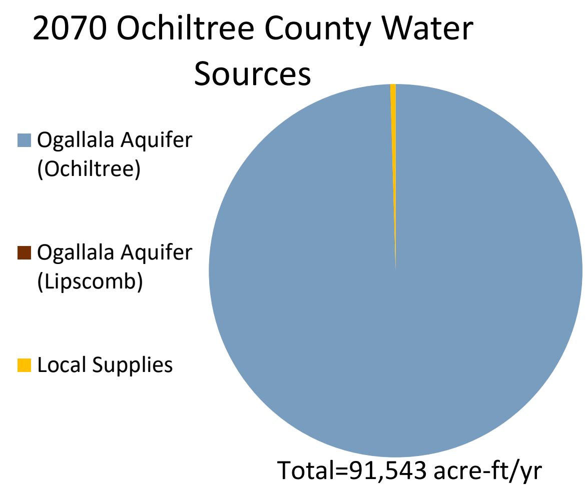
Economy: Agribusiness, Petroleum

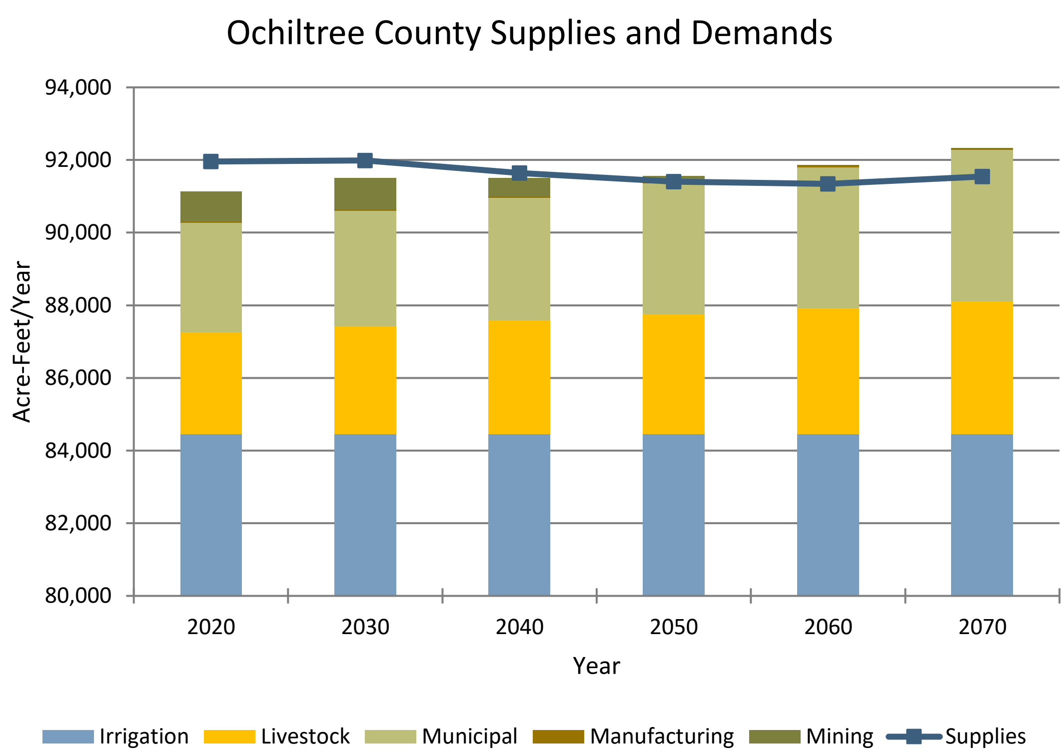
What is the source of my water? Ogallala Aquifer











WATER USER GROUP	STRATEGY
Perryton	Conservation, New Well(s)
Booker	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

OLDHAM COUNTY SUMMARY PAGE

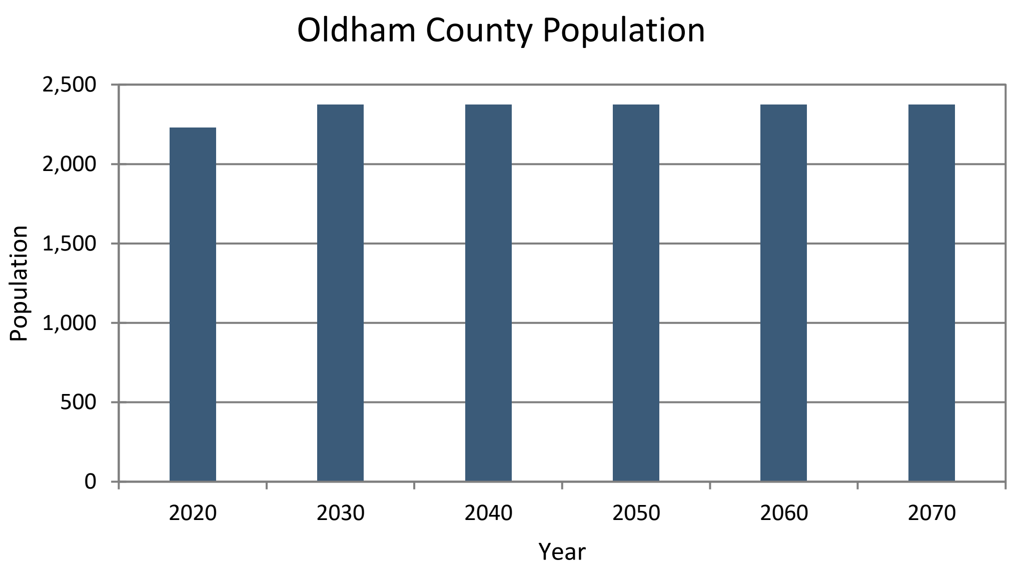
Who are my representatives?

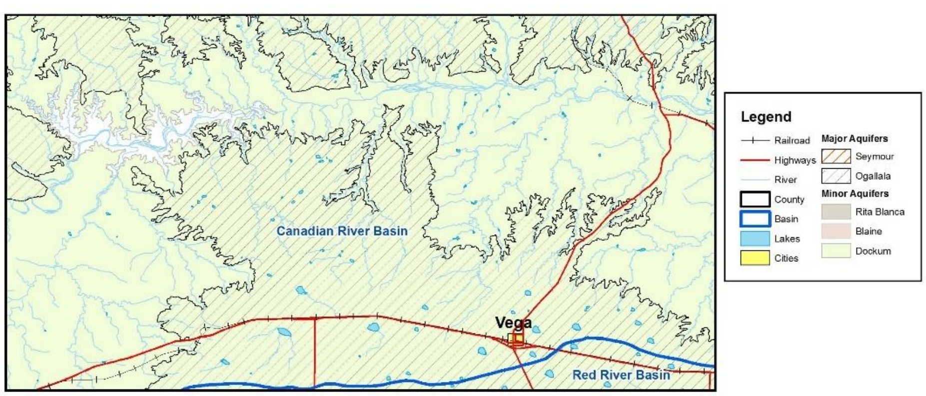
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Don Allred - Oldham County
Danny Krienke - GMA #1

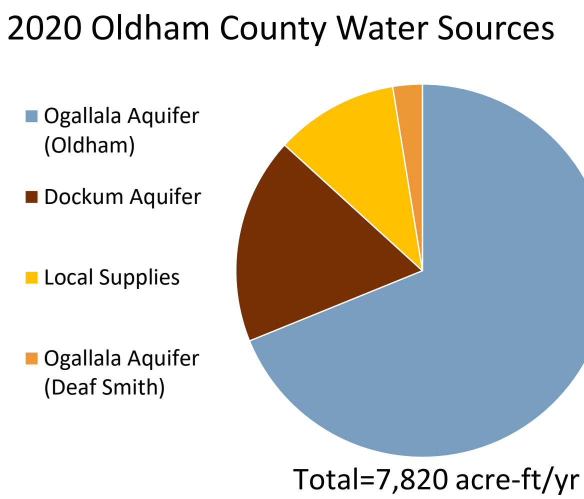
County Seat: City of Vega

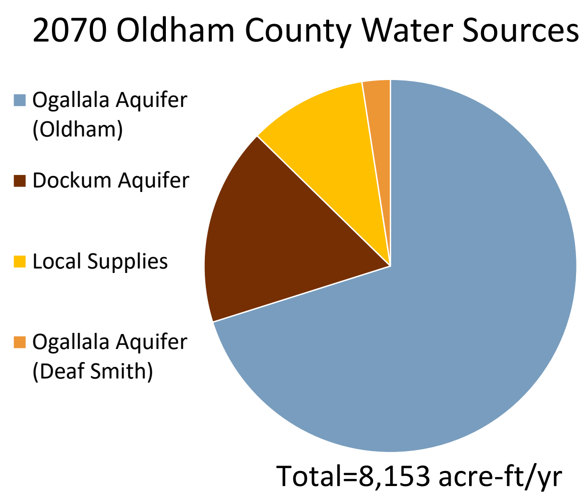
Economy: Agribusiness

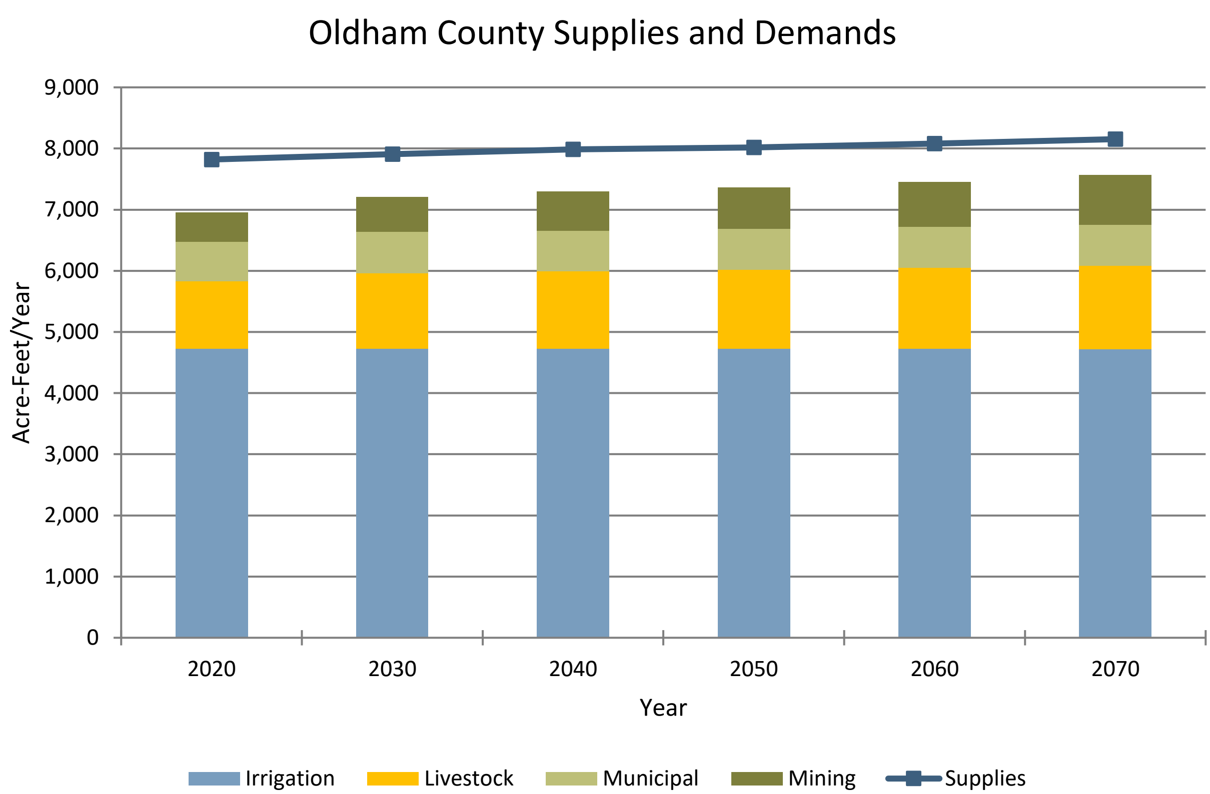
What is the source of my water? Ogallala, Dockum Aquifers











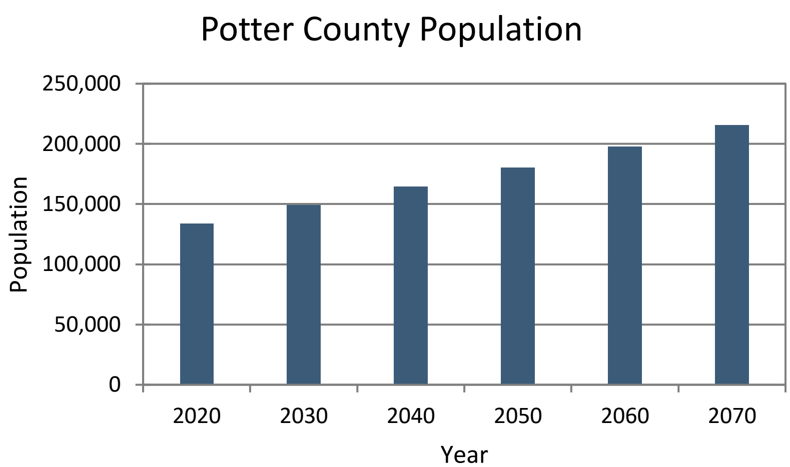
WATER USER GROUP	STRATEGY
Vega	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

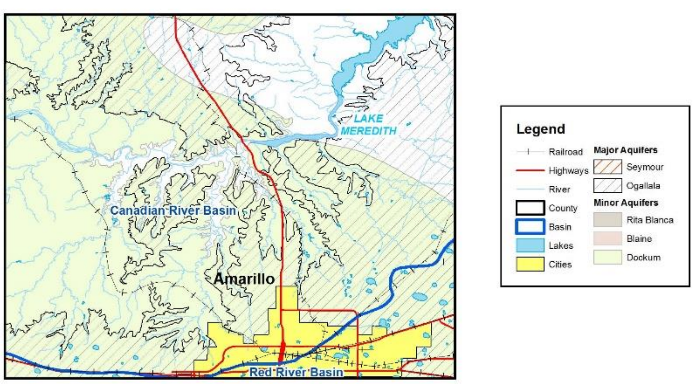
POTTER COUNTY SUMMARY PAGE

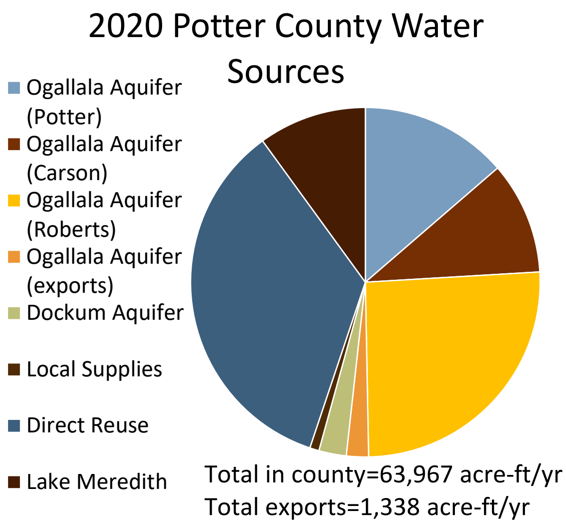
Who are my representatives?

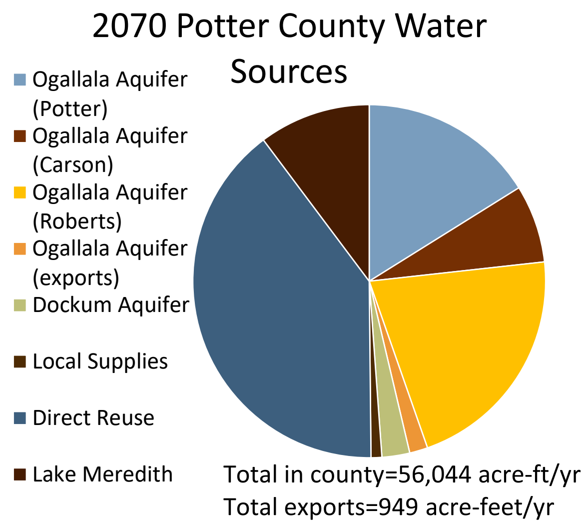
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
Floyd Hartman	- City of Amarillo
Kent Satterwhite	- Canadian River MWA
Roy Messer	- J.D. Heiskell & Co.
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

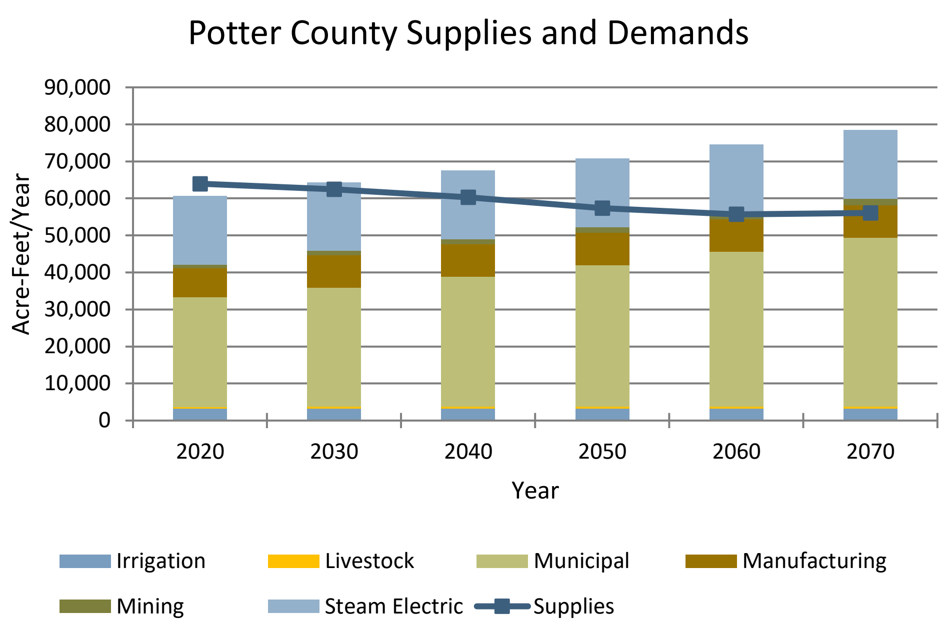
County Seat: City of Amarillo
Economy: Agribusiness, Manufacturing, Petroleum, Tourism
What is the source of my water? Ogallala, Dockum Aquifers, Reuse, Lake Meredith











WATER USER GROUP	WATER MANAGEMENT STRATEGY
Amarillo	Conservation, Potter Co./Carson Co. Well Field, Roberts Co. Well Field, Contractual Supply from CRMWA, Aquifer Storage and Recovery, Direct Potable Reuse
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	Contractual Supply from Amarillo, New Well(s)
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Water Need Identified

RANDALL COUNTY SUMMARY PAGE

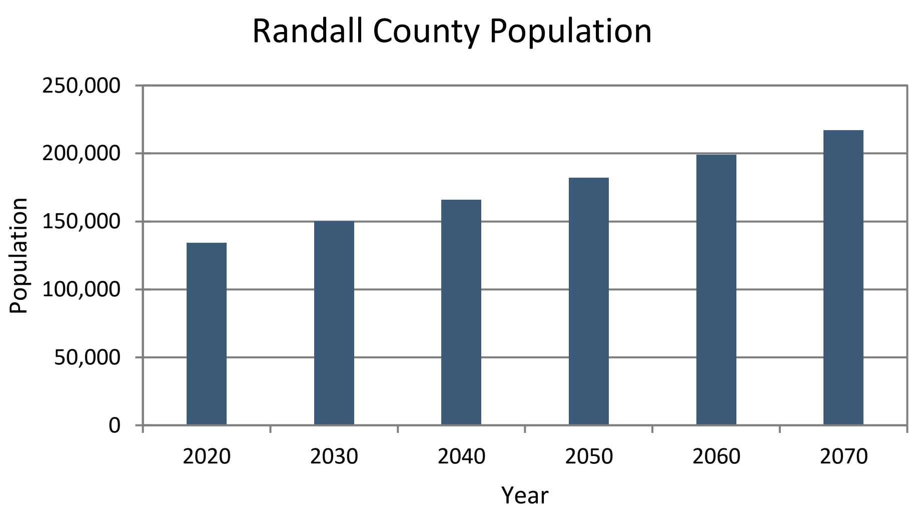
Who are my representatives?

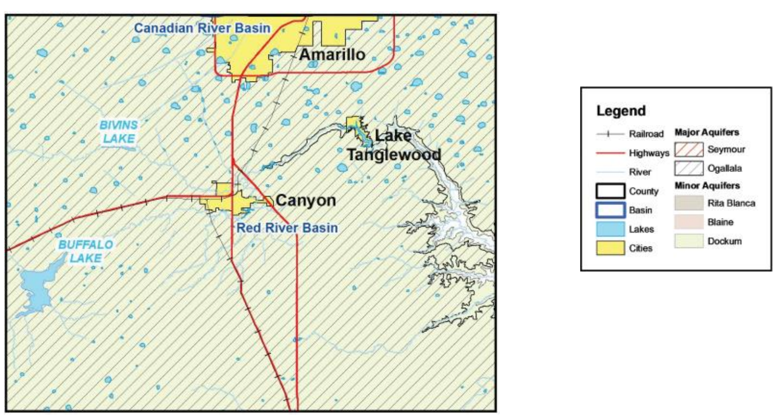
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Floyd Hartman - City of Amarillo
Kent Satterwhite - Canadian River MWA
Dillion Pool - Enviro-Ag
Danny Krienke - GMA #1

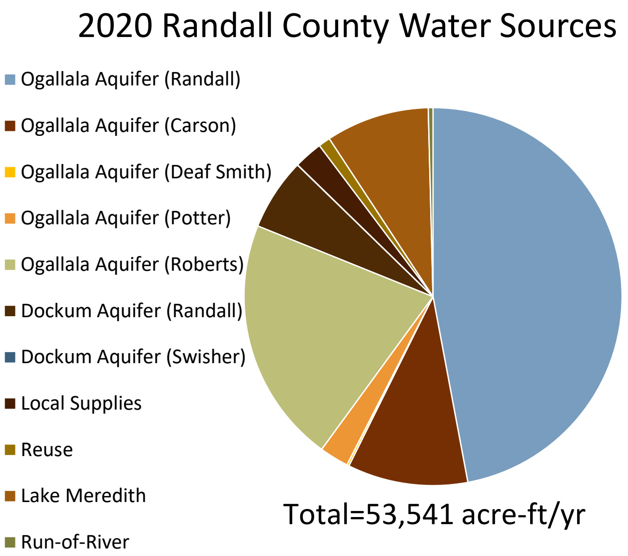
County Seat: City of Canyon

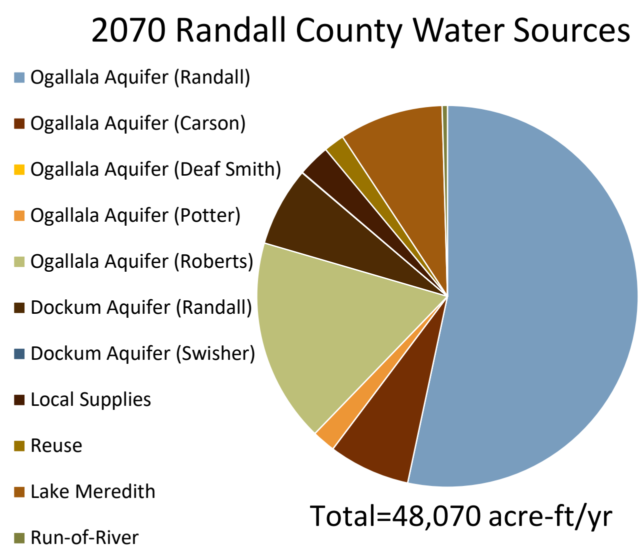
Economy: Agribusiness, Manufacturing, Tourism

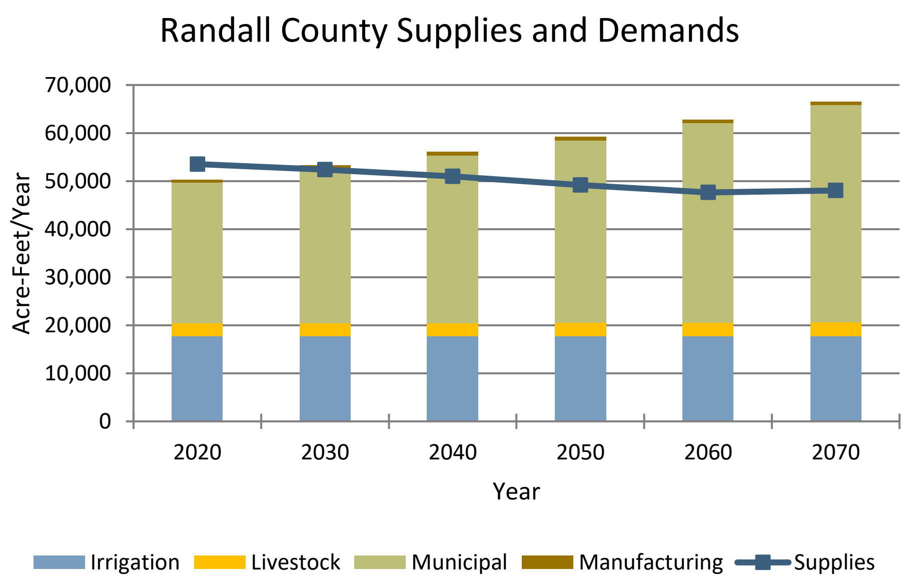
What is the source of my water? Ogallala, Dockum Aquifers, Reuse, Lake Meredith











WATER USER GROUP	STRATEGY
Amarillo	Conservation, Potter Co./Carson Co. Well Field, Roberts Co. Well Field, Contractual Supply from CRMWA, Aquifer Storage and Recovery, Direct Potable Reuse
Canyon	Conservation, New Well(s)
Lake Tanglewood	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	New Well(s), Contractual Supply from Amarillo
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

ROBERTS COUNTY SUMMARY PAGE

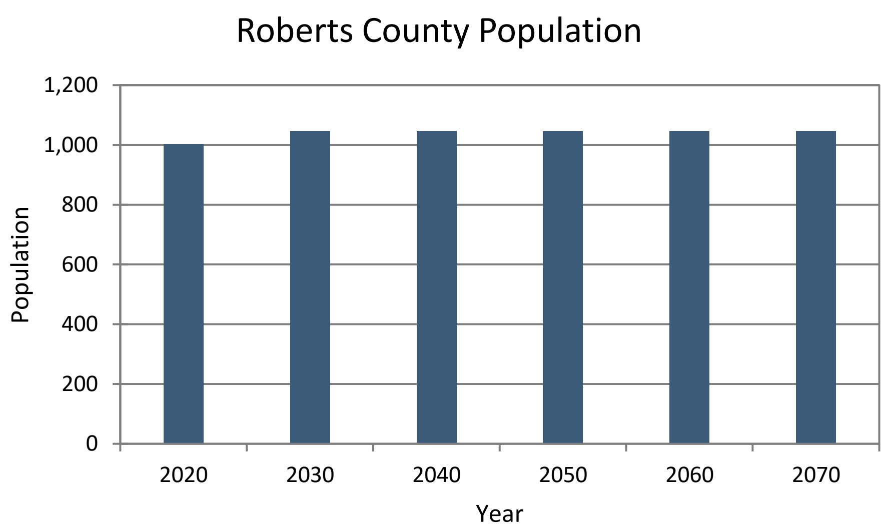
Who are my representatives?

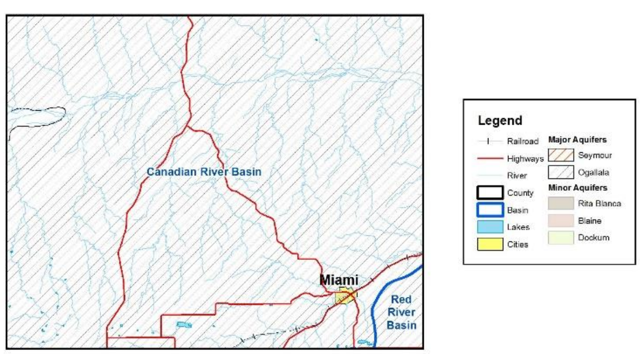
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Judge Vernon Cook- Retired (Roberts County)
C.E. Williams - Panhandle GCD
Kent Satterwhite - Canadian River MWA
Danny Krienke - GMA #1

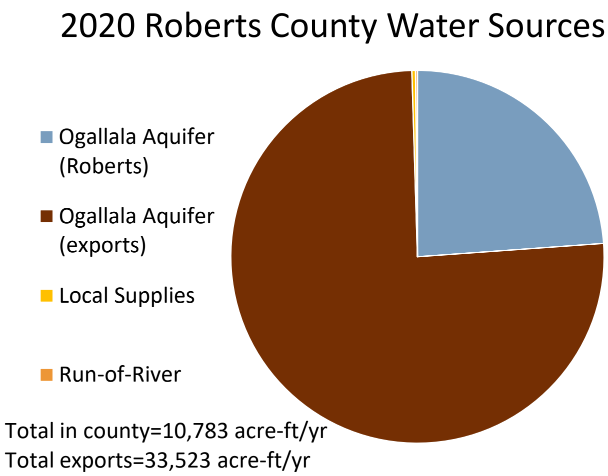
County Seat: City of Miami

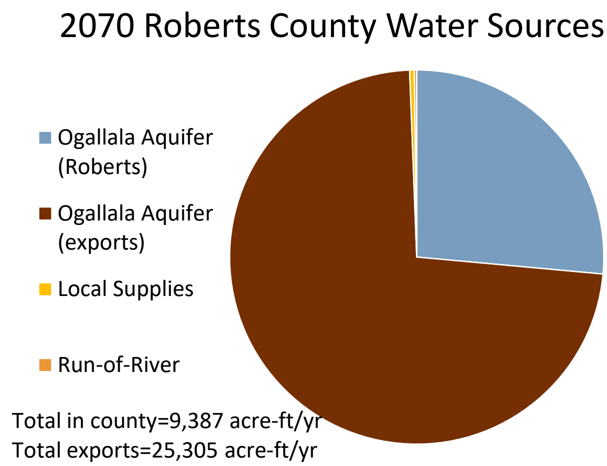
Economy: Agribusiness, Petroleum

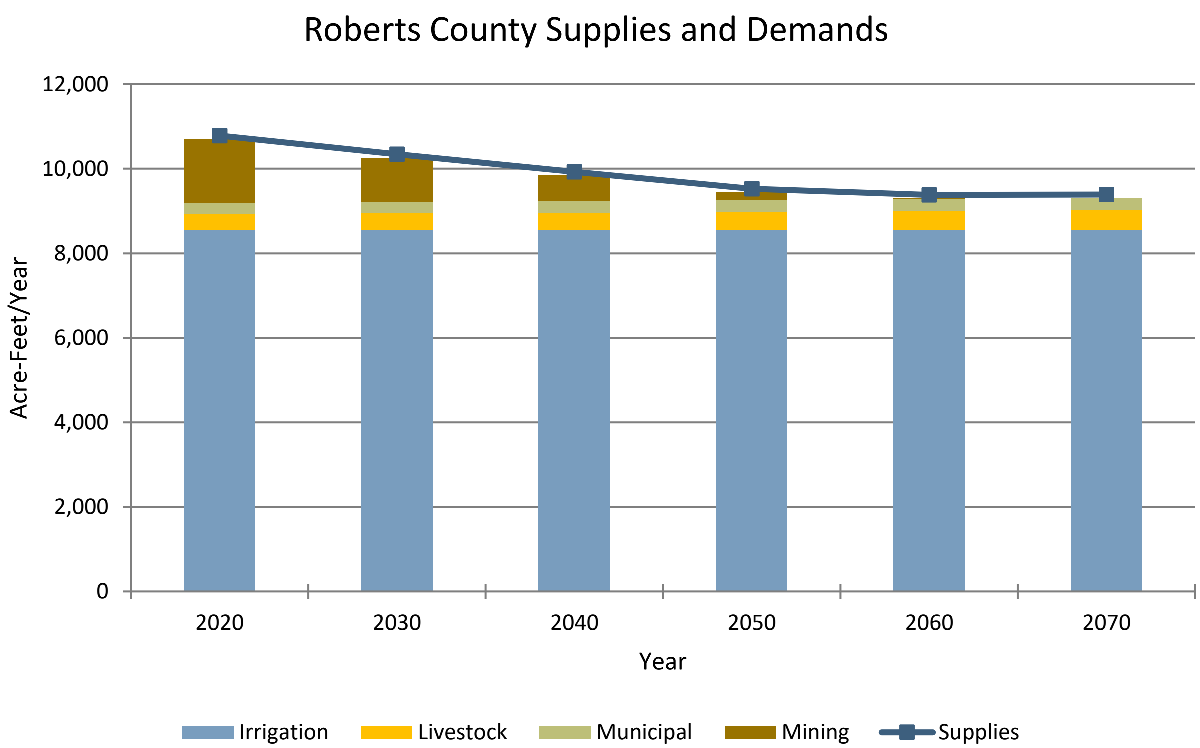
What is the source of my water? Ogallala Aquifer











WATER USER GROUP	STRATEGY
Miami	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

SHERMAN COUNTY SUMMARY PAGE

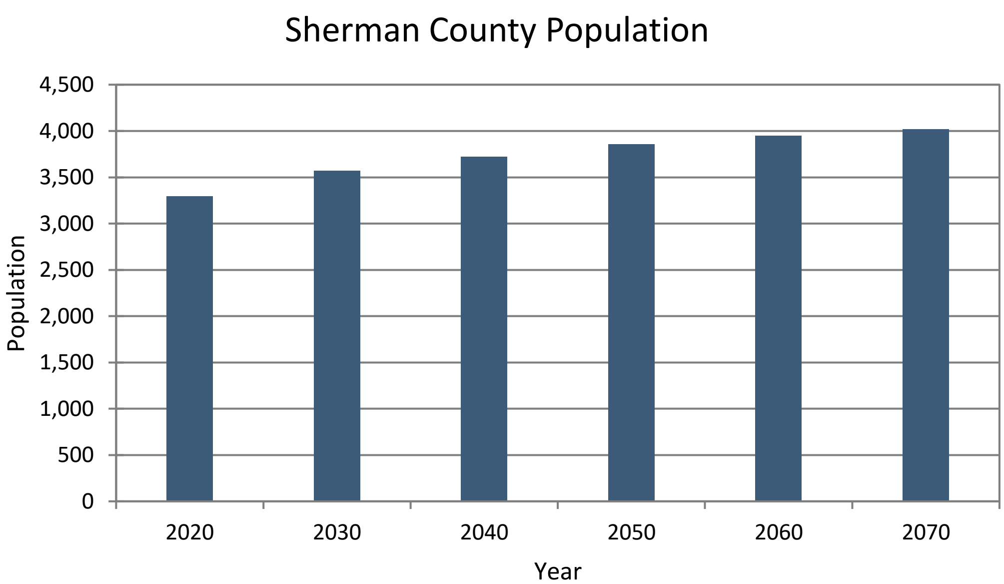
Who are my representatives?

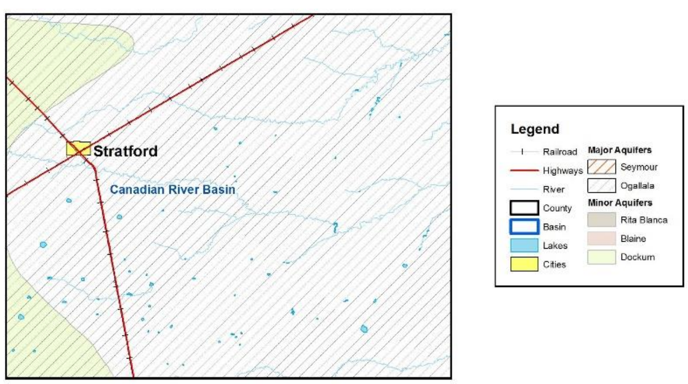
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
Brent Auvermann - Texas A&M AgriLife
Glen Green - Xcel Energy
Rick Gibson - Environmental Consultant
Steve Walthour - North Plains GCD
Danny Krienke - GMA #1

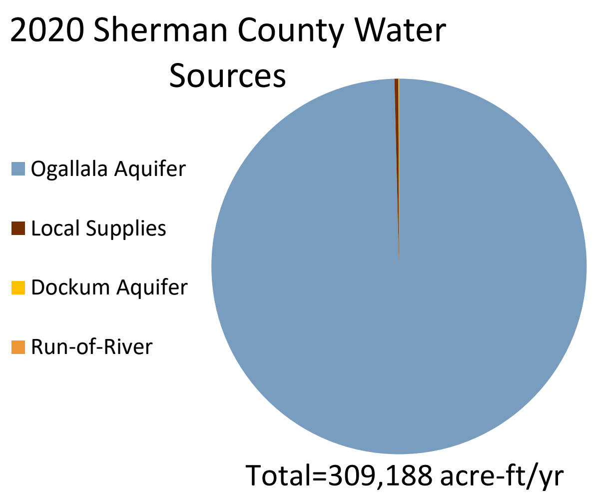
County Seat: City of Stratford

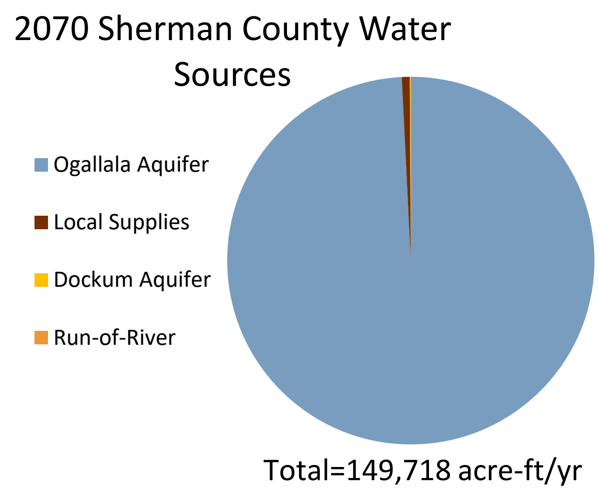
Economy: Agribusiness, Petroleum

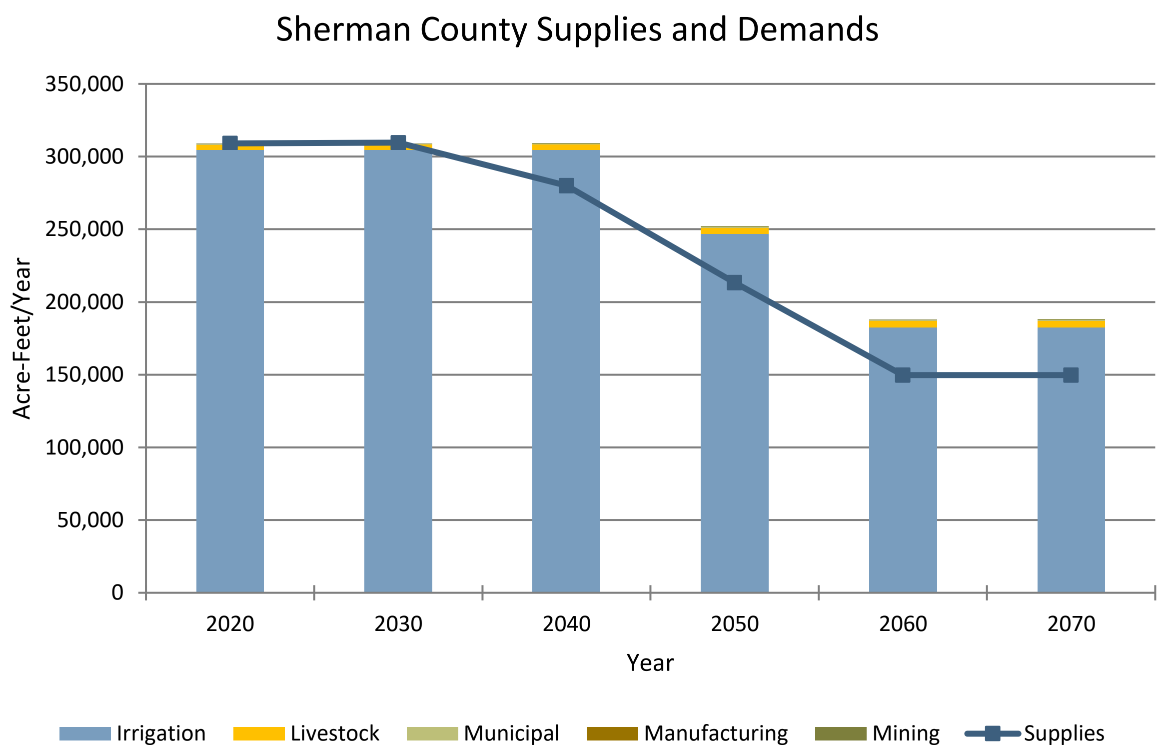
What is the source of my water? Ogallala Aquifer











WATER USER GROUP	STRATEGY
Stratford	Conservation
Texhoma	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

WHEELER COUNTY SUMMARY PAGE

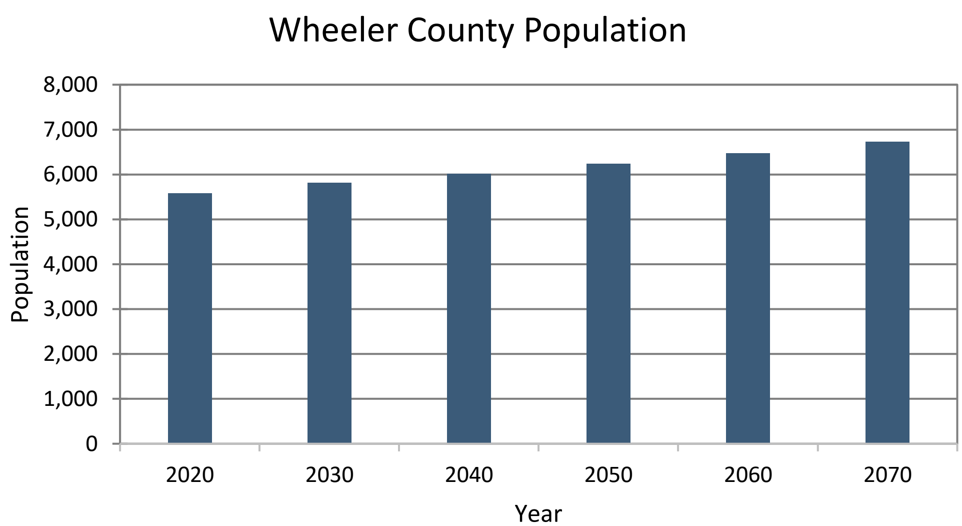
Who are my representatives?

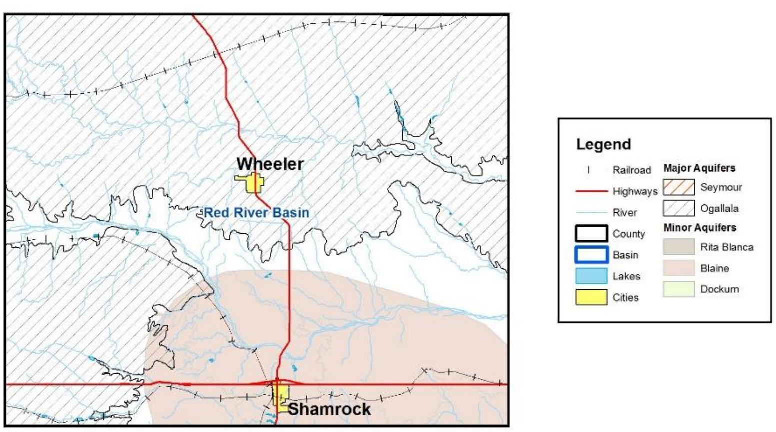
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
Brent Auvermann	- Texas A&M AgriLife
Glen Green	- Xcel Energy
Rick Gibson	- Environmental Consultant
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

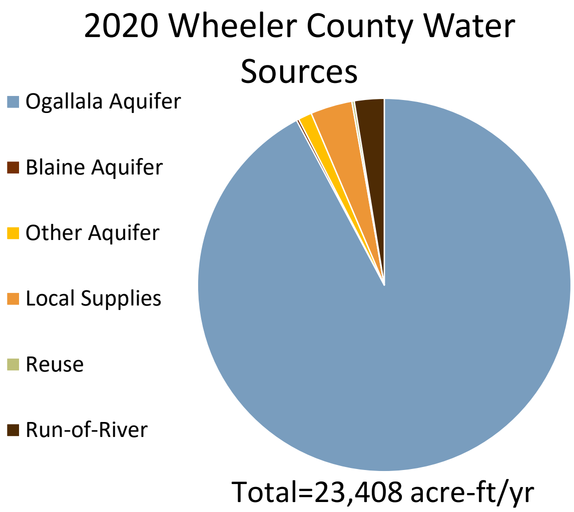
County Seat: City of Wheeler

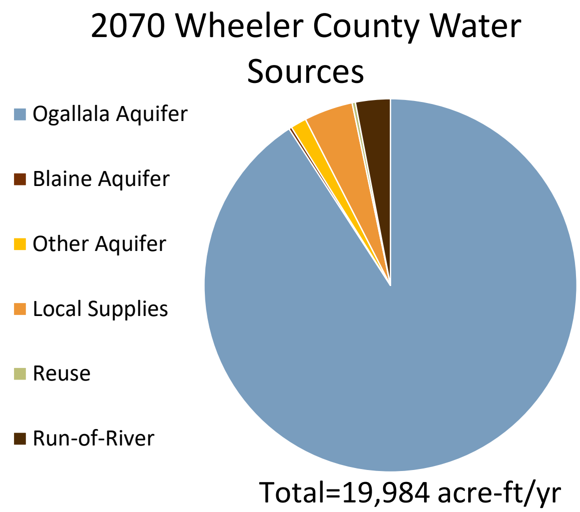
Economy: Agribusiness, Petroleum, Tourism

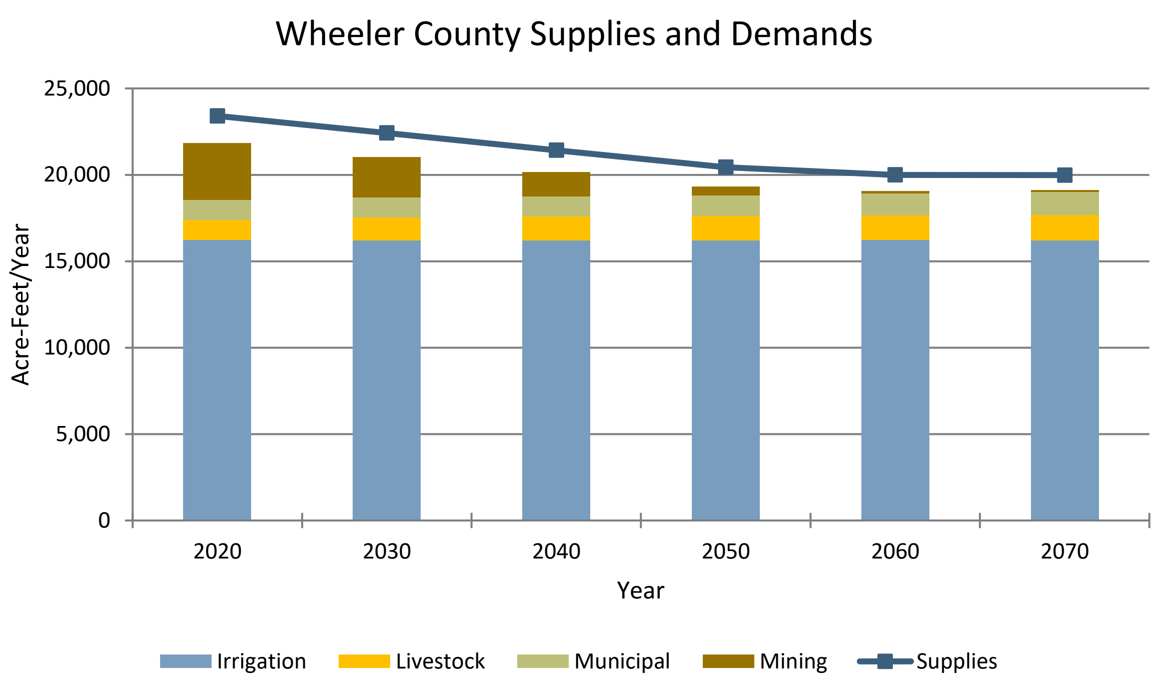
What is the source of my water? Ogallala, Blaine Aquifer











WATER USER GROUP	STRATEGY
Shamrock	Conservation
Wheeler	Conservation, New Well(s)
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands in this Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands in this Category

1 PLANNING AREA DESCRIPTION

1.1 Introduction

In 1997, the 75th Texas Legislature passed Senate Bill One (SB1). The bill was designed to address Texas water supply needs associated with drought of record conditions. SB1 put in place a grass-roots regional planning process to plan for the water needs of all Texans in the next century. To implement this planning process, the Texas Water Development Board (TWDB) created 16 regional water planning areas (RWPA) across the state and established guidelines and rules governing regional planning efforts. The Panhandle Water Planning Area (PWPA) is located in the northern panhandle of Texas (Figure 1-1). It is comprised of 21 counties with similar characteristics and water sources.

PWPA at a Glance:

- 21 Counties
- Mostly rural, with more than half of the region's population in Amarillo
- Major cities include Amarillo, Borger, Canyon, Dumas, and Pampa
- Agriculture is driving economic force, with major crops including corn, wheat, and grain sorghum
- Climate is characterized by rapid and large temperature changes, wind, low humidity, and relatively low rainfall
- 98 percent of total regional water use is from groundwater (primarily Ogallala); 92 percent is used for agriculture
- 5 Major Water Providers
- 6 Groundwater Conservation Districts & 2 Groundwater Management Areas
- 2 Major Aquifers and 3 Minor Aquifers
- 3 Major Reservoirs

The regional water planning groups created pursuant to SB1 are tasked to direct the regional planning process. TWDB regulations require each regional planning group to include representatives of 12 designated interest groups. Additional interest groups may be added at the discretion of the planning group. The Panhandle Water Planning Group (PWPG) added "higher education" as an interest group. Table 1-1 shows the members of the PWPG and the interests they represent. The PWPG hired a team of consultants to conduct technical analyses and prepare the regional water plan under the supervision of the planning group. The consulting team includes Freese and Nichols, Inc., Texas A&M AgriLife Research and Extension Center at Amarillo (AgriLife), and WSP USA (WSP). The Panhandle Regional Planning Commission (PRPC) serves as the political subdivision and contractor.

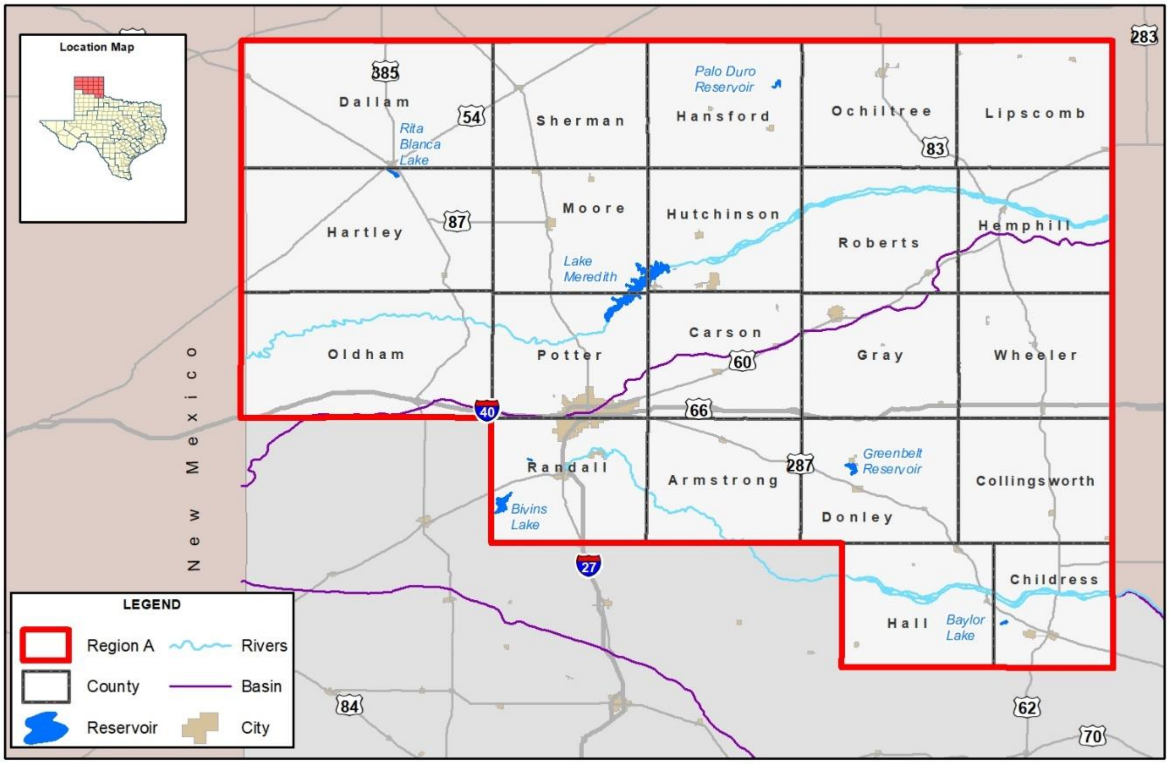


Figure 1-1: Panhandle Water Planning Area

Table 1-1: Voting Members of the Panhandle Water Planning Group

Interest	Name[1]	Entity	County (Location of Interest)
Public	Don Allred	Oldham County	Oldham
Counties	Judge Vernon Cook	Retired (Roberts County)	Roberts
Municipalities	Floyd Hartman	City of Amarillo	Potter and Randall
	David Landis	City of Perryton	Ochiltree
Industries	Roy Messer Bill Hallerberg (former)	J.D. Heiskell & Co.	Potter
	Beverly Stephens	Phillips 66	Hutchinson
Agricultural	Ben Weinheimer	Texas Cattle Feeders Association	Serves entire region
	Joe Baumgardner	Farmer	Collingsworth
	Janet Tregellas	Farm/Ranch	Lipscomb

Interest	Name[1]	Entity	County (Location of Interest)
Environmental	Nolan Clark	Retired (USDA-ARS)	Serves entire region
	Rick Gibson	Environmental Consultant	Serves entire region
	Dillion Pool Donna Raef Kizziar (former)	Enviro-Ag	Randall
Small Businesses	Rusty Gilmore	Water Well Driller	Dallam
Electrical Generating Utilities	Glen Green	Xcel Energy	Potter (serves entire region)
River Authorities	Kent Satterwhite	Canadian River MWA	Multiple counties
Water Districts	Steve Walthour	North Plains GCD	Moore and 7 other counties in the region
	Bobbie Kidd	Greenbelt M and I Water Authority	Donley and 3 other counties in the region
	C.E. Williams	Panhandle Groundwater Conservation Dist. No. 3	Carson and 8 other counties in the region
	Janet Guthrie	Hemphill UGCD	Hemphill
Water Utilities	Dean Cooke	TCW Supply	Hutchinson
Groundwater Management Areas	Danny Krienke	GMA#1	Ochiltree and 17 other counties
	Lynn Smith	GMA#6	Collingsworth, Childress and Hall
Higher Education	Brent Auvermann	Texas A&M AgriLife Research and Extension Center at Amarillo	Entire region

[1] Non-voting members and former members who contributed to this plan are listed in Tables 10-1 and 10-2 in Chapter 10.

The PWPA consists of a 21-county area that includes Armstrong, Carson, Childress, Collingsworth, Dallam, Donley, Gray, Hall, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Potter, Randall, Roberts, Sherman, and Wheeler Counties. This is the fifth regional water supply plan that has been developed for the PWPA since the passage and implementation of SB1.

This plan is a complete update of the 2016 Panhandle Regional Water Plan. Every chapter has been reviewed and updated. Some of the new and/or changed information in this plan include:

- Utility-based planning versus city-based planning
- Designation of Major Water Providers
- Updated water demand projections through 2070 (Agriculture, Industrial and Municipal)
- Updated water supplies, including the use of the Modeled Available Groundwater values for groundwater that were developed and adopted by the Groundwater Management Areas
- Reassessment of water supplies to users and water needs
- Evaluation of new water management strategies, including designation of alternate strategies
- Updated Legislative and other recommendations

Organization of Water Plan:

1. Planning Area Description
2. Current and Projected Population and Water Demand
3. Evaluation of Regional Water Supplies
4. Identification of Water Needs
5. Water Management Strategies
6. Impacts of the Regional Water Plan
7. Drought Response Information, Activities and Recommendations
8. Regulatory, Administrative and Legislative Recommendations
9. Water Infrastructure Funding Recommendations
10. Plan Adoption and Public Participation
11. Implementation and Comparison to Previous Regional Water Plan

1.2 Senate Bills 1 and 2

SB1 was a result of increased awareness of the vulnerability of Texas to drought and to the limits of existing water supplies to meet increasing demands as population grows. According to the most recent population projections, Texas' population is expected to exceed its 2010 level of 25 million, growing to more than 51 million by 2070. Many areas of the state continue to be impacted by water needs.

SB1 established a "bottom up" water planning process by allowing individual representatives of various interest groups to serve as members of Regional Water Planning Groups (RWPGs) charged to prepare regional water plans for their respective areas. The TWDB established 16 distinct planning areas that are directed by volunteers leading diverse RWPGs. The plans developed by the RWPGs detail how to conserve water supplies, meet future water supply needs and respond to future droughts in the planning areas and are designed to ensure that the water needs of all Texans are met.

Senate Bill 2 (SB2), enacted in 2001 by the 77th Legislature, built on policies created in SB1. There were several new requirements and improvements called for within SB2, including:

- Use of the results of state-led water availability models for both ground and surface water
- Provide for conservation as a water management strategy
- Evaluate the impacts of water management strategies on water quality
- Consider recommendations from conservation and drought management plans
- Provide recommendations on the financing of water infrastructure needs.

The fifth round of planning culminates with the 2021 Regional Water Plan, which is to be submitted to TWDB by October 14, 2020. The TWDB must then approve and incorporate these plans into an all-inclusive state plan that is due in January 2022. The plans will continue to be updated every five years.

1.3 Regional Water Planning Area

The PWPA is among the largest water-consuming regions in the State, with over 92 percent of water used for agricultural purposes in 2016. According to the 2016 TWDB Water Use Survey, the Texas state population was approximately 27.9 million people. The PWPA accounted for 1.5 percent of the total state population in 2016 and approximately 15 percent of the State's annual water demand. The TWDB projects that total water use for the region will decline over the 2020-2070 period, primarily due to an expected reduction in agricultural irrigation water use. Future irrigation water use is expected to decline due to a combination of factors, including projected insufficient quantities of groundwater to meet irrigation water demands, implementation of conservation practices, including new crop types and the use of more efficient irrigation technology.

The PWPG is composed of 23 members (Table 1-1), who collectively represent the interest of the public, industry, agriculture, environment, river authorities, counties, municipalities, water districts, water utilities, small business, electrical generation, higher education, and groundwater management areas. Six non-voting members also serve as federal and state agency and neighboring regional water planning region liaisons. The PRPC serves as the political subdivision and contracting agency for the PWPA.

1.3.1 Population

The PWPA population is centered in major cities with some rural counties having total populations less than 5,000 people. The PWPA population is expected to grow from

380,733 in 2010 to 639,220 in 2070. Table 1-2 and Figure 1-2 show the cities with populations greater than 10,000 in the PWPA. Table 1-3 presents the historical decadal populations by county for the region.

Table 1-2: Cities with Populations Greater than 10,000

City	2017 Population
Amarillo	199,826
Borger	12,754
Canyon	15,306
Dumas	14,785
Pampa	17,475

Source: 2017 Census

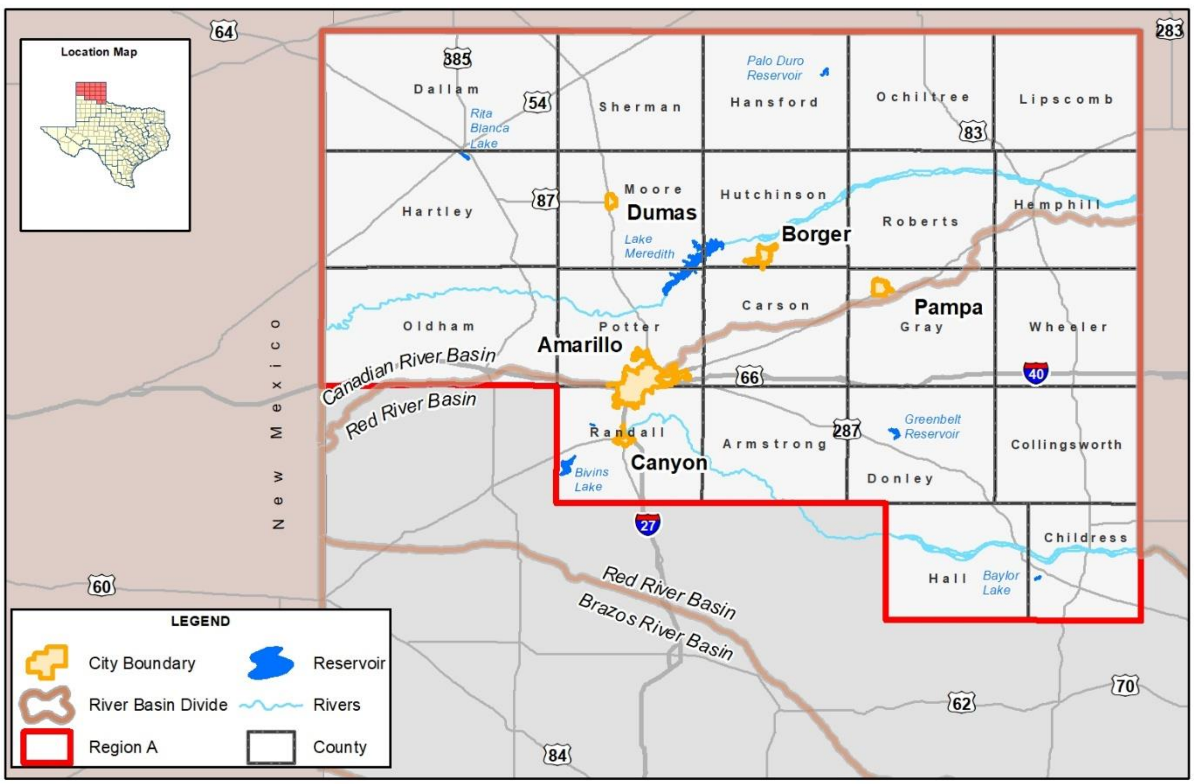


Figure 1-2: Major Cities in the PWPA (>10,000)

Table 1-3: Historical Population of PWPA Counties

County	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2017
Armstrong	1,205	2,682	2,816	3,329	2,495	2,215	1,966	1,895	1,994	2,021	2,153	1,901	1,881
Carson	469	2,127	3,078	7,745	6,624	6,852	7,781	6,358	6,672	6,576	6,503	6,182	6,010
Childress	2,138	9,538	10,933	16,044	12,149	12,123	8,421	6,605	6,950	5,953	7,697	7,041	7,281
Collingsworth	1,233	5,224	9,154	14,461	10,331	9,139	6,276	4,755	4,648	3,573	3,206	3,057	2,978
Dallam	146	4,001	4,528	7,830	6,494	7,640	6,302	6,012	6,531	5,461	6,213	6,703	7,211
Donley	2,756	5284	8,035	10,262	7,487	6,216	4,449	3,641	4,075	3,696	3,814	3,677	3,351
Gray	480	3,405	4,663	22,090	23,911	24,728	31,535	26,949	26,386	23,967	22,742	22,535	22,121
Hall	1,670	8,279	11,137	16,966	12,117	10,930	7,322	6,015	5,594	3,905	3,782	3,353	3,059
Hansford	167	935	1,354	3,548	2,783	4,202	6,208	6,351	6,209	5,848	5,369	5,613	5,483
Hartley	377	1,298	1,109	2,185	1,873	1,913	2,171	2,782	3,987	3,634	5,538	6,062	5,721
Hemphill	815	3,170	4,280	4,637	4,170	4,123	3,185	3,084	5,304	3,720	3,353	3,807	3,945
Hutchinson	303	892	721	14,848	19,069	31,580	34,419	24,443	26,304	25,689	23,864	22,150	21,362
Lipscomb	790	2,634	3,684	4,512	3,764	3,658	3,406	3,486	3,766	3,143	3,050	3,302	3,376
Moore	209	561	571	1,555	4,461	13,349	14,773	14,060	16,575	17,865	20,123	21,904	21,878
Ochiltree	267	1,602	2,331	5,224	4,213	6,024	9,380	9,704	9,588	9,128	9,001	10,223	10,060
Oldham	349	812	709	1,404	1,385	1,672	1,928	2,258	2,283	2,278	2,183	2,052	2,113
Potter	1,820	12,424	16,710	46,080	54,265	73,366	115,580	90,511	98,637	97,874	113,655	121,073	120,518
Randall	963	3,312	3,675	7,071	7,185	13,774	33,913	53,885	75,062	89,673	104,176	120,725	134,433
Roberts	620	950	1,469	1,457	1,289	1,031	1,075	967	1,187	1,025	887	929	937
Sherman	104	1,376	1,473	2,314	2,026	2,443	2,605	3,657	3,174	2,858	3,184	3,034	3,041
Wheeler	636	5,258	7,397	15,555	12,411	10,317	7,947	6,434	7,137	5,879	5,289	5,410	5,326
PWPA Total	**17,517**	**75,764**	**99,827**	**209,117**	**200,502**	**247,295**	**310,642**	**283,852**	**322,063**	**323,766**	**355,782**	**380,733**	**392,085**
% Change		*333%*	*32%*	*109%*	*-4%*	*23%*	*26%*	*-9%*	*13%*	*1%*	*10%*	*7%*	*3%*

1.3.2 Economic Activities

Table 1-4 shows the economic activity by county in the PWPA. The economy of the PWPA can be summarized in the following broad categories: agribusiness, manufacturing, energy, and tourism. Major water-using activities include irrigation, agricultural production, exploration production and refining of oil and gas resources, food processing, chemical and allied products, and electric power generation. The average household income for counties in the PWPA is shown for the year 2017, with the median for the PWPA around $54,000 (Table 1-4). Payroll data, which is available for 2017, show the total payroll in the PWPA to exceed $7 billion, with approximately 45 percent of the payroll reported in Potter County.

The PWPA has an economy that spans major industries ranging from agriculture to technology. The region's economy is beginning to diversify based on regional, statewide, and national trends to meet local needs and the broad needs of the country. The region benefits from a low unemployment rate compared to the rest of Texas and the country. National and statewide initiatives in renewable energy and technology also have a significant influence on the economic activity of the region, with this field rapidly evolving from a growing niche into one of the key industries in the region. Infrastructure issues related to waste disposal and water resources are also key external factors related to the economic viability of the PWPA.

Oil, cattle, and production agriculture have historically driven the PWPA's economy. Developing industries include wind energy, higher education, technology, and tourism. Examples include:

- Electric Reliability Council of Texas (ERCOT) Competitive Renewable Energy Zones (CREZ), multi-billion dollar investments to transfer the PWPA's renewable energy into the ERCOT power grid. Many governmental entities are starting to see great increases in tax income resulting from new wind projects coming online. This trend is expected to continue to rapidly expand.
- Texas Tech School of Veterinary Medicine, which will add hundreds of jobs to the region and will begin educating veterinary students in 2021.
- Bell Helicopter, an employer of hundreds of jobs in the region currently and potentially hundreds more.
- Hodgetown, a multi-purpose event venue in Amarillo, which reported a ten percent increase in sales tax revenue, partially attributed to Hodgetown.

Table 1-4: Economic Activities of Counties in the PWPA

County	Total Annual Wages[1]($) 2017	Median household income[2] ($) 2017	Employment[1] (population) 2017	Major Economic Activities: Agribusiness	Manufacturing	Petroleum	Tourism
Armstrong	13,117,472	68,750	370	X			X
Carson	370,254,961	67,010	4,701	X		X	
Childress	92,307,203	40,432	2,496	X			X
Collingsworth	33,614,011	46,348	847	X			
Dallam	191,055,979	45,580	4,550	X	X		X
Donley	28,210,274	44,429	941	X	X		X
Gray	372,180,647	48,314	7,708	X	X	X	
Hall	22,853,826	31,324	796	X			
Hansford	122,472,052	40,678	2,180	X		X	
Hartley	102,530,782	64,427	2,643	X	X	X	
Hemphill	130,022,209	68,679	2,293	X		X	X
Hutchinson	511,476,625	50,035	8,539	X	X	X	X
Lipscomb	64,147,839	59,583	1,294	X		X	
Moore	493,322,921	52,469	10,886	X		X	
Ochiltree	213,352,385	50,120	4,497	X		X	
Oldham	35,974,658	62,426	910	X			
Potter	3,438,710,776	41,852	78,323	X	X	X	X
Randall	1,294,828,777	65,564	30,479	X	X		X
Roberts	11,905,392	79,167	254	X		X	
Sherman	39,698,448	54,961	956	X			X
Wheeler	79,491,753	50,910	2,007	X		X	X
Total	**7,661,528,990**		**167,670**				
Average	**364,834,714**	**53,955**					

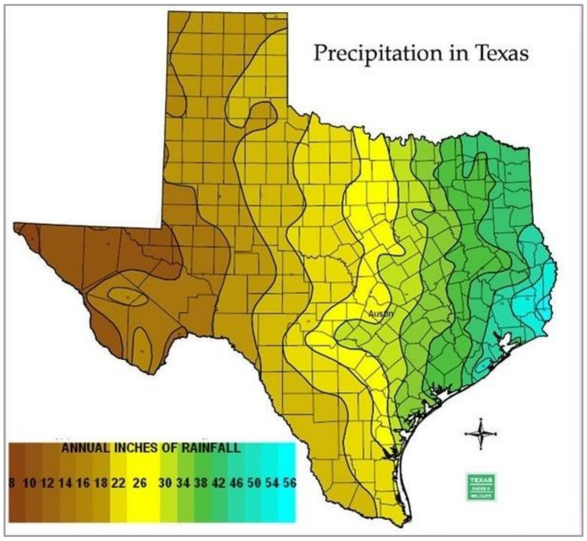
[1] 2017 Quarterly Census of Employment and Wages
[2] Census 2017 American Community Survey

1.3.3 Climate

The climate of the PWPA is characterized by rapid, large temperature changes, wind, and low humidity. The PWPA receives relatively little precipitation, with almost 75 percent of the region's total rainfall occurring between April to September. Snowfall averages 17.9 inches annually in Amarillo with heavy snowfall of 10 inches or more occurring approximately every five years (NWS, 2015). According to the National Climatic Data Center, the average yearly temperature and precipitation measured at the City of Amarillo are 57 degrees Fahrenheit and 20 inches of rainfall.

The PWPA is subject to rapid and large temperature changes, especially during the winter months when cold fronts from the northern Rocky Mountain and Plains states sweep across the area. Temperature drops of 50 to 60 degrees within a 12-hour period are not uncommon. Temperature drops of 40 degrees have occurred within a few minutes.

Humidity averages are low, occasionally dropping below 20 percent in the spring. Low humidity moderates the effect of high summer afternoon temperatures, permits evaporative cooling systems to be very effective, and provides many pleasant evenings and nights. Severe local storms are infrequent, although a few thunderstorms with damaging hail, lightning, and wind in a highly localized area occur most years, usually in spring and summer. These storms are often accompanied by very heavy rain, which produces local flooding, particularly of roads and streets.



Water Related Facts for PWPA:

Two river basins: Red River, Canadian River
Two major aquifers: Ogallala & Seymour
Three minor aquifers: Dockum, Blaine & Rita Blanca
Precipitation ranges from 14 inches in the west to 22 inches in the east.
Groundwater recharge occurs primarily by infiltration, with much of the area experiencing little to no recharge.
As of late 2019, most of the region is out of drought, aided by large rainfall events between 2013 and 2017.

1.4 Major Water Providers

The term Major Water Provider (MWP) was established in rules for the development of the 2022 State Water Plan to allow RWPGs to establish a list of large water providers for which the Plan reports information specific to the MWP. MWPs are defined in 31 TAC §357.10(19) as follows:

"A WUG or WWP of particular significance to the region's water supply as determined by the regional water planning group. This may include public or private entities that provide water for any water use category."

The PWPA has designated five MWPs:

- Canadian River Municipal Water Authority
- City of Amarillo
- City of Borger
- City of Cactus
- Greenbelt Municipal and Industrial Water Authority

1.4.1 Canadian River Municipal Water Authority (CRMWA)

CRMWA was created in 1953 by the Texas Legislature for the purpose of distributing water from the Canadian River Project, in compliance with the Canadian River Compact between Texas, New Mexico, and Oklahoma. The Bureau of Reclamation began construction on the project in 1962 and completed Lake Meredith in 1965. Under the tristate compact, Texas is entitled to store up to 500,000 acre-feet of water in conservation storage. CRMWA received a permit from the State of Texas to impound that water and to divert up to 100,000 acre-feet of water a year for use by the member cities and 51,200 acre-feet for use by industries. Eleven cities formed CRMWA with the following three in the PWPA: Amarillo, Borger and Pampa. The remaining eight are in the Llano Estacado RWPA: Plainview, Lubbock, Slaton, Brownfield, Levelland, Lamesa, Tahoka, and O'Donnell. CRMWA serves approximately 550,000 urban residents and provides water to Borger and Pampa in the Canadian Basin; and Amarillo in the Canadian and Red River basins.

CRMWA is also the largest holder of groundwater rights in Texas. It holds water rights to 456,993 acres in Roberts and adjacent counties. CRMWA has developed a portion of these rights and plans to expand this well field to provide additional supplies to supplement available water from Lake Meredith.

1.4.2 City of Amarillo

The City of Amarillo is the largest city in the PWPA. It currently operates a water system with an average production of 51 million gallons per day to serve approximately 200,000 people. The City gets its water from several active well fields, and an allocation of water from CRMWA that is composed of a blend of Roberts County groundwater and surface water from Lake Meredith. Amarillo supplies wholesale water to the City of Canyon, Palo Duro Canyon State Park and manufacturing. It also supplies reuse water to Xcel Energy for Steam Electric Power needs.

1.4.3 City of Borger

The City of Borger, located in Hutchinson County, currently serves approximately 13,000 people. The source of supply for Borger is groundwater wells, reuse, and an allocation of water from CRMWA that is composed of a blend of Roberts County groundwater and surface water from Lake Meredith. Borger supplies wholesale water to TCW Supply (through a trade agreement with Conoco Phillips) and manufacturing needs.

1.4.4 City of Cactus

The City of Cactus is in Moore County and currently serves approximately 3,000 people. The source of supply for Cactus is groundwater from the Ogallala aquifer. Cactus supplies wholesale water to manufacturing needs.

1.4.5 Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA)

The Greenbelt MIWA provides water from Greenbelt Reservoir on the Salt Fork of the Red River and the Ogallala Aquifer in Donley County. The Greenbelt MIWA is located in Donley County and provides water to local municipalities through an extensive delivery system, including a 121-mile pipeline. There are five member cities, including Clarendon, Hedley, and Childress in the PWPA and Quanah and Crowell in the Region B planning area. The Red River Authority is a non-voting member of the Greenbelt MIWA.

1.5 Sources of Water

Water supplies in the PWPA include both surface and groundwater sources. Statutes and regulations governing the quantity and quality of water in Texas differ according to source of the supply (Table 1-5). Surface water is owned, appropriated, held in trust, and protected by the state on behalf of all citizens, while groundwater is subject to right of capture by the surface landowner. Except as noted below, legal restrictions are not imposed by the State of Texas on landowners regarding withdrawal that would bar them from exercising their right of capture of groundwater from wells on and beneath their property.

Table 1-5: Summary of Policies Affecting Water Quality and Quantity in PWPA

	General Policy Affecting:	
Type of Water	**Water Quantity**	**Water Quality**
Diffuse	Landowner control	TCEQ (urban and industrial), TSSWCB (agriculture and silviculture)
Surface	State (TCEQ) Canadian River Interstate Compact Red River Interstate Compact	State (TCEQ) regulations Federal (EPA) regulations
Ground	Landowner right of capture; Groundwater District Rules	Groundwater District Rules State (TCEQ) Regulations Federal (EPA) regulations

1.5.1 Groundwater Regulation

As part of SB1, the Legislature established that groundwater conservation districts (GCDs) were the preferred entities for groundwater management in Texas. SB1 contained provisions that required the GCDs to prepare management plans. One of the key provisions of SB1 requires TCEQ to determine areas that warrant special consideration and for those areas to encourage the formation of a new GCD or the incorporation of these areas into existing districts. Each GCD is required to submit a water management plan to the TWDB for certification.

SB2 called for the creation of Groundwater Management Areas (GMAs) which were based largely on hydrogeologic and aquifer boundaries instead of political boundaries. The TWDB divided Texas into 16 GMAs, and most contain multiple GCDs. One of the purposes for GMAs was to manage groundwater resources on a more aquifer-wide basis. The PWPA contains two GMAs. GMA 1 covers all of the PWPA counties, with the exception of Childress, Collingsworth and Hall Counties. These counties are located within GMA 6.

The Texas Legislature enacted significant changes to the management of groundwater resources in Texas with the passage of House Bill 1763 (HB 1763) in 2005. A main goal of HB 1763 was to clarify the authority and conflicts between GCDs and RWPGs. The new law clarified that GCDs would be responsible for aquifer planning and developing the amount of groundwater available for use. To accomplish this, the law directed that all GCDs within each GMA to meet and participate in joint groundwater planning efforts. The focus of joint groundwater planning was to determine the Desired Future Conditions (DFCs) for the groundwater resources within the GMA boundaries (before September 1, 2010, and at least once every 5 years after that). The most recent DFCs were developed in 2015. The TWDB was also required to calculate the Modeled Available Groundwater (MAG) for the DFC.

In 2011, Senate Bill 660 required that GMA representatives must participate within each applicable RWPG. It also required the Regional Water Plans to be consistent with the DFCs in place when the regional plans are developed. To implement this requirement, the TWDB developed a policy that the MAG was the maximum amount of groundwater that could be planned for in terms of existing water supply and recommended strategies within a RWPA.

GCDs have played a major role in the management of water resources in the PWPA. Parts or all of 20 counties in the PWPA study area are included in the six groundwater districts shown in Figure 1-3 and presented in Table 1-6. The county of Oldham and portions of Randall, Hutchinson, Moore, and Hartley Counties are not included in a groundwater district. The GCDs work together within the framework of the GMAs to set DFCs which consider the balance between groundwater demands and the need to conserve and preserve groundwater in the region. The GCDs must set goals and objectives consistent with the DFCs adopted by the GMAs. To achieve these goals, GCDs can regulate well spacing, well size, well construction, well production, well closure, and monitoring and protection of groundwater quality.

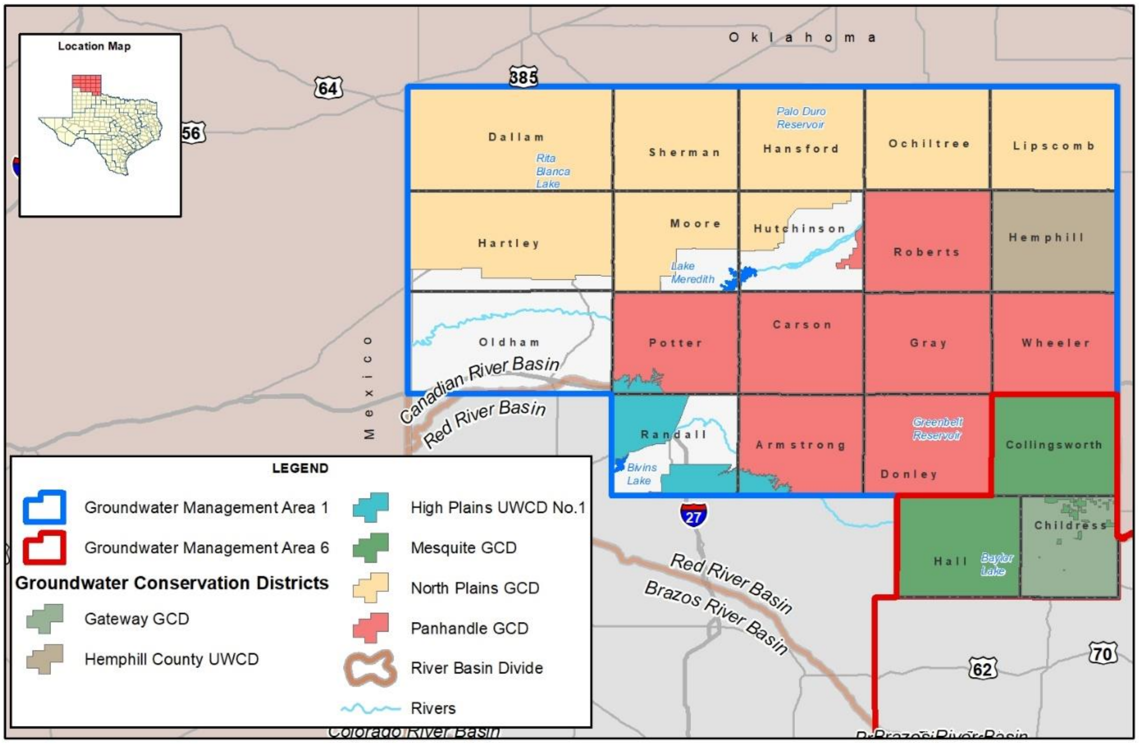


Figure 1-3: Groundwater Conservation Districts and Management Areas in PWPA

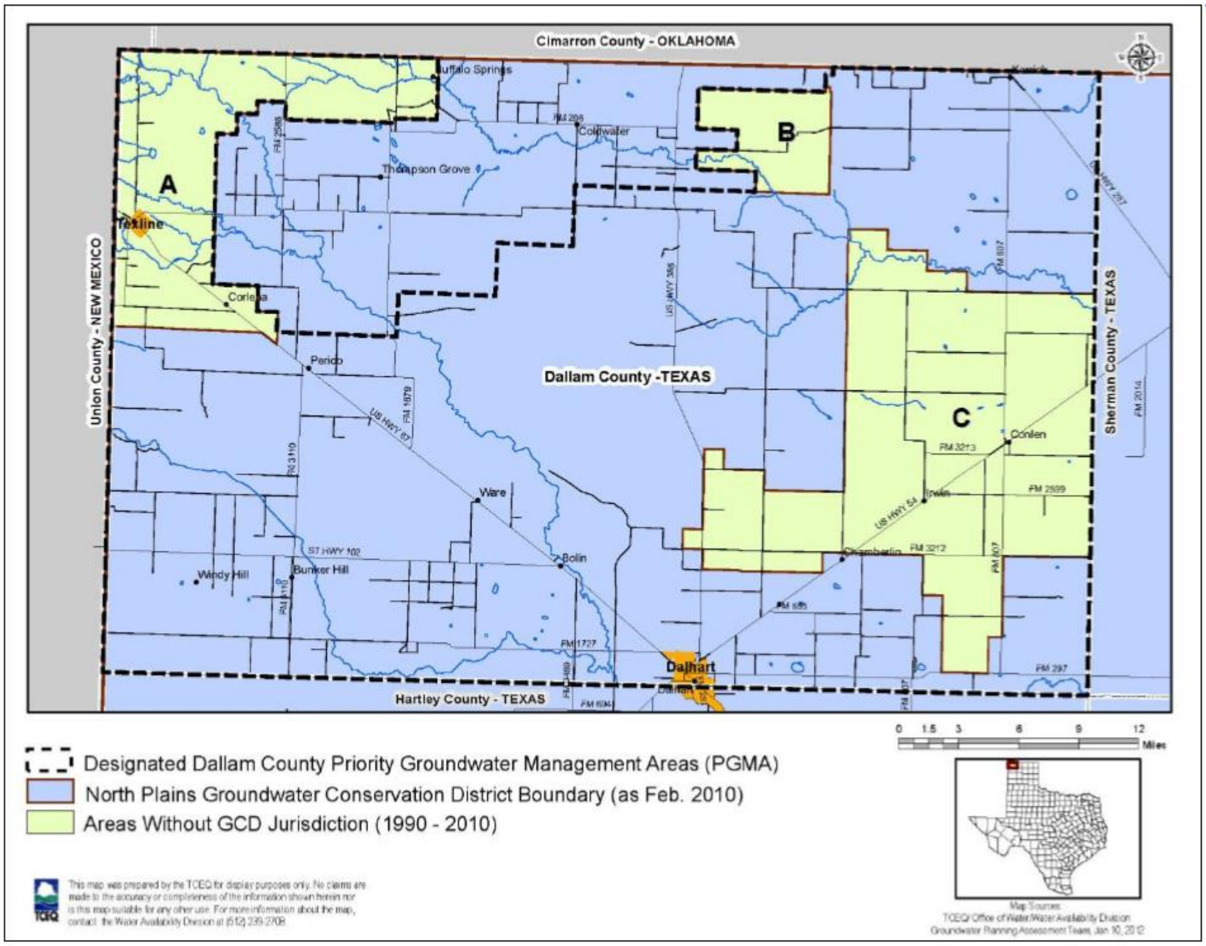
Table 1-6: Groundwater Conservation Districts in PWPA

Groundwater District	Counties Served in PWPA	Aquifers
North Plains GCD	Moore, Hutchinson, Sherman, Hartley, Dallam, Hansford, Ochiltree, Lipscomb	Ogallala Rita Blanca Dockum
Panhandle GCD	Carson, Roberts, Gray, Donley, Armstrong, Potter, Hutchinson, Wheeler	Ogallala Dockum Blaine Seymour Whitehorse
Mesquite GCD	Collingsworth, Hall	Seymour Blaine
Hemphill County UGWD	Hemphill	Ogallala
High Plains UGWD	Potter, Randall, Armstrong	Ogallala Dockum
Gateway GCDt	Childress	Seymour Blaine

For areas within the state that are not regulated by a GCD, the state has the authority to designate as a Priority Groundwater Management Area (PGMA) for purposes of protecting the groundwater resources within the area. This process is initiated by the TCEQ, which designates a PGMA when an area is experiencing critical groundwater problems or is expected to do so within 25 years. These problems include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, or contamination of groundwater supplies. Once an area is designated a PGMA, landowners have two years to create a GCD. Otherwise, the TCEQ is required to create a GCD or to recommend that the area be added to an existing district. The PGMA process is completely independent of the current GMA process and each process has different goals. PGMAs also authorize county commissioners within the PGMA to promulgate groundwater restrictions.

In December 2008, the TCEQ Executive Director recommended that Dallam County PGMA Areas A, B and C (Figure 1-4)) be added to the North Plains GCD. After a contested case hearing, the TCEQ issued an Order dated February 17, 2010. The Order directed that the District vote to add Areas A, B and C and conduct an election within each area. Elections were held in November 2010 after two educational outreach meetings were held by the TCEQ, Texas AgriLife Extension Service, the TWDB, and the District. The propositions did not pass. Some landowners then petitioned for inclusion in the District and approximately 9,100 acres were added to the District via landowner petitions, leaving approximately 400 square miles outside the jurisdiction of a GCD.

With passage of SB 313 in 2011, the TCEQ was authorized to add PGMA areas to any previously recommended GCD no later than September 1, 2012. All remaining Dallam County area that was previously outside of a GCD was added to the North Plains GCD in 2012. The groundwater within the Dallam County PGMA is currently regulated by the North Plains GCD, and to the PWPG’s knowledge, there are no additional restrictions promulgated by the Dallam County Commissioners Court.



Source: TCEQ

Figure 1-4: Dallam County PGMA Boundary

1.5.2 Aquifers

There are two major aquifers in the PWPA, the Ogallala and Seymour aquifers (

Figure 1-5), and three minor aquifers, Blaine, Rita Blanca, and Dockum (

Figure 1-6). The Whitehorse Formation is recognized by local residents as a regional supply source but has not been quantitatively characterized and is therefore not included as a distinct supply source in this Plan. All aquifers serve as water sources for various uses in the PWPA.

Ogallala Aquifer

The Ogallala aquifer is the major water-bearing formation of the PWPA. Vertical hydrologic communication occurs between the overlying Quaternary Blackwater Draw Formation where present and the Cretaceous which lies directly below the Ogallala in a portion of the planning region. Although many communities use water from the Ogallala aquifer as their primary source for drinking water, more than 90 percent of the water obtained from the Ogallala is used for irrigation. The Ogallala supports the major irrigated agricultural production and processing base, as well as the region's municipal and industrial water needs. Water-table elevations generally dip at a similar rate as the land surface and dip from the northwest to the southeast. The aquifer is recharged by precipitation and runoff that drains to lakes, rivers, playas, and streams.

The Ogallala is composed primarily of sand, gravel, clay, and silt deposited during the Tertiary Period. Groundwater, under water-table conditions, moves very slowly through the Ogallala Formation in a southeasterly direction toward the caprock edge or eastern escarpment of the High Plains. Saturated thickness of the aquifer is variable across the region but is greatest where sediments have filled previously eroded drainage channels. Well yields range from as little as 10 gpm to more than 1,000 gpm.

Recharge to the Ogallala occurs primarily by infiltration of precipitation from the surface and, to a lesser extent, by upward leakage from underlying formations. Research has indicated variable recharge over the Ogallala aquifer in the PWPA, with much of the area experiencing little to no recharge. The special study on recharge in the eastern counties in the PWPA confirmed the relatively low levels of recharge to the Ogallala (BEG, 2009). This study found recharge rates of 0 to 1.9 inches per year, with the greatest recharge occurring beneath irrigated agriculture. Playa basins also appear to be a contributing factor for the majority of water naturally recharged to the aquifer.

Since the expansion of irrigated agriculture in the mid-1940s, greater amounts of water have been pumped from the aquifer than have been recharged. As a result, some areas have experienced water level declines in excess of 150 feet from predevelopment to 2010 within the PWPA and will continue to drop into the future. Conservation efforts, implementation of efficient irrigation technologies, crop research, reduced commodity prices and increased power costs have resulted in a reduction in the rate of water level declines.

The quality of Ogallala water is controlled by the composition of the recharge water and the geologic features and deposits above and within the aquifer. According to the results of a study of the Ogallala aquifer (Nativ, 1988) the TDS concentration of the Ogallala in the vicinity of the PWPA averaged 429 mg/L. The major constituent, bicarbonate, averaged 278 mg/L, while minor constituents such as sulfate, calcium, sodium, chloride, and potassium averaged from 8 mg/L to 66 mg/L (Nativ, 1988). During the second round of regional water planning the PWPA conducted a study to build a cross sectional model to evaluate salinity and water quality changes associated with aquifer drawdown in Roberts County. Simulated increases in total dissolved solids were greater than reported by others. Localized increases in total dissolved solids were <500 mg/l with local total dissolved solids averages <10 mg/l increase per year.

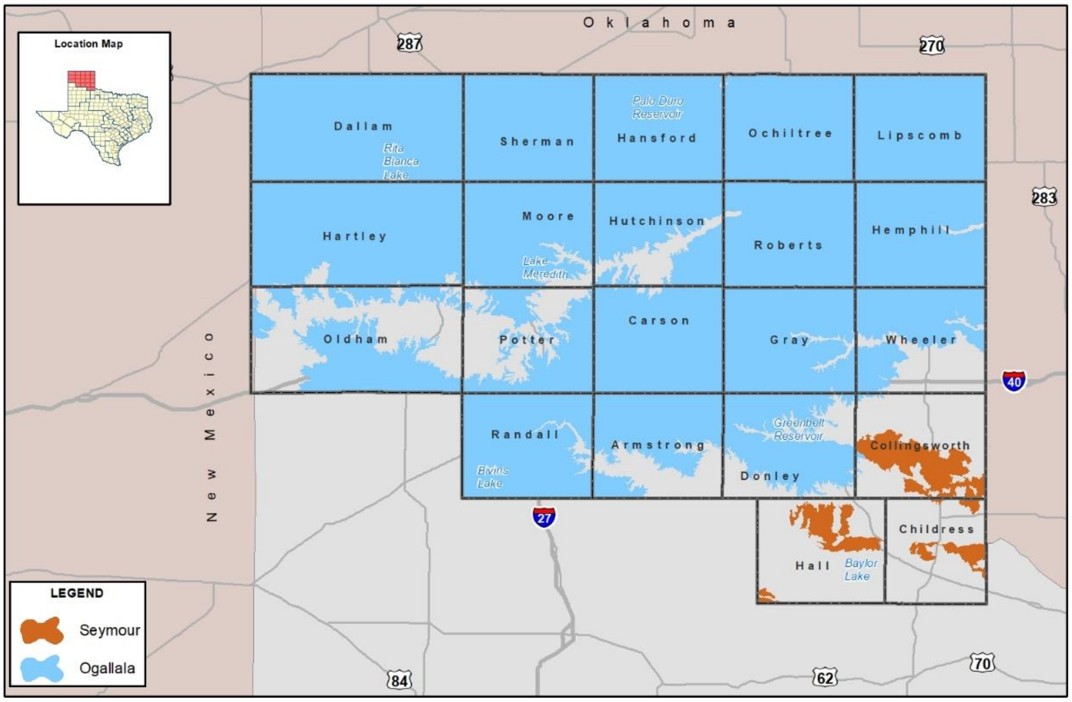


Figure 1-5: Major Aquifers in the PWPA

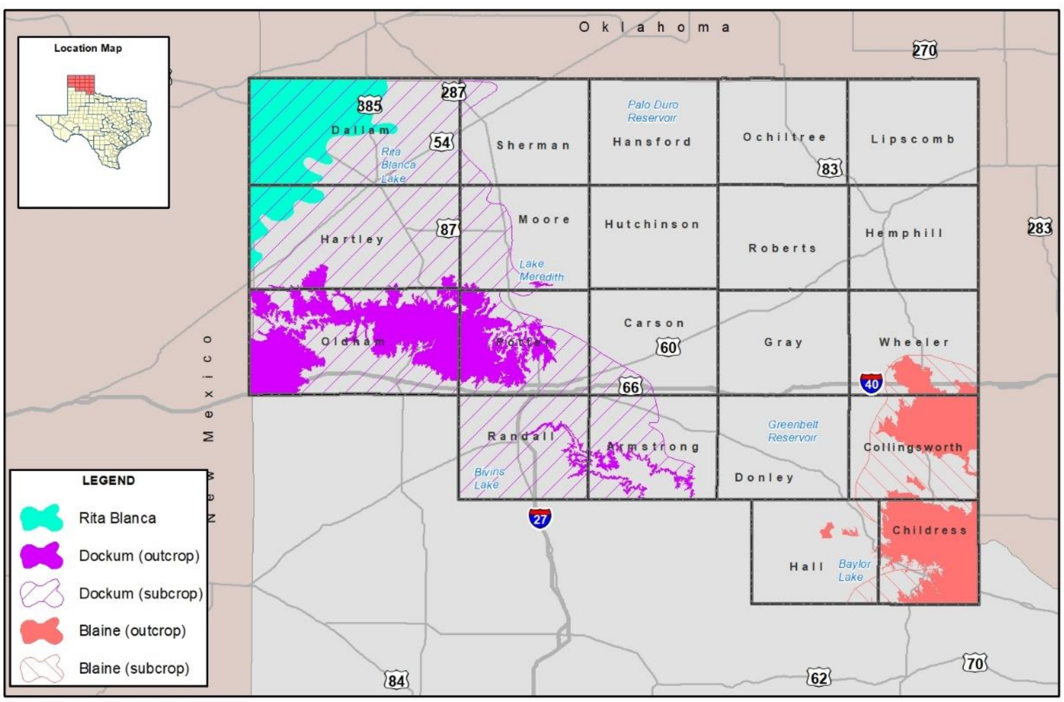


Figure 1-6: Minor Aquifers in the PWPA

Seymour Aquifer

The Seymour is a major aquifer located in north central Texas and some Panhandle counties. The aquifer consists of isolated areas of alluvium that are erosional remnants of a larger area or areas. Although most accumulations are less than 100 feet thick, a few isolated spots in Collingsworth County may exceed 300 feet. These thick accumulations overlie buried stream channels or sinkholes in underlying formations. This aquifer is under water-table conditions in most of its extent, but artesian conditions may occur where the water-bearing zone is overlain by clay.

Fresh to slightly saline groundwater recoverable from storage from all these scattered alluvial aquifers is estimated to be 3.8 million acre-feet, based on the assumption that 75 percent of the total storage is recoverable. Within the PWPA, the estimated recoverable storage is 285,000 acre-feet based on 75 percent of the total storage. Annual effective recharge to the aquifer is approximately 215,200 acre-feet, or five percent of the average annual precipitation that falls on the aquifer outcrop. No significant long-term water-level declines have occurred in areas supplied by groundwater from the Seymour aquifer. The lower, more permeable part of the aquifer produces the greatest amount of groundwater. Yields of wells average about 300 gallons per minute (gpm) and range from less than 100 gpm to as much as 1,300 gpm.

Water quality in these alluvial remnants generally ranges from fresh to slightly saline, although a few higher salinity problems may occur. The salinity has increased in many heavily pumped areas to the point where the water has become unsuitable for domestic uses. Brine pollution from earlier oil-field activities has resulted in localized contamination of formerly fresh ground- and surface-water supplies. Nitrate concentrations in excess of primary drinking-water standards are widespread in the Seymour groundwater (TWDB, 1995).

Dockum Aquifer

The Dockum is a minor aquifer which underlies the Ogallala aquifer and extends laterally into parts of West Texas and New Mexico. The primary water-bearing zone in the Dockum Group, commonly called the "Santa Rosa," consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Aquifer permeability is typically low, and well yields normally do not exceed 300 gal/min (Ashworth & Hopkins, 1995). Recharge to the Dockum aquifer is negligible except in the outcrop areas, where approximately 31,000 acre-feet is estimated to occur annually over the entire formation. Recharge in the PWPA is expected to be less.

Concentrations of TDS in the Dockum aquifer range from less than 1,000 mg/L in the eastern outcrop of the aquifer to more than 20,000 mg/L in the deeper parts of the formation to the west. The highest water quality in the Dockum occurs in the shallowest portions of the aquifer and along outcrops at the perimeter. The Dockum underlying Potter, Moore, Carson, Armstrong, and Randall Counties has a TDS content of around 1,000 mg/L (TWDB, 2003). The lowest water quality (highest salinity) occurs outside of the PWPA. Dockum water, used for municipal supply by several cities, often contains chloride, sulfate, and dissolved solids that are near or exceed EPA/State secondary drinking-water standards (Ashworth & Hopkins, 1995).

Rita Blanca Aquifer

The Rita Blanca is a minor aquifer which underlies the Ogallala Formation in western Dallam and Hartley Counties in the northwest corner of the Texas Panhandle. The portion of the aquifer located in the PWPA makes up a small part of a large aquifer system that extends into Oklahoma, Colorado, and New Mexico.

Groundwater produced from wells completed within the Rita Blanca aquifer is moderately to very hard and fresh to slightly saline. Dissolved-solids concentrations range from 400 mg/L to approximately 1,100 mg/L.

Recharge to the aquifer in Texas occurs by leakage through the Ogallala and by lateral flow from portions of the aquifer system in New Mexico and Oklahoma. Effective recharge and recoverable storage for the Rita Blanca have not been quantified but, historically, have been included with regional recharge and storage estimates for the Ogallala aquifer. Aquifer water-level declines in excess of 50 feet have occurred in some irrigated areas from the early 1970s to the middle 1980s. These declines were the result of pumpage which exceeded effective recharge. Evidence of aquifer declines included the disappearance of many springs in the northern part of Dallam County that once contributed to the constant flow in creeks that are now ephemeral. Since the middle 1980s, the rate of decline has generally slowed. In some areas water-level rises have occurred.

Blaine Aquifer

The Blaine is a minor aquifer located in portions of Wheeler, Collingsworth, and Childress Counties of the RWPA and extends into western Oklahoma. Saturated thickness of the formation in its northern region varies from approximately 10 to 300 feet. Recharge to the aquifer travels along solution channels which contribute to its overall poor water quality. Dissolved solids concentrations increase with depth and in natural discharge areas at the surface, but contain water with TDS concentrations less than 10,000 mg/L. The primary use is for irrigation of highly salt-tolerant crops, with yields varying from a few gallons per minute (gpm) to more than 1,500 gpm (Ashworth and Hopkins, 1995).

Whitehorse Aquifer

The Whitehorse is a Permian aquifer occurring in beds of shale, sand, gypsum, anhydrite, and dolomite. It is an important source of water in and near the outcrop area around Wheeler County. Wells in the Whitehorse aquifer often pump large quantities of fine sand and require screens for larger yields. Water from the Whitehorse is generally used for irrigation, but other uses include domestic and livestock. Dissolved solids range from approximately 400 mg/L to just less than 2,700 mg/L, with better water quality generally occurring in the areas of recharge from the Ogallala (Maderak, 1973). The Whitehorse, not recognized by the State of Texas as a minor aquifer, is considered “Other Aquifer” in this plan.

1.5.3 Springs

Springs are an important transition between groundwater and surface water bodies. A study by the TWDB (1973) identified 281 major and historically significant springs within the state of Texas, 16 of which were located in the PWPA. As observed throughout the state, spring flows in the PWPA have generally declined during the last century due to a variety of reasons including land use practices, increasing demands, droughts, and the development of deep-water irrigation wells. Springs identified by the TWDB study in Donley, Hartley, Oldham, Potter, and Wheeler Counties derive from the Ogallala Formation. The Blaine and Whitehorse Formations produced springs in Collingsworth and Wheeler Counties, and one alluvial spring was identified in Collingsworth County. Brune's Springs of Texas report indicates that many of the region's major springs were already in decline due to irrigation pumping in the 1970s. It is anticipated that many of these springs have continued to decline over the past 30 years. The information on the current status of springs is difficult to assess as many are on private property.

1.5.4 Surface Water

The PWPA is located within portions of the Canadian River and Red River Basins. These two river systems and associated impoundments shown in

Figure 1-7 provide surface water for municipal, agricultural, and industrial users in the area. In 2016, one percent of total water use within the PWPA was from surface water sources. This plan and its implementation are not expected to have any impact to navigable waters or navigation within the state.

Surface Water Management and Classification

The TCEQ is the agency charged with the management of surface water quality and quantity. Water quantity for the state is managed by a permitting system administered by the Office of Water of TCEQ.

Table 1-7 shows that permitted surface water rights greater than 1,000 acre-feet per year total 177,690 acre-feet per year for both the Canadian River Basin and the Red River Basin and actual reported use decreased from 46,259 acre-feet per year in 2006 to 2,494 acre-feet per year in 2014.

Water quality is managed statewide through the Texas Clean Rivers Program (TCRP) and locally through TCRP partners such as the CRMWA and Red River Authority. According to the TCEQ's 2016 Texas Integrated Report (TCEQ, 2016), the principal water quality problems in the Canadian River Basin are elevated dissolved solids, nutrients, and dissolved metals. Natural conditions including the presence of saline springs, seeps, and gypsum outcrops contribute to dissolved solids in most surface waters of the PWPA and elevated metals in localized areas. Elevated nutrients are most often associated with municipal discharge of treated wastewater to surface waters.

Water bodies which are determined by TCEQ as not meeting Texas Surface Water Quality Standards are included on the State of Texas Clean Water Act Section 303(d) list. Eight segments in the PWPA were identified on the final 2016 303(d) list and are shown in Table 1-8. All eight segments are classified by TCEQ as low priority and may be scheduled for Total Maximum Daily Load (TMDL) development (Table 1-8).

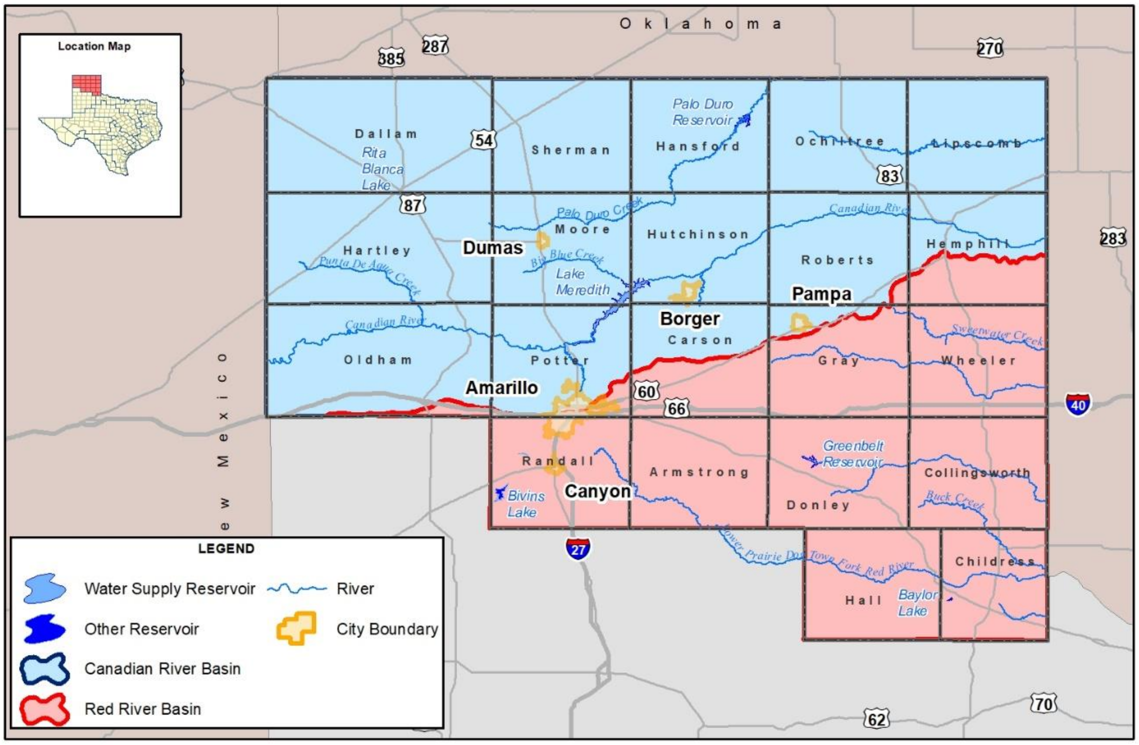


Figure 1-7: Surface Water Features in the PWPA

Table 1-7: Individual Water Rights in the PWPA for Permitted and Actual Use (Greater Than or Equal to 1,000 ac-ft)

County	Water Right Holder	Water Source	Use	Permitted Amount	Use in 2006	Use in 2011	Use in 2014
Canadian River Basin							
Hutchinson	CRMWA	Lake Meredith	Municipal	100,000	39,353	7,894	2,453
			Industrial	51,200	2,482	552	41
Hansford	PDWD	Palo Duro Reservoir	Municipal	10,460	0	0	0
Red River Basin							
Donley	Greenbelt MIWA	Greenbelt Reservoir	Municipal	14,530	4,424	3,697	1,775
			Industrial	500	0	0	0
			Irrigation	250	0	0	0
			Mining	750	0	0	0
Total				**177,690**	**46,259**	**12,143**	**4,269**

Source: TCEQ, 2019

Table 1-8: 2016 303d Listed Segments in the PWPA

Water Body	Segment Number	Constituents of Concern						
		Bacteria	pH	Mercury in Edible Tissue	Dissolved Oxygen	Total Dissolved Solids	Chloride	Sulfate
Canadian River Basin								
Canadian River Below Lake Meredith	0101	X						
Dixon Creek	0101A	X			X			
Lake Meredith	0102			X		X	X	X
Canadian River above Lake Meredith	0103						X	
Rita Blanca Lake	0105		X					
Red River Basin								
South Groesbeck Creek	0206B	X						
Lower Prairie Dog Town Fork of Red River	0207	X						
Salt Fork Red River	0222	X						

Source: TCEQ, 2016

Agricultural and silvicultural nonpoint source water quality problems are managed statewide by the Texas State Soil and Water Conservation Board (TSSWCB) via local soil and water conservation districts. The TSSWCB has a regional office in Hale Center and a field office in Canyon. The Senate Bill 503 process established in 1993 authorizes TSSWCB to work individually with landowners on a volunteer basis to develop and implement site-specific water quality management plans. Conversely, urban and industrial nonpoint source water quality management plans are under the jurisdiction of the TCEQ.

Canadian River Basin

Approximately 13,000 square miles of the Canadian River Basin are located in the PWPA. There are three major reservoirs in the Texas portion of the Basin: Lake Meredith, Palo Duro Reservoir, and Rita Blanca Lake are used for municipal and recreation purposes. Other important reservoirs in the basin include Lake Marvin near the City of Canadian in Hemphill County and Lake Fryer near Perryton in Ochiltree County.

From the Texas-New Mexico state line eastward, the Canadian River enters an area known as the Canadian River Breaks, a narrow strip of rough and broken land extensively dissected by tributaries of the Canadian River. Elevations in the northwestern portion of the basin extend to 4,400 feet MSL in Dallam County. Elevations in the eastern portion of the basin range from 2,175 feet MSL in the riverbed at the Texas-Oklahoma border to

2,400 feet MSL in Lipscomb County. Land use in the Texas portion of the Canadian River watershed is predominantly irrigated and dryland farming and cattle ranching.

Average annual precipitation of the Texas portion of the basin varies from 15 inches near the New Mexico border to 22 inches near the eastern state boundary with Oklahoma. Streamflow has been measured near Amarillo, Texas just upstream of Lake Meredith since 1992 (USGS gage 07227500), and averages 92 cubic feet per second (cfs), or approximately 67,000 acre-feet per year. Streamflow has been measured on Palo Duro Creek just upstream of Palo Duro Reservoir since 1999 (USGS gage 07233500), and averages 3 cfs, or approximately 2,000 acre-feet per year.

Due to the scarcity of local surface water supplies, any additional water needed for the basin will likely come from groundwater or reuse of present supplies. In recent years, the region has experienced record low inflows to Lake Meredith and Palo Duro Reservoir, which prompted increased reliance on groundwater.

In order to maintain the continued suitability of water from Lake Meredith for municipal and manufacturing purposes, the Bureau of Reclamation and the CRMWA jointly constructed an injection well salinity control project near Logan, New Mexico. The injection well field, operated by the CRMWA, is disposing of brine pumped from other wells along the Canadian River near Logan.

Red River Basin

The Red River Basin is bounded on the north by the Canadian River Basin and on the south by the Brazos, Trinity, and Sulphur river basins. The Red River extends from the northeast corner of the State, along the Texas/Arkansas and Texas/Oklahoma state borders, across the Texas Panhandle to its headwaters in eastern New Mexico. The Red River Basin has a drainage area of 48,030 square miles, of which 24,463 square miles occur within Texas. Greenbelt Reservoir is the only surface water lake in the Red River Basin used within the PWPA.

The main stem of the Red River has a total length of 1,217 river miles. The North Fork of the Red River forms near Pampa, Texas and the Salt Fork of the Red River forms about 26 miles east of Amarillo, Texas. Both forks exit Texas into Oklahoma and join the Red River, individually, about 17 miles north of Vernon, Texas. Palo Duro Creek forms near Canyon, Texas and becomes Prairie Dog Town Fork to the east, which in turn becomes the Red River at the 100th meridian. The watershed in Texas receives an average annual precipitation varying from 15 inches near the New Mexico border to 55 inches near the Arkansas border.

1.5.5 Reuse Supplies

There is a total of approximately 23,000 acre-feet per year of wastewater effluent that is being reused in the PWPA. The City of Amarillo sells most of its treated effluent to Xcel Energy for steam electric power use, which is the largest user of reuse supplies. Xcel Energy in turn reuses its wastewater effluent for irrigation purposes. The City of Borger also sells its wastewater for industrial purposes. There are several other cities in the PWPA that currently use their wastewater for irrigation purposes, including the irrigation of city lands and local golf courses. Table 1-9 shows the seller, recipient and amount used.

Table 1-9: Reuse Supplies in the PWPA

Seller	Recipient	Current Use (ac ft/yr)
Amarillo	Steam Electric Power	18,554
Borger	Manufacturing	1,045
Canyon	Irrigation	545
Childress	Irrigation	162
IBP	Irrigation	700
Memphis	Irrigation	100
Pampa	Irrigation	220
Panhandle	Irrigation	58
Wellington	Irrigation	52
Wheeler	Irrigation	49
Xcel Energy	Irrigation	1,500
Total		**22,985**

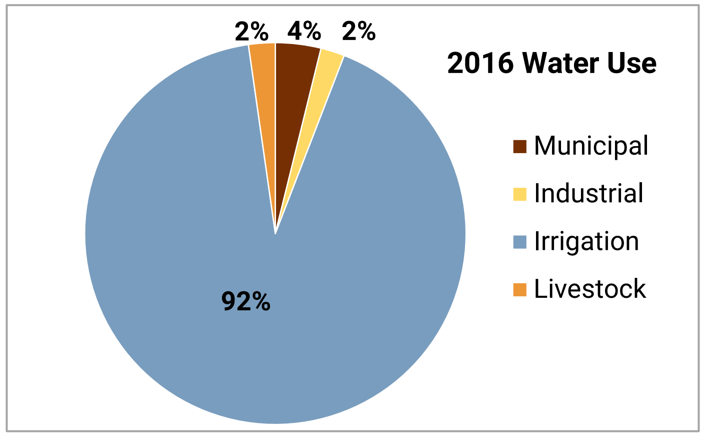
1.6 Current Water Uses and Demand Centers

Water use in the PWPA may be divided into three major categories – municipal, industrial, and agricultural. Industrial water use includes mining, manufacturing, and power generation activities. Agricultural water use includes irrigation and livestock. In 2016, municipal water use in the PWPA accounted for 4 percent of total water use, industrial water use accounted for 2 percent of total water use, and agricultural water use accounted for 94 percent of total water use. This compares with estimates from 2010, which showed that municipal water use in the PWPA accounted for 4 percent of total water use, industrial water use accounted for 4 percent of total water use, and agricultural water use accounted for 92 percent of total water use.

Total Water Use in PWPA:

- 2015 was the year with the lowest water use since TWDB began reporting regional water use in 2000, and 2011 was the year with the highest water use.
- In 2016, municipal entities used the same amount of water that they did in 2000 despite a 10 percent growth in population.
- Irrigation continues to be the largest water user, and its water use has remained relatively flat since 2000.
- Manufacturing use has reduced from approximately 50,000 ac ft/yr in 2000 to approximately 30,000 ac ft/yr in 2016, a 40 percent reduction.

1.6.1 Municipal Use



The TWDB estimates that during 2016, the total municipal water use in the PWPA was 79,934 acre-feet, which is approximately 4 percent of total water use within the region. The amount of water used for municipal purposes is closely tied to population centers. Potter and Randall Counties, which contain the City of Amarillo, comprised 62 percent of the municipal water use in the PWPA, while ten counties (Armstrong, Carson, Collingsworth, Donley, Hall, Hemphill, Lipscomb, Oldham, Roberts, and Sherman) comprise approximately 7 percent.

CRMWA provides water to the cities of Amarillo, Borger, and Pampa in the PWPA. Beginning in late 2001, CRMWA began furnishing a blend of water from Lake Meredith and from groundwater. Member cities supplement CRMWA supplies with groundwater from their own wells. In 2011, approximately 88 percent of the water used by the CRMWA member cities was groundwater. The remaining 12 percent was surface water. For a period from 2012 to 2014 CRMWA relied solely on groundwater due to low lake levels at Lake Meredith but has since made diversions from Lake Meredith. Water usage by CRMWA member cities in 2018 is summarized in Table 1-10.

Table 1-10: Water Used by CRMWA Member Cities in the PWPA during 2018

City	Municipal Water Supplied by CRMWA (ac ft/yr)		
	Surface Water CRMWA	Groundwater CRMWA	Total
Amarillo	8,076	22,007	30,083
Borger	662	2,895	3,557
Pampa	535	1,887	2,422
Total	**9,273**	**26,789**	**36,062**

Greenbelt MIWA provides surface water from Greenbelt Reservoir for municipal, industrial, mining and irrigation uses. In 2016, Greenbelt MIWA supplied 1,961 acre-feet of water to the cities of Childress, Clarendon, Hedley, Memphis, and to the Red River Authority for use in the PWPA. Approximately 700 acre-feet were provided to entities for use in Region B.

1.6.2 Industrial Use

Industrial use includes mining, manufacturing, and power generation, and accounted for approximately 41,916 acre-feet in 2016.

Mining

Based on TWDB data, mining water use totaled approximately 1,310 acre-feet for the entire region in 2016, approximately 3 percent of the total industrial water used. Hemphill County had the highest use with 428 acre-feet (TWDB, 2019). Other recent mining activities associated with the development of natural gas in the eastern portion of the PWPA has increased mining water use for Hemphill, Lipscomb, Ochiltree, Roberts and Wheeler Counties.

Manufacturing

According to the TWDB, manufacturing water use totaled approximately 31,205 acre-feet for the entire region in 2016, approximately 74 percent of the total industrial water used. Hutchinson County had the highest use with 11,008 acre-feet.

Power Generation

Water demand for power generation use includes only water consumed during the power generation process (typically losses due to evaporation during cooling) for the purpose of selling electricity. Water needs for power generation that is part of a manufacturing facility is included in the manufacturing water needs. According to the TWDB, Potter was the only county to have reported water use for power generation activities in 2016. Water use of 9,401 acre-feet accounts for approximately 22 percent of the total industrial water use for that year.

Xcel Energy, the main supplier of electricity in the PWPA, estimates that total water use for power generation in 2010 at approximately 14,000 acre-feet per year for their facilities. Xcel currently uses wastewater from Amarillo for cooling and is considering reuse of wastewater from Plainview and Pampa, as well as cities outside of the PWPA to meet the increasing demand of water for power generation for its Texas facilities.

1.6.3 Agricultural Use

Land Use

Agricultural land use in the PWPA includes irrigated cropland, dryland cropland, and pastureland. According to the 2017 Census of Agriculture estimates, 12 million acres have been devoted to agricultural production with 8 million acres in permanent pasture and the remaining 4 million acres utilized as cropland. The 2001 through 2016 PWPA water plans provide historical estimates of irrigated acreages. In the 2021 plan a three-year average of the annual irrigated acreage planted reported to the Farm Service Agency (FSA) was used to estimate the irrigated acreage by county (Table 1-11). The variation in irrigated acreage between plans can be related to several factors such as: weather; profitability; land leaving because a lack of water; land leaving the conservation reserve program (CRP) and reentering irrigated production; and pastureland being converted to irrigated production. In addition, for the 2016 and 2021 plans irrigated land that was identified as not reporting acreage to FSA was added into the estimates of irrigated land in the appropriate county. In the 2021 planning effort it was estimated that 1.5 million irrigated crop acres were within the PWPA, with seven counties (Carson, Dallam, Hansford, Hartley, Moore, Ochiltree and Sherman) accounting for 82 percent of the irrigated acreage. Several irrigated crops are grown within the region, with four primary crops (corn, cotton, sorghum, and wheat) being reported as being planted on more than 88 percent of the irrigated acreage.

Irrigation

As part of this study, the Texas A&M AgriLife Research and Extension Service in Amarillo (Texas A&M AgriLife) developed updated irrigated agriculture water demands in the PWPA. Irrigation for crop production represents the most significant use of water and accounts for approximately 92 percent of all water use within the PWPA in 2016. According to TWDB data, use of irrigation water totaled approximately 2 million acre-feet in 2016. Five counties (Dallam, Hansford, Hartley, Moore, and Sherman) accounted for approximately 72 percent of the total irrigation water applied in 2016 (TWDB, 2019).

Livestock

Texas is the nation's leading livestock producer, accounting for approximately 11 percent of the total United States production. Although livestock production is an important component of the Texas economy, the industry consumes a relatively small amount of water as compared to irrigated cropland in the region. In 2016, livestock water use was estimated to account for 2.4 percent of the total agricultural water use in the region.

Estimating livestock water consumption consists of estimating water consumption for a livestock unit and the total number of head for each livestock unit. The Texas Agricultural Statistics service and the Census of Agriculture provide some of the current and historical numbers of livestock by livestock type and county used in the region. However due to disclosure reasons, inventory numbers of confined livestock operations (CLOs) are generally not available from these sources. The region being home to more than 1.3 million fed beef, 550,000 hogs and 100,000 dairy cows make it one of the most concentrated areas in the country for CLOs. Texas A&M AgriLife, working together with representatives of the livestock industry including CLOs, university experts and secondary data, developed updated data on livestock inventories by type and county, water-use rates, estimated in gallons per day per head, for each type of livestock: cattle, poultry, sheep and lambs, hogs and pigs, horses, and goats. Water-use rates are then multiplied by the number of head for each livestock type for each county.

Agriculture in PWPA:

- Irrigation accounts for 92 percent of all water use, at approximately 2 million acre feet/year
- Five counties accounted for approximately 70 percent of irrigation water use and irrigated acres in 2016. Alphabetically, they are:
    - Dallam
    - Hansford
    - Hartley
    - Moore
    - Sherman
- Corn, sorghum grain, cotton and wheat are the primary crops.
- It is estimated that there are approximately 1.5 million irrigated acres in PWPA.

Table 1-11: Reported Irrigated Acreage by County and Water Plan

County Name	2001 RWP	2006 RWP	2011 RWP	2016 RWP	2021 RWP
Armstrong	9,476	12,233	4,813	4,828	6,379
Carson	93,010	96,966	54,940	58,204	77,111
Childress	3,486	9,640	8,392	10,560	13,971
Collingsworth	20,789	21,459	36,252	36,854	39,203
Dallam	284,588	251,606	232,707	294,502	249,198
Donley	12,543	18,268	21,766	22,390	26,819
Gray	35,041	29,409	21,901	22,298	30,440
Hall	15,787	20,212	22,423	23,236	25,162
Hansford	193,117	127,128	122,447	132,913	146,204
Hartley	139,290	216,022	210,890	255,623	278,004
Hemphill	4,421	3,179	1,982	3,032	10,348
Hutchinson	28,253	61,292	36,295	35,520	35,520
Lipscomb	24,640	12,241	19,012	20,015	34,561
Moore	171,405	156,302	140,832	142,470	144,123
Ochiltree	57,459	96,929	59,607	59,634	72,165
Oldham	30,182	4,607	3,917	3,986	4,376
Potter	28,219	5,616	2,859	2,587	1,361
Randall	46,855	28,953	20,883	20,489	15,424
Roberts	8,332	18,442	5,665	5,633	6,856
Sherman	152,205	235,347	180,208	184,844	227,943
Wheeler	4,340	9,572	10,873	11,326	12,972
Total	**1,363,438**	**1,435,423**	**1,218,664**	**1,350,944**	**1,458,140**

Source: Farm Service Agency and previous Panhandle Regional Water Plans

Water requirements of livestock are influenced by type and size of animal, feed intake and composition, rate of gain, condition of pregnancy, activity, ambient temperature, and water quality (Chirase et al., 1997). The estimate of total use for livestock watering is based on the total number of livestock in the region and application of a uniform water consumption rate for each type of animal. The different species of livestock considered for the PWPA livestock demands include beef cows and calves, feedlot cattle, dairy cattle, and stockers on pasture winter or summer, poultry, and hogs and pigs.

The majority of current livestock water used in the PWPA is accounted for by feedlot cattle, dairy and swine operations. Sixteen of the twenty-one counties in the PWPA have fed cattle operations. The largest inventory of cattle on feed are in Hansford and Hartley Counties. Other counties with estimated inventories of more than 100,000 head are: Dallam, Moore, Randall and Sherman. Dallam, Gray, Hartley, Hutchinson, Moore, Ochiltree, Randall and Sherman Counties all have dairy operations. Swine production is concentrated generally in counties along the northern portion of the PWPA.

Total livestock water use for the PWPA in 2016 was estimated at 46,833 acre-feet. Four counties (Dallam, Hansford, Hartley, and Sherman) accounted for approximately 58 percent of total livestock water use in the PWPA in 2016.

Table 1-12: Reported 2016 Water Use in the PWPA (ac-ft/yr)

County	MUN	IND	IRR	STK	Total
Armstrong	330	0	6,812	292	7,434
Carson	834	1,172	104,202	349	106,557
Childress	1,604	0	15,090	227	16,921
Collingsworth	618	0	53,144	385	54,147
Dallam	1,881	45	338,797	8,308	349,031
Donley	371	0	29,946	865	31,182
Gray	3,345	264	41,766	2,112	47,487
Hall	748	0	35,129	269	36,146
Hansford	1,136	293	168,461	5,036	174,926
Hartley	1,231	0	392,870	7,912	402,013
Hemphill	778	433	5,691	1,238	8,140
Hutchinson	6,301	11,094	64,479	372	82,246
Lipscomb	655	530	42,592	670	44,447
Moore	4,727	9,244	185,683	3,622	203,276
Ochiltree	3,004	153	80,565	2,906	86,628
Oldham	663	38	5,224	1,016	6,941
Potter	25,138	17,809	3,184	479	46,610
Randall	24,497	576	17,709	3,213	45,995
Roberts	170	40	9,545	353	10,108
Sherman	514	2	285,432	6,040	291,988
Wheeler	1,389	223	17,419	1,169	20,200
Total	**79,934**	**41,916**	**1,903,740**	**46,833**	**2,072,423**

Source: TWDB, 2019

1.7 Natural Resources

1.7.1 Natural Region

A natural region is classified primarily on the common characteristics of climate, soil, landforms, microclimates, plant communities, watersheds, and native plants and animals. The PWPA includes the Rolling Plains and the High Plains natural regions (Figure 1-8). The Rolling Plains is the larger of the two regions. It includes three subregions: the Mesquite Plains, Escarpment Breaks, and the Canadian Breaks. The Mesquite Plains subregion is gently rolling with mesquite brush and short grasses. Steep slopes, cliffs, and canyons occurring below the edge of the High Plains Caprock comprise the Escarpment Breaks subregion. The Breaks are a transition zone between the High Plains grasslands and the mesquite savanna of the Rolling Plains. The Canadian Breaks subregion is similar to the Escarpment Breaks, but also includes the floodplain and sandhills of the Canadian River in the northern Panhandle. The Rolling Plains Region, together with the High Plains Region, is the southern end of the Great Plains of the Central United States.

The Canadian, the Colorado, the Red, and the Concho Rivers begin in the western portions of the Rolling Plains and the breaks of the Caprock Escarpment. Excessive grazing and other historical agricultural practices have caused considerable damage to this region.

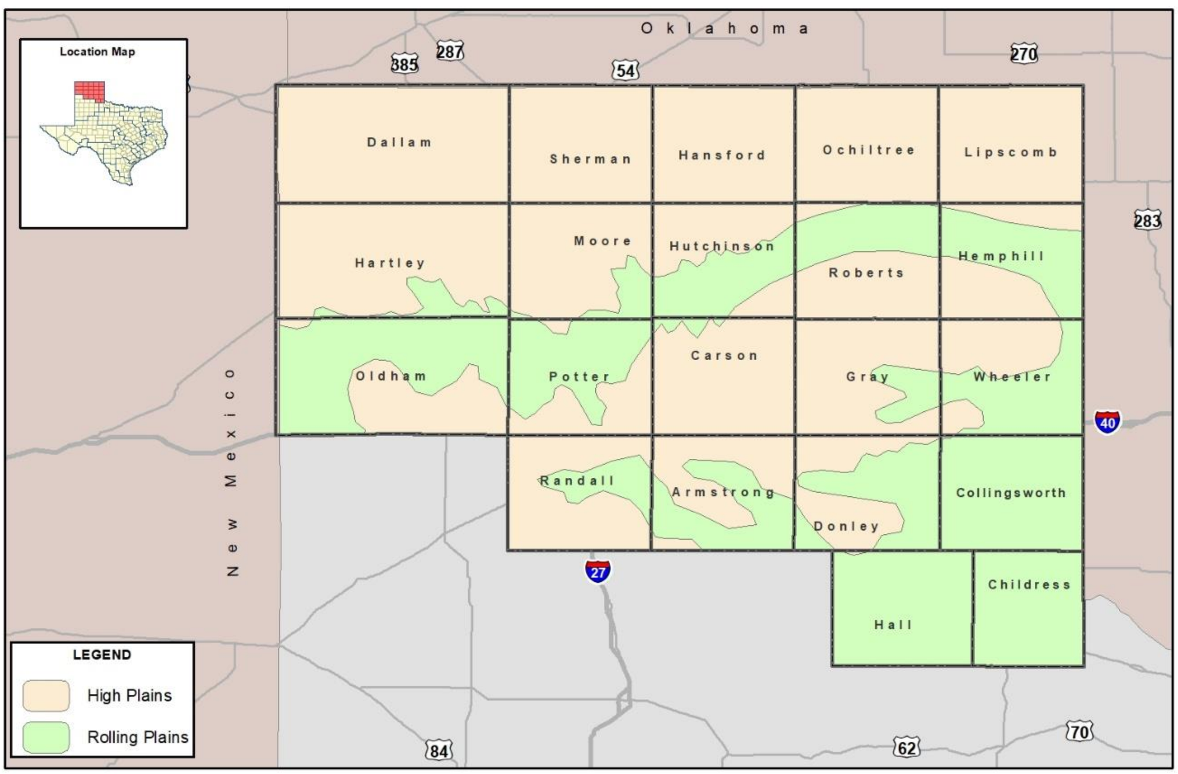


Figure 1-8: Natural Regions in the PWPA

1.7.2 Regional Vegetation

The PWPA is located in two vegetation regions which generally correspond to the natural regions described in the previous section – the High Plains and Rolling Plains.

Figure 1-9 illustrates the types of vegetation characteristic of the PWPA.

The vegetation of the High Plains is variously classified as mixed prairie, shortgrass prairie, and in some locations on deep, sandy soils as tallgrass prairie. Blue grama, buffalo grass, and galleta are the principal vegetation on the clay and clay loam sites. Characteristic grasses on sandy loam soils are little bluestem, western wheatgrass, sideoats grama, and sand dropseed, while shinnery oak and sand sagebrush are restricted to sandy sites. The High Plains are characteristically free from brush, but sand sagebrush and western honey mesquite, along with prickly pear and yucca, have invaded the sandy and sandy loam areas. Several species of dropseeds are abundant on coarse sands. Various aquatic species such as curltop smartweed are associated with the playa lakes (TAMU, 1999b).

Generally, as a result of overgrazing and abandonment of cropland, woody invaders such as mesquite, lotebush, prickly pear, algerita, tasajillo, and others are common on all soils. Shinnery oak and sand sagebrush invade the sandy lands while redberry juniper has spread from rocky slopes to grassland areas. Western ragweed and annual broomweed are also common invaders (TAMU, 1999b).

Brush encroachment is a concern in the Canadian River Breaks and the North Rolling Plains (the eastern panhandle counties of Collingsworth, Hall, Donley, and Wheeler). Brush canopies range from light to heavy in these counties and in the Canadian River Breaks (Potter, Moore, and Oldham Counties especially). The major species of concern is mesquite, which has been shown to be increasing in plant population virtually everywhere it is found. Other species that are encroaching are sand sagebrush, sand shinoak, and yucca. Salt cedar, a phreatophyte, now infests much of the Canadian River stream banks and has moved out onto the adjacent river terraces. Plants such as salt cedar are likely to use much more water than the upland species brush. According to the NRCS Resource Data and Concerns files in the local field offices, there are approximately 1,200,000 acres of brushy species that would be classified as medium to high priority for treatment within the PWPA.

Salt Cedar

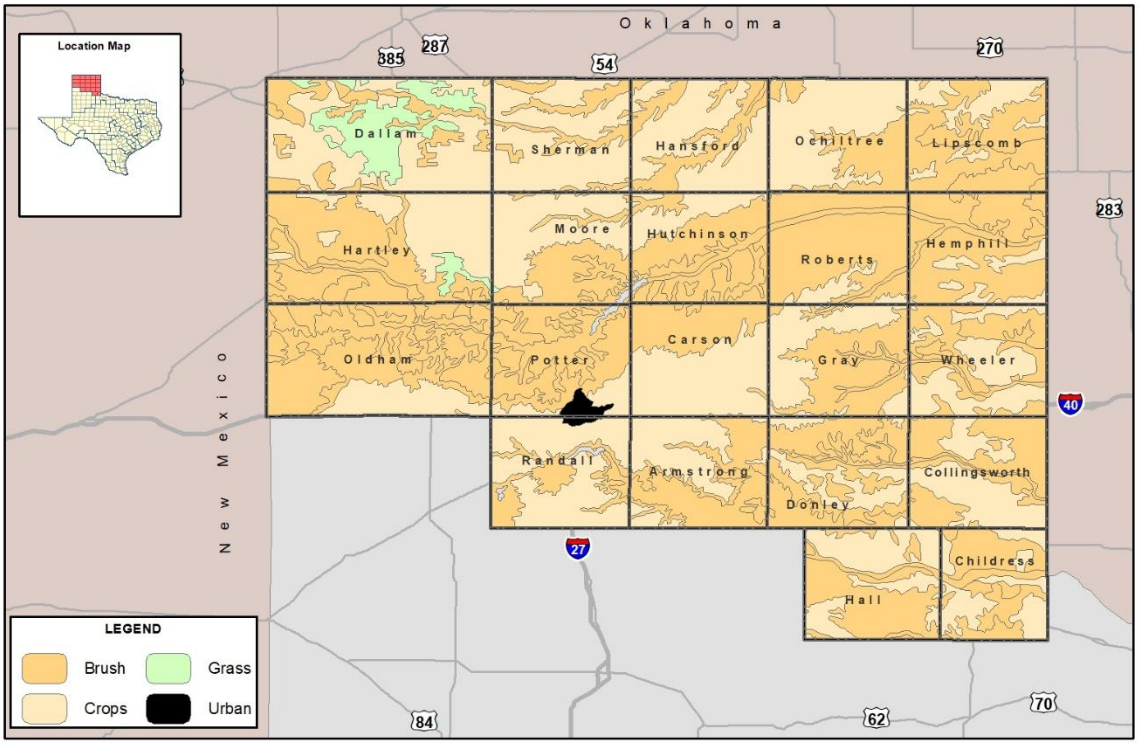


Figure 1-9: Regional Vegetation in the PWPA

A program initiated through the Texas State Soil and Water Conservation Board (TSSWCB) included a study of the feasibility of brush management in eight Texas watersheds, including portions of the Canadian River Basin. The studies, completed in 2010, focused on economic aspects and potential changes in water availability related to brush management. For the Canadian River Basin, the study examined the water availability benefits of controlling moderate to heavy concentrations of mesquite and mixed brush. CRMWA, in partnership with local landowners, TSSWCB and the NRCS have targeted thousands of acres for removal of brush. Between 2010 and 2011 the Legislature has approved over $4.5 million for controlling invasive brush through herbicidal spraying. Research has shown that removing one acre of salt cedar equals 2 to 5 acre-feet per year of water savings and to date, over 16,850 acres have been treated.

1.7.3 Regional Geology

The geology of the Panhandle is composed of sandstone and shale beds of the Cenozoic, Mesozoic and Paleozoic Ages. Major geologic systems which are found in the PWPA include the Tertiary, Triassic, Cretaceous, and Permian (Figure 1-10). Throughout the PWPA, the outcropping geology consists of eastward-dipping Permian, Triassic and Tertiary age sandstone, shale, limestone, dolomite and gypsum. The Tertiary Ogallala Group can be found along the western section of the

PWPA and includes the Birdwell/Couch Formation.

In the Southern High Plains, the Ogallala formation was deposited by ancient rivers that once flowed west to east from the mountains of New Mexico. Remnant paleo-valleys such as the Winkler, Simanola, and Portales valleys have been identified and mapped by geologists that have studied the area. These valleys were sequentially abandoned as the Pecos Valley formed and provided a new path to the Rio Grande and ultimately to the Gulf of Mexico. The water contained within the Ogallala sands and gravels deposited by these ancient streams were subsequently covered and preserved by aeolian deposits, such as the Blackwater Draw formation.

The eastern portion of the PWPA includes the Ogallala, Dockum, Quartermaster, Whitehorse, and Pease River groups. The Dockum Group formation includes the Santa Rosa, Trujillo, and Chinle Formations. The Whitehorse Group formations are undifferentiated in the west due to widespread solution, collapse, and erosional features. The Blaine Gypsum is the primary formation within the Pease River Group (AAPG, 1979).

1.7.4 Mined Resources

Natural resources that are mined in the PWPA (Table 1-13) are primarily oil and natural gas. Technical advances in natural gas development have increased mining activities in the Woodford Shale formation, which lies in the northeastern part of the region within the Anadarko Basin. Non-petroleum mined products include sand, gravel, caliche, stone, and helium. Three counties (Dallam, Hall, and Randall) reportedly do not have any significant mining production.

Table 1-13: Mined Products for Counties in the PWPA

County	Sand	Gravel	Caliche	Stone	Oil	Gas	Helium
Armstrong	X	X					
Carson					X	X	
Childress					X		
Collingsworth					X	X	
Dallam							
Donley						X	
Gray					X	X	
Hall							
Hansford				X	X	X	X
Hartley					X	X	
Hemphill					X	X	
Hutchinson	X	X			X	X	
Lipscomb					X	X	
Moore					X	X	X

County	Sand	Gravel	Caliche	Stone	Oil	Gas	Helium
Lipscomb					X	X	
Moore					X	X	X
Ochiltree		X	X		X	X	
Oldham	X	X		X	X	X	
Potter					X	X	
Randall							
Roberts					X	X	
Sherman					X	X	
Wheeler					X	X	

Source: Ramos, 2000

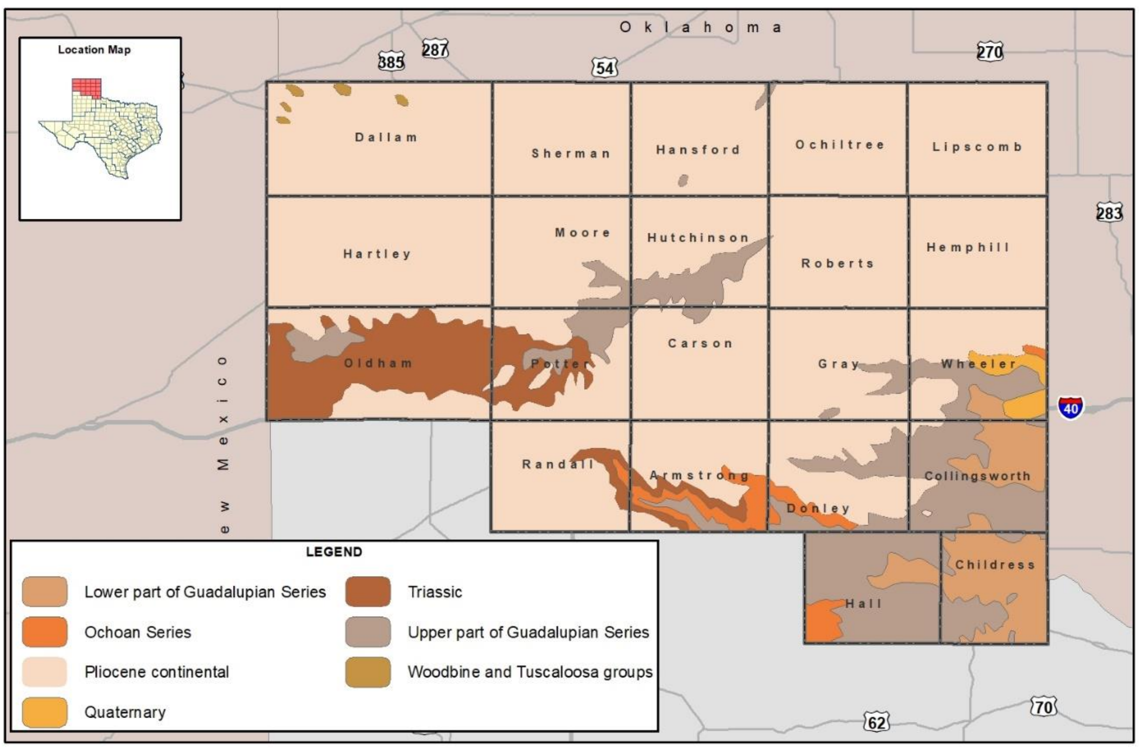


Figure 1-10: Regional Geology of the PWPA

1.7.5 Soils

Soils of the High Plains formed under grass cover in Rocky Mountain outwash and sediment of variable sand, silt, clay, and lime content (Runkles, 1968). Calcium carbonate and, to some extent, gypsum are present in most soil profiles, and rainfall has been insufficient to leach these carbonates from the soil profiles. Many of the surface soils are moderately alkaline to calcareous and low in organic matter. The major soil associations found in the PWPA may be characterized as nearly level or outwash soils (

Figure 1-11). Most of the nearly level soils in the PWPA have loamy surfaces and clayey subsoils. The major associations involving these nearly level soils are:

- Pullman-Olton-Mansker
- Sherm-Gruver-Sunray
- Dallam-Sunray-Dumas
- Sunray-Conlen-Gruver

Much of the irrigation is on these soils because they are highly productive if sufficient water is available. Much of the eastern portion of the PWPA is characterized by red to brown soils formed from outwash of the clayey to silty red beds. Many of these soils have loamy surface layers and loamy subsoils. Some are shallow over indurated caliche. The major associations included in these outwash soils are:

- Mansker-Berda-Potter
- Woodward-Quinlan-Vernon
- Miles-Springer-Woodward

Infiltration rate of soils used as cropland is primarily affected by soil properties such as texture, structure, aggregate stability, and salinity status. Surface crusting tendencies and organic matter content, which are influenced by tillage management, play an important role in influencing infiltration rates. High soil density in the lower tillage zone (plow pan) restricts hydraulic conductivity and consequent irrigation application rates in many soils, thus enhancing runoff. Irrigation water quality also influences infiltration rate over time, especially with regard to total salinity, sodium concentration, and organic matter content when wastewater is used. Infiltration rates can vary significantly within a field and over time due to soil differences and cultural practices.

The nearly level soils are finer textured and have a restrictive horizon below the plowed layer that greatly reduces water intake after initial wetting to below 0.06 inches per hour (1.5 mm/hr). This profoundly affects soil management and irrigation practices. Root zone permeabilities for most other soils are usually well above 0.2 inches per hour (5 mm/hr). Plant available water holding capacities (i.e., difference in water content between field capacity at –0.33 bars matric potential and wilting point at –15 bars) varies from 0.7 to 2.4 inches per foot within the root zone. Soils with loam, silt loam, and clay load textures generally have higher water holding capacities than sandier soils. Each additional inch of plant available water in the soil at planting time can boost crop yields significantly. Therefore, soil water storage during a fallow season is an important consideration.

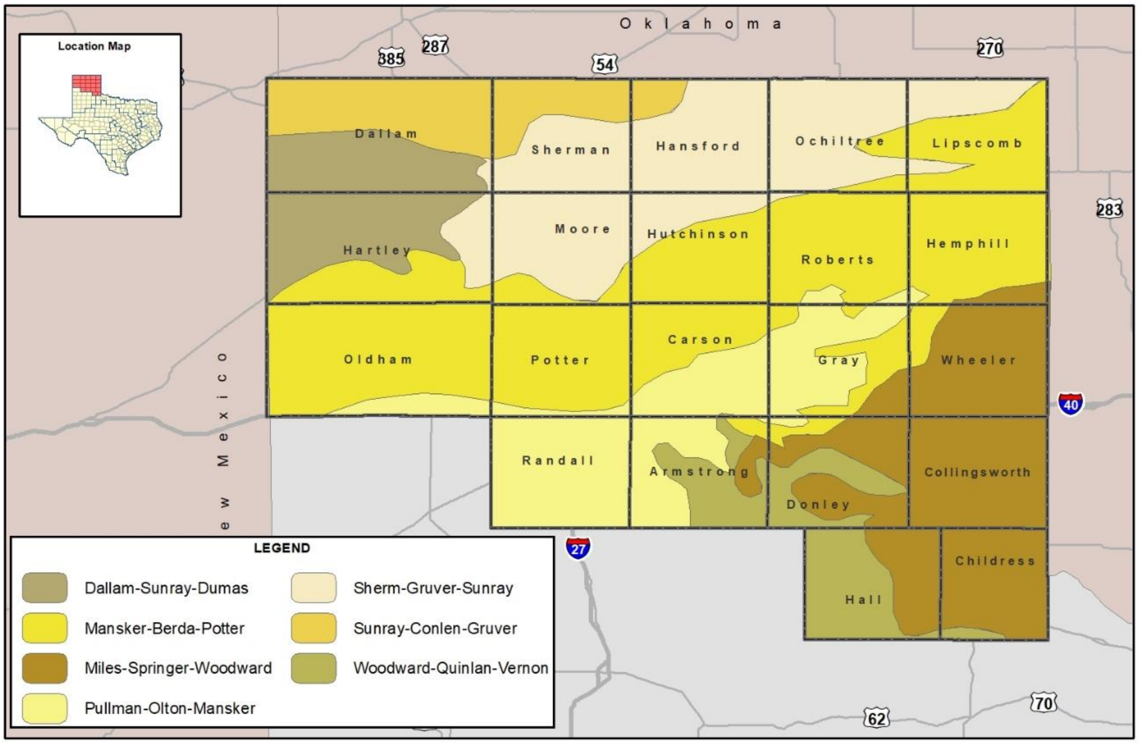


Figure 1-11: Regional Soils of the PWPA

1.7.6 Wetlands

Wetlands are especially valued because of their location on the landscape, the wide variety of functions they perform, and the uniqueness of their plant and animal communities. Ecologically, wetlands can provide high quality habitat in the form of foraging and nesting areas for wildlife and spawning and nursery habitat for fish.

The most visible and abundant wetland features within the PWPA are playa basins. These are ephemeral wetlands found within the region and throughout the Texas Panhandle. The Texas High Plains playa basins are an important element of surface hydrology and ecological diversity. Most playas are seasonally flooded basins, receiving their water only from rainfall or snowmelt. In good years, these shallow basins collect about three or four feet of water. Over time, the moisture either evaporates or filters through the soil to recharge the aquifer.

Playa basins in the High Plains have a variety of shapes and sizes which influence the rapidity of runoff and rates of water collection. Playas have relatively flat bottoms resulting in a relatively uniform water depth throughout most of the basin and are generally circular to oval in shape. Typically, the soil in the playas is the Randall Clay. In addition to their biological importance as wetlands, playas provide local recharge to the Ogallala aquifer.

Playa basins may supply excellent cover to resident wildlife. These formations provide mesic sites in a semi-arid region and therefore are likely to support a richer, denser vegetative cover than surrounding areas. Moreover, the perpetual flooding and drying of the basins promotes the growth of plants such as smartweeds, barnyard grass, and cattails that provide both food and cover. The concentric zonation of plant species and communities in response to varying moisture levels in basin soils enhances interspersion of habitat types.

Playas offer the most significant wetland habitats in the southern quarter of the Central Flyway for migrating and wintering birds. Up to two million ducks and hundreds of thousands of geese take winter refuge here. Shorebirds, wading birds, game birds, hawks and owls, and a variety of mammals also find shelter and sustenance in playas (TPWD, 1999). The abundance of playas in counties of the PWPA varies considerably with some counties having none and others with up to 3 percent of the county covered by playas (Table 1-14).

Table 1-14: Physical Characteristics of Playas in the PWPA

County	Number of Playa Lakes	Total Playa Area (acres)	Percent of County Area	Largest Playa (acres)	Smallest Playa (acres)	Average Perimeter (miles)
Armstrong	994	15,356	2.62%	348	0.002	0.54
Carson	595	15,074	2.55%	409	0.000	0.67
Childress	7	116	0.03%	24	7.478	0.64
Collingsworth	0	0	0.00%	0	0.000	0.00
Dallam	262	4,471	0.46%	141	0.000	0.54
Donley	109	1,978	0.33%	181	1.274	0.56
Gray	792	13,529	2.28%	237	0.018	0.51
Hall	0	0	0.00%	0	0.000	0.00
Hansford	381	7,483	1.27%	444	0.003	0.49
Hartley	222	4,281	0.46%	131	0.062	0.52
Hemphill	9	102	0.02%	34	2.301	0.47
Hutchinson	191	3,129	0.55%	116	0.000	0.50
Lipscomb	19	225	0.04%	36	2.652	0.54
Moore	214	5,036	0.86%	246	0.083	0.61
Ochiltree	693	16,263	2.76%	527	0.131	0.58
Oldham	173	4,249	0.44%	195	0.000	0.67
Potter	118	3,472	0.59%	406	0.063	0.61
Randall	594	13,373	2.26%	201	0.117	0.77
Roberts	109	1,350	0.23%	278	0.933	0.44

County	Number of Playa Lakes	Total Playa Area (acres)	Percent of County Area	Largest Playa (acres)	Smallest Playa (acres)	Average Perimeter (miles)
Sherman	218	4,202	0.71%	163	0.114	0.55
Wheeler	0	0	0.00%	0	0.000	0.00
Total	**5,700**	**113,689**	**0.98%**	**527**	**<1**	**0.49**

Source: Playa Lakes Joint Venture, 2015

1.7.7 Aquatic Resources

Rivers and reservoirs within the planning area are recognized as important ecological resources. These are sources of diverse aquatic flora and fauna. Important river systems in the planning area are the Canadian River and the Red River. Reservoirs in the PWPA include Lake Meredith, Palo Duro Reservoir, Rita Blanca Lake, Marvin Lake, and Fryer Lake in the Canadian River Basin, and Greenbelt Reservoir, Bivens Reservoir, McClellan Lake, Lake Tanglewood, Baylor Lake, Lake Childress, and Buffalo Lake in the Red River Basin.

The high salinity of some of the area's surface and groundwater resources, largely due to natural salt deposits, presents a challenge to natural resource planners and managers. Municipal, agricultural, and industrial water users strive to lower the salinity of certain surface-water supplies for higher uses. One method for this is by intercepting and disposing of the naturally saline flows of certain streams, usually originating from natural salt springs and seeps, in order to improve the quality of downstream surface-water supplies. There are several such chloride control projects, both existing and proposed, in the study area.

Ecologically Unique Resources

SB1 requires that the State Water Plan identify river and stream segments of unique ecological value. The identification of such resources may be done regionally by each RWPG or by the state. Several criteria are used to identify streams with unique ecological values. These include biological and hydrologic functions, riparian conservation areas, high water quality, exceptional aquatic life, or high aesthetic quality. Also, stream or river segments where water development projects would have significant detrimental effects on state or federally listed threatened or endangered species may be considered ecologically unique. There are no designated ecologically unique resources in the PWPA.

1.7.8 Wildlife Resources

The abundance and diversity of wildlife in the PWPA is influenced by vegetation and topography, with areas of greater habitat diversity having the potential for more wildlife species. The Rolling Plains have a greater diversity of wildlife habitat, such as the Canadian Breaks and escarpment canyons. Mule deer, white-tailed deer, wild turkey are found along canyons and wooded streams. Antelope occur on the undulating prairies of the Canadian Breaks area and on the level margins of the High Plains. A number of wildlife species occur throughout the PWPA, including various lizards and snakes, rodents, owls and hawks, coyote, skunks, raccoons, and feral hogs.

Land in the High Plains is generally used for rangeland and cropland and support pronghorn (antelope), prairie dogs, jackrabbits, coyotes, and small mammals. Playas and grain fields attract large numbers of migratory ducks, geese and sandhill cranes. Pheasants and scaled (blue) quail can be locally abundant near corn and other grain fields.

The presence or potential occurrence of threatened or endangered species is an important consideration in planning and implementing any water resource project or water management strategy. Both the state and federal governments have identified species that need protection. Species listed by the U.S. Fish and Wildlife Service (USFWS) are afforded the most legal protection, but the TPWD also has regulations governing state-listed species. Table 1-15 contains the state or federally protected species which have the potential to occur within the PWPA. This list does not include species without official protection such as those proposed for listing or species that are considered rare or otherwise of special concern.

1.8 Threats and Constraints to Water Supply

Threats and constraints to water supply in the PWPA are related to surface water and groundwater sources. The actual and potential threats may be similar or unrelated for surface or groundwater. Because much of the water use in the PWPA is primarily for agriculture, some of the impacts of the constraints on water use may differ from those for water used for human consumption. However, in most cases the same water sources are used for both agricultural and potable water supply.

Issues that are of concern for water supply in the PWPA include aquifer depletions due to pumping that exceeds recharge; surface water and groundwater quality; invasive brush; and drought related needs for both surface water and groundwater. Potential degradation of water quality may supersede water quantity as a consideration in evaluating the amount of water available for a use. However, the increasing ability to use brackish groundwater for some applications (oil and gas operations, fracking, livestock) might help slow potential water quality degradation).

Most water used in the PWPA is supplied from the Ogallala, making aquifer depletion a potentially major constraint on future water supply in the region. Depletions lower the water levels, making pumping more expensive and reducing the potential available supply. Another potential constraint to both groundwater pumping and maintenance of stream flows relates to restrictions that could be implemented due to the presence of endangered or threatened species. The Federal listing of the Arkansas River Shiner as a threatened species has the potential to affect water resource projects as well as other activities in Hemphill, Hutchinson, Oldham, Potter, and Roberts Counties.

Drought is a major threat to surface water supplies in the PWPA and groundwater supplies that rely heavily on recharge (such as the Seymour aquifer). The Lake Meredith watershed is currently experiencing its lowest inflows since the reservoir was constructed. This impacts water supplies to users in both the PWPA and Llano Estacado

Region. To better understand some of the factors contributing to the decline in inflows, a special study on the Lake Meredith watershed was conducted as part of the 2011 regional water plan. A concurrent study on drought in the Canadian River Basin was conducted by the Bureau of Reclamation, in conjunction with others. The findings of the studies indicated that changes in average precipitation and evaporation were not a factor in the low inflows to the reservoir. The changes in inflow are most likely associated with changes in reduced rainfall intensities, invasion of brush and changes in operations of Ute Reservoir. Changes in water use and practices in New Mexico may have an impact on flows in the Canadian River Basin, and ultimately water supply in Lake Meredith.

Potential contamination of groundwater may be associated with oil-field practices, including seepage of brines from pits into the groundwater; brine contamination from abandoned wells; and broken or poorly constructed well casings. Agricultural and other practices may have contributed to elevated nitrates in groundwater and surface water. Surface waters in the PWPA may also experience elevated salinity due to brines from oil-field operations, nutrients from municipal discharges, and other contaminants from industrial discharges. Other potential sources of contaminants include industrial facilities such as the Pantex plant near Amarillo; the Celanese plant at Pampa; an abandoned smelter site at Dumas; and concentrated animal feeding operations in various locations throughout the PWPA. However, most of these potential sources of contamination are regulated and monitored by TCEQ or other state agencies. Naturally occurring brine seeps also restrict the suitability of surface waters in some areas for certain uses.

Invasive brush has been shown to impact stream flows and water supplies. On-going efforts to control brush in the PWPA is discussed in Section 1.7.2.

Table 1-15: Threatened and Endangered Species in the PWPA

Species		Status*		County																				
Common Name	Scientific Name	Federal	State	Armstrong	Carson	Childress	Collingsworth	Dallam	Donley	Gray	Hall	Hansford	Hartley	Hemphill	Hutchinson	Lipscomb	Moore	Ochiltree	Oldham	Potter	Randall	Roberts	Sherman	Wheeler
Birds																								
Black Rail	*Laterallus jamaicensis*		T			S																		
Common Black Hawk	*Buteogallus anthranus*		T																	S				
Interior Least Tern	*Sterna antilarrum athalossas*	E	E			B					B			B								B		
White-Faced Ibis	*Plegadis chihi*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Whooping Crane	*Grus americana*	E	E		B	B	B		B	B	B	B		B	S	B		B				B		B
Fish																								
Arkansas River Shiner	*Notropis girardi*	T	T											B	B				B	B		B		
Peppered Chub	*Macrhybopsis tetranema*		T																S	S		S		
Prairie Chub	*Macrhybopsis australis*		T			S	S																	
Red River Pupfish	*Cyprinodon rubrofluviatilis*		T	S		S			S	S	S			S	S						S	S		S
Mammals																								
Black Bear	*Ursus americanus*		T	S	S			S					S											
Palo Duro Mouse	*Peromyscus truei comanche*		T	S	S				S											S	S			
Texas Kangaroo Rat	*Dipodomys elator*		T			S					S													
Reptiles																								
Texas Horned Lizard	*Phrynosoma cornutum*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

****Status:***
T - Threatened
E - Endangered
R - Recovery

Key:
F - Federal listings only (US Fish and Wildlife Service. 2020. Endangered Species List. http://www.fws.gov/endangered/)
S - State listings only (Texas Parks and Wildlife Department. 2020. Annotated County Lists of Rare Species. http://tpwd.texas.gov/gis/rtest/)
B - Both Federal and State listings

1.8.1 Drought of Record

The drought of record is commonly defined as the worst drought to occur in a region during the entire period of hydrologic and/or meteorological record keeping. For the PWPA, the region is currently in the drought of record. All three major reservoirs in the PWPA are currently in the critical drought period. For the Lake Meredith watershed, the drought began in 2000 and intensified from 2010 to 2015. After 2015 lake levels rose but the lake remained less than 40 percent capacity as of May 2019. More discussion on drought and droughts of record is presented in Chapter 7.

1.8.2 Drought Preparedness and Response

A summary of the drought preparedness and response is included in Chapter 7. As the PWPG is a planning body only, with no implementation authority, it should be carefully considered as to what appropriate drought response should be included in the Plan. Currently, local public water suppliers and water districts are required to have adopted a Drought Contingency Plan. These drought contingency plans contain drought responses unique to each specific entity. As these entities are the only ones who have the authority to manage their particular water supply or area of authority, it could be suggested that these are the only entities that can describe or implement a drought response.

Drought contingency plans are required by the TCEQ for wholesale water suppliers, irrigation districts and retail water suppliers. To aid in the preparation of the water plans, workshops sponsored by the Texas Rural Water Association (TRWA), Texas Water Utilities Association (TWUA), TCEQ and TWDB have been provided for those required to submit plans.

In addition to the individual entities' Drought Contingency Plans, the PWPG has prepared this regional water plan to be in general accordance with groundwater districts and net depletion rules and management goals.

1.9 Water Loss and Water Audit

For regional planning, retail public water utilities are required to complete and submit a water loss audit form to the TWDB. The first water loss audit reports were submitted to the TWDB by March 31, 2006. Entities with greater than 3,300 connections are now required to submit their water loss audit to TWDB on an annual basis. In addition, all other retail public suppliers are required to submit a water loss audit once every five years with the next scheduled audit due May 1, 2021. The water audit reporting requirements follow the International Water Association (IWA) and American Water Works Association (AWWA) Water Loss Control Committee methodology.

The primary purposes of a water audit loss are to account for all of the water being used and to identify potential areas where water can be saved. Water audits track multiple sources of water loss that are commonly described as apparent loss and real loss. Apparent loss is the paper loss of water. It includes losses associated with customer meters under-registering, billing adjustment and waivers, and unauthorized consumption. Real loss is the actual water loss of water from the system, and includes main breaks and leaks, customer service line breaks and leaks, and storage overflows. The sum of the apparent loss and the real loss make up the total water loss for a utility.

In the PWPA in 2017, seven public water suppliers submitted a water loss audit to TWDB. The total real loss was calculated for each water supplier using a corrected input volume. The corrected input volume is water delivered divided by master meter accuracy, which represents the actual amount of water that was delivered to the utility. On a regional basis, the percentage of total water loss for the PWPA is 19 percent. The amount of total water loss for cities, water supply corporations and municipal utility districts are slightly above the range of acceptable water loss (less than or equal to 12 percent). Table 1-16 summarizes the water loss audit information that was collected by the TWDB for the 2017 year. Reductions in water loss is considered for municipal conservation in Chapter 5.

Table 1-16: Summary of PWPA TWDB Water Loss Audits

	Real Loss for WUGs with < 32 Connections per Mile (gal/mi/day)	Real Loss for WUGs with >= 32 Connections per Mile (gal/con/day)	Apparent Loss (gal/con/day)	Total GPCD	Water Loss GPCD	Percent of Total Nonrevenue Water (%)
Median	450.88	64.66	5.19	168.98	25.99	18.98
Average	450.88	56.99	8.91	241.53	28.51	19.18

Source: 2017 Water Loss Audit Dataset from TWDB

1.10 Water-Related Threats to Agricultural and Natural Resources

Water-related threats to agricultural and natural resources in the PWPA include insufficient groundwater water supplies and water quality concerns.

Most of the PWPA depends on groundwater for irrigation. Based on the findings of this plan, the projected agricultural demand exceeds the available groundwater supply in several counties. The inability to meet these demands threatens the region's agricultural resources, which is a major economic driver in the PWPA.

Water quality concerns for agriculture are largely limited to saltwater pollution, both from natural and man-made sources. As previously discussed, improperly abandoned oil and gas wells may contribute to salt contamination of local aquifers. In some areas, excessive pumping may cause naturally occurring poor quality water to migrate into freshwater zones. Water with high total dissolved solids and/or salt concentrations can limit crop production and crop types. Excessive salts can form a hardpan layer on the surface, limiting infiltration of applied water to crops.

Reservoir development, groundwater development and invasion by brush have altered natural stream flow patterns in the PWPA. Spring flows in the PWPA have generally declined over the past several decades. Much of the impact to springs is because of groundwater development, the spread of high water use plant species such as mesquite and salt cedar, or the loss of native grasses and other plant cover. High water use plant species have reduced reliable flows for many tributary streams. Reservoir development also changes natural hydrology by diminishing flood flows and capturing low flows. Continued depletion of the local aquifers will likely continue to impact base flows of local streams and rivers in the PWPA.

The recommended water management strategies in Chapter 5 address the potential threats to agriculture and natural resources. Conservation is recommended for all irrigation water users to help alleviate groundwater stress. Seven irrigation strategies and three potential combinations of these strategies are considered based on water savings and cost of implementation. Elevated nitrate and chloride levels from water supplies in the Blaine and Seymour aquifers for municipalities are also addressed with water treatment strategies. Salt cedar removal in the Lake Meredith watershed is a recommended strategy to increase flow into the Canadian River, improve water quality, and improve habitat.

1.11 Summary of Existing Local and Regional Water Plans

1.11.1 Assessment of Potential Water Supplies for Greenbelt MIWA

In 2011, Greenbelt MIWA conducted a study on the reliability of Greenbelt Reservoir and identification of potential water sources to supplement the current surface water supplies. The study found that the lake is in current drought of record conditions, which make it difficult to determine the reliable supply with certainty. Evaluations of inflow to the lake found that local springs are critical to the reliable supply of the lake. Based on historical spring flows, it was determined that the reservoir could continue to supply water at the current level of about 3,850 acre-feet per year. Over time this may decrease due to impacts to spring flows and reductions in storage of the reservoir from sediment accumulation. The review of potential supplemental water sources recommended the development of groundwater from the Ogallala in northern Donley County. This source provides the highest reliability for a long-term supply.

1.11.2 Canadian River Watershed Study

Brauer, Baumhardt, Gitz, Gowda and Mahan, published a study in 2011 evaluating the impact of Lake Meredith as a municipal water supply reservoir. The study focused on the four primary impoundments upstream of and including Lake Meredith (Eagle Nest Lake, Conchas Lake, Ute Lake), and four major USGS Gages (07211500, 07221500, 07227000, and 07227500). The primary finding from the analysis is that flows at the Amarillo gage must average 150,000 acre-feet on an annual basis to maintain the conservation storage in Lake Meredith and supply 80,000 acre-feet for municipal use.

1.11.3 2016 Panhandle Regional Water Plan

This plan was the culmination of the effort of the PWPG and water users in the region to quantify water demands, assess available supplies to meet these demands and identify strategies to address potential water needs. During this process it was found that the projected demands exceeded the currently developed supplies on a regional basis by approximately 170,000 acre-feet per year in 2020, growing to approximately 252,000 acre-feet per year in 2070. Most of this need is associated with irrigation use in Dallam and Hartley Counties. There were 14 counties with 33 water user groups with projected water needs during the planning period. The largest needs were associated with irrigation use, followed by municipal and manufacturing.

There are supplies in the region that are not fully utilized, including untapped groundwater, which could possibly be used for some of the identified needs. Conservation and demand management are important strategies to meet the irrigation needs and offset dependence on expanding supply development. The PWPA considered conservation a priority in maintaining future supplies.

Most of the recommended strategies included development of additional groundwater supplies and/or conservation. The region has large quantities of undeveloped groundwater. This supply can easily be developed to meet most municipal water needs, but it is limited for irrigated agricultural due to geographical constraints. The primary strategy for irrigation needs was conservation. The total amount of potential water savings from recommended water conservation strategies in the PWPA was 140,669 acre-feet per year in 2020 and increasing to 523,563 acre-feet per year by 2070. Most of these savings were associated with recommendations for irrigated agriculture. Comparison of the 2016 Water Plan to this plan is presented in Chapter 11.

1.12 Existing Programs and Goals

1.12.1 Federal Programs

Clean Water Act

The 1972 Federal Water Pollution Control Act, which, as amended, is known as the Clean Water Act (CWA), is the federal law with the most impact on water quality protection in the PWPA. The CWA (1) establishes the framework for monitoring and controlling industrial and municipal point source discharges through the National Pollutant Discharge Elimination System (NPDES); (2) authorizes federal assistance for the construction of municipal wastewater treatment facilities; and (3) requires cities and certain industrial activities to obtain permits for stormwater or non-point source pollution (NPS) discharges. The CWA also includes provisions to protect specific aquatic resources. Section 303 of the CWA establishes a non-degradation policy for high quality waters and provides for establishment of state standards for receiving water quality. Section 401 of the CWA allows states to enforce water quality requirements for federal projects such as dams. Section 404 of the CWA provides safeguards for wetlands and other waters from the discharge of dredged or fill material. In accordance with Section 305 of the CWA, TCEQ prepares and submits to the U.S. Environmental Protection Agency a Water Quality Inventory. Other provisions protect particular types of ecosystems such as lakes (Section 314), estuaries (Section 320) and oceans (Section 403). Several of these provisions are relevant to specific water quality concerns in the PWPA.

Safe Drinking Water Act (SDWA)

The SDWA, passed in 1974 and amended in 1986 and 1996, allows the U.S. Environmental Protection Agency to set drinking water standards. These standards are divided into two categories: National Primary Drinking Water Regulations (primary standards that must be met by all public water suppliers) and National Secondary Water Regulations (secondary standards that are not enforceable but are recommended). Primary standards protect water quality by limiting contaminant levels that are known to adversely affect public health and are anticipated to occur in water. Secondary standards have been set to help control contaminants that may pose a cosmetic or aesthetic risk to water quality (e.g., taste, odor or color).

North American Waterfowl Management Playa Joint Ventures

The Playa Lakes Joint Venture -- a partnership of state and federal agencies, landowner's conservation groups and businesses -- was established in 1990 to coordinate habitat protection and enhancement efforts on the southern High Plains. Because the playa lakes region provides crucial wintering, migrating and breeding habitat for waterfowl in the Central Flyway, this is one of 10 priority efforts under the North American Waterfowl Management Plan, an agreement between the United States, Canada and Mexico to restore declining waterfowl populations across the continent.

Almost all of the 25,000 playas in Texas, Kansas, New Mexico, Oklahoma, and Colorado are privately owned, and much of the surrounding landscape is in agriculture. Programs are being developed that will provide incentives to private landowners to manage playas for waterfowl and other wildlife.

Joint Venture efforts focus on providing:

- Sufficient wetland acres to avoid undesirable concentrations of waterfowl that lead to disease outbreaks
- Enough feeding areas for both breeding and wintering birds
- Healthy upland and wetland habitats to maximize waterfowl production and winter survival

Agricultural Improvement Act of 2018

The 2018 Farm Bill, governing federal farm programs for the next five years, was signed into law in December 2018. After substantial changes were made in the Agricultural Act of 2014 from previous farm bills, the 2018 farm bill left all the provisions in place while only slightly modifying certain components. Overall, funding for the 2018 farm bill largely remained the same as the 2014 farm bill. All commodity provisions as well as the crop insurance programs were retained with minor modifications. These include Agricultural Risk Coverage (a shallow revenue loss program) and Price Loss Coverage, as well as new subsidized crop insurance products such as Stacked Income Protection Plan for cotton, and Supplemental Coverage Option.

However, funding reallocations in the conservation provisions may lead to positive water savings for the region. The nationwide cap on Conservation Reserve Program (CRP) acreage was increased from 24 to 27 million acres, which may keep irrigated acreage in the area enrolled in the CRP from leaving or entice additional irrigated acreage into the CRP. Funding or the EQIP program is scheduled to increase, reaching $2.025 billion by 2023 and the Regional Conservation Partnership Program received an increase to $300 million annually. Improvements in irrigation systems and water conservation strategies are priorities to receive funding from both programs, thus could potentially lead to additional water savings in the area.

1.12.2 Interstate Programs

Canadian River Compact

Entered into by New Mexico, Oklahoma and Texas, the compact guarantees that Oklahoma shall have free and unrestricted use of all waters of the Canadian River in Oklahoma, and that Texas shall have free and unrestricted use of all water of the Canadian River in Texas subject to limitations upon storage of water (500,000 acre-feet of storage in Texas) until such time as Oklahoma has acquired 300,000 acre-feet of conservation storage, at which time Texas' limitation shall be 200,000 acre-feet plus the amount stored in Oklahoma reservoirs. New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of the Canadian River above Conchas Dam, and free and unrestricted use of all waters originating in the drainage basin of the Canadian River below Conchas Dam, provided that the amount of conservation storage in New Mexico available for impounding waters originating below Conchas Dam shall be limited to 200,000 acre-feet. Water originating from the North Canadian River in Texas is limited to domestic and municipal use.

Red River Compact

The Red River Compact was entered into by the states of Arkansas, Oklahoma, Louisiana and Texas for the purpose of apportioning the water of the Red River and its tributaries. The Red River is defined as the stream below the crossing of the Texas-Oklahoma state boundary at longitude 100 degrees west. Reach I is defined as the Red River and its tributaries from the New Mexico-Texas state boundary to Denison Dam, which is the reach that falls in the PWPA.

In Reach I, four subbasins are defined and the annual flow within the subbasins located within the PWPA is apportioned as follows:

- Subbasin 1 (Buck Creek, Sand Creek, Salt Fork Red River, Elm Creek, North Fork Red River, Sweetwater Creek and Washita River, together will all their tributaries within Texas west of the 100th Meridian) - 60 percent to Texas and 40 percent to Oklahoma.
- Subbasin 3 (Tributaries of the Red River in Texas, beginning from Dennison Dam and upstream to include Prairie Dog Town Fork Red River) - Texas has free and unrestricted use of water in Subbasin 3.

1.12.3 State Programs

The TCEQ is the state lead agency for water resource protection, administering both state and federally mandated programs, such as the Resource Conservation and Recovery Act; the Clean Water Act; the Comprehensive Environmental Response, Compensation Liability and Recovery Act; the Safe Drinking Water Act; and state management plan development for prevention of pesticide contamination of groundwater under the Federal Insecticide, Fungicide, and Rodenticide Act. The TCEQ conducts regulatory groundwater protection programs that focus on: (1) prevention of contamination; and (2) identification, assessment, and remediation of existing problems (TCEQ, 1997).

Texas Pollutant Discharge Elimination System (TPDES) Program

The TPDES is the state program to carry out the National Pollutant Discharge Elimination System (NPDES) promulgated under the Clean Water Act. The Railroad Commission of Texas maintains authority in Texas over discharges associated with oil, gas, and geothermal exploration and development activities. The TPDES program covers all permitting, inspection, public assistance, and enforcement associated with:

- discharges of industrial or municipal waste
- discharges and land application of manure from concentrated animal feeding operations
- discharges of industrial and construction site storm water
- discharges of storm water associated with city storm sewers
- oversight of municipal pretreatment programs
- disposal and use of sewage sludge

Texas Clean Rivers Program (TCRP)

The TCRP was established with the promulgation of the Texas Clean Rivers Act of 1991. TCRP provides for biennial assessments of water quality to identify and prioritize water quality problems within each watershed and subwatershed. In addition, TCRP seeks to develop solutions to water quality problems identified during each assessment.

State Authority and Programs for Water Supply

Following are major State Water departments that may have relevance to municipal, industrial, agricultural, and utility water users (TCEQ, 2014):

- TCEQ, Office of Water – water availability, water planning, water quality and water supply
- TCEQ, Office of Compliance and Enforcement – remediation, field operation, support, enforcement
- Public Utilities Commission – Public Water Supplier reporting and database
- Texas Department of Licensing and Regulations – licenses well drilling operators
- Groundwater Districts - regulate aspects of groundwater use and conservation such as well spacing, size, construction, closure, and the monitoring and protection of groundwater quality
- TWDB, Water Science and Conservation Division – conservation and innovative technologies, surface water resources, and groundwater
- TWDB, Water Supply and Infrastructure Division – regional water planning and development, program administration, water use and projections

Notable state programs for water quality protection includes: (a) wellhead protection areas; and (b) Texas Wetlands Conservation Plan.

Wellhead Protection Areas

The Texas Water Code provides for a wellhead source water protection zone around public water supply wells extending to activities within a 0.25-mile radius. Specific types of sources of potential contamination within this wellhead/source water protection zone may be further restricted by TCEQ rule or regulation. For example, wellhead/source water protection zones have been designated for many public water supply wells within or near Pantex (May and Block, 1997). More specific information on well head protection zones is available from TCEQ.

The Texas Water Code further provides for all wells to be designed and constructed according to TCEQ well construction standards (30 TAC 290). These standards require new wells to be encased with concrete extending down to a depth of 20 feet, or to the water table or a restrictive layer, whichever is the lesser. An impervious concrete seal must extend at least 2 feet laterally around the well head and a riser installed at least 1 foot high above the impervious seal.

Texas Wetlands Conservation Plan

The State Wetlands Conservation Plan is an outgrowth of the National Wetlands Policy Forum, which was convened in 1987 at the request of the Environmental Protection Agency. In September 1994, a Statewide Scoping Meeting was held that led to the development of the Texas Wetlands Conservation Plan. The primary principles identified during the Plan's development were: 1) improve the transfer of information between agencies, groups and citizens; 2) develop incentives that encourage landowners to conserve wetlands on their property; and 3) increase the assessment of wetlands projects and research on conservation options. Additionally, the five general categories of wetlands issues identified during the development process were: 1) education; 2) economic incentives; 3) conservation; 4) private ownership; and 5) governmental relations. The Plan was finalized in the spring of 1997.

Water for Texas (2017)

Texas Water Code, §16.051 states that: The State Water Plan shall provide for the orderly development, management, and conservation of water resources and preparation for and response to drought conditions, in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the entire State. The Water for Texas Plan was adopted by the TWDB.

The 2017 State Water Plan was a culmination of a 4-year effort by local, regional, and State representatives. One of the more unique aspects in regional water planning is the broad level of public involvement that occurs throughout the process. Numerous public meetings and hearings, along with technical assistance and support from the State's natural resource agencies, (TWDB, TPWD, Texas Department of Agriculture [TDA], and TCEQ), demonstrate the broad commitment of Texas to ensuring adequate water supplies to meet future needs. To ensure that as many individuals and organizations as possible would have an opportunity to provide comments on the draft 2017 State Water Plan, public meetings were held across Texas.

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(14) Texas Commission on Environmental Quality (TCEQ) 2014. TCEQ Organization Chart, available online at http://www.tceq.state.tx.us/about/organization.

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2 POPULATION AND WATER DEMANDS

In April 2018, the Texas Water Development Board (TWDB) approved population and water demand projections for the Panhandle Water Planning Area (PWPA) for use in the 2021 Regional Water Plan. As part of this regional water planning update, these projections were reviewed by the region and revised as needed. Modifications were made to projected populations and municipal water demands for the cities of Texline, Sunray, and Canyon based on local input. Changes were also made for the agricultural and steam electric power water demands. Due to the continuing changes in the agricultural sector in the region, a study of the current and projected agricultural water use was conducted for this plan. Modifications to agricultural water demand projections were made as a result of this study.

The TWDB distributes its population and demand projections by Water User Groups. Each WUG has an associated water demand that is aggregated on a county/basin basis. Only municipal WUGs have population projections.

Other categories of water users include wholesale water providers and major water providers. A wholesale water provider (WWP) can be a utility, river authority, water district or other entity that sells water wholesale to another entity (such as a different water user group or another wholesale provider). If a wholesale provider also sells water retail, then the provider is considered both a water user group and wholesale provider (e.g., Amarillo Water Utility). A major water provider (MWP) is a WUG or WWP of particular significance to the region's water supply as determined by the Panhandle Water Planning Group (PWPG). This entity may provide water for any use category.

All projections in this chapter are aggregated by the county where the water is used. Projected demands on water sources are addressed in Chapter 3. Specifically, expected demands on the Ogallala aquifer by county are included in Table 3-16. Demands on other sources are accounted for through the allocation of water supplies to users and recommended water management strategies.

A Water User Group (WUG) is:

- Privately owned utilities that provide an average of more than 100 acre feet per year for municipal use for all owned water systems
- Water systems serving institutions or facilities owned by the state or federal government that provide more than 100 acre feet per year for municipal use
- All other retail public utilities that provide more than 100 acre feet per year for municipal use
- Rural/unincorporated areas of municipal water use, known as County Other (aggregated on a county/basin basis)
- Manufacturing (aggregated on a county/basin basis)
- Steam electric power (aggregated on a county/basin basis)
- Mining (aggregated on a county/basin basis)
- Irrigation (aggregated on a county/basin basis)
- Livestock (aggregated on a county/basin basis)

This chapter documents the projected estimates of population and water demands of WUGs in the PWPA, as well as the demands on designated major water providers. Projections divided by WUG, county and basin may be found in the tables at the end of this chapter (Attachment 2-1). The projections were developed by decade and cover the period from 2020 to 2070.

2.1 Population Projections

In 2010, the population of the State of Texas was approximately 25.1 million people. The population of the PWPA in 2010 was estimated to be 380,733[1]. This represents approximately 1.5 percent of the state's population. Most of the region's population is in Potter and Randall Counties, which contains Amarillo. The remaining population in the PWPA is distributed among the other 19 counties, ranging from populations of less than 1,000 in Roberts County to over 20,000 in Gray, Hutchison, and Moore Counties.

For the 2021 regional water plans, municipal water users were redefined based on the service area boundary rather than city boundaries. For most of the cities in the PWPA, the city boundary and service area boundary are the same or very similar. Since there was no new U.S. Census for this plan, the county and regional populations were kept the same as used in the 2016 regional water plan. However, populations for individual WUGs were adjusted based on service area boundaries rather than political boundaries. In addition, ten new municipal WUGs (including county splits for Red River Authority) were identified for the 2021 PWPA water plan. The initial population projections for each WUG relied on several sources, including the 2010 U.S. Census, water connections data, and self-reported data to the TWDB and Texas Commission on Environmental Quality (TCEQ). For two cities, the anticipated growth used in the 2016 plan had not been realized. These cities (Texline in Dallam County and Sunray in Moore County) requested lower projected population growth for the 2021 regional water plan. Also, the Canyon Water Utility provided corrected service area information, which resulted in increased populations. These were the only population projection modifications that were requested and approved.

The population for the PWPA is projected to increase from 418,345 in 2020 to 637,412 in 2070, or an average annual growth rate of 0.85 percent. As shown on Table 2-1, approximately 75 percent of the region's growth is expected to occur in Randall and Potter Counties, with much of this growth occurring outside of the city limits of Amarillo. Other counties showing increases in population include Dallam, Gray, Moore, and Ochiltree counties. The 2020 population and 2070 population projections by county are shown in Table 2-1.

Table 2-1: PWPA Population by County from 2020 to 2070

County Name	2020	2030	2040	2050	2060	2070
Armstrong	1,911	1,911	1,911	1,911	1,911	1,911
Carson	6,354	6,520	6,632	6,632	6,632	6,632
Childress	7,269	7,546	7,776	8,001	8,225	8,443
Collingsworth	3,236	3,408	3,522	3,653	3,755	3,844
Dallam	7,718	8,668	9,667	10,650	11,594	12,503
Donley	3,788	3,788	3,788	3,788	3,788	3,788
Gray	24,439	27,046	30,168	34,186	37,388	40,730
Hall	3,393	3,487	3,487	3,487	3,487	3,487
Hansford	5,959	6,368	6,710	7,017	7,330	7,634
Hartley	6,281	6,631	6,817	6,950	7,069	7,164
Hemphill	4,209	4,609	4,948	5,297	5,609	5,895
Hutchinson	22,957	23,779	23,990	23,990	23,990	23,990
Lipscomb	3,599	3,858	4,011	4,211	4,350	4,465
Moore	25,513	28,864	32,429	36,050	39,824	43,690
Ochiltree	11,305	12,158	13,075	14,061	15,122	16,264
Oldham	2,230	2,376	2,376	2,376	2,376	2,376
Potter	134,031	148,960	164,757	180,486	197,638	215,701
Randall	134,269	150,044	165,835	182,010	199,219	217,095
Roberts	1,003	1,047	1,047	1,047	1,047	1,047
Sherman	3,294	3,571	3,720	3,853	3,949	4,020
Wheeler	5,587	5,809	6,019	6,239	6,478	6,733
Total	**418,345**	**460,448**	**502,685**	**545,895**	**590,781**	**637,412**

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SCALE: 1:2,500,000

DATUM & COORDINATE SYSTEM: GCS NORTH AMERICAN 1983

PREPARED BY: JLA

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PANHANDLE WATER PLANNING AREA

POPULATION PROJECTIONS FOR COUNTIES IN THE PWPA

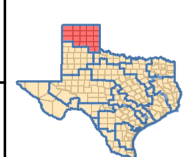

FIGURE 2-1

2.2 Historical Water Use and Projected Water Demand

Water use in the PWPA during 2010 totaled over 1.78 million acre-feet, or approximately 13 percent of the state total. Three counties in the PWPA, Dallam, Hartley and Sherman, reported water use of over 200,000 acre-feet with a combined water use of more than 0.95 million acre-feet in 2010. Water use by these three counties represents approximately 54 percent of the total water use in the PWPA during 2010. Projections for water demand indicate that total water usage in the PWPA will be approximately 2.1 million acre-feet in 2020, and then decline over time to 1.6 million acre-feet by 2070 (Figure 2-2) due to reductions in agricultural use. Most of the water use will continue to be used in the three large agricultural counties noted above. Figure 2-3 shows the distribution of total water demands by county. The largest water use in the PWPA is for agricultural purposes, followed by municipal water use.

Figure 2-4 shows the distribution of water demand by use type. Tables at the end of this chapter contain detailed information on projected water use by municipal, manufacturing, mining, irrigation, livestock, and steam-electric water users (see Attachment 2-1).

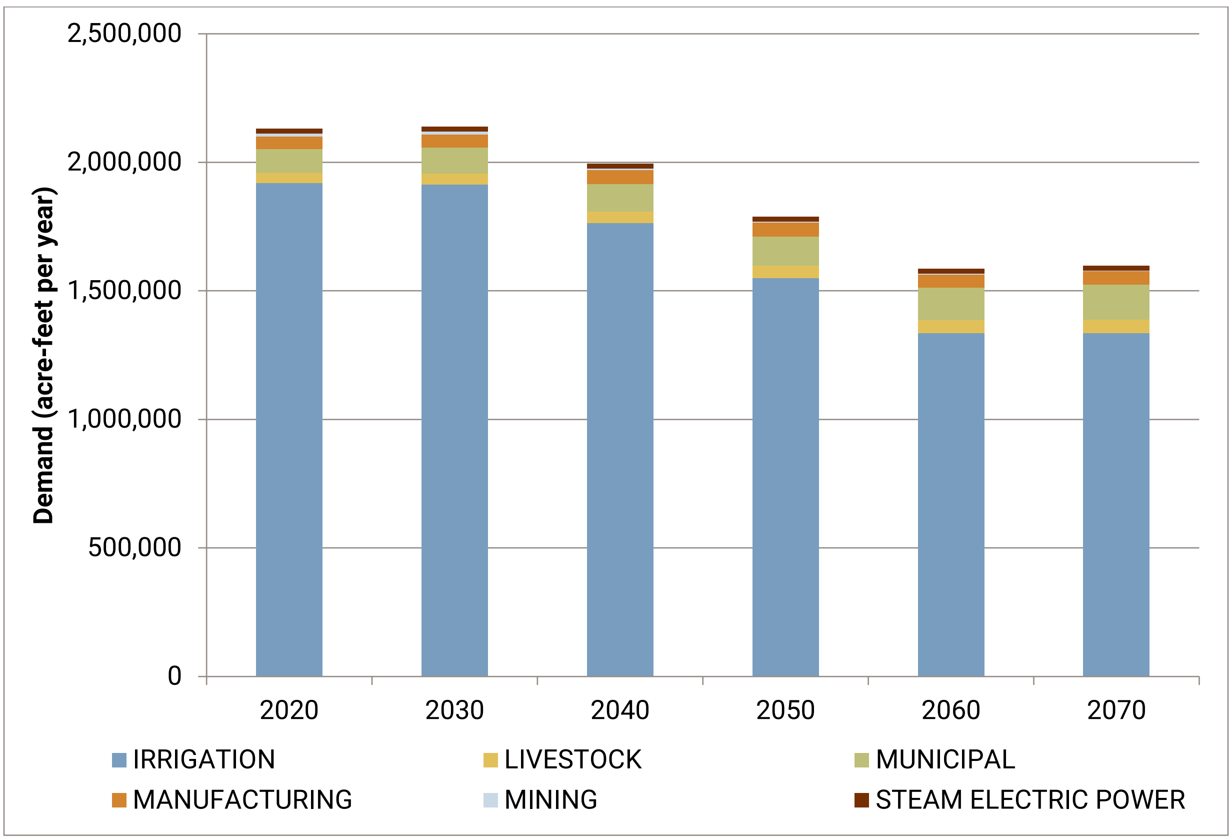

Figure 2-2: Total Water Use for PWPA from 2020 to 2070

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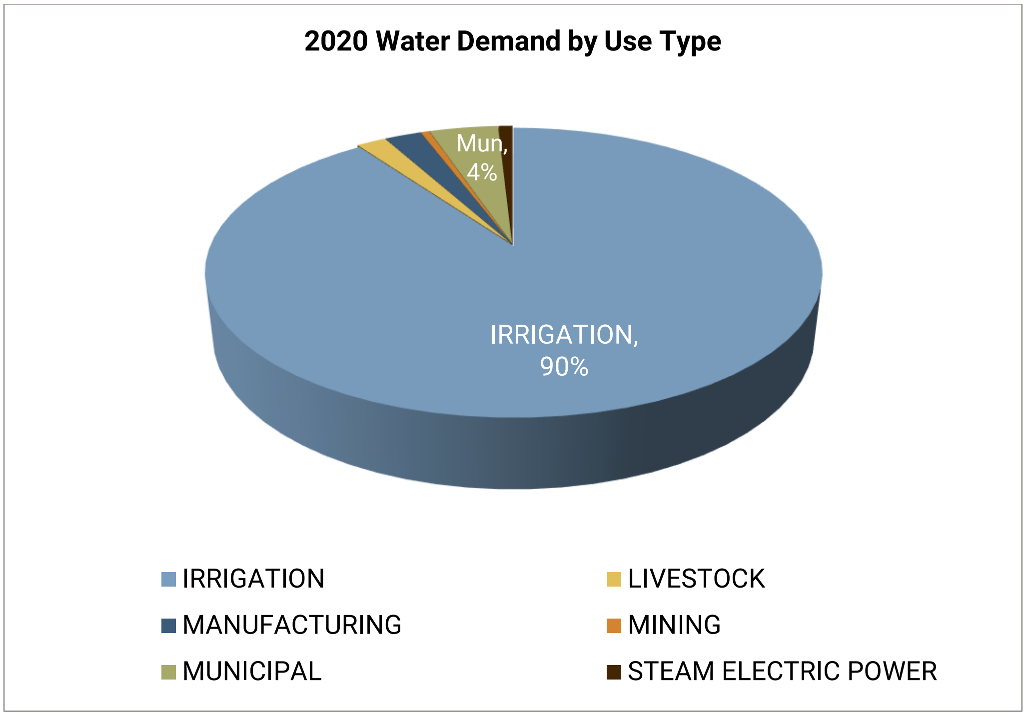
PANHANDLE WATER PLANNING AREA

TOTAL WATER DEMAND PROJECTIONS FOR COUNTIES IN THE PWPA

FIGURE 2-3



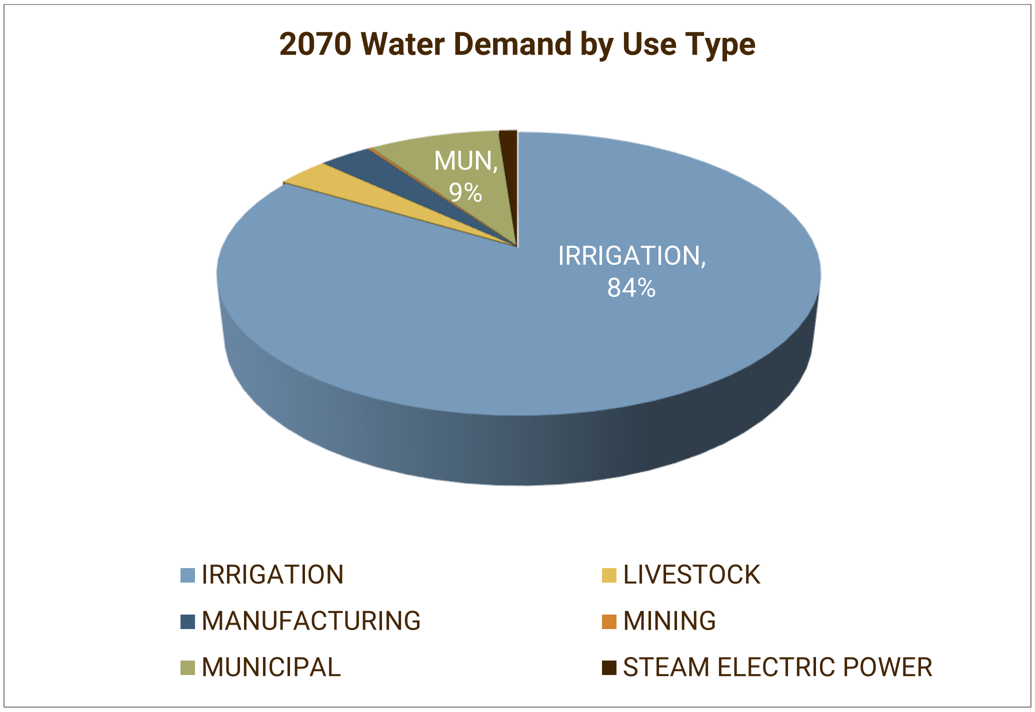


Figure 2-4: Water Demand by Use Type

2.3 Municipal Water Demands

The distribution of municipal water use in the PWPA corresponds closely to the distribution of population centers in the PWPA. Projections of municipal water demands are calculated based on estimated changes in populations for cities and rural areas and on estimates of daily per capita water use. For this plan, year 2011 was used as the basis for per capita water use. Through implementation of the Plumbing Code Fixture Act, per capita water use is estimated to decrease for each decade of the planning period under the assumption that water efficient appliances and plumbing fixtures will be installed and result in lower water use. These conservation savings by county are shown in Table 2-2. On a regional basis, the total amount of municipal water savings associated with water efficient appliances and plumbing fixtures is estimated to be approximately 13,000 acre-feet per year by 2070.

Table 2-2: Municipal Water Savings Incorporated into Demands

County	Water Savings (ac ft/ yr)					
	2020	2030	2040	2050	2060	2070
Armstrong	21	31	38	40	40	40
Carson	73	103	127	137	139	139
Childress	37	55	70	78	80	82
Collingsworth	75	111	143	159	167	170
Dallam	85	136	179	212	235	253
Donley	41	60	74	79	80	82
Gray	276	440	597	703	779	855
Hall	37	55	69	74	73	74
Hansford	65	100	126	142	149	157
Hartley	65	95	117	129	134	136
Hemphill	46	72	93	105	114	120
Hutchinson	279	401	481	494	502	502
Lipscomb	40	59	71	82	86	88
Moore	289	456	606	726	813	897
Ochiltree	124	188	243	283	310	333
Oldham	27	40	48	50	51	51
Potter	1,452	2,284	3,033	3,593	4,002	4,389
Randall	1,448	2,287	3,034	3,600	4,005	4,386
Roberts	11	16	21	22	22	22
Sherman	37	58	74	81	85	85
Wheeler	60	91	118	128	135	142
Total	**4,588**	**7,138**	**9,362**	**10,917**	**12,001**	**13,003**

Municipal water use in the PWPA accounts for approximately 4 percent of total water use in the PWPA in 2020. With the projected population growth, the municipal water demand for the PWPA is projected to increase from 92,446 acre-feet in 2020 to 134,386 acre-feet in 2070. As shown in Table 2-2, per person water usage is estimated to decline due to municipal conservation over the planning horizon. However, population growth causes an overall increase in municipal water demand through 2070. There is approximately a 45 percent increase in water demand. Potter and Randall Counties represent most of the municipal water use increase over the planning period. In these counties, the populations and municipal water demands in the County-Other municipal water user group are growing at nearly twice the rate of the population within the City of Amarillo. Since most of these users are not supplied by municipal water supply systems but domestic wells, water user needs in these areas are occurring now and need to be carefully considered. Figure 2-5 shows the increasing trend in projected municipal water demand for users in the PWPA through 2070. Figure 2-6 shows the municipal use by county.

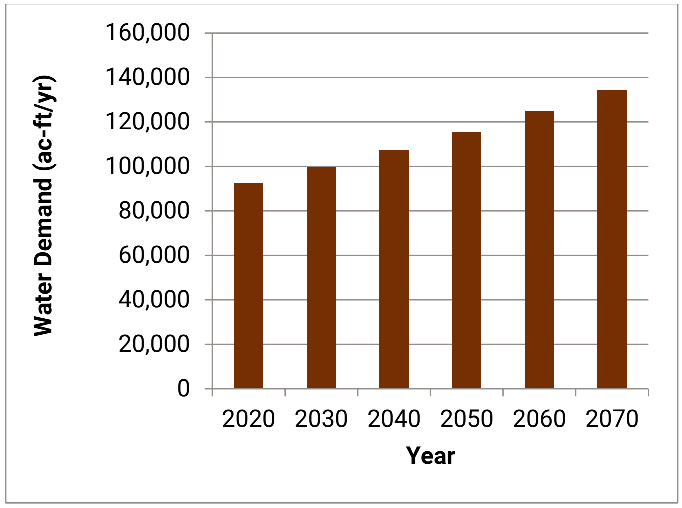


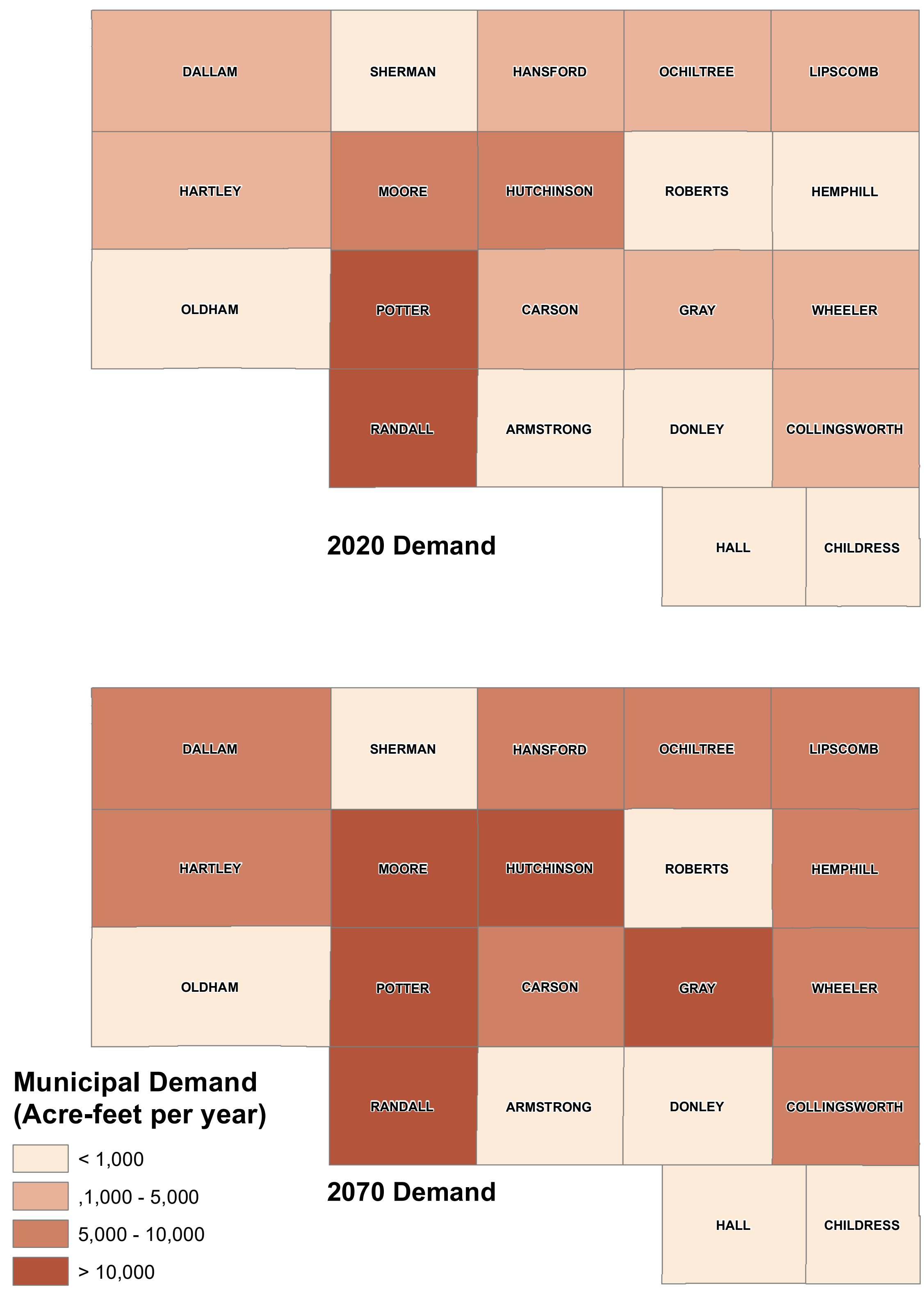
Figure 2-5: Projected Municipal Water Demand

The TWDB defines industrial water use as water required in the production process of manufactured products, including water used by employees for drinking and sanitation purposes. The industrial use category includes manufacturing, steam power generation, and mining. Each of these categories is discussed below. Figure 2-7 shows the total industrial water demand in the PWPA by county for years 2020 and 2070.

2.4 Industrial Water Demands

2.4.1 Manufacturing

Most of the manufacturing industries in the PWPA are associated with agribusiness or energy production (oil and gas). There are twelve counties in the region with manufacturing water use. The larger users are in Hutchinson, Moore, and Potter Counties. Manufacturing demands for 2020 and 2030 are estimated by the TWDB based on highest historical reported use from 2010 to 2014 and employment growth data over the last ten years.



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PROJECTED MUNICIPAL PWPA WATER DEMAND BY COUNTY

Location Map

FIGURE 2-6

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PANHANDLE WATER PLANNING AREA

INDUSTRIAL WATER DEMAND PROJECTIONS FOR COUNTIES IN THE PWPA

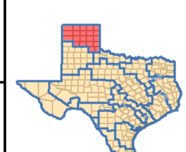


FIGURE 2-7

Figure 2-8 shows the total projected water demand of manufacturing users in the PWPA through 2070. Total manufacturing water demand for the PWPA is projected to increase from 49,370 acre-feet in 2020 to 52,834 acre-feet by 2030. After 2030, the manufacturing demands are held constant through 2070. Manufacturing water use represents 2 to 3 percent of the total water use in the PWPA over the planning period.

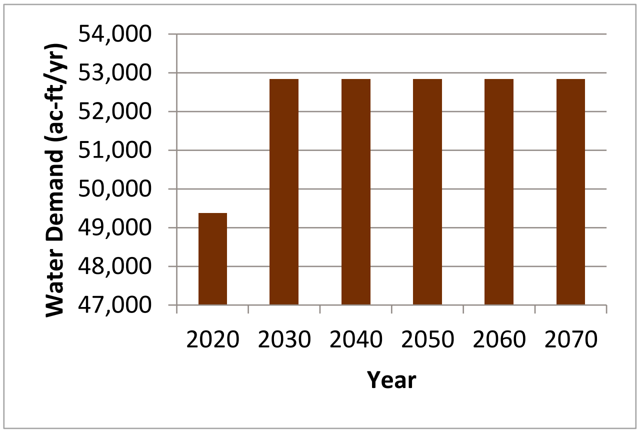


Figure 2-8: Projected Manufacturing Water Use

2.4.2 Steam Electric Power

Xcel Energy has a power generation plant in Potter County that accounts for all the current water use by power generators in the PWPA. There are no new facilities currently being considered for development. As a result, only demands for this facility are included in the PWPA power generation projections. These projections are shown to hold constant at 18,554 acre-feet per year over the planning horizon.

2.4.3 Mining

Mining activities in the PWPA consist primarily of oil and gas extraction and removal of industrial minerals such as sand, gravel, and gypsum. Technological advancements in natural gas development have increased mining activities in the Woodford Shale Formation in the Panhandle Region. This has resulted in increased mining water use in several northeastern counties in the region. These activities are expected to continue over the next 10 to 20 years, and then decrease over time. Water use for other oil and gas activities has seen recent fluctuation with the volatility of the energy market. In response to these changes, the TWDB sponsored a study of long-term mining use associated with the oil and gas industry across the State that were used as the basis for mining demands in the 2016 regional water plans[(2),(3)]. These demands were carried forward for the 2021 regional water plans. No changes were made to the projected demands.

Mining water use is projected for 14 counties in the PWPA, totaling 11,330 acre-feet in 2020 and reducing to 2,968 acre-feet by 2070. Mining water use represents a small fraction of the total water use in the region (less than 1 percent). Figure 2-9 shows the projected water demands for mining in the PWPA.

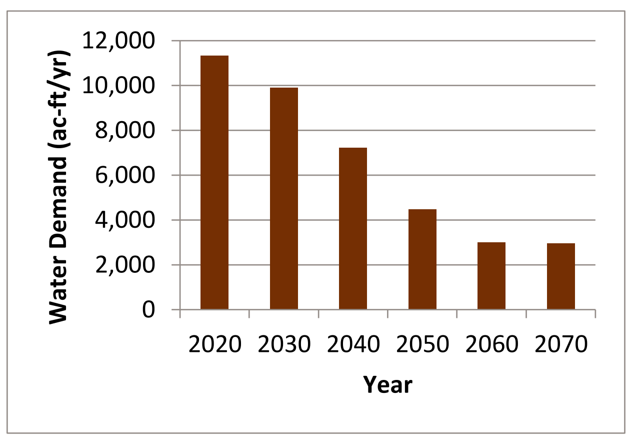


Figure 2-9: Projected Mining Water Use

2.5 Agricultural Water Demands

Agricultural water demands include water used for irrigation purposes and water for livestock production. It does not include water for processing agricultural or livestock products. This demand is included under manufacturing. Agricultural water use accounts for approximately 92 percent of the total water demand in the PWPA.

Figure 2-12 (following page) shows the agricultural water use by county in the region. The largest agricultural water users are in Dallam, Hartley, Moore and Sherman Counties.

2.5.1 Irrigation Water Demands

Irrigation water use accounts for most of the water used in the PWPA. The baseline irrigation estimates were developed using a ten-year running average of historical water use as reported by the TWDB. This provides a realistic demand that incorporates dry to wet years. Since nearly all the irrigation water is groundwater, it was assumed that the irrigation demand would remain at similar levels if there was sufficient groundwater. As groundwater availabilities decline, the irrigation demand would also decline. Therefore, the projections for 2020 through 2070 reflect the projected trends in the groundwater availabilities. For most counties there are no decreases in the projected irrigation demands. Irrigation demands decline in five counties: Collingsworth, Dallam, Hartley, Moore, and Sherman. The demand was held constant between 2060 and 2070 because there were no groundwater availabilities determined for 2070 in these counties. Based on this analysis, the irrigation water demand in the PWPA is expected to be 1,919,070 acre-feet in 2020, declining to 1,335,673 acre-feet by 2070. The agricultural demand report is provided in Appendix A.

Figure 2-10 shows the total projected irrigation water demand in the PWPA.

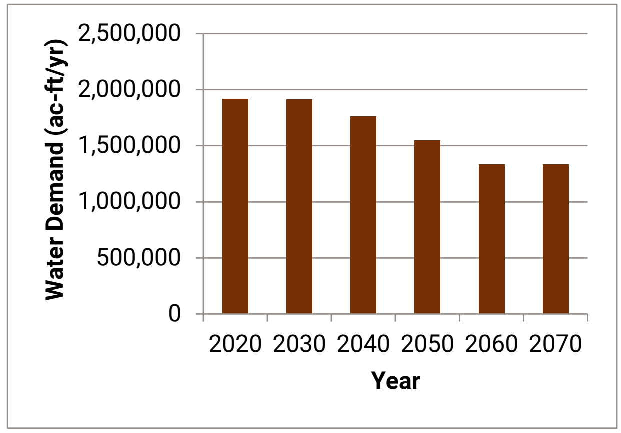


Figure 2-10: Projected Water Use for Irrigation

2.5.2 Livestock Water Demands

Livestock water use is part of the total agricultural demand in the PWPA. While comprising only about 2 percent of the region's current water use, livestock production is an important component of the overall economy of the PWPA. Changes to types of livestock production impact not only this demand sector but also associated agribusinesses. Due to recent trends in future livestock production, the demands for livestock water use were reviewed and updated by Texas A&M AgriLife. The report is included in Appendix A. Figure 2-11shows the projected livestock demand.

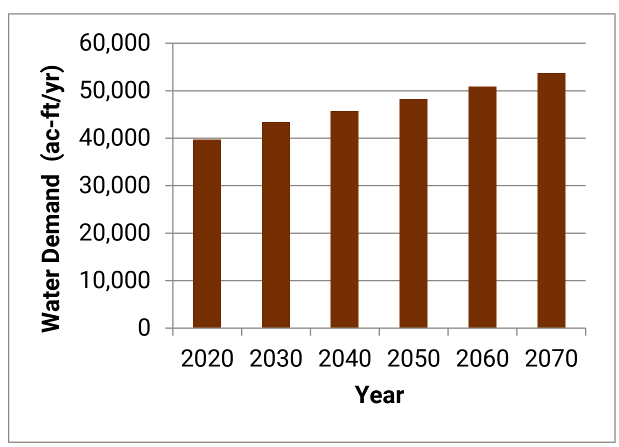
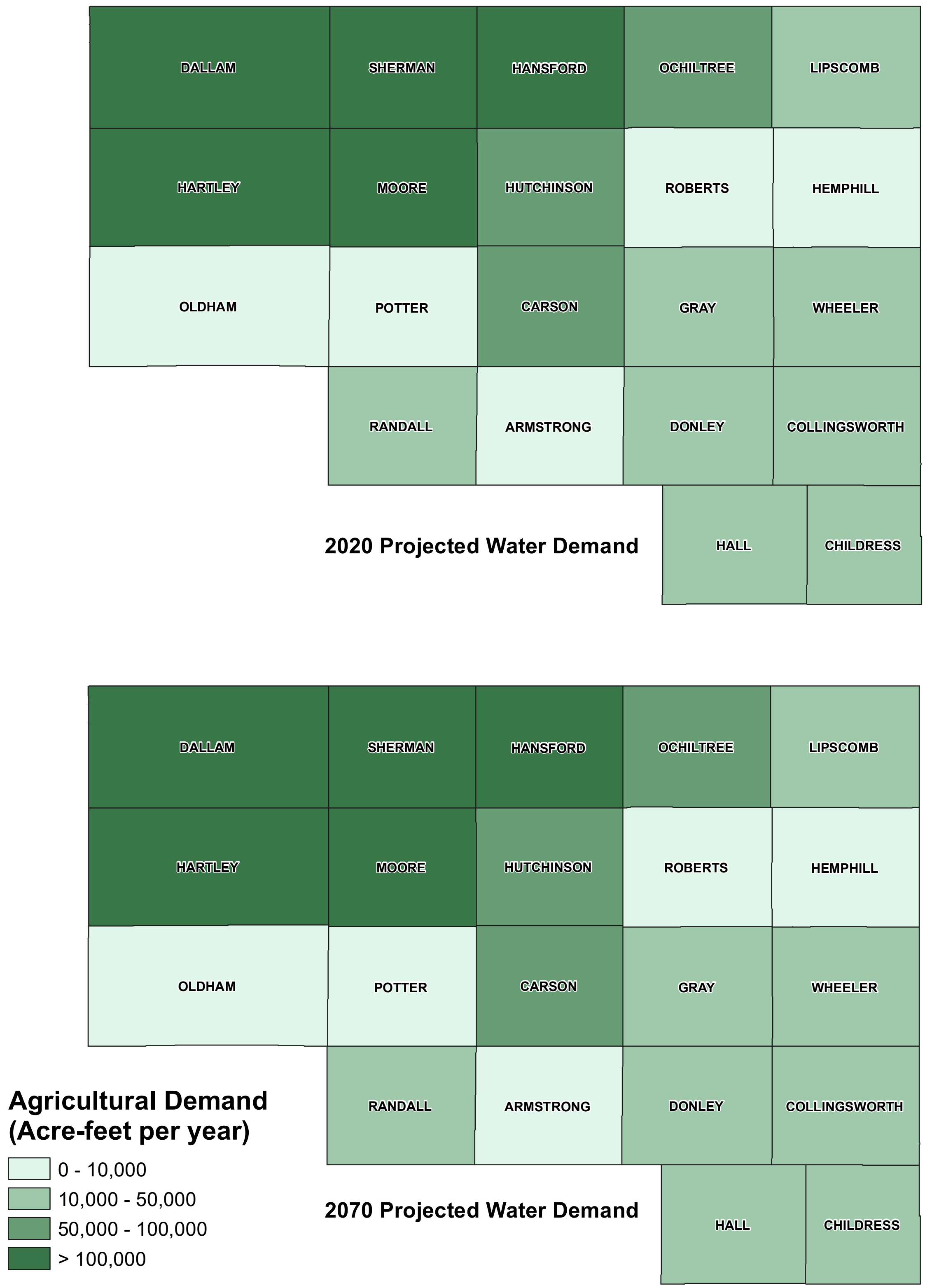


Figure 2-11: Projected Livestock Water Demands



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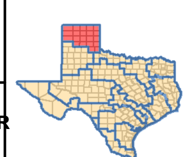
N W E S

PANHANDLE WATER PLANNING AREA

AGRICULTURAL WATER DEMAND PROJECTIONS FOR COUNTIES IN THE PWPA



FIGURE

2-12

New projections developed by Texas A&M AgriLife included the most recent inventories of various livestock species for each county, estimates of annual industry growth rates, and updated regional species-level water use estimates. Future trends were developed with input from the PWPG Agricultural Committee.

Inventories of current livestock production, along with estimates of water use by species, result in an estimated livestock use of 39,759 acre-feet in 2020 and increasing to 53,700 acre-feet per year by 2070. The largest livestock water use group is the fed cattle industry with an annual usage of about 21,900 acre-feet per year by 2070. The forecasted expansion of the dairy industry results in a water usage estimate by 2070 of nearly 15,000 acre-feet per year. These two user groups account for 68 percent of projected livestock water use in 2070. Overall, water use in the PWPA livestock sector is predicted to increase 35 percent from 2020 to 2070.

Figure 2-13 illustrates the water demand by major livestock category for the planning period. Detailed livestock population and water demand data is contained in the Texas A&M AgriLife report in Appendix A.

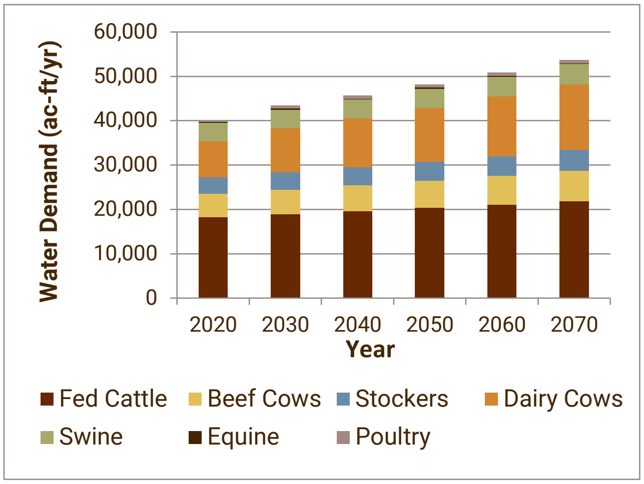


Figure 2-13: Projected Livestock Water Demands by Animal Category

2.5.3 Uncertainty in Agricultural Demand Projections

The methodology used to develop the agricultural water demands is based on estimates of current production and expected trends in the agricultural sectors. These trends are contingent upon many factors, including changing market conditions, government subsidies, and availability of resources. Commodity and fuel prices also play important roles in agricultural water demands. These economic factors are often the driving force in the types of crops planted, irrigated acreage and ultimately the amount of water needed. These trends can result in both location and quantity changes to demands on the region's water sources and will need to be monitored and updated for subsequent planning efforts.

Irrigation Water Demand Uncertainty

Irrigation demands in five counties are projected to decline over time due to declining groundwater availability. How these declining water levels affect irrigation demand will depend upon many factors, including economic considerations of irrigation improvements and profitability of produced crops.

2.6 Major Water Providers

PWPA Major Water Providers

- City of Amarillo
- Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA)
- Canadian River Municipal Water Authority (CRMWA)
- City of Borger
- City of Cactus

The category of Major Water Provider (MWP) was created to identify water providers of significance to the region. This could include entities that provide large quantities of water, either retail or wholesale, or provide water to a large geographic area. The planning groups could also consider other factors that warranted designation. The PWPG has designated five MWPs in the region. These include the Canadian River Municipal Water Authority (CRMWA), cities of Amarillo, Borger, and Cactus, and Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA). Descriptions of each of these water providers are provided in Section 1.4 of this plan.

CRMWA and Greenbelt MIWA provide water to customers in the PWPA and adjoining regions. CRMWA provides water to customer cities in the Llano Estacado Water Planning Region (Region O) and Greenbelt MIWA provides water to customers in Region B. The following discussions represent the projected water demand on each of the PWPA's MWPs. These demands include current contractual obligations and expected future demands of existing customers.

2.6.1 City of Amarillo

In 2020, the City of Amarillo is projected to provide 75,136 acre-feet of water to their retail service area and wholesale customers. Their customers include the City of Canyon, Texas Parks and Wildlife Department (Palo Duro State Park), and industrial use by ASARCO, Tyson, Owens Corning, and Xcel Energy. All supplies from Amarillo to Xcel Energy in 2020 is assumed to be treated wastewater. By 2070, Amarillo is expected to provide approximately 101,680 acre-feet per year to their retail service area and existing wholesale customers. Most of the increase in projected demand on Amarillo is associated with municipal growth within the city's service area and increased local manufacturing needs. As the surrounding County-Other in Potter and Randall Counties continues to grow, additional demands may be placed on Amarillo.

Table 2-3: Projected Water Demands for the City of Amarillo

Customers	Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
City of Amarillo	49,454	53,992	58,861	64,093	70,074	76,402
Potter County Manufacturing	5,527	6,118	6,118	6,118	6,118	6,118
City of Canyon	1,000	1,000	1,000	1,000	0	0
Randall County Manufacturing	576	576	576	576	576	576
Palo Duro State Park	25	26	27	28	29	30
Xcel Energy (Steam Electric Power)	18,554	18,554	18,554	18,554	18,554	18,554
Total Demand	**75,136**	**80,266**	**85,136**	**90,369**	**95,351**	**101,680**

2.6.2 Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA)

Greenbelt MIWA provides water to four cities in the PWPA, three cities in Region B, and to the Red River Authority (RRA) for subsequent sales in both regions. Approximately 70 percent of the current demand on Greenbelt MIWA is from the cities of Childress, Clarendon, Hedley, and Memphis, and to the RRA for sales in the PWPA. The remaining sales are to the cities of Chillicothe, Crowell, and Quanah, and to the RRA in Region B. Demand projections for Greenbelt MIWA were developed based on each recipient's projected water demand and the percentage of the historical water demands that the Greenbelt MIWA had supplied. The demand on Greenbelt MIWA is expected to remain about the same through the planning period.

Table 2-4: Projected Water Demands for Greenbelt MIWA

Customers	Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
PWPA						
City of Childress	1,624	1,657	1,685	1,722	1,767	1,814
City of Clarendon	371	362	354	350	349	349
City of Hedley	56	56	56	56	56	56
City of Memphis	37	37	37	37	37	37
Red River Authority - Childress County	232	236	239	245	252	258
Red River Authority - Collingsworth County	16	16	16	16	16	16
Red River Authority - Donley County	30	30	30	30	30	30
Red River Authority - Hall County	100	100	100	100	100	100
Region B						
City of Chillicothe	40	40	40	40	40	40
City of Crowell	138	133	131	131	131	130
City of Quanah	396	391	387	394	397	400
Hardeman County Manufacturing	190	190	190	190	190	190
Red River Authority - Foard County	262	262	262	262	262	262
Red River Authority - Hardeman County	140	140	140	140	140	140
Total Demand	**3,631**	**3,649**	**3,666**	**3,712**	**3,766**	**3,821**

2.6.3 Canadian River Municipal Water Authority (CRMWA)

CRMWA is the largest wholesale water provider in the PWPA. In 2020, CRMWA is projected to supply over 101,000 acre-feet of water to customers in the PWPA and Llano Estacado Region. CRMWA delivers water to Amarillo, Borger, and Pampa in the PWPA and to eight cities in the Llano Estacado Region, including Lubbock. Projected water demands on CRMWA through the planning period are anticipated to increase to approximately 121,600 acre-feet per year.

Table 2-5: Projected Water Demands for CRMWA

Customers	Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
PWPA						
City of Pampa	2,361	2,833	3,196	3,989	4,628	4,680
City of Borger	7,054	7,091	7,072	7,068	7,064	7,063
City of Amarillo	46,000	50,000	50,000	50,000	50,000	50,000
Llano Estacado Region						
City of Lamesa	1,750	1,950	2,300	2,750	2,750	2,750
City of O'Donnell	124	125	123	123	128	132
City of Plainview	2,500	3,000	3,250	3,500	3,500	3,500
City of Levelland	2,301	2,400	2,500	2,588	2,671	2,743
City of Lubbock	35,600	39,000	43,500	47,000	47,000	47,000
City of Slaton	1,405	1,430	1,455	1,479	1,477	1,477
City of Tahoka	476	486	477	470	492	503
City of Brownfield	1,500	1,550	1,650	1,750	1,750	1,750
Total Demand	**101,071**	**109,865**	**115,523**	**120,717**	**121,460**	**121,598**

2.6.4 City of Borger

The City of Borger provides wholesale water to industrial customers in Hutchinson County and retail services to its city customers and Graceland East (Hutchinson County-Other). Currently, the industrial demands on Borger total about 8,000 acre-feet per year, which accounts for about 25 percent of the manufacturing demand in Hutchinson County. It is expected that Borger will continue to provide water for 25 percent of the projected manufacturing demands.

Table 2-6: Projected Water Demands for the City of Borger

Customers	Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Borger	3,163	3,201	3,182	3,177	3,172	3,172
Hutchinson County Manufacturing	7,903	8,291	8,225	8,171	8,127	8,082
Hutchinson County-Other	16	16	16	16	16	16
Total Demand	**11,082**	**11,508**	**11,423**	**11,364**	**11,315**	**11,270**

2.6.5 City of Cactus

The City of Cactus provides wholesale water to manufacturers in Moore County and retail water to its municipal customers, including the Etter Community. The City has a contract for 3.2 MGD with a meat packing plant in Moore County, which accounts for nearly all its manufacturing demand.

Table 2-7: Projected Water Demands for the City of Cactus

Customers	Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
City of Cactus	985	1,107	1,242	1,382	1,532	1,685
Moore County Manufacturing	3,247	3,370	3,370	3,370	3,370	3,370
Total Demand	**4,232**	**4,477**	**4,612**	**4,752**	**4,902**	**5,055**

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List of References

(1) Freese and Nichols, Inc., *2016 Panhandle Water Plan*, prepared for the Panhandle Water Planning Group, December 2015.

(2) Bureau of Economic Geology, *Current and Projected Water Use in the Texas Mining and Oil and Gas Industry*, prepared for the Texas Water Development Board, June 2011.

(3) Bureau of Economic Geology, *Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report*, prepared from the Texas Oil and Gas Association, September 2012.

ATTACHMENT 2-1

POPULATION AND WATER DEMAND PROJECTIONS

Region A Water User Group (WUG) Population

	POPULATION					
	2020	2030	2040	2050	2060	2070
CLAUDE MUNICIPAL WATER SYSTEM	1,209	1,209	1,209	1,209	1,209	1,209
COUNTY-OTHER	702	702	702	702	702	702
RED BASIN TOTAL	**1,911**	**1,911**	**1,911**	**1,911**	**1,911**	**1,911**
ARMSTRONG COUNTY TOTAL	**1,911**	**1,911**	**1,911**	**1,911**	**1,911**	**1,911**
WHITE DEER	520	539	549	549	549	549
COUNTY-OTHER	1,198	1,215	1,238	1,238	1,238	1,238
CANADIAN BASIN TOTAL	**1,718**	**1,754**	**1,787**	**1,787**	**1,787**	**1,787**
GROOM MUNICIPAL WATER SYSTEM	568	568	568	568	568	568
PANHANDLE MUNICIPAL WATER SYSTEM	2,509	2,601	2,650	2,650	2,650	2,650
WHITE DEER	681	707	720	720	720	720
COUNTY-OTHER	878	890	907	907	907	907
RED BASIN TOTAL	**4,636**	**4,766**	**4,845**	**4,845**	**4,845**	**4,845**
CARSON COUNTY TOTAL	**6,354**	**6,520**	**6,632**	**6,632**	**6,632**	**6,632**
CHILDRESS	6,303	6,543	6,743	6,938	7,132	7,321
RED RIVER AUTHORITY OF TEXAS	942	978	1,007	1,036	1,066	1,094
COUNTY-OTHER	24	25	26	27	27	28
RED BASIN TOTAL	**7,269**	**7,546**	**7,776**	**8,001**	**8,225**	**8,443**
CHILDRESS COUNTY TOTAL	**7,269**	**7,546**	**7,776**	**8,001**	**8,225**	**8,443**
RED RIVER AUTHORITY OF TEXAS	576	642	701	759	815	860
WELLINGTON MUNICIPAL WATER SYSTEM	2,318	2,441	2,522	2,616	2,689	2,753
COUNTY-OTHER	342	325	299	278	251	231
RED BASIN TOTAL	**3,236**	**3,408**	**3,522**	**3,653**	**3,755**	**3,844**
COLLINGSWORTH COUNTY TOTAL	**3,236**	**3,408**	**3,522**	**3,653**	**3,755**	**3,844**
DALHART	5,986	6,741	7,534	8,317	9,069	9,794
TEXLINE	566	615	666	714	759	801
COUNTY-OTHER	1,166	1,312	1,467	1,619	1,766	1,908
CANADIAN BASIN TOTAL	**7,718**	**8,668**	**9,667**	**10,650**	**11,594**	**12,503**
DALLAM COUNTY TOTAL	**7,718**	**8,668**	**9,667**	**10,650**	**11,594**	**12,503**
CLARENDON	2,053	2,053	2,053	2,053	2,053	2,053
RED RIVER AUTHORITY OF TEXAS	950	1,059	1,156	1,252	1,345	1,432
COUNTY-OTHER	785	676	579	483	390	303
RED BASIN TOTAL	**3,788**	**3,788**	**3,788**	**3,788**	**3,788**	**3,788**
DONLEY COUNTY TOTAL	**3,788**	**3,788**	**3,788**	**3,788**	**3,788**	**3,788**
PAMPA MUNICIPAL WATER SYSTEM	19,384	21,451	23,928	27,115	29,654	32,305
COUNTY-OTHER	2,781	3,079	3,433	3,890	4,256	4,635
CANADIAN BASIN TOTAL	**22,165**	**24,530**	**27,361**	**31,005**	**33,910**	**36,940**
MCLEAN MUNICIPAL WATER SUPPLY	868	960	1,071	1,214	1,327	1,447
COUNTY-OTHER	1,406	1,556	1,736	1,967	2,151	2,343
RED BASIN TOTAL	**2,274**	**2,516**	**2,807**	**3,181**	**3,478**	**3,790**
GRAY COUNTY TOTAL	**24,439**	**27,046**	**30,168**	**34,186**	**37,388**	**40,730**

Region A Water User Group (WUG) Population

	POPULATION					
	2020	2030	2040	2050	2060	2070
MEMPHIS	2,338	2,402	2,402	2,402	2,402	2,402
RED RIVER AUTHORITY OF TEXAS	364	406	442	479	442	470
TURKEY MUNICIPAL WATER SYSTEM	408	418	418	418	418	418
COUNTY-OTHER	283	261	225	188	225	197
RED BASIN TOTAL	**3,393**	**3,487**	**3,487**	**3,487**	**3,487**	**3,487**
HALL COUNTY TOTAL	**3,393**	**3,487**	**3,487**	**3,487**	**3,487**	**3,487**
GRUVER	1,480	1,640	1,779	1,896	2,014	2,122
SPEARMAN MUNICIPAL WATER SYSTEM	3,501	3,644	3,755	3,869	3,987	4,109
COUNTY-OTHER	978	1,084	1,176	1,252	1,329	1,403
CANADIAN BASIN TOTAL	**5,959**	**6,368**	**6,710**	**7,017**	**7,330**	**7,634**
HANSFORD COUNTY TOTAL	**5,959**	**6,368**	**6,710**	**7,017**	**7,330**	**7,634**
DALHART	2,816	2,923	2,980	3,021	3,058	3,087
HARTLEY WSC	652	697	722	739	754	767
COUNTY-OTHER	2,813	3,011	3,115	3,190	3,257	3,310
CANADIAN BASIN TOTAL	**6,281**	**6,631**	**6,817**	**6,950**	**7,069**	**7,164**
HARTLEY COUNTY TOTAL	**6,281**	**6,631**	**6,817**	**6,950**	**7,069**	**7,164**
CANADIAN	3,160	3,542	3,867	4,201	4,500	4,773
COUNTY-OTHER	729	742	751	762	771	780
CANADIAN BASIN TOTAL	**3,889**	**4,284**	**4,618**	**4,963**	**5,271**	**5,553**
COUNTY-OTHER	320	325	330	334	338	342
RED BASIN TOTAL	**320**	**325**	**330**	**334**	**338**	**342**
HEMPHILL COUNTY TOTAL	**4,209**	**4,609**	**4,948**	**5,297**	**5,609**	**5,895**
BORGER	13,514	13,998	14,122	14,122	14,122	14,122
FRITCH	2,968	3,075	3,102	3,102	3,102	3,102
STINNETT	1,987	2,058	2,077	2,077	2,077	2,077
TCW SUPPLY	2,027	2,098	2,118	2,118	2,118	2,118
COUNTY-OTHER	2,461	2,550	2,571	2,571	2,571	2,571
CANADIAN BASIN TOTAL	**22,957**	**23,779**	**23,990**	**23,990**	**23,990**	**23,990**
HUTCHINSON COUNTY TOTAL	**22,957**	**23,779**	**23,990**	**23,990**	**23,990**	**23,990**
BOOKER	1,740	1,948	2,071	2,232	2,344	2,436
DARROUZETT	428	459	477	500	517	531
FOLLETT	425	456	474	497	514	527
HIGGINS MUNICIPAL WATER SYSTEM	433	464	482	506	523	537
COUNTY-OTHER	573	531	507	476	452	434
CANADIAN BASIN TOTAL	**3,599**	**3,858**	**4,011**	**4,211**	**4,350**	**4,465**
LIPSCOMB COUNTY TOTAL	**3,599**	**3,858**	**4,011**	**4,211**	**4,350**	**4,465**
CACTUS MUNICIPAL WATER SYSTEM	4,232	4,824	5,455	6,095	6,763	7,444
DUMAS	17,119	19,513	22,063	24,650	27,349	30,115
FRITCH	14	15	16	19	20	23
SUNRAY	1,983	2,042	2,103	2,166	2,230	2,296

Region A Water User Group (WUG) Population

	POPULATION					
	2020	2030	2040	2050	2060	2070
COUNTY-OTHER	2,165	2,470	2,792	3,120	3,462	3,812
CANADIAN BASIN TOTAL	**25,513**	**28,864**	**32,429**	**36,050**	**39,824**	**43,690**
MOORE COUNTY TOTAL	**25,513**	**28,864**	**32,429**	**36,050**	**39,824**	**43,690**
BOOKER	22	33	45	58	74	92
PERRYTON MUNICIPAL WATER SYSTEM	9,263	9,954	10,697	11,496	12,353	13,276
COUNTY-OTHER	2,020	2,171	2,333	2,507	2,695	2,896
CANADIAN BASIN TOTAL	**11,305**	**12,158**	**13,075**	**14,061**	**15,122**	**16,264**
OCHILTREE COUNTY TOTAL	**11,305**	**12,158**	**13,075**	**14,061**	**15,122**	**16,264**
VEGA	1,036	1,036	1,036	1,036	1,036	1,036
COUNTY-OTHER	947	1,063	1,063	1,063	1,063	1,063
CANADIAN BASIN TOTAL	**1,983**	**2,099**	**2,099**	**2,099**	**2,099**	**2,099**
COUNTY-OTHER	247	277	277	277	277	277
RED BASIN TOTAL	**247**	**277**	**277**	**277**	**277**	**277**
OLDHAM COUNTY TOTAL	**2,230**	**2,376**	**2,376**	**2,376**	**2,376**	**2,376**
AMARILLO	72,959	81,086	89,685	98,247	107,584	117,417
COUNTY-OTHER	8,490	9,435	10,436	11,432	12,518	13,662
CANADIAN BASIN TOTAL	**81,449**	**90,521**	**100,121**	**109,679**	**120,102**	**131,079**
AMARILLO	48,035	53,386	59,047	64,685	70,831	77,305
COUNTY-OTHER	4,547	5,053	5,589	6,122	6,705	7,317
RED BASIN TOTAL	**52,582**	**58,439**	**64,636**	**70,807**	**77,536**	**84,622**
POTTER COUNTY TOTAL	**134,031**	**148,960**	**164,757**	**180,486**	**197,638**	**215,701**
AMARILLO	98,242	109,855	121,479	133,386	146,055	159,215
CANYON	14,802	16,552	18,304	20,097	22,006	23,989
HAPPY	68	76	84	93	101	111
LAKE TANGLEWOOD	1,129	1,129	1,129	1,129	1,129	1,129
COUNTY-OTHER	20,028	22,432	24,839	27,305	29,928	32,651
RED BASIN TOTAL	**134,269**	**150,044**	**165,835**	**182,010**	**199,219**	**217,095**
RANDALL COUNTY TOTAL	**134,269**	**150,044**	**165,835**	**182,010**	**199,219**	**217,095**
MIAMI	617	627	628	628	628	628
COUNTY-OTHER	383	417	416	416	416	416
CANADIAN BASIN TOTAL	**1,000**	**1,044**	**1,044**	**1,044**	**1,044**	**1,044**
COUNTY-OTHER	3	3	3	3	3	3
RED BASIN TOTAL	**3**	**3**	**3**	**3**	**3**	**3**
ROBERTS COUNTY TOTAL	**1,003**	**1,047**	**1,047**	**1,047**	**1,047**	**1,047**
STRATFORD	2,317	2,511	2,617	2,710	2,778	2,828
TEXHOMA	347	376	392	406	416	424
COUNTY-OTHER	630	684	711	737	755	768
CANADIAN BASIN TOTAL	**3,294**	**3,571**	**3,720**	**3,853**	**3,949**	**4,020**
SHERMAN COUNTY TOTAL	**3,294**	**3,571**	**3,720**	**3,853**	**3,949**	**4,020**

Region A Water User Group (WUG) Population

	POPULATION					
	2020	2030	2040	2050	2060	2070
SHAMROCK MUNICIPAL WATER SYSTEM	1,973	2,051	2,126	2,203	2,288	2,378
WHEELER	1,599	1,662	1,722	1,784	1,853	1,926
COUNTY-OTHER	2,015	2,096	2,171	2,252	2,337	2,429
RED BASIN TOTAL	**5,587**	**5,809**	**6,019**	**6,239**	**6,478**	**6,733**
WHEELER COUNTY TOTAL	**5,587**	**5,809**	**6,019**	**6,239**	**6,478**	**6,733**
REGION A TOTAL POPULATION	**418,345**	**460,448**	**502,685**	**545,895**	**590,781**	**637,412**

Region A Water User Group (WUG) Demands

	WUG DEMAND (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
CLAUDE MUNICIPAL WATER SYSTEM	360	354	349	347	347	347
COUNTY-OTHER	88	84	82	82	82	82
LIVESTOCK	332	449	467	485	504	524
IRRIGATION	6,244	6,244	6,244	6,244	6,244	6,244
RED BASIN TOTAL	**7,024**	**7,131**	**7,142**	**7,158**	**7,177**	**7,197**
ARMSTRONG COUNTY TOTAL	**7,024**	**7,131**	**7,142**	**7,158**	**7,177**	**7,197**
WHITE DEER	113	114	114	114	114	114
COUNTY-OTHER	157	155	155	153	152	152
MANUFACTURING	17	18	18	18	18	18
MINING	14	14	14	14	14	14
LIVESTOCK	236	322	334	346	358	372
IRRIGATION	22,518	22,518	22,518	22,518	22,518	22,518
CANADIAN BASIN TOTAL	**23,055**	**23,141**	**23,153**	**23,163**	**23,174**	**23,188**
GROOM MUNICIPAL WATER SYSTEM	177	174	172	171	171	171
PANHANDLE MUNICIPAL WATER SYSTEM	576	585	586	581	580	580
WHITE DEER	147	150	150	149	149	149
COUNTY-OTHER	115	113	113	112	112	112
MANUFACTURING	1,038	1,118	1,118	1,118	1,118	1,118
LIVESTOCK	79	108	112	116	120	124
IRRIGATION	64,771	64,771	64,771	64,771	64,771	64,771
RED BASIN TOTAL	**66,903**	**67,019**	**67,022**	**67,018**	**67,021**	**67,025**
CARSON COUNTY TOTAL	**89,958**	**90,160**	**90,175**	**90,181**	**90,195**	**90,213**
CHILDRESS	1,624	1,657	1,685	1,722	1,767	1,814
RED RIVER AUTHORITY OF TEXAS	232	236	239	245	252	258
COUNTY-OTHER	5	5	5	5	5	6
LIVESTOCK	342	460	478	497	517	538
IRRIGATION	14,142	14,142	14,142	14,142	14,142	14,142
RED BASIN TOTAL	**16,345**	**16,500**	**16,549**	**16,611**	**16,683**	**16,758**
CHILDRESS COUNTY TOTAL	**16,345**	**16,500**	**16,549**	**16,611**	**16,683**	**16,758**
RED RIVER AUTHORITY OF TEXAS	142	155	167	179	192	203
WELLINGTON MUNICIPAL WATER SYSTEM	524	540	548	566	581	595
COUNTY-OTHER	71	66	60	55	50	46
LIVESTOCK	459	583	607	633	660	688
IRRIGATION	47,471	42,542	39,713	38,215	33,451	33,451
RED BASIN TOTAL	**48,667**	**43,886**	**41,095**	**39,648**	**34,934**	**34,983**
COLLINGSWORTH COUNTY TOTAL	**48,667**	**43,886**	**41,095**	**39,648**	**34,934**	**34,983**
DALHART	1,814	2,014	2,228	2,447	2,665	2,877
TEXLINE	219	235	252	269	286	302
COUNTY-OTHER	140	150	165	181	197	213
MANUFACTURING	6	6	6	6	6	6
LIVESTOCK	4,521	4,860	5,115	5,390	5,686	6,006
IRRIGATION	343,830	343,830	286,928	228,243	174,217	174,217
CANADIAN BASIN TOTAL	**350,530**	**351,095**	**294,694**	**236,536**	**183,057**	**183,621**
DALLAM COUNTY TOTAL	**350,530**	**351,095**	**294,694**	**236,536**	**183,057**	**183,621**
CLARENDON	371	362	354	350	349	349
RED RIVER AUTHORITY OF TEXAS	234	255	275	296	318	338

Region A Water User Group (WUG) Demands

	WUG DEMAND (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
COUNTY-OTHER	113	94	78	65	52	40
LIVESTOCK	971	994	1,019	1,046	1,073	1,102
IRRIGATION	30,910	30,910	30,910	30,910	30,910	30,910
RED BASIN TOTAL	**32,599**	**32,615**	**32,636**	**32,667**	**32,702**	**32,739**
DONLEY COUNTY TOTAL	**32,599**	**32,615**	**32,636**	**32,667**	**32,702**	**32,739**
PAMPA MUNICIPAL WATER SYSTEM	3,685	3,964	4,331	4,892	5,341	5,815
COUNTY-OTHER	472	512	563	634	692	753
MANUFACTURING	459	502	502	502	502	502
MINING	7	7	6	6	5	4
LIVESTOCK	189	214	224	235	247	259
IRRIGATION	8,395	8,395	8,395	8,395	8,395	8,395
CANADIAN BASIN TOTAL	**13,207**	**13,594**	**14,021**	**14,664**	**15,182**	**15,728**
MCLEAN MUNICIPAL WATER SUPPLY	210	227	250	281	307	334
COUNTY-OTHER	239	259	285	320	350	381
MINING	68	67	61	54	48	43
LIVESTOCK	1,706	1,934	2,022	2,117	2,222	2,337
IRRIGATION	23,894	23,894	23,894	23,894	23,894	23,894
RED BASIN TOTAL	**26,117**	**26,381**	**26,512**	**26,666**	**26,821**	**26,989**
GRAY COUNTY TOTAL	**39,324**	**39,975**	**40,533**	**41,330**	**42,003**	**42,717**
MEMPHIS	386	385	375	372	372	372
RED RIVER AUTHORITY OF TEXAS	89	98	105	113	104	111
TURKEY MUNICIPAL WATER SYSTEM	120	121	119	119	119	119
COUNTY-OTHER	84	76	65	54	65	57
LIVESTOCK	340	357	375	394	414	435
IRRIGATION	31,792	31,792	31,792	31,792	31,792	31,792
RED BASIN TOTAL	**32,811**	**32,829**	**32,831**	**32,844**	**32,866**	**32,886**
HALL COUNTY TOTAL	**32,811**	**32,829**	**32,831**	**32,844**	**32,866**	**32,886**
GRUVER	350	380	407	431	457	481
SPEARMAN MUNICIPAL WATER SYSTEM	670	681	689	703	723	745
COUNTY-OTHER	117	123	133	141	150	158
MANUFACTURING	285	321	321	321	321	321
MINING	577	904	602	309	16	1
LIVESTOCK	4,030	4,204	4,388	4,580	4,783	4,995
IRRIGATION	171,900	171,900	171,900	171,900	171,900	171,900
CANADIAN BASIN TOTAL	**177,929**	**178,513**	**178,440**	**178,385**	**178,350**	**178,601**
HANSFORD COUNTY TOTAL	**177,929**	**178,513**	**178,440**	**178,385**	**178,350**	**178,601**
DALHART	853	873	881	889	899	907
HARTLEY WSC	227	239	246	251	255	260
COUNTY-OTHER	531	557	568	577	588	598
MINING	7	7	6	5	4	3
LIVESTOCK	6,589	7,375	7,924	8,519	9,165	9,866
IRRIGATION	406,990	406,990	345,197	283,865	226,681	226,681
CANADIAN BASIN TOTAL	**415,197**	**416,041**	**354,822**	**294,106**	**237,592**	**238,315**
HARTLEY COUNTY TOTAL	**415,197**	**416,041**	**354,822**	**294,106**	**237,592**	**238,315**
CANADIAN	823	906	978	1,057	1,130	1,199
COUNTY-OTHER	97	95	92	94	95	95

Region A Water User Group (WUG) Demands

	WUG DEMAND (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
MANUFACTURING	4	4	4	4	4	4
MINING	926	706	498	293	89	27
LIVESTOCK	663	680	699	718	739	760
IRRIGATION	3,919	3,919	3,919	3,919	3,919	3,919
CANADIAN BASIN TOTAL	**6,432**	**6,310**	**6,190**	**6,085**	**5,976**	**6,004**
COUNTY-OTHER	42	41	41	41	41	42
MANUFACTURING	1	2	2	2	2	2
MINING	1,388	1,057	746	439	134	41
LIVESTOCK	454	466	478	492	505	520
IRRIGATION	1,760	1,760	1,760	1,760	1,760	1,760
RED BASIN TOTAL	**3,645**	**3,326**	**3,027**	**2,734**	**2,442**	**2,365**
HEMPHILL COUNTY TOTAL	**10,077**	**9,636**	**9,217**	**8,819**	**8,418**	**8,369**
BORGER	3,163	3,201	3,182	3,177	3,172	3,172
FRITCH	592	598	591	589	588	588
STINNETT	454	460	456	455	454	454
TCW SUPPLY	690	705	705	701	700	700
COUNTY-OTHER	263	269	270	269	269	269
MANUFACTURING	29,366	31,335	31,335	31,335	31,335	31,335
MINING	184	231	170	113	56	34
LIVESTOCK	600	636	666	699	734	771
IRRIGATION	59,910	59,910	59,910	59,910	59,910	59,910
CANADIAN BASIN TOTAL	**95,222**	**97,345**	**97,285**	**97,248**	**97,218**	**97,233**
HUTCHINSON COUNTY TOTAL	**95,222**	**97,345**	**97,285**	**97,248**	**97,218**	**97,233**
BOOKER	496	547	576	618	648	673
DARROUZETT	124	131	135	141	145	149
FOLLETT	129	137	141	147	152	156
HIGGINS MUNICIPAL WATER SYSTEM	127	134	138	144	149	153
COUNTY-OTHER	137	124	117	109	103	99
MANUFACTURING	362	400	400	400	400	400
MINING	1,098	758	446	142	21	3
LIVESTOCK	605	631	658	688	718	750
IRRIGATION	40,870	40,870	40,870	40,870	40,870	40,870
CANADIAN BASIN TOTAL	**43,948**	**43,732**	**43,481**	**43,259**	**43,206**	**43,253**
LIPSCOMB COUNTY TOTAL	**43,948**	**43,732**	**43,481**	**43,259**	**43,206**	**43,253**
CACTUS MUNICIPAL WATER SYSTEM	985	1,107	1,242	1,382	1,532	1,685
DUMAS	3,584	3,993	4,446	4,930	5,461	6,011
FRITCH	3	3	3	4	4	4
SUNRAY	450	454	461	471	484	499
COUNTY-OTHER	293	323	356	393	435	479
MANUFACTURING	9,277	9,629	9,629	9,629	9,629	9,629
MINING	16	16	16	15	15	15
LIVESTOCK	5,414	6,192	6,698	7,251	7,855	8,515
IRRIGATION	200,550	200,550	171,892	136,086	102,919	102,919
CANADIAN BASIN TOTAL	**220,572**	**222,267**	**194,743**	**160,161**	**128,334**	**129,756**
MOORE COUNTY TOTAL	**220,572**	**222,267**	**194,743**	**160,161**	**128,334**	**129,756**
BOOKER	6	9	13	16	20	25
PERRYTON MUNICIPAL WATER SYSTEM	2,693	2,851	3,030	3,238	3,475	3,734

Region A Water User Group (WUG) Demands

	WUG DEMAND (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
COUNTY-OTHER	310	322	337	360	386	415
MANUFACTURING	36	41	41	41	41	41
MINING	824	853	503	161	23	3
LIVESTOCK	2,801	2,962	3,120	3,286	3,462	3,647
IRRIGATION	84,460	84,460	84,460	84,460	84,460	84,460
CANADIAN BASIN TOTAL	**91,130**	**91,498**	**91,504**	**91,562**	**91,867**	**92,325**
OCHILTREE COUNTY TOTAL	**91,130**	**91,498**	**91,504**	**91,562**	**91,867**	**92,325**
VEGA	292	287	284	282	282	282
COUNTY-OTHER	279	309	305	305	304	304
MINING	456	540	613	644	708	776
LIVESTOCK	821	916	938	961	985	1,010
IRRIGATION	3,588	3,588	3,588	3,588	3,588	3,588
CANADIAN BASIN TOTAL	**5,436**	**5,640**	**5,728**	**5,780**	**5,867**	**5,960**
COUNTY-OTHER	73	80	79	79	79	79
MINING	19	23	26	27	29	32
LIVESTOCK	289	323	330	338	347	356
IRRIGATION	1,133	1,133	1,133	1,133	1,133	1,133
RED BASIN TOTAL	**1,514**	**1,559**	**1,568**	**1,577**	**1,588**	**1,600**
OLDHAM COUNTY TOTAL	**6,950**	**7,199**	**7,296**	**7,357**	**7,455**	**7,560**
AMARILLO	16,458	17,919	19,536	21,251	23,234	25,346
COUNTY-OTHER	1,517	1,651	1,801	1,960	2,141	2,336
MANUFACTURING	682	755	755	755	755	755
MINING	640	781	912	988	1,109	1,245
STEAM ELECTRIC POWER	18,554	18,554	18,554	18,554	18,554	18,554
LIVESTOCK	423	440	458	477	498	518
IRRIGATION	1,029	1,029	1,029	1,029	1,029	1,029
CANADIAN BASIN TOTAL	**39,303**	**41,129**	**43,045**	**45,014**	**47,320**	**49,783**
AMARILLO	10,835	11,797	12,863	13,991	15,297	16,687
COUNTY-OTHER	812	884	965	1,049	1,147	1,251
MANUFACTURING	7,214	7,985	7,985	7,985	7,985	7,985
MINING	301	368	429	465	522	586
LIVESTOCK	87	90	94	98	102	107
IRRIGATION	2,147	2,147	2,147	2,147	2,147	2,147
RED BASIN TOTAL	**21,396**	**23,271**	**24,483**	**25,735**	**27,200**	**28,763**
POTTER COUNTY TOTAL	**60,699**	**64,400**	**67,528**	**70,749**	**74,520**	**78,546**
AMARILLO	22,161	24,276	26,462	28,851	31,543	34,369
CANYON	3,632	3,981	4,342	4,735	5,178	5,642
HAPPY	10	11	12	13	14	16
LAKE TANGLEWOOD	438	433	429	427	427	427
COUNTY-OTHER	3,088	3,379	3,684	4,018	4,394	4,790
MANUFACTURING	621	716	716	716	716	716
LIVESTOCK	2,663	2,705	2,741	2,778	2,819	2,862
IRRIGATION	17,720	17,720	17,720	17,720	17,720	17,720
RED BASIN TOTAL	**50,333**	**53,221**	**56,106**	**59,258**	**62,811**	**66,542**
RANDALL COUNTY TOTAL	**50,333**	**53,221**	**56,106**	**59,258**	**62,811**	**66,542**
MIAMI	225	226	224	223	223	223

Region A Water User Group (WUG) Demands

	WUG DEMAND (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
COUNTY-OTHER	47	49	47	47	47	47
MINING	1,457	1,010	593	183	19	2
LIVESTOCK	373	391	411	432	453	477
IRRIGATION	8,116	8,116	8,116	8,116	8,116	8,116
CANADIAN BASIN TOTAL	**10,218**	**9,792**	**9,391**	**9,001**	**8,858**	**8,865**
COUNTY-OTHER	1	1	1	1	1	1
MINING	45	31	18	6	1	0
LIVESTOCK	10	11	11	12	13	13
IRRIGATION	427	427	427	427	427	427
RED BASIN TOTAL	**483**	**470**	**457**	**446**	**442**	**441**
ROBERTS COUNTY TOTAL	**10,701**	**10,262**	**9,848**	**9,447**	**9,300**	**9,306**
STRATFORD	496	526	539	554	567	577
TEXHOMA	122	131	135	139	143	145
COUNTY-OTHER	105	110	112	116	118	121
MANUFACTURING	2	2	2	2	2	2
MINING	35	207	151	98	44	20
LIVESTOCK	3,576	3,813	4,006	4,212	4,432	4,669
IRRIGATION	304,360	304,360	304,360	246,760	182,536	182,536
CANADIAN BASIN TOTAL	**308,696**	**309,149**	**309,305**	**251,881**	**187,842**	**188,070**
SHERMAN COUNTY TOTAL	**308,696**	**309,149**	**309,305**	**251,881**	**187,842**	**188,070**
SHAMROCK MUNICIPAL WATER SYSTEM	350	353	357	369	382	397
WHEELER	493	505	517	533	553	574
COUNTY-OTHER	296	297	299	309	320	332
MINING	3,268	2,329	1,413	503	139	119
LIVESTOCK	1,186	1,321	1,358	1,396	1,436	1,479
IRRIGATION	16,224	16,224	16,224	16,224	16,224	16,224
RED BASIN TOTAL	**21,817**	**21,029**	**20,168**	**19,334**	**19,054**	**19,125**
WHEELER COUNTY TOTAL	**21,817**	**21,029**	**20,168**	**19,334**	**19,054**	**19,125**
REGION A TOTAL DEMAND	**2,130,529**	**2,138,483**	**1,995,398**	**1,788,541**	**1,585,584**	**1,598,115**

Region A Major Water Provider Demands by Use Type

Major Water Provider	Category of Use	2020	2030	2040	2050	2060	2070
Amarillo	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	6,103	6,694	6,694	6,694	6,694	6,694
	Mining	0	0	0	0	0	0
	Municipal	50,479	55,017	59,886	65,118	70,099	76,427
	Municipal Non-potable	1,682	1,682	1,682	1,682	1,682	1,682
	Steam Electric Power	18,554	18,554	18,554	18,554	18,554	18,554
	Potable Demand	**56,582**	**61,711**	**66,580**	**71,812**	**76,793**	**83,121**
	Non-Potable Demand	**20,236**	**20,236**	**20,236**	**20,236**	**20,236**	**20,236**
CRMWA[1]	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	0	0	0	0	0
	Mining	0	0	0	0	0	0
	Municipal	101,071	109,865	115,523	120,717	121,460	121,598
	Steam Electric Power	0	0	0	0	0	0
	Total	**101,071**	**109,865**	**115,523**	**120,717**	**121,460**	**121,598**
Greenbelt MIWA[2]	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	190	190	190	190	190	190
	Mining	0	0	0	0	0	0
	Municipal	3,441	3,459	3,476	3,522	3,576	3,631
	Steam Electric Power	0	0	0	0	0	0
	Total	**3,631**	**3,649**	**3,666**	**3,712**	**3,766**	**3,821**
Cactus	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	3,247	3,370	3,370	3,370	3,370	3,370
	Mining	0	0	0	0	0	0
	Municipal	985	1,107	1,242	1,382	1,532	1,685
	Steam Electric Power	0	0	0	0	0	0
	Total	**4,232**	**4,477**	**4,612**	**4,752**	**4,902**	**5,055**
Borger	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	7,342	7,834	7,834	7,834	7,834	7,834
	Mining	0	0	0	0	0	0
	Municipal	3,179	3,217	3,198	3,193	3,188	3,188
	Steam Electric Power	0	0	0	0	0	0
	Total	**10,521**	**11,051**	**11,032**	**11,027**	**11,022**	**11,022**

[1] Includes demand from Region O
[2] Includes demand from Region B

3 EVALUATION OF REGIONAL WATER SUPPLIES

This chapter presents an evaluation of water supplies available to the Panhandle region for use during a repeat of the drought of record. This evaluation consists of two major components: 1) evaluation of available water from sources located within the region, and 2) evaluation of the amount of water that is currently available to water user groups within the region. Section 3.1 focuses on the first component: availability by source. Section 3.2 discusses the availability of supplies to water user groups and wholesale water providers.

3.1 Water Supplies by Source

3.1.1 Groundwater Regulation in Texas and the PWPA

The history of groundwater regulations in Texas is discussed in Chapter 1, Section 1.5.1 and emphasizes the role of Groundwater Conservation Districts (GCDs) as the preferred method of groundwater management in the state. This section discusses how groundwater regulation affects water supply planning. Specifically, one of the significant changes to the management of groundwater resources in Texas was the passage of House Bill 1763 (HB 1763) in 2005. This law is the foundation for the joint planning between GCDs, Groundwater Management Areas (GMAs) and RWPGs for the purpose of water supply planning (Figure 3-1). Key to the joint planning effort is the development of Desired Future Conditions (DFCs) for groundwater resources and the resulting Modeled Available Groundwater (MAG) volumes.

Desired Future Conditions are defined by statute to be "the desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint groundwater planning process." DFCs are quantifiable management goals that reflect what the GCDs want to protect in their

Definitions

Desired Future Conditions (DFC): Quantifiable management goals that reflect what the GCDs want to protect in their area, typically measured as groundwater levels, water quality, and/or spring flow.

Modeled Available Groundwater (MAG): Groundwater determined to be available during the planning period, based on the DFC. Used as a cap on groundwater production that is applied in regional planning on a county basis.

Groundwater Availability Model (GAM): Computer model used to translate an area's goals for its groundwater into an amount of groundwater that is available during the planning period.

Reservoir Firm Yield: The amount of water that could be relied on during the drought of record, which is the period from the last time the reservoir spills before reaching its minimum content to the next time the reservoir spills.

Reservoir Safe Yield: The amount of water that can be diverted annually, leaving a minimum of a one year supply in reserve during the critical period.

particular area. The most common DFCs are based on the volume of groundwater in storage over time, water levels (limiting decline within the aquifer), water quality (limiting deterioration of quality) or spring flow (defining a minimum flow to sustain).

After the DFCs are determined by the GMAs, the TWDB performs quantitative analysis to determine the amount of groundwater available for production that does not exceed the DFC. For aquifers where a Groundwater Availability Model (GAM) exists, the GAM is used to develop the MAG. The MAG estimated through this process is then used by RWPGs as the available groundwater for the planning period. For all of the major and minor aquifers in the PWPA, GAMs were used to develop MAG values. For aquifers or local groundwater that are not listed as a minor or major aquifer, the water availability is based on historical use and available hydrogeological records. The methodology used for the 2070 MAG values for the Ogallala Aquifer was assumed to be the same as the values for 2060.

TWDB technical guidelines for the current round of planning establishes that the MAG (within each county and basin) is the maximum amount of groundwater that can be used for existing uses and new strategies in Regional Water Plans. In other words, the MAG volumes are a cap on groundwater production for regional water planning purposes.

3.1.2 Groundwater Supplies

Two major aquifers, the Ogallala and Seymour, and three minor aquifers, the Blaine, Dockum, and Rita Blanca supply the majority of all water uses in the PWPA (Figure 3-2:). The Ogallala aquifer supplies the predominant share of groundwater, with additional supplies obtained from the remaining aquifers.

The region contains two GMAs. GMA 1 covers all the PWPA counties, except for Childress, Collingsworth and Hall Counties. These counties are located within GMA 6. In 2016, the GMA 1 adopted desired future conditions (DFCs) for the combined Ogallala/ Rita Blanca aquifer system. In GMA 1 only, the 50-year planning cycle for the model runs is from 2012 to 2062, and these are the years for DFC comparison. However, within GAM Run 16-029 MAG, the TWDB only calculated MAGs for these DFCs by county and by GCD for year 2062. They did not quantify MAGs by county-aquifer-basin for year 2070. Therefore, all GMA-1 MAG values for year 2060 have been copied forward to year 2070 in this report.

The adopted DFCs for the Ogallala/Rita Blanca state that the aquifers shall have 40 percent of the aquifer storage remaining in 50 years for the four western counties (Dallam, Hartley, Sherman and Moore), 80 percent of the storage remaining in Hemphill County, and 50 percent of the storage remaining in the other counties in the GMA, except for Randall, and those portions of Armstrong and Potter Counties located within the High Plains UWCD. In these areas, the DFC is approximately 20 feet of total average drawdown for the period from 2012 to 2062. In 2010, GMA 1 adopted DFCs for the Dockum and Blaine aquifers. For the Dockum, the DFC states that average water level decline shall be no more than 30 feet over the next 50 years in Carson and Oldham Counties, and in the portions of Armstrong and Potter Counties within the Panhandle GCD. In Dallam, Hartley, Moore and Sherman Counties, at least 40 percent of the available drawdown should remain in 50 years. Total average drawdown of approximately 40 feet shall remain in 50 years in Randall County, and in the portions of Armstrong and Potter counites within the High Plains UWCD. In 2016, both the Ogallala aquifer in Collingsworth County within the Mesquite GCD and the Blaine aquifer in Wheeler County were designated to be non-relevant for planning purposes.

GMA 6 contains three counties that are entirely within the PWPA: Childress, Collingsworth and Hall. GMA 6 adopted DFCs for the portions of the Blaine and Seymour aquifers that fall within these counties. The Seymour and Blaine aquifers are the only major and minor aquifers that the GMA 6 DFCs address as the Ogallala does not underlie these three counties, except for a very small area in western Collingsworth County.

GMA 6 has divided the Seymour into separate sections (Pods) for DFC designation purposes. The Pod numbers for the Seymour aquifer appear on the inset map located in the section below about the Seymour aquifer. The DFCs for the portions of Seymour Pods 1, 2 and 3 that are within the Mesquite and Gateway GCDs in Childress, Collingsworth and Hall Counties (Mesquite GCD) require that no more than 33 feet of drawdown in Childress and Collingsworth Counties, and 15 feet in Hall County will occur in 50 years. For the portion of Seymour Pod 4, located in the Gateway GCD in Childress County, the adopted DFC requires that total decline in water levels will not exceed one foot over the 50-year planning period.

The Blaine aquifer DFC for the part of Childress County north of the Red River, located in the Mesquite GCD, all of Collingsworth and Hall Counties, also located within the Mesquite GCD, and that part of Childress County north of the Red River located in the Gateway GCD is that the total decline in water levels will be no more than 9 feet during the period from 2020 to 2070. For the part of Childress County south of the Red River, located in the Mesquite & Gateway GCDs, the total decline in water levels should be no more than 2 feet during the period from 2020 to 2070.

GMA 6 also has groundwater resources designated as Other aquifer in Childress, Collingsworth, and Hall Counties. The groundwater supply associated with Other aquifer is from either the Quartermaster Formation aquifer or the Permian Whitehorse-Artesia aquifer, which underlies the Quartermaster Formation and overlies the Blaine aquifer.

In previous planning cycles, the availability of water from the Northern Ogallala/Rita Blanca aquifer was determined using the Northern Ogallala Groundwater Availability Model (GAM) (Dutton, Reedy and Mace, 2001; Dutton 2004). In 2010, an updated version of the Northern Ogallala GAM was completed to help support regional planning. In 2015, the High Plains Aquifer System (HPAS) GAM, which includes the Ogallala, Rita Blanca, and Dockum, was released by the TWDB (Intera, 2015). This GAM was subsequently adopted by GMA 1 for purposes of assessing the DFCs and MAGs.

As requested by GMA 1, GAM Run 16-029 MAG was completed in 2017 for the Ogallala, Rita Blanca, and Dockum aquifer MAGs, which were adopted by GMA 1. Available supplies of groundwater from the Dockum aquifer were determined using the HPAS GAM.

In GMA 6, the current MAG volumes of water available from the Seymour and Blaine aquifers were determined using Version 1.01 of the Seymour GAM (Ewing el al., 2004). This model has been used to determine availability for the 2006 MAGs and all subsequent planning cycles. In GMA 6, available supplies of groundwater from the Dockum aquifer were determined using the HPAS GAM.

The 2017 GAM Run 16-031 MAG includes the MAG results for the Seymour, Blaine, and Dockum aquifers. These GAM runs are the basis of the supply for the 2021 Regional Water Plan.

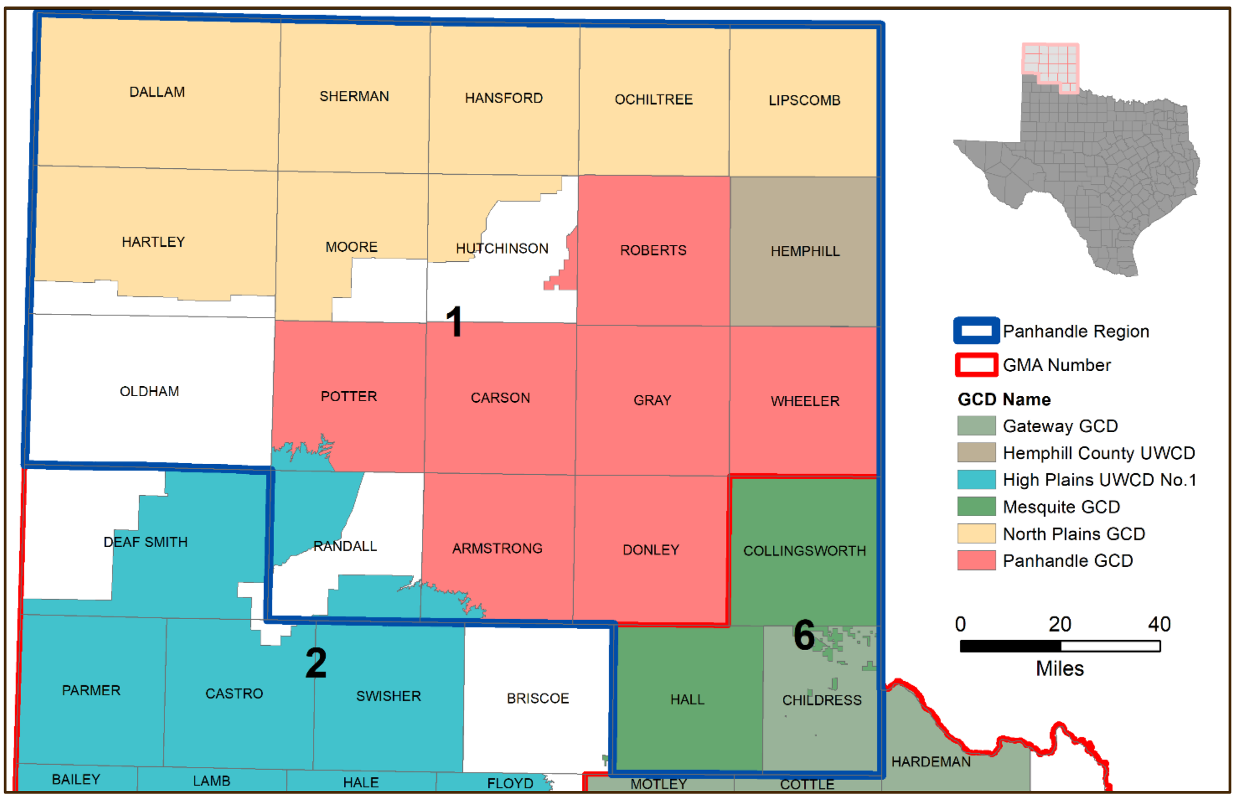


Figure 3-1: Groundwater Conservation Districts and Groundwater Management Areas

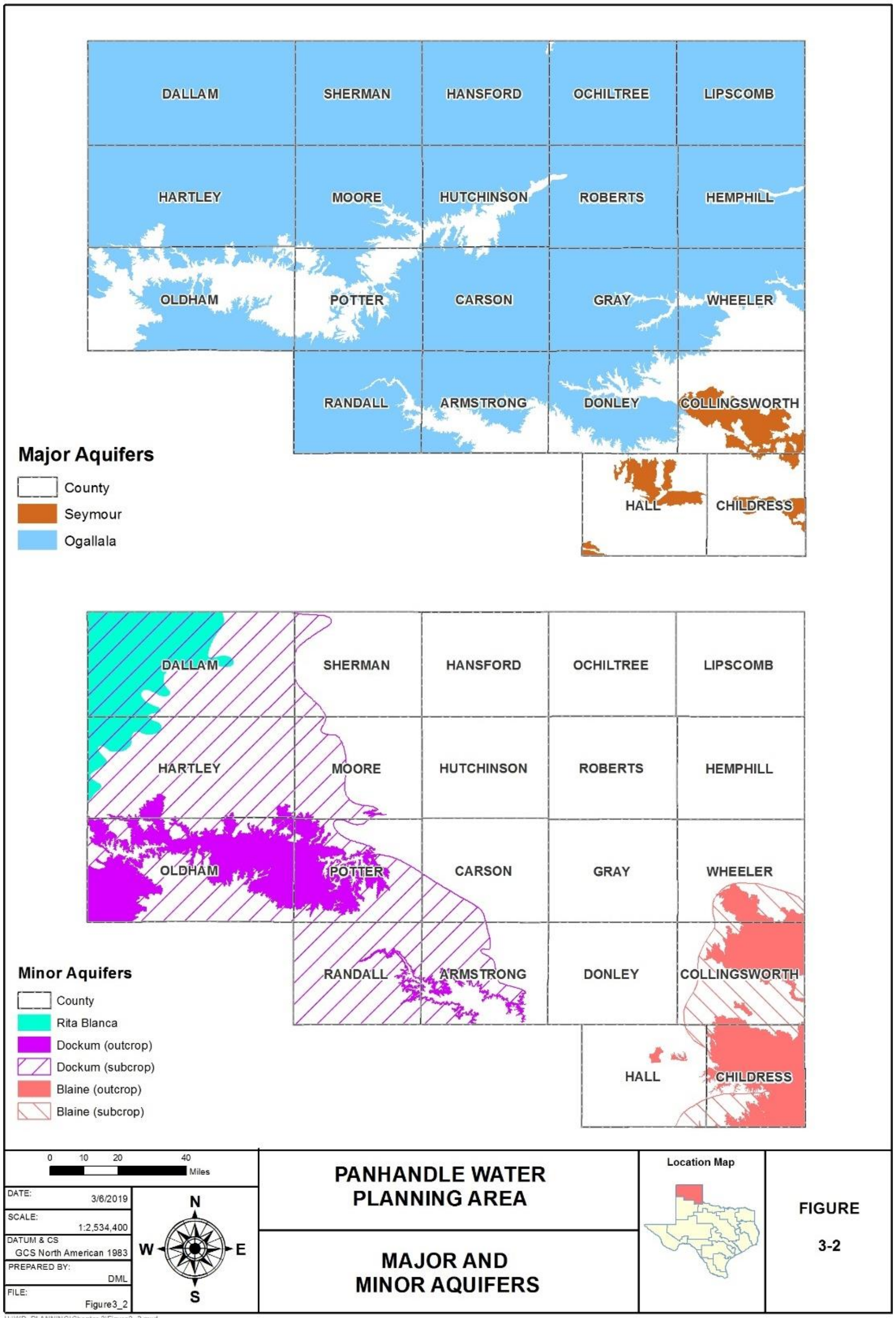
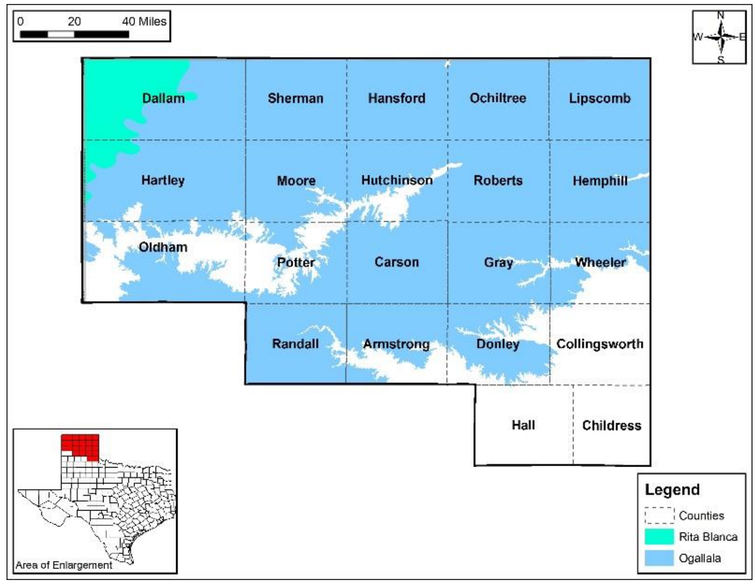


Figure 3-2: Major and Minor Aquifers

Ogallala/ Rita Blanca Aquifer



The Ogallala aquifer is present in all counties in the PWPA except for Childress, Collingsworth, and Hall Counties and is the region's largest source of water. (There is tiny sliver of Ogallala in western Collingsworth County, however, it has been declared to be non-relevant.)

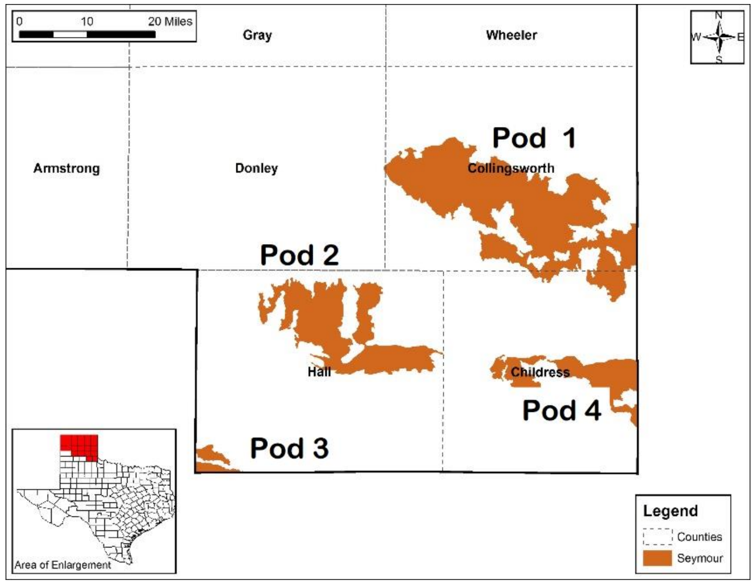
The Ogallala aquifer in the study area consists of Tertiary-age alluvial fan, fluvial, lacustrine, and eolian deposits derived from erosion of the Rocky Mountains. The Ogallala unconformably overlies Permian, Triassic, and other Mesozoic formations and in turn may be covered by Quaternary fluvial, lacustrine, and eolian deposits (Dutton et. al. 2000a). Recharge to the Ogallala is limited and water generally does not move through the aquifer as freely as some other major aquifers in the state.

The Rita Blanca is a minor aquifer that underlies the Ogallala Formation and extends into New Mexico, Oklahoma, and Colorado. The portion of the aquifer which underlies the PWPA is located in western Dallam and Hartley Counties. Groundwater in the Rita Blanca occurs in sand and gravel formations of Cretaceous and Jurassic Age. The Romeroville Sandstone of the Dakota Group yields small quantities of water, whereas the Cretaceous Mesa Rica and Lytle Sandstones yield small to large quantities of water. Small quantities of groundwater are also located in the Jurassic Exeter Sandstone and sandy sections of the Morrison Formation (Ashworth & Hopkins, 1995).

Recharge to the aquifer occurs by lateral flow from portions of the aquifer system in New Mexico and Colorado and by downward leakage from the Ogallala. Supplies from the Rita Blanca were modeled in the Ogallala GAM and these supplies are included in Ogallala availability numbers.

Table 3-1 presents the Ogallala and Rita Blanca MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070. MAG volumes are the largest amount of water that can be withdrawn from a given source without violating DFCs. Table 3-1 includes county aquifer combinations where a DFC has been defined by a GCD/GMA and the MAG subsequently has been determined by the TWDB using the GAM. As shown in Table 3-1, the total Ogallala/Rita Blanca MAGs in the PWPA range from 3,553,273 acre-feet per year (ac-ft/yr) in 2020 to 2,293,523 acre-feet per year by 2070. Figure 3-3 shows the Ogallala MAGs by county for planning decades 2020, 2040 and 2060.

Seymour Aquifer



The Seymour is a major aquifer located in north central Texas and some Panhandle counties. For the PWPA, the Seymour is located entirely within the Red River Basin in Childress, Collingsworth and Hall Counties. Groundwater in the Seymour formation is found in unconsolidated sediments representing erosional remnants from the High Plains. The saturated thickness of the Seymour Formation is less than 100 feet throughout its extent and is typically less than 50 feet thick in the PWPA. Nearly all recharge to the aquifer is a result of direct infiltration of precipitation on the land surface. Surface streams are at a lower elevation than water levels in the Seymour aquifer and do not contribute to the recharge. Leakage from underlying aquifers also appears to be insignificant (Duffin, 1992).

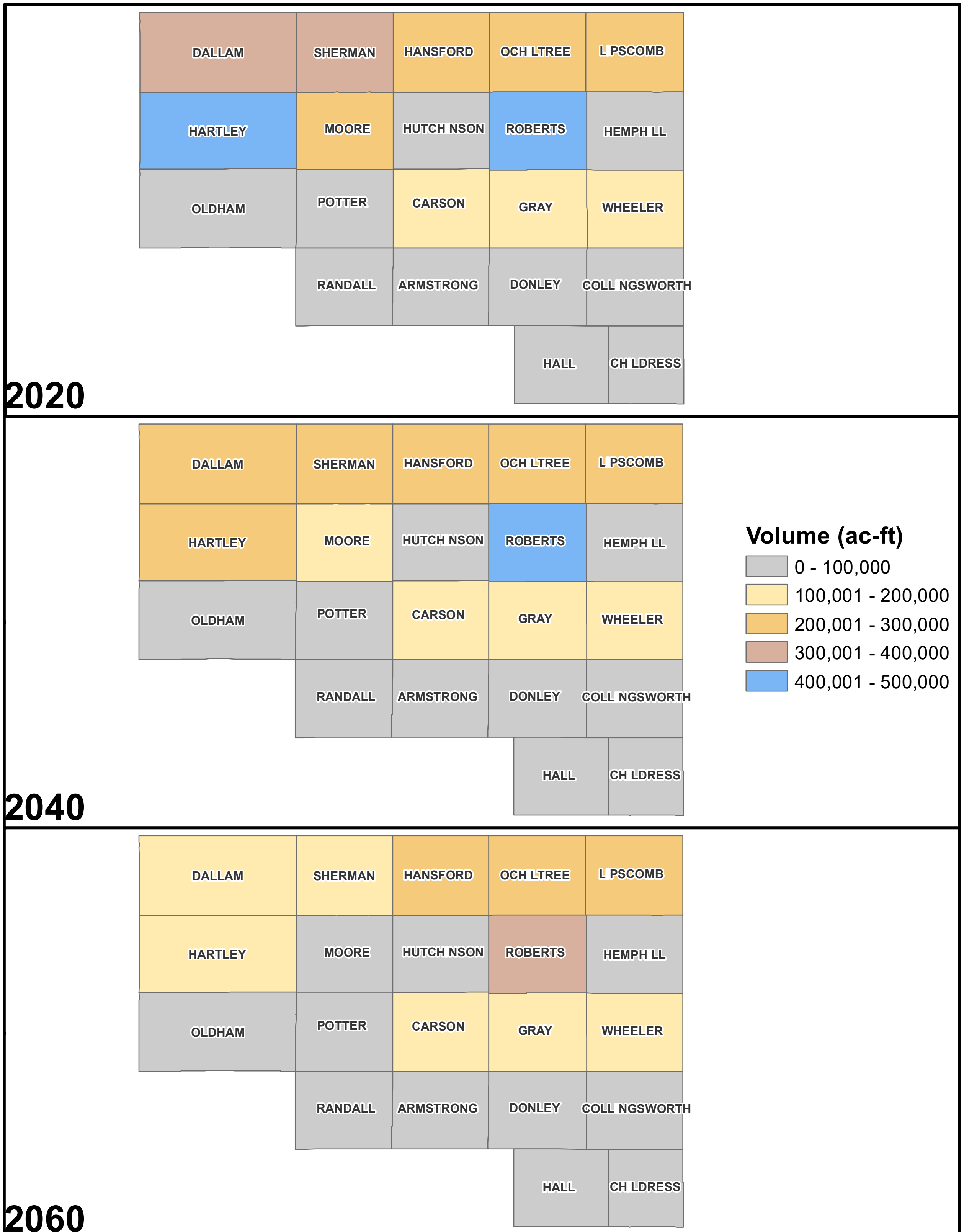
Annual effective recharge to the Seymour aquifer in the PWPA is approximately 33,000 acre-feet or five percent of the average annual rainfall that falls on the outcrop area.

Table 3-2 presents the Seymour aquifer MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070 (GAM Run 16-031_MAG). MAG volumes are the largest amount of water that can be withdrawn from a given source without violating DFCs. Table 3-2 includes county aquifer combinations where a DFC has been defined by a GCD/GMA and the MAG subsequently has been determined by the TWDB using the GAM. As shown on Table 3-2, the total Seymour MAGs in the PWPA range from 59,752 acre-feet per year in 2020 and decrease to 50,661 acre-feet per year by 2070.

Table 3-1: Modeled Available Groundwater in the Ogallala/Rita Blanca Aquifer (ac-ft/yr)

County	Basin	2020	2030	2040	2050	2060	2070
Armstrong	Red	59,270	54,462	49,036	44,185	39,470	39,470
Carson	Canadian	77,157	74,542	69,042	62,520	55,902	55,902
	Red	114,978	109,721	100,889	91,247	81,313	81,313
Dallam	Canadian	387,471	287,205	225,573	166,890	112,864	112,864
Donley	Red	74,808	76,289	72,962	67,873	62,058	62,058
Gray	Canadian	44,778	42,146	37,337	32,130	27,432	27,432
	Red	136,327	133,121	125,316	116,583	106,999	106,999
Hansford	Canadian	275,016	272,656	271,226	270,281	269,589	269,589
Hartley	Canadian	417,113	289,162	226,848	165,580	108,423	108,423
Hemphill	Canadian	27,789	30,260	31,999	33,363	34,058	34,058
	Red	24,407	21,958	20,268	18,942	18,278	18,278
Hutchinson	Canadian	94,985	95,694	94,161	92,372	90,858	90,858
Lipscomb	Canadian	266,809	266,710	266,640	266,591	266,559	266,559
Moore	Canadian	223,785	181,219	146,914	111,202	78,172	78,172
Ochiltree	Canadian	243,778	243,932	244,002	244,051	244,082	244,082
Oldham	Canadian	37,367	34,376	29,078	23,039	17,800	17,800
	Red	7,232	5,827	4,345	3,168	1,790	1,790
Potter	Canadian	9,552	9,196	8,519	7,898	7,214	7,214
	Red	7,642	6,849	6,148	5,487	4,843	4,843
Randall	Red	63,910	61,932	54,341	47,805	42,030	42,030
Roberts	Canadian	408,968	430,269	401,642	365,119	326,457	326,457
	Red	21,650	24,860	25,576	25,128	24,002	24,002
Sherman	Canadian	398,056	348,895	281,690	212,744	148,552	148,552
Wheeler	Red	130,425	138,810	137,385	132,312	124,778	124,778
Total		**3,553,273**	**3,240,091**	**2,930,937**	**2,606,510**	**2,293,523**	**2,293,523**

Source: 2017 GAM Run 16-029 MAG Report developed by TWDB.



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N W E S

PANHANDLE WATER PLANNING AREA

Modeled Available Groundwater in the Ogallala Aquifer

Location Map

FIGURE 3-3

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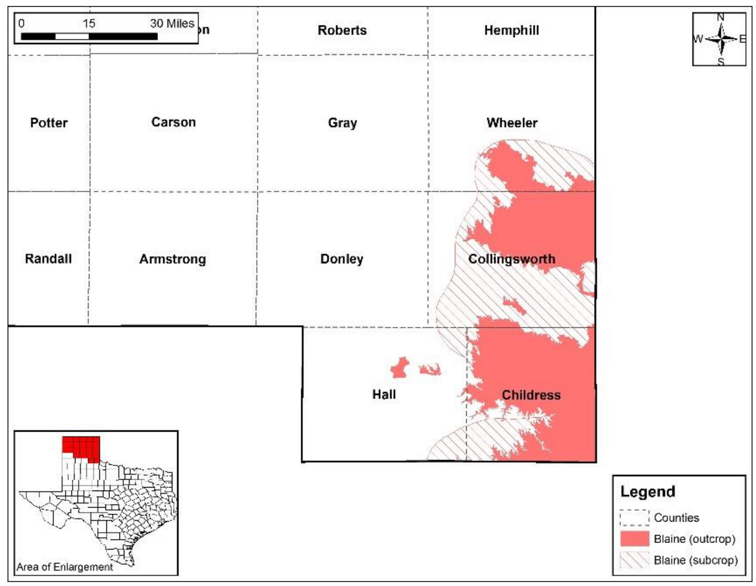
Table 3-2: Modeled Available Groundwater in the Seymour Aquifer (ac-ft/yr)

County	Basin	2020	2030	2040	2050	2060	2070
Childress	Red	2,961	3,246	3,317	3,308	3,317	3,297
Collingsworth	Red	41,345	31,492	28,657	27,165	22,395	22,769
Hall	Red	15,446	16,751	19,666	22,861	25,861	24,595
Total		**59,752**	**51,489**	**51,640**	**53,334**	**51,573**	**50,661**

Source: 2017 GAM Run 16-031 MAG Report developed by TWDB

Blaine Aquifer



The Blaine Formation is considered a minor aquifer and is composed of anhydrite and gypsum with interbedded dolomite and clay. Water occurs primarily under water-table conditions in numerous solution channels. Natural salinity in the aquifer from halite dissolution and upward migration of deeper, more saline waters limits the water quality of this aquifer. The aquifer is located in four counties in the PWPA, including, Childress, Collingsworth, a small portion of Hall, and Wheeler. It lies completely within the Red River basin.

Effective recharge to the Blaine is estimated to be 91,500 acre-feet per year throughout its extent in the PWPA (TWDB, 2005). Precipitation in the outcrop area is the primary source of recharge. Annual effective recharge is estimated to be five percent of the mean annual precipitation, with higher recharge rates occurring in areas with sandy soil surface layers. No significant water level declines have yet been identified in the Blaine aquifer. Declines that have occurred are due to heavy irrigation use and are quickly recharged after seasonal rainfall (TWDB, 1997).

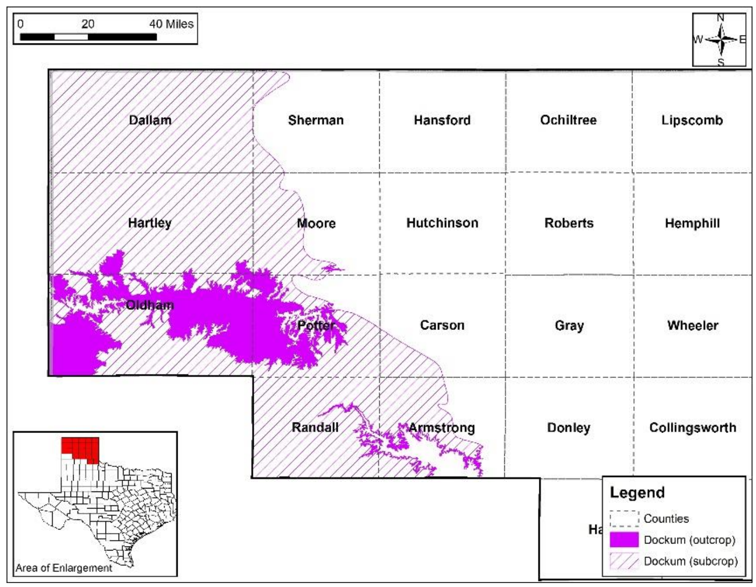
Table 3-3 presents the MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070. As shown on Table 3-3, the total Blaine MAGs in the PWPA range from 31,491 acre-feet per year in 2020, decreasing to 31,404 acre-feet per year by 2070. The Blaine aquifer in Wheeler County was designated to be non-relevant for planning purposes. Water supply in Wheeler County is based on the average historical use during the past ten years of available data (2007 – 2016).

Table 3-3: Modeled Available Groundwater in the Blaine Aquifer (ac-ft/yr)

County	Basin	2020	2030	2040	2050	2060	2070
Childress	Red	23,575	23,510	23,575	23,510	23,575	23,510
Collingsworth	Red	2,060	2,054	2,060	2,054	2,060	2,054
Hall	Red	5,856	5,840	5,856	5,840	5,856	5,840
Total		31,491	31,404	31,491	31,404	31,491	31,404

Source: 2017 GAM Run 16-031 MAG Report developed by TWDB

Dockum Aquifer



The Dockum is a minor aquifer that underlies the Ogallala aquifer and extends laterally into parts of West Texas and New Mexico. The primary water-bearing zone in the Dockum Group, commonly called the "Santa Rosa", consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Domestic use of the Dockum occurs in Oldham, Potter, and Randall Counties. The effective recharge rate to the Dockum aquifer is estimated to be 23,500 acre-feet per year and is primarily limited to outcrop areas. Oldham and Potter Counties are the main sources of recharge in the PWPA. Differences in chemical makeup of Ogallala and Dockum groundwater indicate that very little leakage (<0.188 in/year) occurs into the Dockum from the overlying Ogallala formation (BEG, 1986).

Table 3-4 presents the Dockum MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070. As shown on Table 3-4, the total Dockum MAGs in the PWPA decrease from 261,079 acre-feet per year in 2020 to 232,128 acre-feet per year in 2060.

Other Aquifer

Within the PWPA, small quantities of water within the named aquifers were designated as "non-relevant" by the GMAs. However, the PWPA does have some groundwater supplies provided by aquifers designated as "other." Within six counties in the PWPA (Armstrong, Childress, Collingsworth, Donley, Hall and Wheeler), the groundwater supply associated with "Other aquifer" is from either the Quartermaster Formation, which underlies the Dockum, or the Permian Whitehorse-Artesia aquifer, which underlies the Quartermaster Formation and overlies the Blaine aquifer.

Table 3-4: Modeled Available Groundwater in the Dockum Aquifer (ac-ft/yr)

County	Basin	2020	2030	2040	2050	2060	2070
Armstrong	Red	7,227	9,024	9,588	9,704	9,535	9,535
Carson	Canadian	4	10	15	19	23	23
	Red	64	98	125	150	175	175
Dallam	Canadian	14,192	14,188	14,186	14,184	14,184	14,184
Hartley	Canadian	55,249	55,035	54,928	54,864	54,837	54,837
Moore	Canadian	5,219	5,107	5,020	4,926	4,789	4,789
Oldham	Canadian	128,938	128,771	120,466	111,146	101,365	101,365
	Red	63	58	52	50	48	48
Potter	Canadian	38,641	38,983	36,832	34,409	31,900	31,900
	Red	183	130	105	96	108	108
Randall	Red	11,172	14,016	14,863	15,113	15,069	15,069
Sherman	Canadian	127	127	127	127	95	95
Total		**261,079**	**265,547**	**256,307**	**244,788**	**232,128**	**232,128**

Source: 2017 GAM Run 16-029 MAG Report developed by TWDB

To calculate groundwater availability for these sources, the estimate of recoverable volume for the Whitehorse and Quartermaster formations was calculated using average depth from TWDB driller's logs for each county/formation and GIS coverage areas from the Geological Atlas of Texas outcrops for each of the counties/areas. The average well depth from recent driller's logs (2003-2017) was subtracted from the average water level that was measured at time of drilling to get an estimated saturated thickness for each county. The surface area was then multiplied by the estimated saturated thickness and a specific yield of 0.25% to get the estimated recoverable volume of water in storage.

Table 3-5 presents the groundwater availability volumes for Other aquifer derived using this methodology. (Note that all of these counties are located in the Red River basin.) Table 3-5 also shows the water availability for non-relevant portions of the Ogallala aquifer in Collingsworth County and the Blaine aquifer in Wheeler County. Historical use was used to estimate the availability for Wheeler County. However, there is no reported historical use from the Ogallala aquifer in Collingsworth County. The small quantity of water reported in Table 3-5 for the non-relevant portion of the Ogallala aquifer in Collingsworth is based on estimates of the extent and depth of the aquifer in this county.

Table 3-5: Available Groundwater in Other and Non-Relevant Aquifers (ac-ft/yr)

Aquifer Status	County	Aquifer	Supply
Other	Armstrong	Whitehorse/ Quartermaster	370
	Childress		233
	Collingsworth		309
	Donley		479
	Hall		1,086
	Wheeler		276
	Total Other		**2,753**
Non-Relevant	Collingsworth	Ogallala	50
	Wheeler	Blaine	1,750
	Total Non-Relevant		**1,800**

3.1.3 Water Supply Reservoirs

Major surface water supplies in the PWPA include Lake Meredith, Palo Duro Reservoir, and Greenbelt Reservoir (see Figure 3-4). A brief description of each of the three major reservoirs is presented below in Table 3-6.

Table 3-6: Descriptive Information of Water Supply Reservoirs in the PWPA

	Palo Duro Reservoir	Lake Meredith	Greenbelt Reservoir
Owner/Operator	PDRA	CRMWA	GMIWA
Stream	Palo Duro Creek	Canadian River	Salt Fork Red River
Dam	Palo Duro	Sanford	Greenbelt
Use	Municipal	Municipal and Industrial; Flood Control; Sediment Storage	Municipal, Industrial, and Mining
Impoundment	January 1991	January 1965	December 1966
Conservation Storage (most recent survey)	60,897 ac-ft (1974)	817,970 ac-ft[1] (1995) (includes sediment storage)	59,110 ac-ft (1965)
Permitted Diversion	10,460 ac-ft/yr	151,200 ac-ft/yr	16,030 ac-ft/yr[2]

[1] The Canadian River Compact allows 500,000 ac-ft of conservation storage. Any water stored in excess of 500,000 ac-ft is subject to release at the call of the State of Oklahoma.
[2] Of this amount, 11,750 ac-ft/yr can be diverted directly from the lake, 4.030 ac-ft/yr diverted from Lelia Lake Creek, and 250 ac-ft/yr diverted directly from Salt Fork of the Red River.

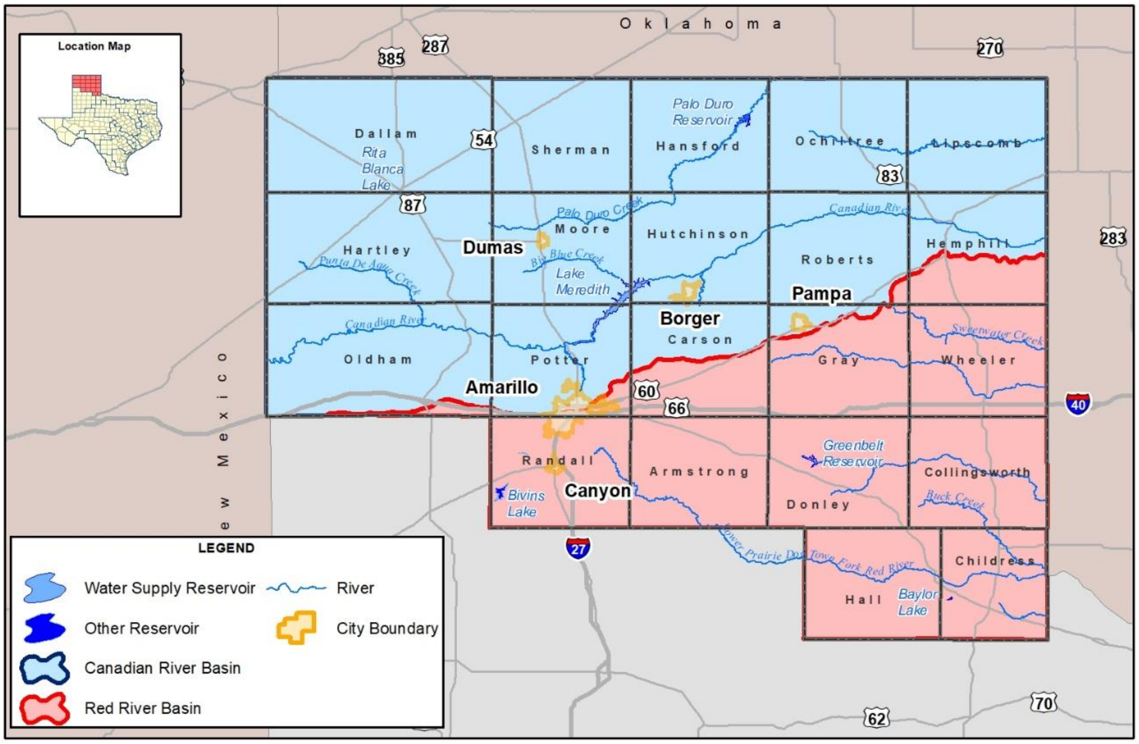


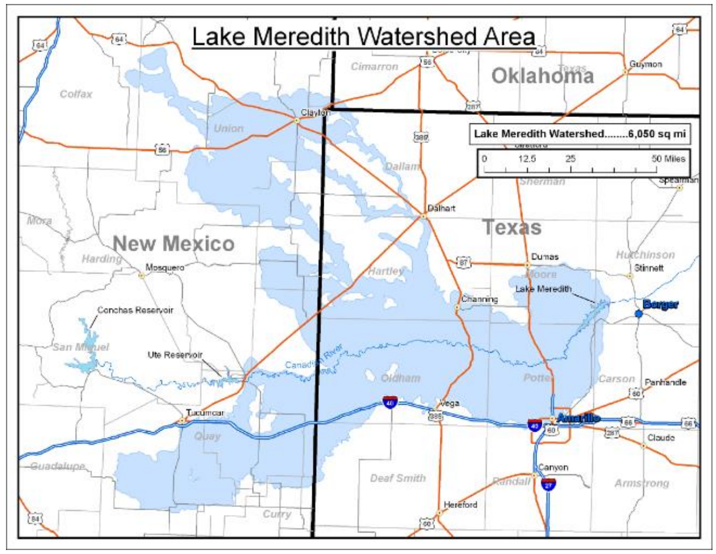
Figure 3-4: Surface Water Supplies in PWPA

The available supply from a reservoir is often referred to as the reservoir yield. The firm yield for a reservoir is defined as the dependable water supply available during a critical drought. Ideally, the period of analysis for a yield study includes the entire critical drought period. This "critical period" of a reservoir is that time period between the date of minimum content and the date of the last spill. If a reservoir has reached its minimum content but has not yet filled enough to spill, then it is considered to still be in its critical period. A definition of the critical period for each reservoir is essential to determine the yield or estimate of available water supply. (See Chapter 7, Table 7-1 for critical periods of reservoirs in the PWPA.) The one-year safe yield is defined as the amount of water that can be diverted annually, leaving a minimum of a one-year supply in reserve during the critical period. Conservation storage is the storage volume that is available for diversions for water supply. It does not include storage capacity used for flood control and, in some cases, sediment accumulation.

The TWDB guidelines specify that the TCEQ-approved Water Availability Models (WAMs) are used to assess available supplies for regional water planning purposes. However, the Canadian River WAM (for Lake Meredith) and the Red River WAM (for Greenbelt Reservoir) cover a period-of-record from 1948 to 1998 and do not include the recent drought, which is the new drought of record for much of the region. The reliable supply of surface water is reduced by a new drought of record. For this reason, a mass-balance reservoir model was used to estimate the yields of these reservoirs with hydrology covering a period from 1940 to 2016 for Greenbelt Reservoir and 1940 to 2017 for Lake Meredith. The yield estimates from the 2016 PWPA Regional Water Plan were retained for Palo Duro Reservoir. This reservoir is currently not used for water supply. A brief description of the reservoir supplies is presented below. Additional information on the WAMs can be found in Appendix B.

Lake Meredith

Lake Meredith is owned and operated by the Canadian River Municipal Water Authority (CRMWA). It was built by the Bureau of Reclamation with conservation storage of 500,000 acre-feet, limited by the Canadian River Compact. Impoundment of Lake Meredith began in January 1965, but hydrological and climatic conditions have prevented the reservoir from ever spilling. Most of the inflow to Lake Meredith originates below the Ute Reservoir in New Mexico. (TWDB, 1974)



Source: http://www.CRMWA.com

Several yield studies have been published for Lake Meredith since its construction in 1965 (HDR, 1987; Lee Wilson and Associates, 1993, Freese and Nichols, Inc., 2004). Both the HDR (1987) and Lee Wilson and Associates (1993) studies estimated the firm yield of Lake Meredith at about 76,000 acre-feet per year. The Freese and Nichols study (2004) for the 2006 Panhandle Water Plan reported the firm yield at 69,700 acre-feet per year.

Since about year 2000, the water levels in Lake Meredith have declined and the ability to use water from Lake Meredith has greatly diminished. For the 2011 Panhandle Regional Water Plan, a special study was conducted to assess the potential factors that may be contributing to the reduced water levels (Freese, 2010). This study confirmed that the Lake Meredith watershed is losing its ability to generate runoff and stream flow to the Canadian River, but no one factor or event appeared to be the major contributor. The study reported that a combination of factors, including reduced rainfall intensities, increasing shrubland and declining groundwater levels, may have resulted in tipping the hydrologic balance of the watershed to the point that inflows to Lake Meredith (generated below Ute Reservoir) is now about 20 percent of inflows observed in the 1940s. While the activities in the watershed above the Logan gage (New Mexico) cannot be ignored with respect to the total amount of inflow to Lake Meredith, there are changes in the watershed below Ute Reservoir that have contributed to reduced stream flows.

To estimate the supply from Lake Meredith for the 2021 Plan, firm yield and safe yield analyses were conducted using the same reservoir model developed for the 2016 Plan. Input parameters for the model were compiled from several sources. Inflow and net evaporation data from 1940 to September 2004 came from the Canadian River Basin WAM updated for the 2006 Regional Plan (Canadian2000 WAM). The hydrology was extended to December 2017 based on CRMWA records. Estimated reservoir inflows from 2001 to 2013 averaged 35,000 ac-ft/yr and were substantially lower than the 1965 to 2000 average (120,000 ac-ft/yr), corresponding with declining reservoir storage and the recent critical drought (Figure 3-5). Inflows greater than 120,000 ac-ft/yr in 2015 and 2017 allowed the reservoir to partially recover. Assuming critical drought conditions do not recur, a meaningful yield analysis can be conducted for the reservoir. Based on the updated analyses, projections of conservation storage, firm yield and safe yield for Lake Meredith during the planning period are shown in Table 3-7.

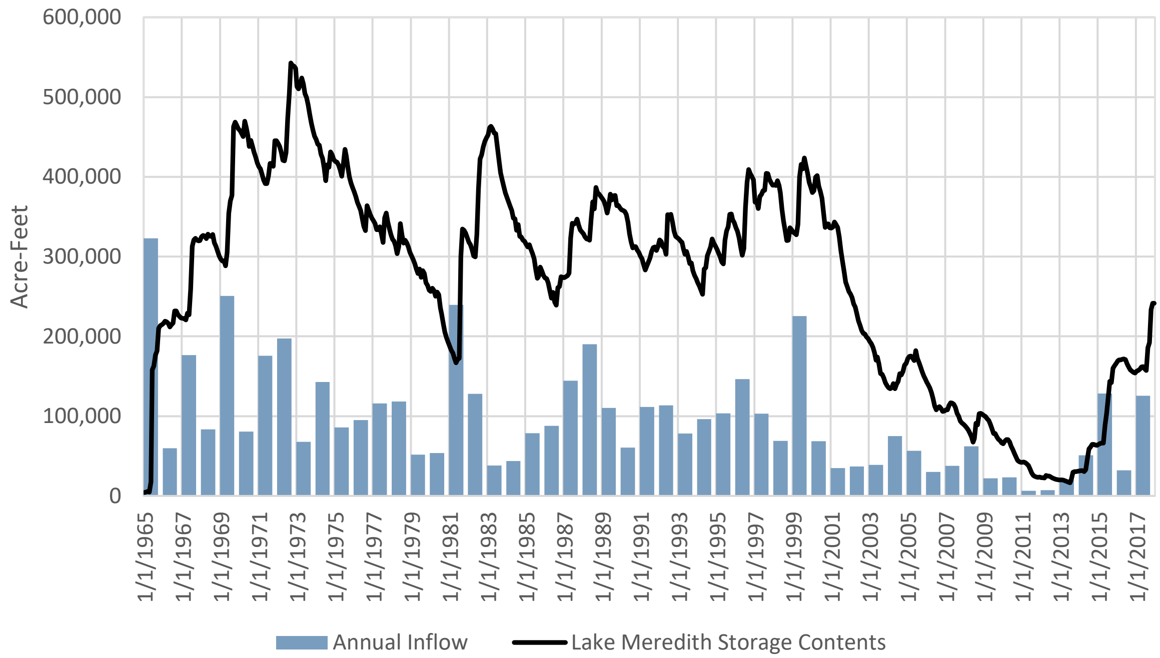


Figure 3-5: Annual Inflows and Historical Storage Contents for Lake Meredith (1965-2017)

Table 3-7: Projected Firm and Safe Yields of Lake Meredith

	2020	2030	2040	2050	2060	2070
Conservation Storage [1] (ac-ft)	500,000	500,000	500,000	500,000	500,000	500,000
Firm Yield (ac-ft/yr)	28,221	28,242	28,263	28,284	28,305	28,326
Safe Yield (ac-ft/yr)	24,669	24,635	24,602	24,568	24,534	24,501

[1] Limited by provisions of the Canadian River Compact

Palo Duro Reservoir

The Palo Duro River Authority owns and operates the Palo Duro Reservoir as a water supply for its six member cities of Cactus, Dumas, Sunray, Spearman, Gruver, and Stinnett. The reservoir is located on Palo Duro Creek in Hansford County, 12 miles north of Spearman. The original conservation storage capacity of the reservoir was estimated to be 60,897 acre-feet. The dam began impounding water in January 1991 but has never filled. Although the reservoir recovered somewhat in 2015, the minimum storage levels in 2017 and 2018 were even lower than the minimum in 2015, which was the lowest up to that point.

A study by Freese and Nichols (1974) estimated the yield to be approximately 8,700 acre-feet per year. The yield from Palo Duro Reservoir was assessed using a version of the WAM prepared for the 2006 Regional Plan. This version of the WAM considered a period of record from January 1940 to September 2004 and estimated a firm yield of about 4,000 ac-ft per year. On-going drought has likely reduced the firm yield further.

In all these studies inflows from January 1946 through September 1979 are based on flow measurement at the gage on Palo Duro Creek near Spearman. This gage was discontinued in September 1979 but was reactivated in June 1999 and currently is an active gage. The data of this gage is missing for much of the critical period of Palo Duro. Estimates of inflow have been made in several yield studies using correlation with other nearby gages or a mass balance approach. USGS gages in nearby watersheds are not well correlated with the Spearman gage, although they provide the best means of predicting reservoir inflows. The large scatter indicates a degree of uncertainty in estimated inflow to Palo Duro Reservoir during the critical period. Without a stronger correlation in inflows between the two gages, the yield for the reservoir is difficult to define.

Normally, a volumetric balance can be used to estimate inflows to existing reservoirs. However, the balance for Palo Duro shows large apparent losses from the reservoir. The apparent monthly net runoff (runoff less losses) is normally negative for the operation period from May 1991 to September 2004. The negative net runoff estimates mean that some outflow or losses have not been accounted for in the mass balance. There are some losses due to infiltration and leaking that are not being quantified. Large losses are not impossible when a reservoir is filling. To quantify these losses, an independent estimate of inflows is required.

The projected firm yield of Palo Duro Reservoir is expected to decrease from 3,917 acre-feet in 2020 to 3,708 acre-feet by 2070. Table 3-8 shows the projected yield and available supply from Palo Duro Reservoir during the planning period based on a linear interpolation of the most recent yield estimate. The lake does not provide water supply to users at this time due to the lack of a delivery system. Unless appropriate infrastructure is built to connect the supplies, the available supply from the lake will be zero.

Table 3-8: Projected Yield and Available Supply of Palo Duro Reservoir

	2020	2030	2040	2050	2060	2070
Conservation Capacity (ac-ft)	57,942	57,062	56,182	55,302	54,422	53,542
Firm Yield (ac-ft/yr)	3,917	3,875	3,833	3,792	3,750	3,708
Available Supply (ac-ft/yr)	0	0	0	0	0	0

Greenbelt Reservoir

Greenbelt Reservoir is owned and operated by the Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA), and is located on the Salt Fork of the Red River near the city of Clarendon. Construction of Greenbelt Reservoir was completed in March 1968 and impoundment of water began in December 1966 (Freese and Nichols, 1978). The original storage capacity of Greenbelt was 59,100 acre-feet at the spillway elevation of 2,663.65 feet (TWDB, 1974). The reservoir has never filled. Historical storage reached a high point in 1975 and has trended significantly downward since then.

Similar to Lake Meredith, Greenbelt Reservoir experienced declining water levels in response to the recent drought. A 2011 study by Freese and Nichols noted that the lake has historically relied on local springs for inflows, which has allowed the lake to recover following droughts. This is a critical component for the reliable supply for the reservoir. If the spring flow is impacted by drought or local groundwater use, the ability of Greenbelt Reservoir to recover from droughts may be impacted.

The hydrology for the TCEQ-approved Red River WAM has a period of record from 1948 to 1998, so it does not include the on-going drought (2010 to present). Analyses of the firm yield of Lake Greenbelt using the TCEQ-approved Red River WAM would overestimate its yield. To provide a more accurate yield estimate, a reservoir operation model was used with hydrology covering a period from 1940 to 2016. This set of inflows was used instead of the WAM hydrology to assess the firm and safe yields of the reservoir. A summary of the yield analyses is shown in Table 3-9.

Table 3-9: Projected Firm and Safe Yields of Greenbelt Reservoir

	2020	2030	2040	2050	2060	2070
Conservation Capacity (ac-ft)	48,628	46,606	44,584	42,562	40,540	38,518
Firm Yield (ac-ft/yr)	3,964	3,826	3,689	3,551	3,413	3,276
Safe Yield (ac-ft/yr)	3,112	2,941	2,769	2,598	2,427	2,256

3.1.5 Run of the River Supplies

According to the TCEQ water rights database there are 103 run-of-river water rights permit holders in the PWPA. Run of river supplies are diversions directly from a stream or river. In this Plan, reliable supply from a run-of-river right is defined as the minimum annual diversion from the TCEQ WAM simulation. Table 3-10 summarizes these rights by county in the PWPA. The permitted diversions total 7,226 acre-feet per year. There are no individual run of river diversions that are greater 1,000 acre-feet/year (note: aggregated diversions total more than 1,000 acre-feet per year for some counties). The reliable supply from these sources is 2,538 acre-feet per year. A complete list of the water rights is included in Appendix B.

Table 3-10: Total Run of the River Water Rights by County in the PWPA (ac-ft/yr)

County	Basin Name	Permitted Diversion	Reliable Supply
Carson	Red	335[1]	277
Childress	Red	38.5	19
Collingsworth	Red	1,194	851
Dallam	Canadian	190	0
Donley	Red	464	166
Gray	Canadian	4	1
Gray	Red	130	55
Hall	Red	101	52
Hansford	Canadian	530	22
Hartley	Canadian	0	0
Hemphill	Canadian	0	0
Hemphill	Red	0	0
Hutchinson	Canadian	356[2]	98
Lipscomb	Canadian	122	66
Moore	Canadian	345	7
Ochiltree	Canadian	0	0
Oldham	Canadian	30	0
Potter	Canadian	349	0
Randall	Red	1,074	217
Roberts	Canadian	640	72
Sherman	Canadian	275	32
Wheeler	Red	1,048	603
Total		**7,226**	**2,538**

[1] 110 ac-ft/yr authorized recapture of produced groundwater is not included.
[2] 290 ac-ft/yr that may be diverted for non-consumptive uses is not included.

3.1.6 Other Potential Surface Water Sources

Nine minor reservoirs in the PWPA have been identified as other potential sources of surface water. These include Lake McClellan, Buffalo Lake, Lake Tanglewood, Rita Blanca Lake, Lake Marvin, Baylor Lake, Lake Childress, Lake Fryer, and Bivins Lake. The historical or current supply of these water bodies has not been quantified through yield studies. The following paragraphs discuss the available information about each of these water bodies. Table 3-11 summarizes descriptive information about each of the minor reservoirs.

Lake McClellan

Lake McClellan is located in the Red River Basin and is also known as McClellan Creek Lake. It was constructed on McClellan Creek twenty-five miles south of Pampa in southern Gray County. It was built in the late 1940's by the Panhandle Water Conservation Authority, primarily for soil conservation, flood control, recreation, and promotion of wildlife. The U.S. Forest Service has a recreational water right associated with McClellan Creek National Grassland (TCEQ, 2009). Lake McClellan has a capacity of 5,005 acre-feet (Breeding, 1999).

Buffalo Lake

Buffalo Lake is a reservoir impounded by Umbarger Dam, three miles south of the city of Umbarger on upper Tierra Blanca Creek in western Randall County. The reservoir is in the Red River basin. The original dam was built in 1938 by the Federal Farm Securities Administration to store water for recreational purposes. The lake's drainage area is 2,075 square miles, of which 1,500 square miles are probably noncontributing. Buffalo Lake has a water right for storage of 14,363 acre-feet, with no diversion rights. In 1982 and 1992, the low water dam was reworked to become a flood control structure. Several species of waterfowl use the lake as a winter refuge (Breeding, 1999).

Lake Tanglewood

Lake Tanglewood is located in the Red River Basin and is formed by an impoundment constructed in the early 1960's on Palo Duro Creek in northeastern Randall County. Lake Tanglewood, Inc., a small residential development is located along the lake shore (Breeding, 1999). Lake Tanglewood has a water right for storage of 4,897 acre-feet with a diversion right of 90 acre-feet per year for irrigation purposes (TCEQ, 2009). The lake is also used for recreational purposes.

Rita Blanca Lake

Rita Blanca Lake is on Rita Blanca Creek, a tributary of the Canadian River, in the Canadian River basin three miles south of Dalhart in Hartley County. The Rita Blanca Lake project was started in 1938 by the WPA in association with the Panhandle Water Conservation Authority. In June 1951, Dalhart obtained a ninety-nine-year lease for the operation of the project as a recreational facility without any right of diversion (Breeding, 1999). The lake is currently owned by the Texas Parks and Wildlife Department and is operated and managed jointly by Hartley and Dallam county commissioners for recreational purposes. The two counties have joint recreational water rights. The lake has a capacity of 12,100 acre-feet and a surface area of 524 acres at an elevation of 3,860 feet above mean sea level. The drainage area above the dam is 1,062 square miles. The City of Dalhart discharges treated domestic wastewater to Rita Blanca Lake.

Lake Marvin

Lake Marvin, also known as Boggy Creek Lake, was constructed in the 1930s on Boggy Creek, in east central Hemphill County by the Panhandle Water Conservation Authority. The lake is in the Canadian River basin and was constructed for soil conservation, flood control, recreation, and promotion of wildlife (Breeding, 1999). The reservoir has a capacity of 553 acre-feet and is surrounded by the Panhandle National Grassland. The USFS has a water right for recreational use of Marvin Lake (TCEQ, 2009).

Table 3-11: Descriptive Information of Minor Reservoirs in the PWPA

Reservoir	Stream	River Basin	Use	Water Rights	Date of Impoundment	Capacity* (ac ft)
Lake McClellan	McClellan Creek	Red	soil conservation, flood control, recreation, promotion of wildlife	U.S. Forest Service (recreational)	1940s	5,005
Buffalo Lake	Tierra Blanca Creek	Red	flood control, promotion of wildlife	N/A	1938	18,121
Lake Tanglewood	Palo Duro Creek	Red	recreation, irrigation	Lake Tanglewood, Inc.	1960s	4,897
Rita Blanca Lake	Rita Blanca Creek	Canadian	recreation	Dallam & Hartley Counties (recreational)	1941	5,500
Lake Marvin	Boggy Creek	Canadian	soil conservation, flood control, recreation, promotion of wildlife	U.S. Forest Service (recreational)	1930s	553
Baylor Lake	Baylor Creek	Red	recreation	City of Childress (397 ac-ft/yr)	1949	7,820
Lake Childress	unnamed tributary to Baylor Creek	Red	N/A	N/A	1923	4,725
Lake Fryer	Wolf Creek	Canadian	soil conservation, flood control, recreation	N/A	1938	862
Bivins Lake	Palo Duro Creek	Red	ground water recharge	N/A	1926	5,122

Source: Breeding, 1999
*Permitted capacity (TCEQ, 2014)
N/A – data are not available

Baylor Lake

Baylor Lake is on Baylor Creek in the Red River Basin, ten miles northwest of Childress in western Childress County. The reservoir is owned and operated by the city of Childress. Although the City has water rights to divert up to 397 acre-feet per year from the reservoir (TCEQ, 2009), there is currently no infrastructure to divert water for municipal use. Construction of the earth fill dam was started on April 1, 1949 and completed in February 1950. Deliberate impoundment of water was begun in December 1949. Baylor Lake has a capacity of 9,220 acre-feet and a surface area of 610 acres at the operating elevation of 2,010 feet above mean sea level. The drainage area above the dam is forty square miles. (Breeding, 1999).

Lake Childress

Lake Childress is eight miles northwest of Childress in Childress County. This reservoir, built in 1923 on a tributary of Baylor Creek, in the Red River Basin, adjacent to Baylor Lake. In 1964 it was still part of the City of Childress' water supply system, as was the smaller Williams Reservoir to the southeast (Breeding, 1999). It is no longer used for water supply. The reservoir is permitted to store 4,725 acre-feet for recreational purposes (TCEQ, 2009).

Lake Fryer

Lake Fryer, originally known as Wolf Creek Lake, was formed by the construction of an earthen dam on Wolf Creek, in the Canadian River Basin, in eastern Ochiltree County. After the county purchased the site, construction on the dam was begun in 1938 by the Panhandle Water Conservation Authority. The dam was completed by the late summer of 1940. During the next few years Wolf Creek Lake was used primarily for soil conservation, flood control, and recreation. In 1947, a flash flood washed away the dam, but it was rebuilt in 1957. During the 1980s the lake and the surrounding park were owned and operated by Ochiltree County and included a Girl Scout camp and other recreational facilities (Breeding, 1999).

Bivens Lake

Bivens Lake, also known as Amarillo City Lake, is a reservoir formed by a dam on Palo Duro Creek, in the Red River Basin, ten miles southwest of Amarillo in western Randall County. It is owned and operated by the city of Amarillo to recharge the groundwater reservoir that supplies the City's well field. The project was started in 1926 and completed a year later. It has a capacity of 5,120 acre-feet and a surface area of 379 acres at the spillway crest elevation of 3,634.7 feet above mean sea level. Water is not diverted directly from the lake, but the water in storage recharges, by infiltration, a series of ten wells that are pumped for the City supply. Because runoff is insufficient to keep the lake full, on several occasions there has been no storage. The drainage area above the dam measures 982 square miles, of which 920 square miles are probably noncontributing (Breeding, 1999).

Playa Lakes

The most visible and abundant wetlands features within the PWPA are playa lakes. These are ephemeral wetlands which are an important element of surface hydrology and ecological diversity. Most playa lakes are seasonally flooded basins, receiving their water only from rainfall or snowmelt. Moisture loss occurs by evaporation and infiltration through the soil to underlying aquifers. In some years there is little to no water in the playa lakes of the PWPA.

Wetlands are especially valued because of the wide variety of functions they perform, and the uniqueness of their plant and animal communities. Ecologically, wetlands can provide high quality habitat in the form of foraging and nesting areas for wildlife and spawning and nursery habitat for fish. Approximately 5,450 playa lakes are located in the PWPA, covering approximately one percent of the surface area (NRCS, 2009). Playa lakes have a variety of sizes that influence the rapidity of runoff and rates of water collection. Playa lakes have relatively flat bottoms, resulting in a relatively uniform water depth, and are generally circular to oval in shape. Typically, the soil in the playa lakes is the Randall Clay.

Playa lakes also supply important habitat for resident wildlife. The lakes provide sites with a moderate amount of moisture in a semi-arid region and therefore are likely to support a richer, denser vegetative cover than surrounding areas. Moreover, the perpetual flooding and drying of the lakes promotes the growth of plants such as smartweeds, barnyard grass, and cattails that provide both food and cover. The concentric zonation of plant species and communities in response to varying moisture levels in lake soils enhances interspersion of habitat types. Playa lakes offer the most significant wetland habitats in the southern quarter of the Central Flyway (a bird migration route that generally follows the Great Plains in the U.S.) for migrating and wintering birds. Up to two million ducks and hundreds of thousands of geese take winter refuge here. Shorebirds, wading birds, game birds, hawks and owls, and a variety of mammals also find shelter and sustenance in playas. Table 3-12 shows the estimated acreage and water storage for playa lakes in the PWPA.

3.1.7 Reuse Supplies

Direct reuse is used in the PWPA for irrigation and industrial water uses. Currently, the largest producer of treated effluent for reuse is the city of Amarillo. Most of the city's wastewater is sold to Xcel Energy for steam electric power use. The city of Borger also sells a portion of its wastewater effluent for manufacturing and industrial use. Most of the other reuse in the PWPA is used for irrigation. A summary of the estimated direct reuse in the PWPA is shown in Table 3-13. Values are based on historical use amounts or contract amounts. For Amarillo, the direct reuse is estimated at 40 percent of Amarillo's municipal demand and Potter County manufacturing demands on Amarillo. There are no permitted indirect reuse projects in the PWPA.

Table 3-12: Acreage and Estimated Maximum Storage of Playa Lakes in the PWPA

County	Estimated Area[1] (acres)	Estimated Maximum Storage[2] (acre feet)
Armstrong	15,356	46,069
Carson	15,074	45,223
Childress	116	347
Collingsworth	0	0
Dallam	4,471	13,413
Donley	1,978	5,933
Gray	13,529	40,588
Hall	0	0
Hansford	7,483	22,449
Hartley	4,281	12,842
Hemphill	102	306
Hutchinson	3,129	9,388
Lipscomb	225	675
Moore	5,036	15,109
Ochiltree	16,263	48,788
Oldham	4,249	12,746
Potter	3,472	10,417
Randall	13,373	40,118
Roberts	1,350	4,051
Sherman	4,202	12,607
Wheeler	0	0
Total	**113,689**	**341,069**

[1] Playa Lakes Joint Venture, 2015

[2] Fish, et. al., 1997 (Based on average depth of 3 feet)

Table 3-13: Direct Reuse in the PWPA (ac-ft/yr)

County	2020	2030	2040	2050	2060	2070
Armstrong	0	0	0	0	0	0
Carson	58	59	59	58	58	58
Childress	162	166	169	172	177	181
Collingsworth	52	54	55	57	58	60
Dallam	0	0	0	0	0	0
Donley	0	0	0	0	0	0
Gray	220	220	220	220	220	220
Hall	100	100	100	100	100	100
Hansford	0	0	0	0	0	0
Hartley	0	0	0	0	0	0
Hemphill	0	0	0	0	0	0
Hutchinson	1,100	1,100	1,100	1,100	1,100	1,100
Lipscomb	0	0	0	0	0	0
Ochiltree	0	0	0	0	0	0
Oldham	0	0	0	0	0	0
Potter	26,192	28,244	30,192	32,284	34,677	37,208
Randall	545	597	651	710	777	846
Roberts	0	0	0	0	0	0
Sherman	0	0	0	0	0	0
Wheeler	49	51	52	53	55	57
Total	**28,478**	**30,591**	**32,598**	**34,754**	**37,222**	**39,830**

3.1.8 Local Supplies

Local supplies are those surface water supplies that cannot be quantified from the WAM models. These include water sources that do not require a State water right permit, such as local stock ponds for livestock use. The amounts of available supplies for these uses are based on data collected by the TWDB on historical water use. Reliability of these supplies are predicated on the continuity of use. For planning purposes, the values represent 20 percent above the maximum historical reported use from 2006 to 2011. A summary of the local supplies by county is shown in Table 3-14.

3.1.9 Summary of Water Supplies in the PWPA

The available water supplies in the PWPA total over 3.9 million acre-feet per year in 2020, decreasing to 2.7 million acre-feet per year by 2070 (Table 3-15). Most of this supply is associated with groundwater, primarily the Ogallala aquifer. Surface water supplies are an important component of the available supply to counties where groundwater is limited. However, if the reliability of surface water supplies decreases due to on-going droughts, the reliance on groundwater will increase.

Table 3-14: Summary of Local Supplies in the PWPA (ac-ft/yr)

	Livestock Local Supply					
County	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Armstrong	122	122	122	122	122	122
Carson	134	134	134	134	134	134
Childress	49	49	49	49	49	49
Collingsworth	29	29	29	29	29	29
Dallam	2,488	2,488	2,488	2,488	2,488	2,488
Donley	283	283	283	283	283	283
Gray	799	799	799	799	799	799
Hall	91	91	91	91	91	91
Hansford	2,617	2,617	2,617	2,617	2,617	2,617
Hartley	3,193	3,193	3,193	3,193	3,193	3,193
Hemphill	421	421	421	421	421	421
Hutchinson	281	281	281	281	281	281
Lipscomb	110	110	110	110	110	110
Moore	1,000	1,000	1,000	1,000	1,000	1,000
Ochiltree	421	421	421	421	421	421
Oldham	835	835	835	835	835	835
Potter	562	562	562	562	562	562
Randall	1,312	1,312	1,312	1,312	1,312	1,312
Roberts	139	139	139	139	139	139
Sherman	1,052	1,052	1,052	1,052	1,052	1,052
Wheeler	845	845	845	845	845	845
Total	**16,783**	**16,783**	**16,783**	**16,783**	**16,783**	**16,783**

The supplies shown in Table 3-15 and Figure 3-6 represent the amount of water supply that is located in the PWPA and includes supplies that are currently developed and potential future supplies that could be developed. For reservoirs, the supply used for planning purposes is shown. For groundwater, the availabilities adopted by the PWPG are shown (MAGs for major and minor aquifers and adopted supplies for Other and Non-Relevant Aquifers). These values do not consider infrastructure constraints, contractual agreements, or the economic feasibility of developing these sources. They also do not consider the ultimate location of use (e.g., exports to Regions O and B). These values are reported by source location, which is the PWPA. In some counties the available groundwater supplies are significantly greater than the historical use. In other counties, current groundwater use exceeds the available supply. Consideration of the amount of water that is currently developed and available to water users in the PWPA is discussed in Section 3.2.

Table 3-15: Summary of Available Water Supplies in the PWPA (ac-ft/yr)

Lake Meredith (safe yield)	24,669	24,635	24,602	24,568	24,534	24,501
Greenbelt Lake (safe yield)	3,112	2,941	2,770	2,599	2,428	2,256
Palo Duro Reservoir*	3,917	3,875	3,833	3,792	3,750	3,708
Canadian Run-of-River	298	298	298	298	298	298
Red Run-of-River	2,240	2,240	2,240	2,240	2,240	2,240
Ogallala & Rita Blanca Aquifers	3,553,323	3,240,141	2,930,987	2,606,560	2,293,573	2,293,573
Seymour Aquifer	59,752	51,489	51,640	53,334	51,573	50,661
Blaine Aquifer	33,241	33,154	33,241	33,154	33,241	33,154
Dockum Aquifer	261,079	265,547	256,307	244,788	232,128	232,128
Other Aquifer	2,753	2,753	2,753	2,753	2,753	2,753
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	28,478	30,591	32,598	34,754	37,222	39,830

*No current infrastructure

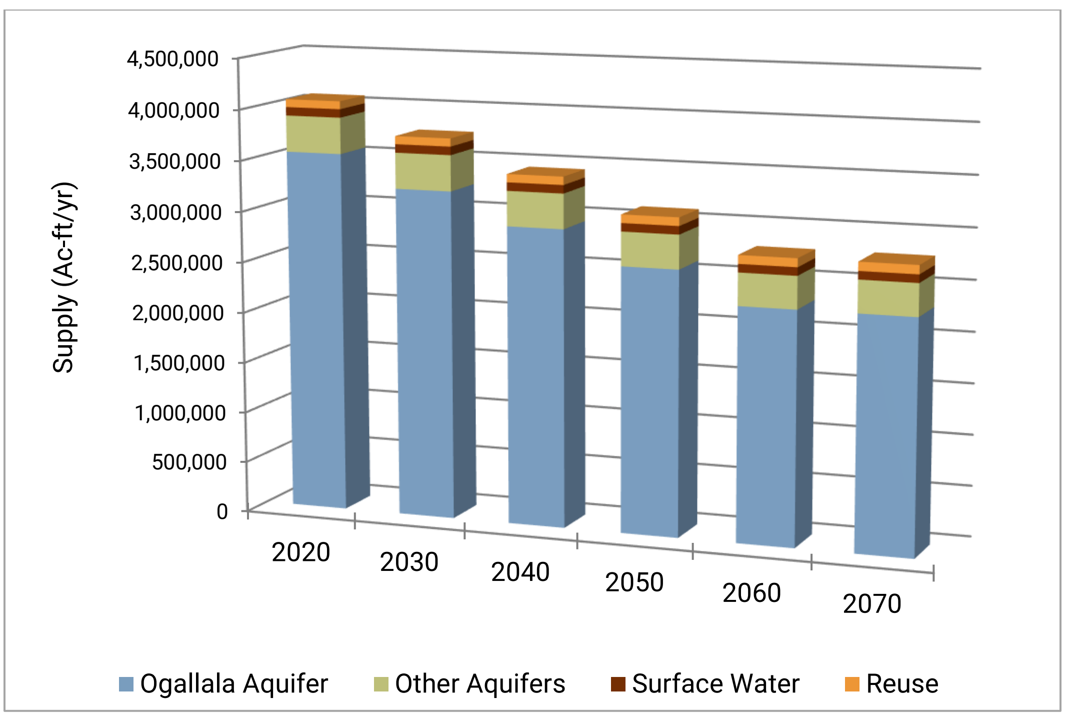


Figure 3-6: Summary of Available Supplies in PWPA

3.2 Currently Developed Supplies to Water User Groups

As part of the regional water planning process, water supplies are allocated to water user groups based on the most limiting factor to deliver or use the water. These limitations may include the availability of the water source (such as firm yield of a reservoir or the adopted aquifer storage depletion restriction), well field capacity, water rights permits, contractual agreements, delivery infrastructure constraints, and water treatment capacities where appropriate.

Appropriate constraints were identified for each of the PWPA water user groups. Agricultural water use considered locations of irrigable acreages and historical use data provided by the TWDB and local groundwater conservation districts (GCDs). For some counties irrigable acres are limited in extent across the county. Most of the crops in the PWPA are irrigated with groundwater. Allocations to other water user groups considered sales from wholesale water providers and historical water use as reported by the TWDB.

The allocation of water supplies also considers the source of water, the location of the water, and current imports and exports of water in the region. All water supplies from aquifers stated in this plan comply with the adopted MAG values or developed supplies for “Other aquifer”.

It should be noted that in some cases, local GCD rules may be more restrictive in certain areas as permitting requirements based on geographic extent may limit withdrawals beyond the availability shown in this plan.

3.2.1 Allocation of Ogallala Supplies to Water Users

In the PWPA the Ogallala aquifer provides most of the water in the region and some water to users outside of the region. Considering the demands on this resource and the available supply determined for regional water planning, the demands exceed the supply in several counties in some decades. Table 3-16 shows the projected demand on the Ogallala aquifer by county if there were no restrictions to supplies. As shown on this table the total demands on the Ogallala in 2020 exceed 1.8 million acre-feet.

Figure 3-7 shows the Northern Ogallala saturated thickness from the GAM run that was used to develop the MAGs at the beginning and end of the predictive simulations (years 2020 and 2060). In 2020 most of the aquifer within Northern Ogallala GAM in Texas has a finite saturated thickness. By 2060, in conformance with the desired future conditions, there is a significant reduction of the aquifer saturated thickness in many PWPA counties, including Dallam, Hartley, Moore and Sherman Counties. The relatively thin saturated thickness in the heavily used portions of the aquifer in the future may result in these regions not being able to support current rates of irrigation pumping.

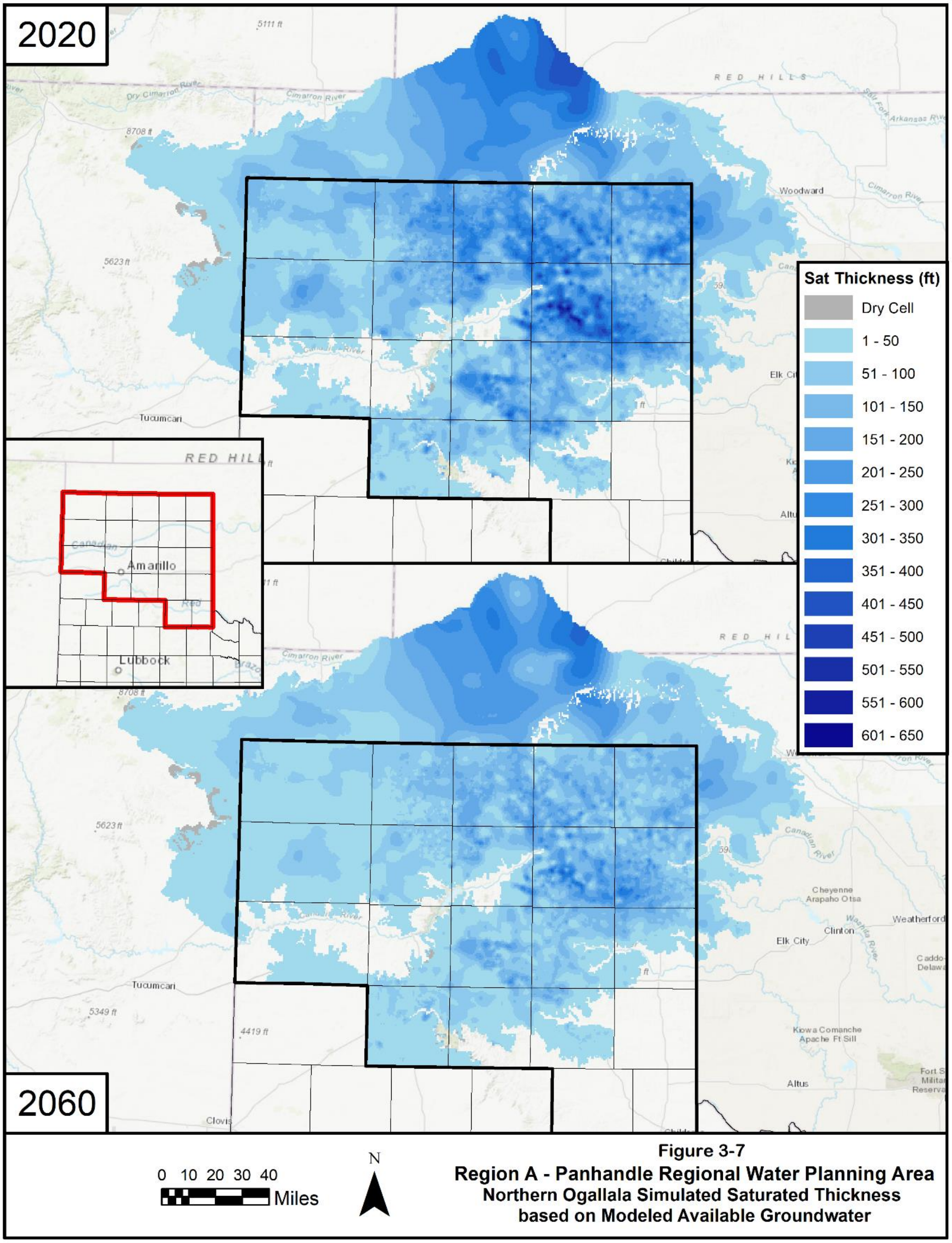


Figure 3-7: Ogallala Simulated Saturated Thickness Based on Modeled Available Groundwater

Table 3-16: Projected Total Production from the Ogallala Aquifer within PWPA (ac-ft/yr)

Source County	2020	2030	2040	2050	2060	2070
Armstrong	7,092	7,162	7,107	7,063	7,034	7,054
Carson	103,917	102,367	100,756	99,389	98,236	98,213
Dallam	306,984	220,001	171,481	129,141	92,620	92,956
Donley	32,826	32,761	32,695	32,646	32,542	32,481
Gray	36,763	36,780	36,615	36,552	33,618	33,819
Hansford	175,559	176,059	175,775	175,388	175,002	175,199
Hartley	319,348	212,476	166,379	123,316	84,317	85,037
Hemphill	9,822	9,396	8,992	8,609	8,223	8,188
Hutchinson	90,509	91,214	90,627	90,150	89,747	89,762
Lipscomb	44,128	43,709	43,332	42,968	42,809	42,829
Moore	206,598	167,286	136,815	104,467	75,446	76,150
Ochiltree	91,529	91,558	91,210	90,968	90,909	91,106
Oldham	5,385	5,473	5,549	5,581	5,647	5,718
Potter	10,264	8,788	9,121	9,350	9,635	10,139
Randall	25,190	25,044	24,975	25,041	25,264	25,646
Roberts	44,095	43,790	41,371	37,377	34,481	34,481
Sherman	307,977	308,401	278,824	212,117	148,539	148,539
Wheeler	21,586	20,598	19,601	18,603	18,174	18,154
Total	**1,839,572**	**1,602,863**	**1,441,225**	**1,248,726**	**1,072,243**	**1,075,471**

Note: The demands on the Ogallala aquifer shown above represent the allocated supplies from the Ogallala aquifer based on Source County.

The HPAS GAM was used to assist with the allocation of Ogallala water to irrigation and municipal users. Model grid cells were assigned to a specific user group using data provided by the GCDs, TCEQ, TWDB and Texas A&M AgriLife Research and Extension Center at Amarillo (Texas A&M Agrilife) as shown on Figure 3-8. A one grid cell buffer zone was applied to all irrigation areas and larger municipal well fields that were not surrounded by competing users. The availabilities were estimated based on the summation of the pumpage for the associated grid cells. For irrigation water users, the lesser of the demands or the availabilities were assigned to the irrigation WUG. Three counties were shown to have irrigation demands greater than the estimated water availability. These include Dallam, Hartley, and Moore Counties. The original model grid designations were performed on the old Northern Ogallala GAM and were transposed onto the new HPAS GAM. While the transfer between the models was relatively smooth, the HPAS GAM has a smaller cell size and has a slightly different rotation. This means that there was not a 1 to 1 transfer between the previous model designations and the new model. However, the majority of the cells do line up with the previous cell designations.

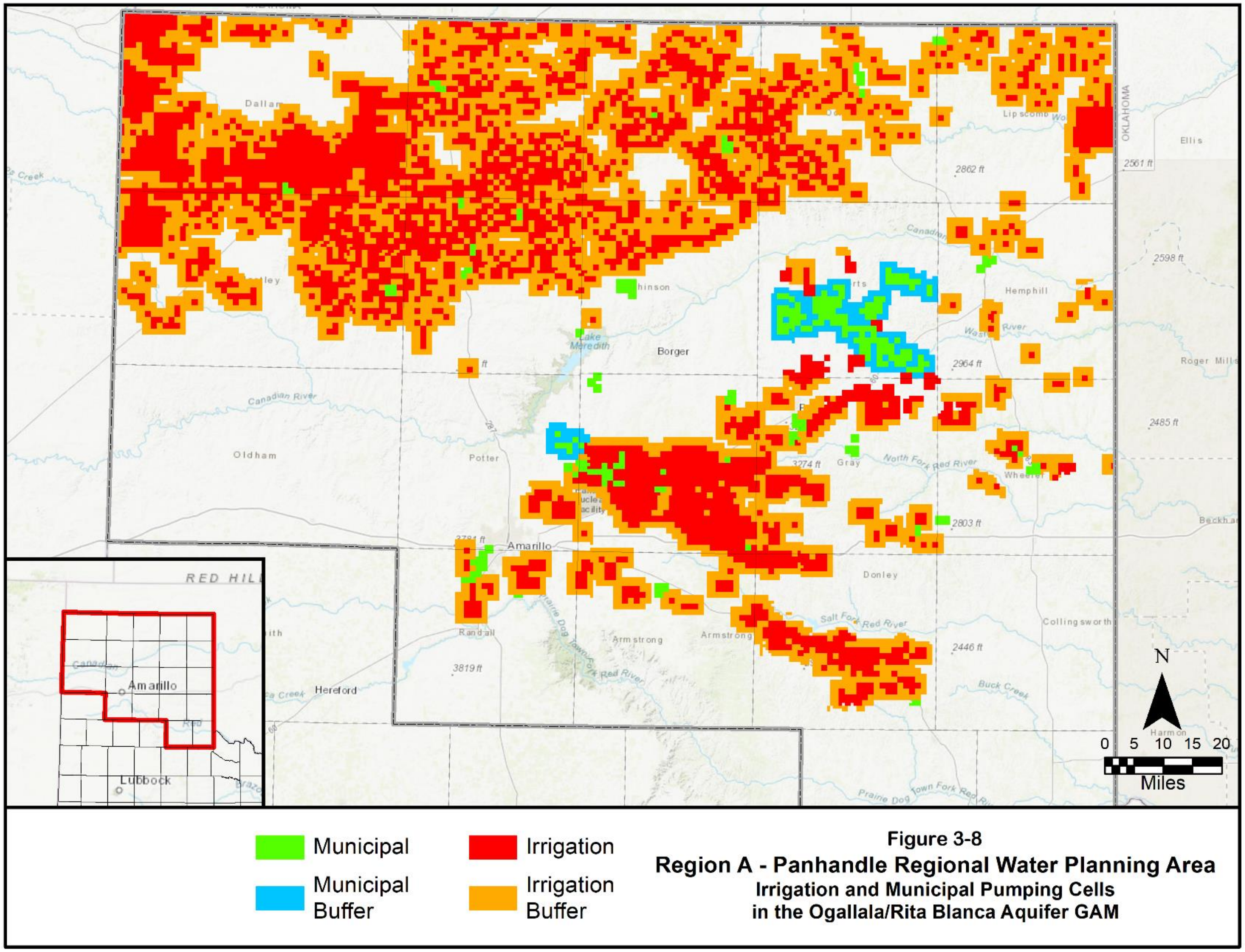


Figure 3-8: Irrigation and Municipal Pumping Cells in Ogallala Aquifer

The allocation of Ogallala water to municipal water users considered several factors, including the availabilities determined using the Ogallala GAM, production capacities and information received from the water user. Allocations to other users (manufacturing, livestock and mining) were generally not constrained if there was sufficient supply in the county. Water supplies to manufacturing users that receive supply from a wholesale water provider were limited if the wholesale water provider did not have sufficient supplies.

3.2.2 Major Water Provider Supplies and Allocation to Users

As part of the water allocation process, water developed by major water providers is distributed to its customers, which are then assigned to the appropriate water user group. Generally, if the major provider has sufficient supplies to meet its contractual demands, the amount of the contracted water supply was allocated to the customer. If the total demand on the major provider exceeded its developed supplies, then the supplies were reduced proportionally to all customers. This reduction in supply was applied to each of the major provider's sources as appropriate. Table 3-17 shows the water supplies available to major water providers in the PWPA.

3.2.3 Imports and Exports

A small amount of water is imported from Deaf Smith County to the PWPA from a well field owned by Amarillo and a well field owned by the City of Vega. The town of Happy imports a small amount of water from the Dockum Aquifer in Swisher County. No other water is currently imported from outside of the PWPA to the region.

There are several exports of water to users in adjoining regions that are associated with sales from CRMWA and Greenbelt MIWA. CRMWA provides water to eleven cities, of which eight are located in the Llano Estacado RWPA (Region O). Water from Lake Meredith, when available, and CRMWA's Roberts County well field are exported to CRMWA's member and customer cities in the Llano Estacado RWPA. The Greenbelt MIWA owns and operates Greenbelt Reservoir. It also operates several wells in the Ogallala aquifer in Donley County. Water from these sources are exported to three cities and the Red River Authority in Region B. Approximately 42,000 acre-feet per year of water may be exported from the PWPA. With the development of additional supplies by CRMWA, this is expected to increase. Table 3-18 shows the amount of existing supplies that are projected to be imported and exported from the region.

Table 3-17: Summary of Water Supplies to Major Water Providers

Major Provider	Source	Supply (ac ft/yr) 2020	2030	2040	2050	2060	2070
Amarillo	Direct Reuse	21,992	24,044	25,992	28,084	30,477	33,008
	Ogallala - Randall County	1,689	1,304	985	763	641	641
	Ogallala - Potter County	5,188	3,295	3,201	3,071	2,895	2,895
	Ogallala - Carson County	12,300	11,260	9,826	8,490	7,384	7,384
	Ogallala - Deaf Smith	100	100	100	100	50	0
	CRMWA[1]	39,300	39,270	36,907	33,154	30,614	30,566
	Total	**80,569**	**79,273**	**77,011**	**73,662**	**72,061**	**74,494**
CRMWA	Lake Meredith	24,669	24,635	24,602	24,568	24,534	24,501
	Ogallala - Roberts County	65,000	65,000	60,674	55,476	49,833	49,833
	Total	**89,669**	**89,635**	**85,276**	**80,044**	**74,367**	**74,334**
Borger	Ogallala - Hutchinson County	6,499	5,841	5,456	5,149	4,890	4,890
	Ogallala - Carson County	800	719	672	634	602	602
	Direct Reuse	1,100	1,100	1,100	1,100	1,100	1,100
	CRMWA[1]	5,558	5,423	5,220	4,686	4,325	4,318
	Total	**13,957**	**13,083**	**12,448**	**11,569**	**10,917**	**10,910**
Cactus	Ogallala - Moore County	2,918	2,122	1,572	1,071	769	769
Greenbelt MIWA	Ogallala - Donley County	1,900	1,615	1,373	1,167	992	843
	Greenbelt Reservoir	3,112	2,941	2,770	2,599	2,428	2,256
	Total	**5,012**	**4,556**	**4,143**	**3,766**	**3,420**	**3,099**

[1] The amount CRMWA sells to other Major Water Providers is included in the supplies reported for CRMWA.

Table 3-18: Summary of Exports and Imports with other Regions (ac-ft/yr)

Source	2020	2030	2040	2050	2060	2070
Exports:						
Lake Meredith	11,188	11,230	11,767	12,142	12,072	12,061
Greenbelt Reservoir	869	895	921	799	748	686
Ogallala (Donley County)	530	492	458	358	306	257
Ogallala (Roberts County)	29,479	29,628	29,022	27,417	24,522	24,528
Total	**42,066**	**42,245**	**42,168**	**40,716**	**37,648**	**37,532**
Imports:						
Ogallala (Deaf Smith County)	300	300	300	300	250	200
Ogallala (Swisher County)	10	10	12	12	12	14
Total	**310**	**310**	**312**	**312**	**262**	**214**

Within the PWPA there are numerous transfers of water between counties. Most of these transfers are associated with municipal well fields that are located in one county and used in another county. Table 3-19 shows the county locations of the imports and exports of water within the PWPA. Transfers of water from reservoirs are not considered in this table.

Table 3-19: Summary of Groundwater Exports and Imports within the PWPA (ac-ft/yr)

Export	Import	2020	2030	2040	2050	2060	2070
Carson	Hutchinson	1,392	1,317	1,263	1,223	1,190	1,190
	Moore	5	5	5	5	5	5
	Potter	6,788	6,198	5,408	4,668	4,060	4,062
	Randall	5,512	5,062	4,418	3,822	3,324	3,322
Dallam	Hartley	675	492	367	256	163	155
Donley	Childress	704	671	637	610	531	456
	Collingsworth	6	6	5	5	4	4
	Hall	411	368	321	276	232	226
Hartley	Moore	2,324	1,865	1,610	1,251	853	853
Lipscomb	Ochiltree	9	9	12	12	13	16
Potter	Randall	1,338	709	842	907	922	949
Roberts	Gray	1,666	1,803	1,679	1,833	1,899	1,918
	Hutchinson	3,829	3,829	3,714	3,248	2,898	2,895
	Potter	16,744	16,760	15,588	13,558	12,273	12,190
	Randall	11,284	11,269	10,671	9,420	8,241	8,302

3.2.4 Summary of Developed Supplies to Water User Groups

The currently developed supply in the PWPA consists mainly of groundwater, 97 percent of total supply, with small amounts of surface water from in-region reservoirs, local supplies and wastewater reuse. The Ogallala is the largest source of water in the PWPA, accounting for nearly 92 percent of the total supply in year 2020.

The total volume of the developed supply for water users in the PWPA in year 2020 is approximately 2,000,000 acre-feet per year and projected to decrease to 1,600,000 by the year 2040 and ultimately to 1,230,000 acre-feet per year in 2070. These supply volumes are shown in Table 3-20.

The developed supply is nearly half of the total available supply that could be developed. The amount of water that is not currently allocated to a water user is available for water management strategies or future water needs. A summary of the unallocated water supplies is presented in Table 3-21 by source and shown by county in Table 3-22 and Figure 3-9.

Table 3-20: Developed Water Supplies to Water User Groups in PWPA (ac-ft/yr)

Source	2020	2030	2040	2050	2060	2070
Lake Meredith[1]	13,480	13,405	12,835	12,426	12,462	12,439
Greenbelt Lake[1]	1,531	1,610	1,684	1,764	1,680	1,570
Palo Duro Reservoir[2]	0	0	0	0	0	0
Canadian River Run-of-River	298	298	298	298	298	298
Red River Run-of-River	2,240	2,240	2,240	2,240	2,240	2,240
Total Surface Water	**17,549**	**17,553**	**17,057**	**16,728**	**16,680**	**16,547**
Ogallala Aquifer[1]	1,839,872	1,603,163	1,441,525	1,249,026	1,072,493	1,075,671
Seymour Aquifer	53,932	47,086	48,032	49,427	47,534	46,956
Blaine Aquifer	15,950	16,051	16,068	16,096	16,141	16,199
Dockum Aquifer	28,640	27,808	27,444	27,362	27,463	27,393
Other Aquifer	2,317	2,317	2,317	2,317	2,317	2,317
Total Groundwater	**1,940,711**	**1,696,425**	**1,535,386**	**1,344,228**	**1,165,948**	**1,168,536**
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	25,040	25,101	25,160	25,224	25,299	25,376
Total Other Supplies	**41,823**	**41,884**	**41,943**	**42,007**	**42,082**	**42,159**
Total Supply	**2,000,083**	**1,755,862**	**1,594,386**	**1,402,963**	**1,224,710**	**1,227,242**

[1] Quantity of water allocated to PWPA users only. Supplies from these sources are also used in other regions. Supplies in excess of the allocations are assigned to the MWP and are not reported in this table.
[2] There is no currently available supply from Palo Duro Reservoir because there is no infrastructure.

Table 3-21: Unallocated Water Supplies in PWPA (ac-ft/yr)

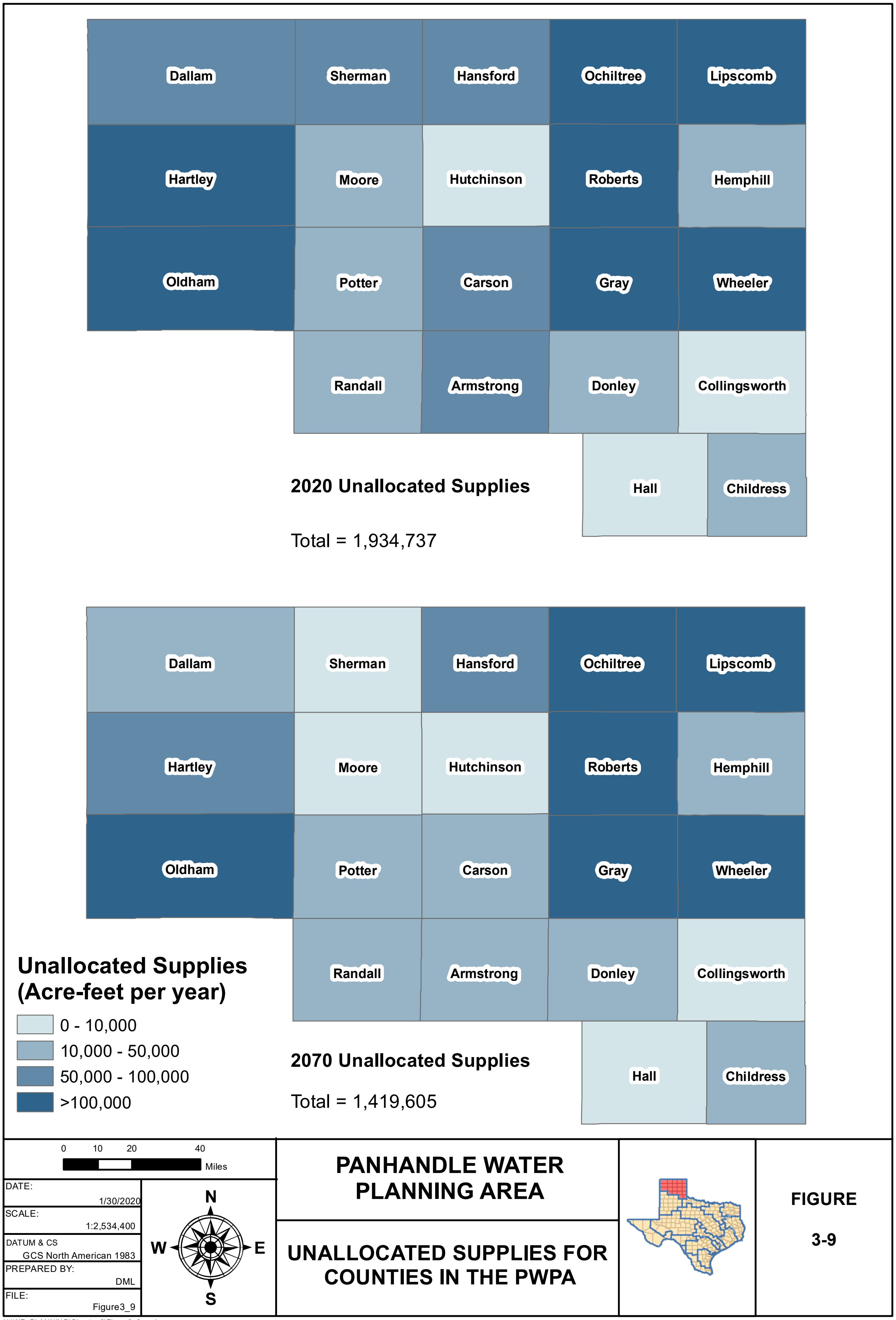
Source	2020	2030	2040	2050	2060	2070
Lake Meredith	0	0	0	0	0	0
Greenbelt Lake[1]	712	436	165	36	0	0
Palo Duro Reservoir[1]	3,917	3,875	3,833	3,792	3,750	3,708
Canadian River Run-of-River	0	0	0	0	0	0
Red River Run-of-River	0	0	0	0	0	0
Total Surface Water	**4,629**	**4,311**	**3,998**	**3,828**	**3,750**	**3,708**
Ogallala Aquifer	1,680,158	1,604,971	1,460,198	1,330,038	1,196,497	1,193,312
Seymour Aquifer	5,820	4,403	3,608	3,907	4,039	3,705
Blaine Aquifer	17,291	17,103	17,173	17,058	17,100	16,955
Dockum Aquifer	232,449	237,750	228,875	217,439	204,679	204,751
Other Aquifer	436	436	436	436	436	436
Total Groundwater	**1,936,154**	**1,864,663**	**1,710,290**	**1,568,878**	**1,422,751**	**1,419,159**
Local Supply	0	0	0	0	0	0
Direct Reuse	0	0	0	0	0	0
Total Other Supplies	**0**	**0**	**0**	**0**	**0**	**0**
Total Unallocated Supply	**1,940,783**	**1,868,974**	**1,714,288**	**1,572,706**	**1,426,501**	**1,422,867**

[1] The amounts shown are actually fully allocated to the respective water Authorities, but there is an unused surplus.

Table 3-22: Unallocated Water Supplies in PWPA by County (ac-ft/yr)

County	2020	2030	2040	2050	2060	2070
Armstrong	59,675	56,570	51,742	47,031	42,159	42,139
Carson	88,286	82,004	69,315	54,547	39,177	39,200
Childress	12,239	12,386	12,522	12,438	12,492	12,386
Collingsworth	3,365	1,629	752	1,036	1,148	812
Dallam	82,856	69,493	56,420	40,150	22,760	22,424
Donley	41,113	42,893	39,823	34,947	29,306	29,416
Gray	144,342	138,487	126,038	112,161	100,813	100,612
Hall	5,856	5,840	5,856	5,840	5,848	5,811
Hansford	98,385	96,361	95,451	94,893	94,587	94,390
Hartley	143,630	123,101	106,981	88,682	70,293	69,573
Hemphill	42,374	42,822	43,275	43,696	44,113	44,148
Hutchinson	4,476	4,479	3,532	2,219	1,106	1,091
Lipscomb	222,681	223,001	223,308	223,623	223,750	223,730
Moore	21,457	18,318	14,469	11,007	6,776	6,072
Ochiltree	152,249	152,374	152,792	153,083	153,173	152,976
Oldham	166,815	162,159	146,992	130,422	113,956	113,885
Potter	44,098	44,760	40,928	37,036	32,979	32,475
Randall	46,592	47,579	40,918	34,577	28,541	28,231
Roberts	355,046	380,000	356,825	325,453	291,456	291,450
Sherman	90,079	40,494	2,866	627	13	13
Wheeler	110,540	119,913	119,485	115,410	108,305	108,325
Total	**1,936,154**	**1,864,663**	**1,710,290**	**1,568,878**	**1,422,751**	**1,419,159**

Note: The amounts shown do not include surplus surface water supplies, which are technically fully allocated.



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PANHANDLE WATER PLANNING AREA

UNALLOCATED SUPPLIES FOR COUNTIES IN THE PWPA

FIGURE 3-9

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(1) Deeds, N.E., and Jigmond, M, 2015. *Numerical Model Report for the High Plains Aquifer System Groundwater Availability Model*, prepared for the Texas Water Development Board.

(2) Duffin, G.L., and Beynon, B., 1992. *Evaluation of water resources in parts of the Rolling Prairies Region of North-Central Texas*, Texas Water Development Board Report 337.

(3) Dutton, A.R., 2004. *Adjustment of parameters to improve the calibration of the Og-n model of the Ogallala aquifer, Panhandle water planning area: prepared for Freese and Nichols, Inc. and Panhandle Water Planning Group*.

(4) Ewing, J., Jones, T.L., Pickens, J.F., Chastain-Howley, A., Dean, K.E., and Spear, A.A.,2004. *Final Report: Groundwater Availability Model for the Seymour aquifer*.

(5) TWDB, 2017. GAM Run 16-029 MAG: Modeled Available Groundwater for the aquifers in Groundwater Management Area 1.

(6) TWDB, 2017. GAM Run 16-031 MAG: Modeled Available Groundwater for the Seymour, Blaine, Ogallala, and Dockum aquifers in Groundwater Management Area 6.

ATTACHMENT 3-1

EXISTING WATER SUPPLIES TO WATER USER GROUPS
AND
MAJOR WATER PROVIDERS BY USE TYPE

Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
CLAUDE MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | ARMSTRONG COUNTY	584	537	464	402	354	354
COUNTY-OTHER	A	DOCKUM AQUIFER | ARMSTRONG COUNTY	16	16	16	16	16	16
COUNTY-OTHER	A	OGALLALA AQUIFER | ARMSTRONG COUNTY	84	84	84	84	84	84
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	122	122	122	122	122	122
LIVESTOCK	A	OGALLALA AQUIFER | ARMSTRONG COUNTY	180	297	315	333	352	372
LIVESTOCK	A	OTHER AQUIFER | ARMSTRONG COUNTY	30	30	30	30	30	30
IRRIGATION	A	DOCKUM AQUIFER | ARMSTRONG COUNTY	54	78	99	119	136	136
IRRIGATION	A	OGALLALA AQUIFER | ARMSTRONG COUNTY	6,244	6,244	6,244	6,244	6,244	6,244
		RED BASIN TOTAL	**7,314**	**7,408**	**7,374**	**7,350**	**7,338**	**7,358**
		ARMSTRONG COUNTY TOTAL	**7,314**	**7,408**	**7,374**	**7,350**	**7,338**	**7,358**
WHITE DEER	A	OGALLALA AQUIFER | CARSON COUNTY	136	137	137	137	137	137
COUNTY-OTHER	A	OGALLALA AQUIFER | CARSON COUNTY	238	226	218	215	199	177
MANUFACTURING	A	OGALLALA AQUIFER | CARSON COUNTY	17	18	18	18	18	18
MINING	A	OGALLALA AQUIFER | CARSON COUNTY	14	14	14	14	14	14
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	59	59	59	59	59	59
LIVESTOCK	A	OGALLALA AQUIFER | CARSON COUNTY	177	263	275	287	299	313
IRRIGATION	A	OGALLALA AQUIFER | CARSON COUNTY	22,518	22,518	22,518	22,518	22,518	22,518
		CANADIAN BASIN TOTAL	**23,159**	**23,235**	**23,239**	**23,248**	**23,244**	**23,236**
GROOM MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | CARSON COUNTY	187	187	187	187	187	187
PANHANDLE MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | CARSON COUNTY	738	124	0	0	0	0
WHITE DEER	A	OGALLALA AQUIFER | CARSON COUNTY	176	180	180	179	179	179
COUNTY-OTHER	A	OGALLALA AQUIFER | CARSON COUNTY	206	196	189	186	172	153
MANUFACTURING	A	OGALLALA AQUIFER | CARSON COUNTY	1,038	1,118	1,118	1,118	1,118	1,118
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	75	75	75	75	75	75
LIVESTOCK	A	OGALLALA AQUIFER | CARSON COUNTY	4	33	37	41	45	49
IRRIGATION	A	DIRECT REUSE	58	59	59	58	58	58
IRRIGATION	A	OGALLALA AQUIFER | CARSON COUNTY	64,771	64,771	64,771	64,771	64,771	64,771
IRRIGATION	A	RED RUN-OF-RIVER	277	277	277	277	277	277
		RED BASIN TOTAL	**67,530**	**67,020**	**66,893**	**66,892**	**66,882**	**66,867**
		CARSON COUNTY TOTAL	**90,689**	**90,255**	**90,132**	**90,140**	**90,126**	**90,103**
CHILDRESS	A	GREENBELT LAKE/RESERVOIR	1,008	1,070	1,127	1,188	1,139	1,071
CHILDRESS	A	OGALLALA AQUIFER | DONLEY COUNTY	616	587	558	534	465	399
RED RIVER AUTHORITY OF TEXAS*	A	GREENBELT LAKE/RESERVOIR	144	152	160	169	163	152
RED RIVER AUTHORITY OF TEXAS*	A	OGALLALA AQUIFER | DONLEY COUNTY	88	84	79	76	66	57
COUNTY-OTHER	A	OTHER AQUIFER | CHILDRESS COUNTY	3	3	3	3	3	3
COUNTY-OTHER	A	SEYMOUR AQUIFER | CHILDRESS COUNTY	3	3	3	3	3	3
LIVESTOCK	A	BLAINE AQUIFER | CHILDRESS COUNTY	180	216	216	226	246	267
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	49	49	49	49	49	49
LIVESTOCK	A	SEYMOUR AQUIFER | CHILDRESS COUNTY	185	222	222	222	222	222
IRRIGATION	A	BLAINE AQUIFER | CHILDRESS COUNTY	13,829	13,829	13,829	13,829	13,829	13,829
IRRIGATION	A	DIRECT REUSE	162	166	169	172	177	181
IRRIGATION	A	OTHER AQUIFER | CHILDRESS COUNTY	230	230	230	230	230	230
IRRIGATION	A	RED RUN-OF-RIVER	19	19	19	19	19	19
IRRIGATION	A	SEYMOUR AQUIFER | CHILDRESS COUNTY	100	100	100	100	100	100

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
		RED BASIN TOTAL	**16,616**	**16,730**	**16,764**	**16,820**	**16,711**	**16,582**
		CHILDRESS COUNTY TOTAL	**16,616**	**16,730**	**16,764**	**16,820**	**16,711**	**16,582**
RED RIVER AUTHORITY OF TEXAS*	A	GREENBELT LAKE/RESERVOIR	10	10	11	11	10	9
RED RIVER AUTHORITY OF TEXAS*	A	OGALLALA AQUIFER | DONLEY COUNTY	6	6	5	5	4	4
RED RIVER AUTHORITY OF TEXAS*	A	SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	126	139	151	163	178	190
WELLINGTON MUNICIPAL WATER SYSTEM	A	SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	0	0	0	0	0	0
COUNTY-OTHER	A	BLAINE AQUIFER | COLLINGSWORTH COUNTY	3	3	2	2	2	2
COUNTY-OTHER	A	OTHER AQUIFER | COLLINGSWORTH COUNTY	9	8	8	7	6	5
COUNTY-OTHER	A	SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	76	68	61	54	48	43
LIVESTOCK	A	BLAINE AQUIFER | COLLINGSWORTH COUNTY	189	254	272	290	307	323
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	29	29	29	29	29	29
LIVESTOCK	A	OTHER AQUIFER | COLLINGSWORTH COUNTY	276	276	276	276	276	276
LIVESTOCK	A	SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	19	24	30	38	48	60
IRRIGATION	A	BLAINE AQUIFER | COLLINGSWORTH COUNTY	1,700	1,700	1,700	1,700	1,700	1,700
IRRIGATION	A	DIRECT REUSE	52	54	55	57	58	60
IRRIGATION	A	OTHER AQUIFER | COLLINGSWORTH COUNTY	24	25	25	26	27	28
IRRIGATION	A	RED RUN-OF-RIVER	851	851	851	851	851	851
IRRIGATION	A	SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	37,977	29,779	27,799	25,986	21,074	21,743
		RED BASIN TOTAL	**41,347**	**33,226**	**31,275**	**29,495**	**24,618**	**25,323**
		COLLINGSWORTH COUNTY TOTAL	**41,347**	**33,226**	**31,275**	**29,495**	**24,618**	**25,323**
DALHART	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	1,435	1,134	928	706	484	492
TEXLINE	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	274	274	274	274	274	274
COUNTY-OTHER	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	140	150	165	181	197	213
MANUFACTURING	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	6	6	6	6	6	6
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	2,488	2,488	2,488	2,488	2,488	2,488
LIVESTOCK	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	2,033	2,372	2,627	2,902	3,198	3,518
IRRIGATION	A	DOCKUM AQUIFER | DALLAM COUNTY	11,823	11,899	11,858	11,783	11,668	11,668
IRRIGATION	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	302,421	215,573	167,114	124,816	88,298	88,298
		CANADIAN BASIN TOTAL	**320,620**	**233,896**	**185,460**	**143,156**	**106,613**	**106,957**
		DALLAM COUNTY TOTAL	**320,620**	**233,896**	**185,460**	**143,156**	**106,613**	**106,957**
CLARENDON	A	GREENBELT LAKE/RESERVOIR	230	234	237	242	225	206
CLARENDON	A	OGALLALA AQUIFER | DONLEY COUNTY	141	128	117	108	92	77
RED RIVER AUTHORITY OF TEXAS*	A	GREENBELT LAKE/RESERVOIR	19	19	20	21	19	18
RED RIVER AUTHORITY OF TEXAS*	A	OGALLALA AQUIFER | DONLEY COUNTY	215	236	255	275	299	320
COUNTY-OTHER	A	GREENBELT LAKE/RESERVOIR	35	36	37	39	36	33
COUNTY-OTHER	A	OGALLALA AQUIFER | DONLEY COUNTY	134	114	97	82	67	52
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	283	283	283	283	283	283
LIVESTOCK	A	OGALLALA AQUIFER | DONLEY COUNTY	305	328	353	380	407	436
LIVESTOCK	A	OTHER AQUIFER | DONLEY COUNTY	383	383	383	383	383	383
IRRIGATION	A	OGALLALA AQUIFER | DONLEY COUNTY	30,910	30,910	30,910	30,910	30,910	30,910

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
IRRIGATION	A	RED RUN-OF-RIVER	166	166	166	166	166	166
		RED BASIN TOTAL	**32,821**	**32,837**	**32,858**	**32,889**	**32,887**	**32,884**
		DONLEY COUNTY TOTAL	**32,821**	**32,837**	**32,858**	**32,889**	**32,887**	**32,884**
PAMPA MUNICIPAL WATER SYSTEM	A	MEREDITH LAKE/RESERVOIR	481	570	681	812	935	943
PAMPA MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | GRAY COUNTY	1,724	1,431	1,135	903	713	713
PAMPA MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | ROBERTS COUNTY	1,666	1,803	1,679	1,833	1,899	1,918
COUNTY-OTHER	A	OGALLALA AQUIFER | GRAY COUNTY	472	512	563	634	692	753
MANUFACTURING	A	OGALLALA AQUIFER | GRAY COUNTY	482	527	527	527	527	527
MINING	A	OGALLALA AQUIFER | GRAY COUNTY	7	7	6	6	5	4
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	199	199	199	199	199	199
LIVESTOCK	A	OGALLALA AQUIFER | GRAY COUNTY	61	61	61	61	61	61
IRRIGATION	A	CANADIAN RUN-OF-RIVER	1	1	1	1	1	1
IRRIGATION	A	DIRECT REUSE	220	220	220	220	220	220
IRRIGATION	A	OGALLALA AQUIFER | GRAY COUNTY	8,395	8,395	8,395	8,395	5,487	5,487
		CANADIAN BASIN TOTAL	**13,708**	**13,726**	**13,467**	**13,591**	**10,739**	**10,826**
MCLEAN MUNICIPAL WATER SUPPLY	A	OGALLALA AQUIFER | GRAY COUNTY	315	293	266	241	219	219
COUNTY-OTHER	A	OGALLALA AQUIFER | GRAY COUNTY	239	259	285	320	350	381
MINING	A	OGALLALA AQUIFER | GRAY COUNTY	68	67	61	54	48	43
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	600	600	600	600	600	600
LIVESTOCK	A	OGALLALA AQUIFER | GRAY COUNTY	1,106	1,334	1,422	1,517	1,622	1,737
IRRIGATION	A	OGALLALA AQUIFER | GRAY COUNTY	23,894	23,894	23,894	23,894	23,894	23,894
IRRIGATION	A	RED RUN-OF-RIVER	55	55	55	55	55	55
		RED BASIN TOTAL	**26,277**	**26,502**	**26,583**	**26,681**	**26,788**	**26,929**
		GRAY COUNTY TOTAL	**39,985**	**40,228**	**40,050**	**40,272**	**37,527**	**37,755**
MEMPHIS	A	GREENBELT LAKE/RESERVOIR	23	24	25	25	24	22
MEMPHIS	A	OGALLALA AQUIFER | DONLEY COUNTY	373	333	288	245	206	204
RED RIVER AUTHORITY OF TEXAS*	A	GREENBELT LAKE/RESERVOIR	62	65	67	69	64	59
RED RIVER AUTHORITY OF TEXAS*	A	OGALLALA AQUIFER | DONLEY COUNTY	38	35	33	31	26	22
RED RIVER AUTHORITY OF TEXAS*	A	SEYMOUR AQUIFER | HALL COUNTY	10	10	10	13	14	30
TURKEY MUNICIPAL WATER SYSTEM	A	SEYMOUR AQUIFER | HALL COUNTY	120	121	119	119	119	119
COUNTY-OTHER	A	SEYMOUR AQUIFER | HALL COUNTY	84	76	65	54	65	57
LIVESTOCK	A	BLAINE AQUIFER | HALL COUNTY	0	0	0	0	8	29
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	91	91	91	91	91	91
LIVESTOCK	A	OTHER AQUIFER | HALL COUNTY	300	300	300	300	300	300
LIVESTOCK	A	SEYMOUR AQUIFER | HALL COUNTY	15	15	15	15	15	15
IRRIGATION	A	DIRECT REUSE	100	100	100	100	100	100
IRRIGATION	A	OTHER AQUIFER | HALL COUNTY	786	786	786	786	786	786
IRRIGATION	A	RED RUN-OF-RIVER	52	52	52	52	52	52
IRRIGATION	A	SEYMOUR AQUIFER | HALL COUNTY	15,217	16,529	19,457	22,660	25,648	24,374
		RED BASIN TOTAL	**17,271**	**18,537**	**21,408**	**24,560**	**27,518**	**26,260**
		HALL COUNTY TOTAL	**17,271**	**18,537**	**21,408**	**24,560**	**27,518**	**26,260**
GRUVER	A	OGALLALA AQUIFER | HANSFORD COUNTY	410	360	309	251	201	201

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Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
SPEARMAN MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | HANSFORD COUNTY	804	817	702	474	228	228
COUNTY-OTHER	A	OGALLALA AQUIFER | HANSFORD COUNTY	170	170	170	170	170	170
MANUFACTURING	A	OGALLALA AQUIFER | HANSFORD COUNTY	285	321	321	321	321	321
MINING	A	OGALLALA AQUIFER | HANSFORD COUNTY	577	904	602	309	16	1
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	2,617	2,617	2,617	2,617	2,617	2,617
LIVESTOCK	A	OGALLALA AQUIFER | HANSFORD COUNTY	1,413	1,587	1,771	1,963	2,166	2,378
IRRIGATION	A	CANADIAN RUN-OF-RIVER	22	22	22	22	22	22
IRRIGATION	A	OGALLALA AQUIFER | HANSFORD COUNTY	171,900	171,900	171,900	171,900	171,900	171,900
		CANADIAN BASIN TOTAL	**178,198**	**178,698**	**178,414**	**178,027**	**177,641**	**177,838**
		HANSFORD COUNTY TOTAL	**178,198**	**178,698**	**178,414**	**178,027**	**177,641**	**177,838**
DALHART	A	OGALLALA AND RITA BLANCA AQUIFERS | DALLAM COUNTY	675	492	367	256	163	155
HARTLEY WSC	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	250	260	270	280	280	290
COUNTY-OTHER	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	531	557	568	577	588	598
MINING	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	7	7	6	5	4	3
LIVESTOCK	A	DOCKUM AQUIFER | HARTLEY COUNTY	1,035	1,035	1,035	1,035	1,035	1,035
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	3,193	3,193	3,193	3,193	3,193	3,193
LIVESTOCK	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	2,361	3,147	3,696	4,291	4,937	5,638
IRRIGATION	A	DOCKUM AQUIFER | HARTLEY COUNTY	8,349	7,585	7,381	7,411	7,615	7,615
IRRIGATION	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	313,875	206,640	160,229	116,912	77,655	77,655
		CANADIAN BASIN TOTAL	**330,276**	**222,916**	**176,745**	**133,960**	**95,470**	**96,182**
		HARTLEY COUNTY TOTAL	**330,276**	**222,916**	**176,745**	**133,960**	**95,470**	**96,182**
CANADIAN	A	OGALLALA AQUIFER | HEMPHILL COUNTY	988	1,087	1,174	1,268	1,356	1,439
COUNTY-OTHER	A	OGALLALA AQUIFER | HEMPHILL COUNTY	97	95	92	94	95	95
MANUFACTURING	A	OGALLALA AQUIFER | HEMPHILL COUNTY	4	4	4	4	4	4
MINING	A	OGALLALA AQUIFER | HEMPHILL COUNTY	926	706	498	293	89	27
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	248	248	248	248	248	248
LIVESTOCK	A	OGALLALA AQUIFER | HEMPHILL COUNTY	415	432	451	470	491	512
IRRIGATION	A	OGALLALA AQUIFER | HEMPHILL COUNTY	3,919	3,919	3,919	3,919	3,919	3,919
		CANADIAN BASIN TOTAL	**6,597**	**6,491**	**6,386**	**6,296**	**6,202**	**6,244**
COUNTY-OTHER	A	OGALLALA AQUIFER | HEMPHILL COUNTY	42	41	41	41	41	42
MANUFACTURING	A	OGALLALA AQUIFER | HEMPHILL COUNTY	2	2	2	2	2	2
MINING	A	OGALLALA AQUIFER | HEMPHILL COUNTY	1,388	1,057	746	439	134	41
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	173	173	173	173	173	173
LIVESTOCK	A	OGALLALA AQUIFER | HEMPHILL COUNTY	281	293	305	319	332	347
IRRIGATION	A	OGALLALA AQUIFER | HEMPHILL COUNTY	1,760	1,760	1,760	1,760	1,760	1,760
		RED BASIN TOTAL	**3,646**	**3,326**	**3,027**	**2,734**	**2,442**	**2,365**
		HEMPHILL COUNTY TOTAL	**10,243**	**9,817**	**9,413**	**9,030**	**8,644**	**8,609**
BORGER	A	OGALLALA AQUIFER | CARSON COUNTY	800	719	672	634	602	602
BORGER	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	3,470	2,385	2,012	1,537	1,238	1,139
BORGER	A	OGALLALA AQUIFER | ROBERTS COUNTY	2,329	2,129	1,914	1,548	1,298	1,395
FRITCH	A	OGALLALA AQUIFER | CARSON COUNTY	592	598	591	589	588	588
STINNETT	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	581	538	495	457	423	423
TCW SUPPLY	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	691	573	472	386	317	317

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Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
COUNTY-OTHER	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	316	315	314	313	311	311
MANUFACTURING	A	CANADIAN RUN-OF-RIVER	2	2	2	2	2	2
MANUFACTURING	A	DIRECT REUSE	1,100	1,100	1,100	1,100	1,100	1,100
MANUFACTURING	A	MEREDITH LAKE/RESERVOIR	1,729	1,594	1,506	1,438	1,427	1,423
MANUFACTURING	A	OGALLALA AQUIFER | CARSON COUNTY	0	0	0	0	0	0
MANUFACTURING	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	25,038	26,907	26,869	27,016	27,039	27,138
MANUFACTURING	A	OGALLALA AQUIFER | ROBERTS COUNTY	1,500	1,700	1,800	1,700	1,600	1,500
MINING	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	184	231	170	113	56	34
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	281	281	281	281	281	281
LIVESTOCK	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	319	355	385	418	453	490
IRRIGATION	A	CANADIAN RUN-OF-RIVER	96	96	96	96	96	96
IRRIGATION	A	OGALLALA AQUIFER | HUTCHINSON COUNTY	59,910	59,910	59,910	59,910	59,910	59,910
		CANADIAN BASIN TOTAL	**98,938**	**99,433**	**98,589**	**97,538**	**96,741**	**96,749**
		HUTCHINSON COUNTY TOTAL	**98,938**	**99,433**	**98,589**	**97,538**	**96,741**	**96,749**
BOOKER	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	727	577	519	472	435	440
DARROUZETT	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	150	150	150	160	160	160
FOLLETT	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	140	150	160	160	170	170
HIGGINS MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	140	150	150	160	160	170
COUNTY-OTHER	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	137	124	117	109	103	99
MANUFACTURING	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	362	400	360	305	269	261
MINING	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	1,098	758	446	142	21	3
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	110	110	110	110	110	110
LIVESTOCK	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	495	521	548	578	608	640
IRRIGATION	A	CANADIAN RUN-OF-RIVER	66	66	66	66	66	66
IRRIGATION	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	40,870	40,870	40,870	40,870	40,870	40,870
		CANADIAN BASIN TOTAL	**44,295**	**43,876**	**43,496**	**43,132**	**42,972**	**42,989**
		LIPSCOMB COUNTY TOTAL	**44,295**	**43,876**	**43,496**	**43,132**	**42,972**	**42,989**
CACTUS MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | MOORE COUNTY	679	525	423	311	240	256
DUMAS	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	2,274	1,827	1,583	1,234	844	844
DUMAS	A	OGALLALA AQUIFER | MOORE COUNTY	1,907	1,235	855	429	185	185
FRITCH	A	OGALLALA AQUIFER | CARSON COUNTY	5	5	5	5	5	5
SUNRAY	A	OGALLALA AQUIFER | MOORE COUNTY	605	344	125	56	14	14
COUNTY-OTHER	A	OGALLALA AND RITA BLANCA AQUIFERS | HARTLEY COUNTY	50	38	27	17	9	9
COUNTY-OTHER	A	OGALLALA AQUIFER | MOORE COUNTY	243	273	306	343	385	429
MANUFACTURING	A	OGALLALA AQUIFER | MOORE COUNTY	8,269	7,856	7,408	5,498	3,860	3,844
MINING	A	OGALLALA AQUIFER | MOORE COUNTY	16	16	16	15	15	15
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	1,000	1,000	1,000	1,000	1,000	1,000
LIVESTOCK	A	OGALLALA AQUIFER | MOORE COUNTY	4,414	5,192	5,698	6,251	6,855	7,515
IRRIGATION	A	CANADIAN RUN-OF-RIVER	7	7	7	7	7	7
IRRIGATION	A	DOCKUM AQUIFER | MOORE COUNTY	870	722	650	654	739	739
IRRIGATION	A	OGALLALA AQUIFER | MOORE COUNTY	190,465	151,845	121,984	91,564	63,892	63,892
		CANADIAN BASIN TOTAL	**210,804**	**170,885**	**140,087**	**107,384**	**78,050**	**78,754**
		MOORE COUNTY TOTAL	**210,804**	**170,885**	**140,087**	**107,384**	**78,050**	**78,754**
BOOKER	A	OGALLALA AQUIFER | LIPSCOMB COUNTY	9	9	12	12	13	16
PERRYTON MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | OCHILTREE COUNTY	3,488	3,309	3,136	3,045	2,919	2,919

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Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
COUNTY-OTHER	A	OGALLALA AQUIFER | OCHILTREE COUNTY	341	354	371	396	425	457
MANUFACTURING	A	OGALLALA AQUIFER | OCHILTREE COUNTY	36	41	41	41	41	41
MINING	A	OGALLALA AQUIFER | OCHILTREE COUNTY	824	853	503	161	23	3
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	421	421	421	421	421	421
LIVESTOCK	A	OGALLALA AQUIFER | OCHILTREE COUNTY	2,380	2,541	2,699	2,865	3,041	3,226
IRRIGATION	A	OGALLALA AQUIFER | OCHILTREE COUNTY	84,460	84,460	84,460	84,460	84,460	84,460
		CANADIAN BASIN TOTAL	**91,959**	**91,988**	**91,643**	**91,401**	**91,343**	**91,543**
		OCHILTREE COUNTY TOTAL	**91,959**	**91,988**	**91,643**	**91,401**	**91,343**	**91,543**
VEGA	O	OGALLALA AND EDWARDS-TRINITY-HIGH PLAINS AQUIFERS | DEAF SMITH COUNTY	200	200	200	200	200	200
VEGA	A	OGALLALA AQUIFER | OLDHAM COUNTY	95	95	95	95	95	95
COUNTY-OTHER	A	DOCKUM AQUIFER | OLDHAM COUNTY	387	387	387	387	387	387
COUNTY-OTHER	A	OGALLALA AQUIFER | OLDHAM COUNTY	214	207	208	208	208	208
MINING	A	DOCKUM AQUIFER | OLDHAM COUNTY	283	283	283	283	283	283
MINING	A	OGALLALA AQUIFER | OLDHAM COUNTY	173	257	330	361	425	493
LIVESTOCK	A	DOCKUM AQUIFER | OLDHAM COUNTY	358	358	358	358	358	358
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	626	626	626	626	626	626
LIVESTOCK	A	OGALLALA AQUIFER | OLDHAM COUNTY	134	134	134	134	134	134
IRRIGATION	A	DOCKUM AQUIFER | OLDHAM COUNTY	372	372	372	372	372	372
IRRIGATION	A	OGALLALA AQUIFER | OLDHAM COUNTY	3,216	3,216	3,216	3,216	3,216	3,216
		CANADIAN BASIN TOTAL	**6,058**	**6,135**	**6,209**	**6,240**	**6,304**	**6,372**
COUNTY-OTHER	A	OGALLALA AQUIFER | OLDHAM COUNTY	73	80	79	79	79	79
MINING	A	OGALLALA AQUIFER | OLDHAM COUNTY	19	23	26	27	29	32
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	209	209	209	209	209	209
LIVESTOCK	A	OGALLALA AQUIFER | OLDHAM COUNTY	328	328	328	328	328	328
IRRIGATION	A	OGALLALA AQUIFER | OLDHAM COUNTY	1,133	1,133	1,133	1,133	1,133	1,133
		RED BASIN TOTAL	**1,762**	**1,773**	**1,775**	**1,776**	**1,778**	**1,781**
		OLDHAM COUNTY TOTAL	**7,820**	**7,908**	**7,984**	**8,016**	**8,082**	**8,153**
AMARILLO	A	MEREDITH LAKE/RESERVOIR	3,278	3,264	3,125	3,010	3,056	3,072
AMARILLO	A	OGALLALA AQUIFER | CARSON COUNTY	4,093	3,738	3,260	2,815	2,448	2,449
AMARILLO	A	OGALLALA AQUIFER | POTTER COUNTY	2,321	1,559	1,422	1,305	1,190	1,174
AMARILLO	A	OGALLALA AQUIFER | ROBERTS COUNTY	7,428	7,477	7,162	6,357	5,888	5,956
COUNTY-OTHER	A	DOCKUM AQUIFER | POTTER COUNTY	900	900	900	900	900	900
COUNTY-OTHER	A	OGALLALA AQUIFER | POTTER COUNTY	1,517	1,651	1,801	1,960	2,141	2,336
MANUFACTURING	A	DOCKUM AQUIFER | POTTER COUNTY	682	636	581	530	477	477
MINING	A	OGALLALA AQUIFER | POTTER COUNTY	640	781	912	988	1,109	1,245
STEAM ELECTRIC POWER	A	DIRECT REUSE	18,554	18,554	18,554	18,554	18,554	18,554
LIVESTOCK	A	DOCKUM AQUIFER | POTTER COUNTY	1	1	1	1	1	1
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	500	500	500	500	500	500
LIVESTOCK	A	OGALLALA AQUIFER | POTTER COUNTY	17	17	17	17	17	17
IRRIGATION	A	DIRECT REUSE	700	700	700	700	700	700
IRRIGATION	A	DOCKUM AQUIFER | POTTER COUNTY	73	73	73	73	73	73
IRRIGATION	A	OGALLALA AQUIFER | POTTER COUNTY	547	547	547	547	547	547
		CANADIAN BASIN TOTAL	**41,251**	**40,398**	**39,555**	**38,257**	**37,601**	**38,001**
AMARILLO	A	MEREDITH LAKE/RESERVOIR	2,158	2,149	2,057	1,983	2,012	2,022
AMARILLO	A	OGALLALA AQUIFER | CARSON COUNTY	2,695	2,460	2,148	1,853	1,612	1,613
AMARILLO	A	OGALLALA AQUIFER | POTTER COUNTY	1,529	1,027	937	859	783	772
AMARILLO	A	OGALLALA AQUIFER | ROBERTS COUNTY	4,890	4,922	4,716	4,185	3,877	3,921

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Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
COUNTY-OTHER	A	OGALLALA AQUIFER | POTTER COUNTY	812	884	965	1,049	1,147	1,251
MANUFACTURING	A	DIRECT REUSE	2,000	2,000	2,000	2,000	2,000	2,000
MANUFACTURING	A	MEREDITH LAKE/RESERVOIR	1,101	1,114	978	867	804	741
MANUFACTURING	A	OGALLALA AQUIFER | ROBERTS COUNTY	4,426	4,361	3,710	3,016	2,508	2,313
MINING	A	OGALLALA AQUIFER | POTTER COUNTY	301	368	429	465	522	586
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	62	62	62	62	62	62
LIVESTOCK	A	OGALLALA AQUIFER | POTTER COUNTY	25	28	32	36	40	45
IRRIGATION	A	DIRECT REUSE	1,500	1,500	1,500	1,500	1,500	1,500
IRRIGATION	A	OGALLALA AQUIFER | POTTER COUNTY	1,217	1,217	1,217	1,217	1,217	1,217
		RED BASIN TOTAL	**22,716**	**22,092**	**20,751**	**19,092**	**18,084**	**18,043**
		POTTER COUNTY TOTAL	**63,967**	**62,490**	**60,306**	**57,349**	**55,685**	**56,044**
AMARILLO	A	MEREDITH LAKE/RESERVOIR	4,414	4,422	4,232	4,088	4,149	4,165
AMARILLO	O	OGALLALA AND EDWARDS-TRINITY-HIGH PLAINS AQUIFERS | DEAF SMITH COUNTY	100	100	100	100	50	0
AMARILLO	A	OGALLALA AQUIFER | CARSON COUNTY	5,512	5,062	4,418	3,822	3,324	3,322
AMARILLO	A	OGALLALA AQUIFER | POTTER COUNTY	1,338	709	842	907	922	949
AMARILLO	A	OGALLALA AQUIFER | RANDALL COUNTY	1,689	1,304	985	763	641	641
AMARILLO	A	OGALLALA AQUIFER | ROBERTS COUNTY	10,002	10,129	9,701	8,631	7,994	8,076
CANYON	A	DOCKUM AQUIFER | RANDALL COUNTY	1,780	1,691	1,606	1,526	1,450	1,378
CANYON	A	MEREDITH LAKE/RESERVOIR	199	182	160	142	0	0
CANYON	A	OGALLALA AQUIFER | RANDALL COUNTY	1,412	1,341	1,274	1,210	1,150	1,093
CANYON	A	OGALLALA AQUIFER | ROBERTS COUNTY	801	713	606	493	0	0
HAPPY*	O	DOCKUM AQUIFER | SWISHER COUNTY	10	11	12	13	14	16
LAKE TANGLEWOOD	A	DOCKUM AQUIFER | RANDALL COUNTY	500	500	500	500	500	500
LAKE TANGLEWOOD	A	OGALLALA AQUIFER | RANDALL COUNTY	110	87	63	44	32	32
COUNTY-OTHER	A	DOCKUM AQUIFER | RANDALL COUNTY	689	689	689	689	689	689
COUNTY-OTHER	A	MEREDITH LAKE/RESERVOIR	5	5	4	4	3	3
COUNTY-OTHER	A	OGALLALA AQUIFER | RANDALL COUNTY	3,088	3,379	3,684	4,018	4,394	4,790
COUNTY-OTHER	A	OGALLALA AQUIFER | ROBERTS COUNTY	20	17	15	12	11	9
MANUFACTURING	A	MEREDITH LAKE/RESERVOIR	115	105	92	82	76	70
MANUFACTURING	A	OGALLALA AQUIFER | RANDALL COUNTY	50	50	50	50	50	50
MANUFACTURING	A	OGALLALA AQUIFER | ROBERTS COUNTY	461	410	349	284	236	217
LIVESTOCK	A	DOCKUM AQUIFER | RANDALL COUNTY	230	230	230	230	230	230
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	1,312	1,312	1,312	1,312	1,312	1,312
LIVESTOCK	A	OGALLALA AQUIFER | RANDALL COUNTY	1,121	1,163	1,199	1,236	1,277	1,320
IRRIGATION	A	DIRECT REUSE	545	597	651	710	777	846
IRRIGATION	A	DOCKUM AQUIFER | RANDALL COUNTY	101	215	286	355	425	425
IRRIGATION	A	OGALLALA AQUIFER | RANDALL COUNTY	17,720	17,720	17,720	17,720	17,720	17,720
IRRIGATION	A	RED RUN-OF-RIVER	217	217	217	217	217	217
		RED BASIN TOTAL	**53,541**	**52,360**	**50,997**	**49,158**	**47,643**	**48,070**
		RANDALL COUNTY TOTAL	**53,541**	**52,360**	**50,997**	**49,158**	**47,643**	**48,070**
MIAMI	A	OGALLALA AQUIFER | ROBERTS COUNTY	298	298	298	298	298	298
COUNTY-OTHER	A	OGALLALA AQUIFER | ROBERTS COUNTY	50	50	50	50	50	50
MINING	A	OGALLALA AQUIFER | ROBERTS COUNTY	1,457	1,010	593	183	19	2
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	124	124	124	124	124	124
LIVESTOCK	A	OGALLALA AQUIFER | ROBERTS COUNTY	249	267	287	308	329	353
IRRIGATION	A	CANADIAN RUN-OF-RIVER	72	72	72	72	72	72
IRRIGATION	A	OGALLALA AQUIFER | ROBERTS COUNTY	8,044	8,044	8,044	8,044	8,044	8,044

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Existing Water Supplies

WUG NAME	SOURCE REGION	SOURCE DESCRIPTION	EXISTING SUPPLY (ACRE FEET PER YEAR) 2020	2030	2040	2050	2060	2070
		CANADIAN BASIN TOTAL	**10,294**	**9,865**	**9,468**	**9,079**	**8,936**	**8,943**
COUNTY-OTHER	A	OGALLALA AQUIFER | ROBERTS COUNTY	1	1	1	1	1	1
MINING	A	OGALLALA AQUIFER | ROBERTS COUNTY	45	31	18	6	1	0
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	15	15	15	15	15	15
LIVESTOCK	A	OGALLALA AQUIFER | ROBERTS COUNTY	1	1	1	1	1	1
IRRIGATION	A	OGALLALA AQUIFER | ROBERTS COUNTY	427	427	427	427	427	427
		RED BASIN TOTAL	**489**	**475**	**462**	**450**	**445**	**444**
		ROBERTS COUNTY TOTAL	**10,783**	**10,340**	**9,930**	**9,529**	**9,381**	**9,387**
STRATFORD	A	OGALLALA AQUIFER | SHERMAN COUNTY	821	821	821	821	633	633
TEXHOMA	A	OGALLALA AQUIFER | SHERMAN COUNTY	130	140	150	150	160	160
COUNTY-OTHER	A	OGALLALA AQUIFER | SHERMAN COUNTY	105	110	112	116	118	121
MANUFACTURING	A	OGALLALA AQUIFER | SHERMAN COUNTY	2	2	2	2	2	2
MINING	A	OGALLALA AQUIFER | SHERMAN COUNTY	35	207	151	98	44	20
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	1,052	1,052	1,052	1,052	1,052	1,052
LIVESTOCK	A	OGALLALA AQUIFER | SHERMAN COUNTY	2,524	2,761	2,954	3,160	3,380	3,617
IRRIGATION	A	CANADIAN RUN-OF-RIVER	32	32	32	32	32	32
IRRIGATION	A	DOCKUM AQUIFER | SHERMAN COUNTY	127	127	127	127	95	95
IRRIGATION	A	OGALLALA AQUIFER | SHERMAN COUNTY	304,360	304,360	274,634	207,770	144,202	143,986
		CANADIAN BASIN TOTAL	**309,188**	**309,612**	**280,035**	**213,328**	**149,718**	**149,718**
		SHERMAN COUNTY TOTAL	**309,188**	**309,612**	**280,035**	**213,328**	**149,718**	**149,718**
SHAMROCK MUNICIPAL WATER SYSTEM	A	OGALLALA AQUIFER | WHEELER COUNTY	842	842	842	842	842	842
WHEELER	A	OGALLALA AQUIFER | WHEELER COUNTY	704	655	574	486	421	421
COUNTY-OTHER	A	BLAINE AQUIFER | WHEELER COUNTY	15	15	15	15	15	15
COUNTY-OTHER	A	OGALLALA AQUIFER | WHEELER COUNTY	348	348	348	348	348	348
COUNTY-OTHER	A	OTHER AQUIFER | WHEELER COUNTY	22	22	22	22	22	22
MINING	A	OGALLALA AQUIFER | WHEELER COUNTY	3,268	2,329	1,413	503	139	119
LIVESTOCK	A	BLAINE AQUIFER | WHEELER COUNTY	19	19	19	19	19	19
LIVESTOCK	A	LOCAL SURFACE WATER SUPPLY	845	845	845	845	845	845
LIVESTOCK	A	OGALLALA AQUIFER | WHEELER COUNTY	803	803	803	803	803	803
LIVESTOCK	A	OTHER AQUIFER | WHEELER COUNTY	28	28	28	28	28	28
IRRIGATION	A	BLAINE AQUIFER | WHEELER COUNTY	15	15	15	15	15	15
IRRIGATION	A	DIRECT REUSE	49	51	52	53	55	57
IRRIGATION	A	OGALLALA AQUIFER | WHEELER COUNTY	15,621	15,621	15,621	15,621	15,621	15,621
IRRIGATION	A	OTHER AQUIFER | WHEELER COUNTY	226	226	226	226	226	226
IRRIGATION	A	RED RUN-OF-RIVER	603	603	603	603	603	603
		RED BASIN TOTAL	**23,408**	**22,422**	**21,426**	**20,429**	**20,002**	**19,984**
		WHEELER COUNTY TOTAL	**23,408**	**22,422**	**21,426**	**20,429**	**20,002**	**19,984**
		REGION A EXISTING WATER SUPPLY TOTAL	**2,000,083**	**1,755,862**	**1,594,386**	**1,402,963**	**1,224,710**	**1,227,242**

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Major Water Provider Supplies by Use Type

Supplies (acre-feet per year)

Major Water Provider	Category of Use	2020	2030	2040	2050	2060	2070
Amarillo	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	6,103	5,991	5,129	4,249	3,625	3,341
	Mining	0	0	0	0	0	0
	Municipal	52,222	49,238	45,890	41,329	37,959	38,145
	Municipal Non-Potable	3,438	5,490	7,438	9,530	11,923	14,454
	Steam Electric Power	18,554	18,554	18,554	18,554	18,554	18,554
	Total Potable Supply	**61,763**	**60,719**	**58,457**	**55,108**	**53,507**	**55,940**
	Total Reuse Supply	**18,554**	**18,554**	**18,554**	**18,554**	**18,554**	**18,554**
CRMWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	0	0	0	0	0
	Mining	0	0	0	0	0	0
	Municipal	89,669	89,635	85,276	80,044	74,367	74,334
	Steam Electric Power	0	0	0	0	0	0
	Total	**89,669**	**89,635**	**85,276**	**80,044**	**74,367**	**74,334**
Greenbelt MIWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	228	228	228	190	173	154
	Mining	0	0	0	0	0	0
	Municipal	4,784	4,328	3,915	3,576	3,247	2,945
	Steam Electric Power	0	0	0	0	0	0
	Total	**5,012**	**4,556**	**4,143**	**3,766**	**3,420**	**3,099**
Cactus	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	2,239	1,597	1,149	760	529	513
	Mining	0	0	0	0	0	0
	Municipal	679	525	423	311	240	256
	Steam Electric Power	0	0	0	0	0	0
	Total	**2,918**	**2,122**	**1,572**	**1,071**	**769**	**769**
Borger	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	7,342	7,834	7,834	7,834	7,763	7,758
	Mining	0	0	0	0	0	0
	Municipal	6,615	5,249	4,614	3,735	3,154	3,152
	Steam Electric Power	0	0	0	0	0	0
	Total	**13,957**	**13,083**	**12,448**	**11,569**	**10,917**	**10,910**

4 IDENTIFICATION OF WATER NEEDS

4.1 Introduction

Water needs are identified by calculating the difference between currently available supplies developed in Chapter 3 and the projected demands developed in Chapter 2. This chapter outlines first and second tier water needs scenarios, where the first tier needs are based on all supply limitations identified in Chapter 3 and second tier needs are those needs after conservation and direct reuse strategies have been implemented.

This comparison of developed water supply to demands is made for the region, county, basin, major water provider, and water user group. If the projected demands for an entity exceed the developed supplies, then a need is identified (represented by a negative number). For some users, the supplies may exceed the demands (positive number). For groundwater users, this water is not considered surplus, but a supply that will be available for use after 2070.

4.2 First Tier Water Needs Analysis

As discussed in Chapter 3, the Texas Water Development Board (TWDB) specifies that the currently available supplies be defined as the most restrictive of current water rights, contracts and available yields for surface water and historical use and/or modeled available groundwater (MAG) for groundwater. For the Panhandle Water Planning Area (PWPA), geographical and hydrogeological constraints were also considered for irrigation and municipal users of the Ogallala aquifer. For some counties in the region, these constraints are more restrictive than current groundwater regulations. However, this approach provides a reasonable assessment of water demands that may exceed long-term availability.

Considering only developed and connected supplies for the PWPA, the projected need for the region in 2020 is approximately 130,000 acre-feet per year, which increases to nearly 375,000 acre-feet per year by 2070 (Table 4-1 and Figure 4-1).

Table 4-1: Comparison of Supplies and Demands for the PWPA (acre-feet per year)

	2020	2030	2040	2050	2060	2070
Supply	2,000,083	1,755,862	1,594,386	1,402,963	1,224,710	1,227,242
Demand	2,130,529	2,138,483	1,995,398	1,788,541	1,585,584	1,598,115
Surplus/Need	(130,446)	(382,621)	(401,012)	(385,578)	(360,874)	(370,873)

Note: This calculation aggregates surpluses and needs for all water users across the region. Consideration of only the needs for individual entities will be higher.

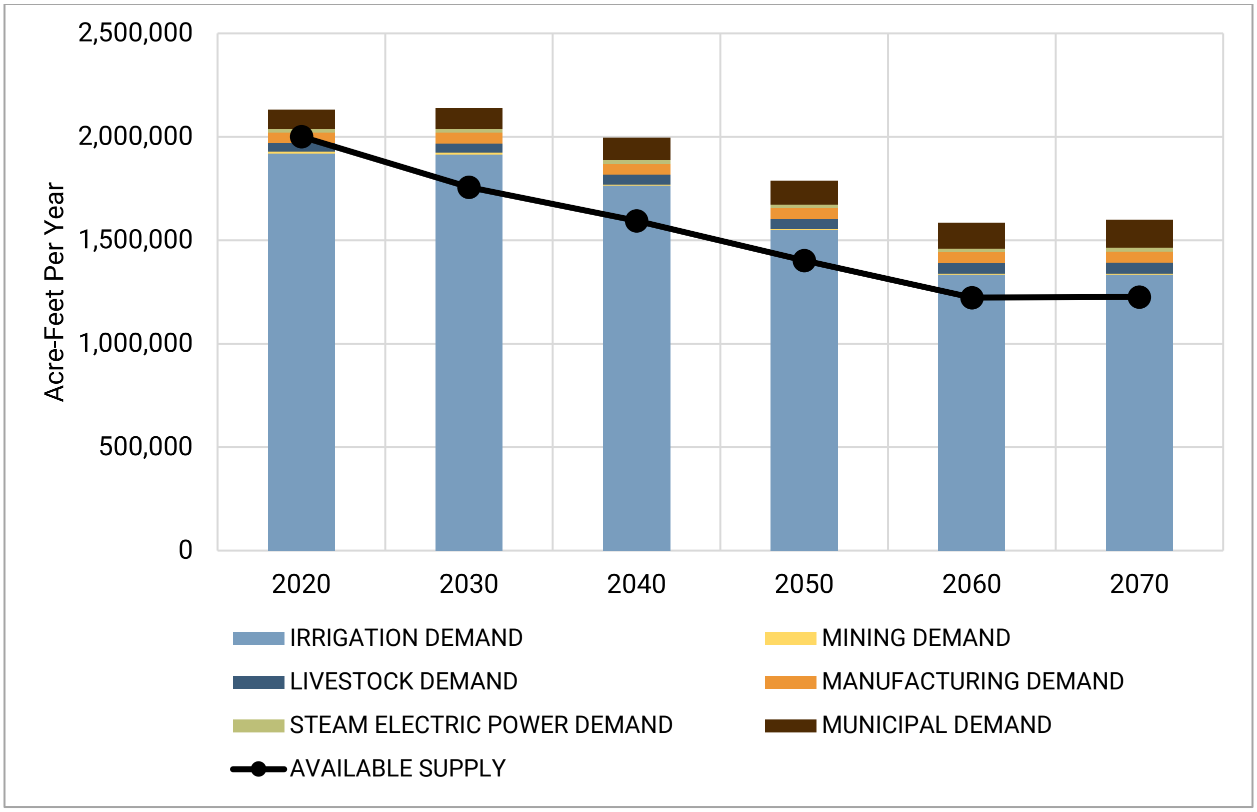


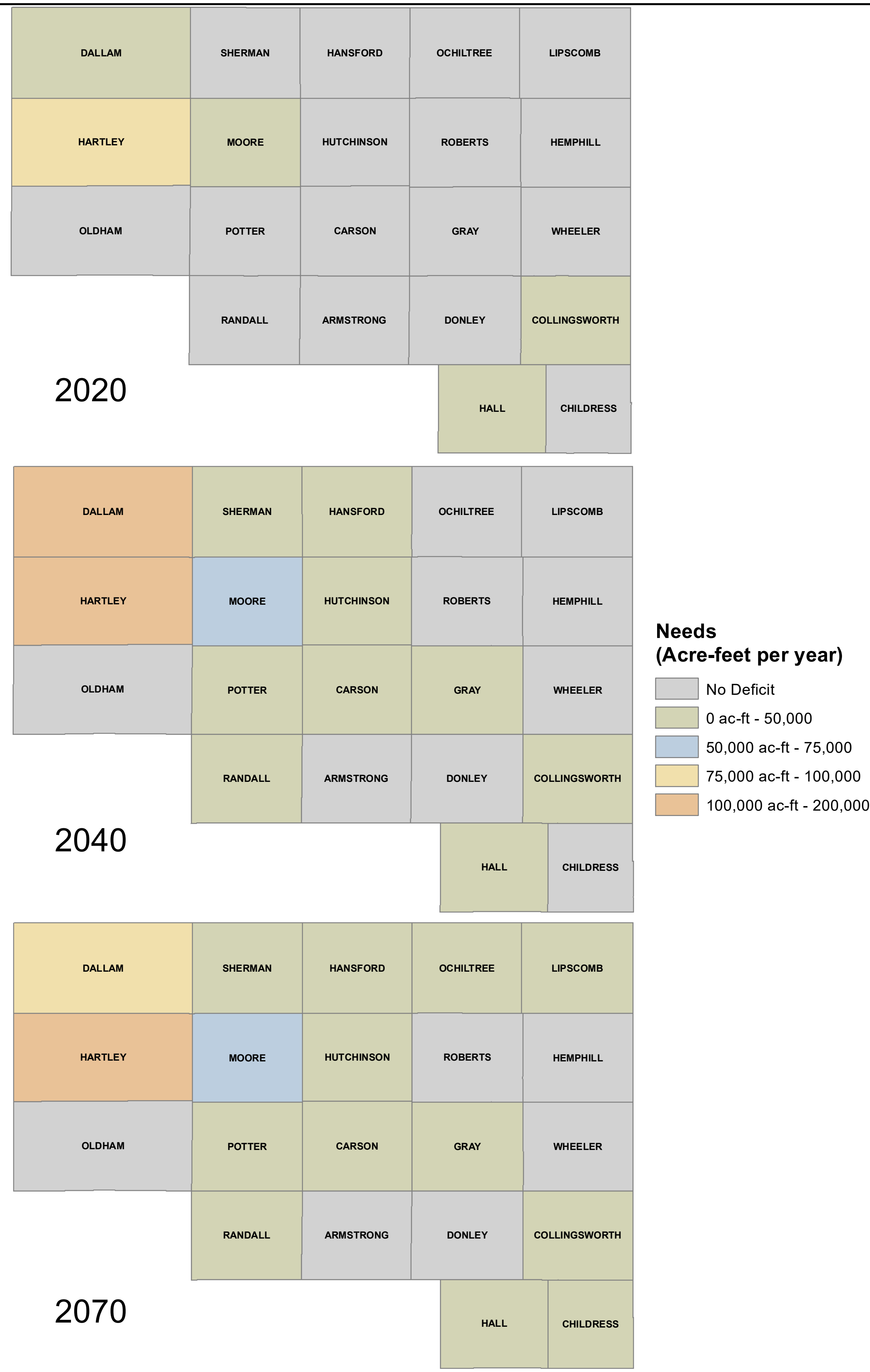
Figure 4-1: PWPA Supplies and Demands (acre-feet per year)

On a county-basis, there are fifteen counties with needs over the planning period. These include Carson, Childress, Collingsworth, Dallam, Gray, Hall, Hansford, Hartley, Hutchinson, Lipscomb, Moore, Ochiltree, Potter, Randall, and Sherman. Table 4-2 presents first tier water needs by county. Figure 4-2 shows the spatial distribution of needs in the region for years 2020, 2040 and 2070. Typically, the counties with the largest needs are those with large irrigation demands. Based on this analysis, there are significant irrigation needs over the 50-year planning period. The municipal needs shown are attributed to growth, reduction of surface water supplies, limitations in developed water rights, or infrastructure limitations. A brief discussion of these needs is presented in the following section.

Table 4-2: Identification of Water Needs/Surplus by County (acre-feet per year)

	Surplus (+) / Need ( )					
County	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Armstrong	290	277	232	192	161	161
Carson	731	95	(43)	(41)	(69)	(110)
Childress	271	230	215	209	28	(176)
Collingsworth	(7,320)	(10,660)	(9,820)	(10,153)	(10,316)	(9,660)
Dallam	(29,910)	(117,199)	(109,234)	(93,380)	(76,444)	(76,664)
Donley	222	222	222	222	185	145
Gray	661	253	(483)	(1,058)	(4,476)	(4,962)
Hall	(15,540)	(14,292)	(11,423)	(8,284)	(5,348)	(6,626)
Hansford	269	185	(26)	(358)	(709)	(763)
Hartley	(84,921)	(193,125)	(178,077)	(160,146)	(142,122)	(142,133)
Hemphill	166	181	196	211	226	240
Hutchinson	3,716	2,088	1,304	290	(477)	(484)
Lipscomb	347	144	15	(127)	(234)	(264)
Moore	(9,768)	(51,382)	(54,656)	(52,777)	(50,284)	(51,002)
Ochiltree	829	490	139	(161)	(524)	(782)
Oldham	870	709	688	659	627	593
Potter	3,268	(1,910)	(7,222)	(13,400)	(18,835)	(22,502)
Randall	3,208	(861)	(5,109)	(10,100)	(15,168)	(18,472)
Roberts	82	78	82	82	81	81
Sherman	492	463	(29,270)	(38,553)	(38,124)	(38,352)
Wheeler	1,591	1,393	1,258	1,095	948	859
Total	**(130,446)**	**(382,621)**	**(401,012)**	**(385,578)**	**(360,874)**	**(370,873)**

Note: Supply values are shown for the county in which it is used, which may differ from the county of the supply source.



0 12.5 25 50 Miles

DATE: JUNE 2019

SCALE: 1:3,168,000

DATUM & COORDINATE SYSTEM: GCS NORTH AMERICAN 1983

PREPARED BY: DML

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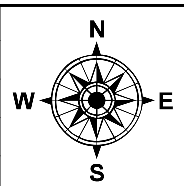


PANHANDLE WATER PLANNING AREA

NEEDS IN PWPA

Location Map

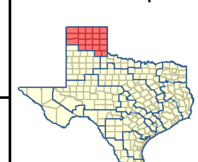


FIGURE 4-2

4.2.1 Identified Needs for Water User Groups

A need occurs when developed supplies are not sufficient to meet projected demands. In the PWPA, there are thirty-five water user groups with identified needs during the planning period. Of these, there are twenty-three cities and county other water users in seventeen counties that are projected to experience a water need by 2070. The largest needs are attributed to high irrigation use or significant increase in municipal demand and comparably limited groundwater resources in Dallam, Hartley, Moore, Potter, and Sherman Counties.

Total needs for all water user groups are projected to be approximately 148,500 acre-feet per year in 2020, increasing to 410,900 acre-feet per year in 2040 and approximately 378,400 acre-feet per year by 2070. In contrast to Table 4-1, these numbers include only the needs (surpluses are set to zero). Irrigation represents approximately 98 percent of the needs in the 2020 projections and around 82 percent of the total need in 2070 with needs ranging from 146,100 to 310,500 acre-feet per year. The needs attributed to the other water use categories total approximately 67,900 acre-feet per year in 2070.

A summary of when the individual water user group needs begin by county and demand type is presented in Table 4-3.

Table 4-3: Decade Need Begins by County and Category

County	Irrigation	Municipal	Manufacturing	Mining	Steam Electric Power	Livestock
Armstrong	-	-	-	-	-	-
Carson	-	2030	-	-	-	-
Childress	-	2060	-	-	-	-
Collingsworth	2020	2020	-	-	-	-
Dallam	2020	2020	-	-	-	-
Donley	-	2060	-	-	-	-
Gray	2060	2030	-	-	-	-
Hall	2020	2030	-	-	-	-
Hansford	-	2030	-	-	-	-
Hartley	2020	2020	-	-	-	-
Hemphill	-	-	-	-	-	-
Hutchinson	-	2030	2040	-	-	-
Lipscomb	-	2040	2040	-	-	-
Moore	2020	2020	2020	-	-	-
Ochiltree	-	2050	-	-	-	-
Oldham	-	-	-	-	-	-
Potter	-	2030	2030	-	-	-
Randall	-	2030	2030	-	-	-
Roberts	-	-	-	-	-	-
Sherman	2040	-	-	-	-	-
Wheeler	-	2050	-	-	-	-

Irrigation

Irrigation needs are identified for seven counties: Collingsworth, Dallam, Gray, Hall, Hartley, Moore, and Sherman Counties (Table 4-4). Five of these counties rely heavily on the Ogallala for irrigation supplies (Dallam, Gray, Hartley, Moore, and Sherman Counties). Irrigators in Collingsworth and Hall Counties rely heavily on the Seymour Aquifer. Five counties have needs starting in 2020 (Table 4-4).

Table 4-4: Projected Irrigation Needs in the PWPA (acre-feet per year)

County	2020	2030	2040	2050	2060	2070
Collingsworth	6,867	10,133	9,283	9,595	9,741	9,069
Dallam	29,586	116,358	107,956	91,644	74,251	74,251
Gray	0	0	0	0	2,687	2,687
Hall	15,637	14,325	11,397	8,194	5,206	6,480
Hartley	84,766	192,765	177,587	159,542	141,411	141,411
Moore	9,208	47,976	49,251	43,861	38,281	38,281
Sherman	0	0	29,567	38,831	38,207	38,423
Total	**146,064**	**381,557**	**385,041**	**351,667**	**309,784**	**310,602**

Municipal

Municipal supplies in the PWPA are typically groundwater while surface water is used in counties with limited groundwater and by river authorities and their member cities to supply their customers. For some cities, there is additional groundwater supply, but it is not fully developed. A list of the municipalities indicating a need is presented in Table 4-5.

Table 4-5: Projected Municipal Needs in the PWPA (acre-feet per year)

Municipality	2020	2030	2040	2050	2060	2070
Amarillo	0	5,670	13,756	23,415	32,128	38,270
Booker	0	0	58	150	220	242
Borger	0	0	0	0	34	36
Cactus	306	582	819	1,071	1,292	1,429
Canyon	0	54	696	1,364	2,578	3,171
Childress	0	0	0	0	163	344
Clarendon	0	0	0	0	32	66
County-Other Moore	0	12	23	33	41	41
Dalhart	557	1,261	1,814	2,374	2,917	3,137
Dumas	0	931	2,008	3,267	4,432	4,982
Gruver	0	20	98	180	256	280
McLean	0	0	0	40	88	115
Memphis	0	28	62	102	142	146
Pampa	0	160	836	1,344	1,794	2,241
Panhandle	0	461	586	581	580	580
Perryton	0	0	0	193	556	815

Municipality	2020	2030	2040	2050	2060	2070
Red River Authority - Childress	0	0	0	0	23	49
Spearman	0	0	0	229	495	517
Stinnett	0	0	0	0	31	31
Sunray	0	110	336	415	470	485
TCW Supply	0	132	233	315	383	383
Texline	0	0	0	0	12	28
Wellington	524	540	548	566	581	595
Wheeler	0	0	0	47	132	153
Total	**1,387**	**9,961**	**21,873**	**35,686**	**49,380**	**58,136**

Manufacturing

There are five counties with manufacturing needs identified in the PWPA. Most manufacturing interests buy water from retail providers or develop their own groundwater supplies. For each of these counties, much of the need is associated with major water providers. For Moore County, these needs are the result of limited groundwater supplies for the city of Cactus. In Potter and Randall Counties, the needs are associated with needs identified with the city of Amarillo. In Hutchinson County, the need is associated with the city of Borger. In Lipscomb County, the need is associated with the city of Booker.

Table 4-6: Projected Manufacturing Needs in the PWPA (acre-feet per year)

County	2020	2030	2040	2050	2060	2070
Hutchinson	0	32	58	79	167	172
Lipscomb	0	0	40	95	131	139
Moore	1,008	1,773	2,221	4,131	5,769	5,785
Potter	0	629	1,471	2,327	2,951	3,209
Randall	0	151	225	300	354	379
Total	**1,008**	**2,585**	**4,015**	**6,932**	**9,372**	**9,684**

Mining

There are no mining needs in the PWPA.

Steam Electric Power

There are no steam electric needs in the PWPA.

Livestock

There are no identified livestock needs in the PWPA. This is because it was assumed if there was sufficient supply available within the county, this supply would be developed by livestock producers. For most counties, water for livestock is from groundwater and/or local stock ponds. In the heavily pumped counties, there will be competition for groundwater supplies. It is assumed that the decrease in water used for irrigation will be available for livestock use.

4.2.2 Identified Needs for Major Water Providers

There are five major water providers located in the PWPA that sell water to wholesale customers. Of these entities, all five are projected to have needs within the planning period: City of Amarillo, City of Borger, City of Cactus, Canadian River Municipal Water Authority (CRMWA), and Greenbelt Municipal & Industrial Water Authority (Greenbelt MIWA). Much of the early needs are associated with the infrastructure constraints for current well field production. These needs increase over the planning cycle due to growth and reduced availability from the Ogallala aquifer with current well fields. Table 4-7 shows the projected water supply needs for the major water providers in the PWPA. Whereas Amarillo, Borger, and Cactus are water user groups in addition to being wholesale water providers, CRMWA and Greenbelt MIWA are strictly wholesale water providers and do not have needs separate from those of their customers. Both CRMWA and Greenbelt MWIA plan to develop water management strategies to help meet their customers' needs and prepare for potential impacts from drought to their current water sources.

Table 4-7: Projected Needs for Major Providers in the PWPA (acre-feet per year)

Major Provider	2020	2030	2040	2050	2060	2070
Amarillo	0	6,482	15,561	26,234	35,209	41,635
Borger	0	0	0	0	105	112
Cactus	1,314	2,355	3,040	3,681	4,133	4,286
CRMWA	11,402	20,230	30,247	40,673	47,093	47,264
Greenbelt MIWA	0	0	0	0	346	723

4.2.3 Summary of First Tier Water Needs

On a water user group basis, the total demands exceed the total developed supply starting in 2020, largely attributed to the geographical constraints of the demand centers and developed supplies. Most of the needs are associated with large irrigation demands that cannot be met with groundwater sources beneath currently irrigated lands. Other needs are due to limitations of infrastructure and/or growth. The evaluation of regional water supplies indicates that groundwater supplies could be further developed. However, often the needed infrastructure is not developed, or the potential source is not located near a water supply need. The first tier needs report provided by TWDB is provided in Attachment 4-1 at the end of this chapter. The region's options and strategies to meet needs is explored in more detail in Chapter 5 and the impacts of these strategies on water quality are discussed in Chapter 6.

4.3 Second Tier Water Needs Analysis

The second-tier water needs analysis compares currently available supplies with demands after reductions from conservation and direct reuse. Conservation and direct reuse are both considered water management strategies and are discussed further in Chapter 5. In the PWPA, conservation was recommended for all municipal and irrigation water users. There is one recommended direct reuse project for Amarillo in the PWPA.

4.3.1 Summary of Second Tier Water Needs for Water User Groups

After the implementation of conservation strategies and direct reuse, the PWPA has a projected water need of 83,207 acre-feet per year in 2020. Most of this is associated with irrigated agriculture that has not fully realized the benefits of conservation. On a regional basis, much of the need after 2060 that cannot be met through conservation is associated with municipal and manufacturing demands. As well fields become depleted and demands increase, the ability to meet these needs with current supplies diminishes. By 2070, the projected need in the PWPA is over 90,000 acre-feet per year. This need is associated with municipal, manufacturing, and irrigation uses. A summary of the secondary needs by use type is shown in Table 4-8.

Table 4-8: Summary of Projected Secondary Needs by Use Type (acre-feet per year)

Use Type	2020	2030	2040	2050	2060	2070
Municipal	1,340	3,858	7,389	18,770	31,730	39,803
Manufacturing	0	4	14	23	30	29
Mining	1,008	2,585	4,015	6,932	9,372	9,684
Steam Electric Power	0	0	0	0	0	0
Livestock	0	0	0	0	0	0
Irrigation	80,859	254,152	122,803	65,007	47,488	42,031
Total	**83,207**	**260,599**	**134,221**	**90,732**	**88,620**	**91,547**

4.3.2 Summary of Secondary Tier Water Needs for Major Water Providers

The projected water needs for major water providers (MWP) after conservation and direct reuse is shown on Table 4-9. For providers that deliver water only to wholesale customers, the conservation savings were estimated as a part of the customer's conservation savings. However, it is uncertain whether those savings will reduce contractual demands on the MWP. For MWPs that also provide retail supplies, the conservation savings reflect the savings estimated for the water user group. Amarillo is the only MWP that has a recommended direct reuse strategy.

Table 4-9: Summary of Projected Secondary Needs for Major Water Providers (acre-feet per year)

Major Provider	2020	2030	2040	2050	2060	2070
Amarillo	0	1,472	6,556	16,716	25,124	30,953
Borger	0	0	0	0	61	68
Cactus	1,301	2,340	3,023	3,662	4,112	4,263
CRMWA	8,861	17,416	27,381	37,760	44,105	44,243
Greenbelt MIWA	0	0	0	0	286	661

ATTACHMENT 4-1

WATER USER GROUP NEEDS
AND
MAJOR WATER PROVIDER NEEDS BY USE TYPE

Region A Water User Group (WUG) Needs/Surplus

WUG supplies and projected demands are entered for each of a WUG's region-county-basin divisions. The needs shown in the WUG Needs/Surplus report are calculated by first deducting the WUG split's projected demand from its total existing water supply volume. If the WUG split has a greater existing supply volume than projected demand in any given decade, this amount is considered a surplus volume. Surplus volumes are shown as positive values, and needs are shown as negative values in parentheses.

	(NEEDS)/SURPLUS (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
ARMSTRONG COUNTY - RED BASIN						
CLAUDE MUNICIPAL WATER SYSTEM	224	183	115	55	7	7
COUNTY-OTHER	12	16	18	18	18	18
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	54	78	99	119	136	136
CARSON COUNTY - CANADIAN BASIN						
WHITE DEER	23	23	23	23	23	23
COUNTY-OTHER	81	71	63	62	47	25
MANUFACTURING	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
CARSON COUNTY - RED BASIN						
GROOM MUNICIPAL WATER SYSTEM	10	13	15	16	16	16
PANHANDLE MUNICIPAL WATER SYSTEM	162	(461)	(586)	(581)	(580)	(580)
WHITE DEER	29	30	30	30	30	30
COUNTY-OTHER	91	83	76	74	60	41
MANUFACTURING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	335	336	336	335	335	335
CHILDRESS COUNTY - RED BASIN						
CHILDRESS	0	0	0	0	(163)	(344)
RED RIVER AUTHORITY OF TEXAS*	0	0	0	0	(23)	(49)
COUNTY-OTHER	1	1	1	1	1	0
LIVESTOCK	72	27	9	0	0	0
IRRIGATION	198	202	205	208	213	217
COLLINGSWORTH COUNTY - RED BASIN						
RED RIVER AUTHORITY OF TEXAS*	0	0	0	0	0	0
WELLINGTON MUNICIPAL WATER SYSTEM	(524)	(540)	(548)	(566)	(581)	(595)
COUNTY-OTHER	17	13	11	8	6	4
LIVESTOCK	54	0	0	0	0	0
IRRIGATION	(6,867)	(10,133)	(9,283)	(9,595)	(9,741)	(9,069)
DALLAM COUNTY - CANADIAN BASIN						
DALHART	(379)	(880)	(1,300)	(1,741)	(2,181)	(2,385)
TEXLINE	55	39	22	5	(12)	(28)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	(29,586)	(116,358)	(107,956)	(91,644)	(74,251)	(74,251)
DONLEY COUNTY - RED BASIN						
CLARENDON	0	0	0	0	(32)	(66)
RED RIVER AUTHORITY OF TEXAS*	0	0	0	0	0	0
COUNTY-OTHER	56	56	56	56	51	45
LIVESTOCK	0	0	0	0	0	0

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Water User Group (WUG) Needs/Surplus

	(NEEDS)/SURPLUS (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
IRRIGATION	166	166	166	166	166	166
GRAY COUNTY - CANADIAN BASIN						
PAMPA MUNICIPAL WATER SYSTEM	186	(160)	(836)	(1,344)	(1,794)	(2,241)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	23	25	25	25	25	25
MINING	0	0	0	0	0	0
LIVESTOCK	71	46	36	25	13	1
IRRIGATION	221	221	221	221	(2,687)	(2,687)
GRAY COUNTY - RED BASIN						
MCLEAN MUNICIPAL WATER SUPPLY	105	66	16	(40)	(88)	(115)
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	55	55	55	55	55	55
HALL COUNTY - RED BASIN						
MEMPHIS	10	(28)	(62)	(102)	(142)	(146)
RED RIVER AUTHORITY OF TEXAS*	21	12	5	0	0	0
TURKEY MUNICIPAL WATER SYSTEM	0	0	0	0	0	0
COUNTY-OTHER	0	0	0	0	0	0
LIVESTOCK	66	49	31	12	0	0
IRRIGATION	(15,637)	(14,325)	(11,397)	(8,194)	(5,206)	(6,480)
HANSFORD COUNTY - CANADIAN BASIN						
GRUVER	60	(20)	(98)	(180)	(256)	(280)
SPEARMAN MUNICIPAL WATER SYSTEM	134	136	13	(229)	(495)	(517)
COUNTY-OTHER	53	47	37	29	20	12
MANUFACTURING	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	22	22	22	22	22	22
HARTLEY COUNTY - CANADIAN BASIN						
DALHART	(178)	(381)	(514)	(633)	(736)	(752)
HARTLEY WSC	23	21	24	29	25	30
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	(84,766)	(192,765)	(177,587)	(159,542)	(141,411)	(141,411)
HEMPHILL COUNTY - CANADIAN BASIN						
CANADIAN	165	181	196	211	226	240
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
HEMPHILL COUNTY - RED BASIN						
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	1	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Water User Group (WUG) Needs/Surplus

	(NEEDS)/SURPLUS (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
HUTCHINSON COUNTY - CANADIAN BASIN						
BORGER	3,436	2,032	1,416	542	(34)	(36)
FRITCH	0	0	0	0	0	0
STINNETT	127	78	39	2	(31)	(31)
TCW SUPPLY	1	(132)	(233)	(315)	(383)	(383)
COUNTY-OTHER	53	46	44	44	42	42
MANUFACTURING	3	(32)	(58)	(79)	(167)	(172)
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	96	96	96	96	96	96
LIPSCOMB COUNTY - CANADIAN BASIN						
BOOKER	231	30	(57)	(146)	(213)	(233)
DARROUZETT	26	19	15	19	15	11
FOLLETT	11	13	19	13	18	14
HIGGINS MUNICIPAL WATER SYSTEM	13	16	12	16	11	17
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	0	0	(40)	(95)	(131)	(139)
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	66	66	66	66	66	66
MOORE COUNTY - CANADIAN BASIN						
CACTUS MUNICIPAL WATER SYSTEM	(306)	(582)	(819)	(1,071)	(1,292)	(1,429)
DUMAS	597	(931)	(2,008)	(3,267)	(4,432)	(4,982)
FRITCH	2	2	2	1	1	1
SUNRAY	155	(110)	(336)	(415)	(470)	(485)
COUNTY-OTHER	0	(12)	(23)	(33)	(41)	(41)
MANUFACTURING	(1,008)	(1,773)	(2,221)	(4,131)	(5,769)	(5,785)
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	(9,208)	(47,976)	(49,251)	(43,861)	(38,281)	(38,281)
OCHILTREE COUNTY - CANADIAN BASIN						
BOOKER	3	0	(1)	(4)	(7)	(9)
PERRYTON MUNICIPAL WATER SYSTEM	795	458	106	(193)	(556)	(815)
COUNTY-OTHER	31	32	34	36	39	42
MANUFACTURING	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
OLDHAM COUNTY - CANADIAN BASIN						
VEGA	3	8	11	13	13	13
COUNTY-OTHER	322	285	290	290	291	291
MINING	0	0	0	0	0	0
LIVESTOCK	297	202	180	157	133	108
IRRIGATION	0	0	0	0	0	0
OLDHAM COUNTY - RED BASIN						
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	248	214	207	199	190	181
IRRIGATION	0	0	0	0	0	0

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Water User Group (WUG) Needs/Surplus

	(NEEDS)/SURPLUS (ACRE FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
POTTER COUNTY - CANADIAN BASIN						
AMARILLO	662	(1,881)	(4,567)	(7,764)	(10,652)	(12,695)
COUNTY-OTHER	900	900	900	900	900	900
MANUFACTURING	0	(119)	(174)	(225)	(278)	(278)
MINING	0	0	0	0	0	0
STEAM ELECTRIC POWER	0	0	0	0	0	0
LIVESTOCK	95	78	60	41	20	0
IRRIGATION	291	291	291	291	291	291
POTTER COUNTY - RED BASIN						
AMARILLO	437	(1,239)	(3,005)	(5,111)	(7,013)	(8,359)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	313	(510)	(1,297)	(2,102)	(2,673)	(2,931)
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	570	570	570	570	570	570
RANDALL COUNTY - RED BASIN						
AMARILLO	894	(2,550)	(6,184)	(10,540)	(14,463)	(17,216)
CANYON	560	(54)	(696)	(1,364)	(2,578)	(3,171)
HAPPY*	0	0	0	0	0	0
LAKE TANGLEWOOD	172	154	134	117	105	105
COUNTY-OTHER	714	711	708	705	703	701
MANUFACTURING	5	(151)	(225)	(300)	(354)	(379)
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	863	1,029	1,154	1,282	1,419	1,488
ROBERTS COUNTY - CANADIAN BASIN						
MIAMI	73	72	74	75	75	75
COUNTY-OTHER	3	1	3	3	3	3
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
ROBERTS COUNTY - RED BASIN						
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	6	5	5	4	3	3
IRRIGATION	0	0	0	0	0	0
SHERMAN COUNTY - CANADIAN BASIN						
STRATFORD	325	295	282	267	66	56
TEXHOMA	8	9	15	11	17	15
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	159	159	(29,567)	(38,831)	(38,207)	(38,423)
WHEELER COUNTY - RED BASIN						
SHAMROCK MUNICIPAL WATER SYSTEM	492	489	485	473	460	445
WHEELER	211	150	57	(47)	(132)	(153)
COUNTY-OTHER	89	88	86	76	65	53
MINING	0	0	0	0	0	0
LIVESTOCK	509	374	337	299	259	216
IRRIGATION	290	292	293	294	296	298

*A single asterisk next to a WUG's name denotes that the WUG is split by two or more planning regions.

Region A Major Water Provider Needs/Surplus

First Tier Needs (acre-feet per year)

Major Water Provider	Category of Use	2020	2030	2040	2050	2060	2070
Amarillo	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	(703)	(1,565)	(2,445)	(3,069)	(3,353)
	Mining	0	0	0	0	0	0
	Municipal	1,743	(5,779)	(13,996)	(23,789)	(32,140)	(38,282)
	Municipal Non-Potable	1,757	3,809	5,757	7,849	10,242	12,773
	Steam Electric Power	0	0	0	0	0	0
	Total Potable Needs	**1,743**	**(6,482)**	**(15,561)**	**(26,234)**	**(35,209)**	**(41,635)**
	Total Non-Potable Needs	**0**	**0**	**0**	**0**	**0**	**0**
CRMWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	0	0	0	0	0
	Mining	0	0	0	0	0	0
	Municipal	(11,402)	(20,230)	(30,247)	(40,673)	(47,093)	(47,264)
	Steam Electric Power	0	0	0	0	0	0
	Total	**-11,402**	**-20,230**	**-30,247**	**-40,673**	**-47,093**	**-47,264**
Greenbelt MIWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	38	38	38	0	(17)	(36)
	Mining	0	0	0	0	0	0
	Municipal	1,342	869	439	54	(329)	(687)
	Steam Electric Power	0	0	0	0	0	0
	Total	**1,380**	**907**	**477**	**54**	**-346**	**-723**
Cactus	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	(1,008)	(1,773)	(2,221)	(2,610)	(2,841)	(2,857)
	Mining	0	0	0	0	0	0
	Municipal	(306)	(582)	(819)	(1,071)	(1,292)	(1,429)
	Steam Electric Power	0	0	0	0	0	0
	Total	**-1,314**	**-2,355**	**-3,040**	**-3,681**	**-4,133**	**-4,286**
Borger	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	1	0	0	0	(71)	(76)
	Mining	0	0	0	0	0	0
	Municipal	3,436	2,032	1,416	542	(34)	(36)
	Steam Electric Power	0	0	0	0	0	0
	Total	**3,437**	**2,032**	**1,416**	**542**	**-105**	**-112**

Region A Major Water Provider Needs/Surplus

Second Tier Needs (acre-feet per year)[1]

Major Water Provider	Category of Use	2020	2030	2040	2050	2060	2070
Amarillo	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	(703)	(1,565)	(2,445)	(3,069)	(3,353)
	Mining	0	0	0	0	0	0
	Municipal	6,281	(769)	(4,991)	(14,271)	(22,055)	(27,600)
	Municipal Non-Potable	1,757	3,809	5,757	7,849	10,242	12,773
	Steam Electric Power	0	0	0	0	0	0
	Total Potable Needs	**6,281**	**(1,472)**	**(6,556)**	**(16,716)**	**(25,124)**	**(30,953)**
	Total Non-Potable Needs	**1,757**	**3,809**	**5,757**	**7,849**	**10,242**	**12,773**
CRMWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	0	0	0	0	0	0
	Mining	0	0	0	0	0	0
	Municipal	(8,861)	(17,416)	(27,381)	(37,760)	(44,105)	(44,243)
	Steam Electric Power	0	0	0	0	0	0
	Total	**(8,861)**	**(17,416)**	**(27,381)**	**(37,760)**	**(44,105)**	**(44,243)**
Greenbelt MIWA	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	38	38	38	0	(17)	(36)
	Mining	0	0	0	0	0	0
	Municipal	1,385	941	521	138	(241)	(596)
	Steam Electric Power	0	0	0	0	0	0
	Total	**1,423**	**979**	**559**	**138**	**(258)**	**(632)**
Cactus	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	(1,008)	(1,773)	(2,221)	(2,610)	(2,841)	(2,857)
	Mining	0	0	0	0	0	0
	Municipal	(293)	(567)	(802)	(1,052)	(1,271)	(1,406)
	Steam Electric Power	0	0	0	0	0	0
	Total	**(1,301)**	**(2,340)**	**(3,023)**	**(3,662)**	**(4,112)**	**(4,263)**
Borger	Irrigation	0	0	0	0	0	0
	Livestock	0	0	0	0	0	0
	Manufacturing	1	0	0	0	(71)	(76)
	Mining	0	0	0	0	0	0
	Municipal	3,477	2,075	1,459	585	9	7
	Steam Electric Power	0	0	0	0	0	0
	Total	**3,478**	**2,075**	**1,459**	**585**	**(62)**	**(69)**

[1]Second Tier Needs are needs after conservation and direct reuse.

5 WATER MANAGEMENT STRATEGIES

Chapter 5 identifies and discusses the water management strategies to meet identified water needs as outlined in Chapter 4. These needs are met through a variety of strategies that have been developed through coordination with the water users in PWPA.

There are 36 water users and five Major Water Providers (MWP) that are identified with a projected need over the planning period. As previously discussed, the largest quantities of water needs are associated with irrigated agriculture, but this plan also identified over 70,000 acre-feet per year of needs for municipal and manufacturing water use by 2070.

Chapter 5 is divided into four main parts. Chapter 5A discusses the types of potentially feasible water management strategies, the process used to develop the strategies, and the factors considered in evaluating the strategies. Chapter 5B discusses the water conservation strategies that were considered and recommended for the PWPA. This includes the identification and evaluation for municipal and irrigation conservation measures. Chapter 5C presents the recommended water management strategies for the five MWPs in the PWPA. Chapter 5D addresses the recommended strategies for each water user group with identified needs and summarizes the water management plans by county.

The water management strategies identified in the following subchapters are for water users with projected needs. For aggregated water users, such as "County-Other", the identification of needs can be challenging due to the nature of the data evaluation. If water quantity or quality needs for smaller entities (municipalities with populations less than 500) became known to the PWPG, strategies for these needs are also included in this plan. However, the PWPG considers the development of water strategies for smaller entities that may not show a need consistent with the Panhandle Water Plan.

The report assumes that management strategies to meet any identified needs are employed or implemented by the respective water user. The PWPG does not take responsibility in planning or implementing the strategies.

Chapter 5

Chapter 5A: Identification of Water Management Strategies

Chapter 5B: Water Conservation

Chapter 5C: Major Water Provider Strategies

Chapter 5D: Water Management Strategies by County

Associated Appendices/Attachments

Appendix D: Water Management Strategy Cost Estimates

Attachment 5 1: List of potentially feasible strategies

Attachment 5 2: Strategy Evaluation Matrix and Quantified Environmental Impact Matrix

Attachment 5 3: Recommended municipal conservation goals

5A IDENTIFICATION OF POTENTIALLY FEASIBLE WATER MANAGEMENT STRATEGIES

This section provides a review of the types of water management strategies (WMS) considered for the PWPA and the approach for identifying the potentially feasible water management strategies for water users with needs. Once a list of potentially feasible strategies has been identified, the most feasible strategies are recommended for implementation. Alternative strategies can also be identified, in case the recommended strategies become unfeasible. Where appropriate, regional strategies to supply water were considered. These strategies are discussed in more detail in later subchapters. All strategies were evaluated under drought of record conditions. This subchapter identifies the potentially feasible strategies for water users and MWPs that were found to have a projected need in Chapter 4.

5A.1 Water Management Strategy Types

Identification of a supply source as a potentially feasible strategy depends on the availability of the source, the accessibility of the source to the entity developing the strategy, and the feasibility of developing a strategy from the source of supply. It should be noted that there can be potentially feasible strategies that are not identified through this process for an entity but could be identified in the future. The methodology to identify potentially feasible strategies and a list of the strategy types considered for each water user with a need is included in Attachment 5-1.

The purpose of this chapter is to provide a big picture discussion on the various strategy types that were identified to potentially reduce the WUG/MWP needs.

While each of these strategy types were considered by the PWPA, not all were determined as viable options for addressing needs in the region. Strategies were determined as unfeasible when the associated costs involved with implementation of the strategy outweighed the overall benefits. Such costs can include, but are not limited to, economic feasibility and negative impacts on other water users.

Water Management Strategy Categories

- Water Conservation
- Drought Management Measures
- Wastewater Reuse
- Management and/or Expanded Use of Existing Supplies
  - System Operation
  - Conjunctive Use of Groundwater and Surface Water
  - Reallocation of Reservoir Storage
  - Voluntary Redistribution of Water Resources
  - Voluntary Subordination of Existing Water Rights
  - Yield Enhancement
  - Water Quality Improvement
- New Supply Development
  - Surface Water Resources
  - Groundwater Resources
  - Brush Control
  - Desalination
  - Water Right Cancellation
  - Rainwater Harvesting
  - Aquifer Storage and Recovery (ASR)
  - Precipitation Enhancement
- Interbasin Transfers
- Emergency Transfers of Water

The strategy types (and associated subcategories) that were determined as potentially feasible strategies for entities within the PWPA are: 1) water conservation and drought management 2) wastewater reuse 3) expanded use of existing supplies (groundwater supplies, surface water supplies, local supplies, conjunctive use, water quality improvements, and voluntary transfer), 4) new groundwater supply development, including brackish groundwater desalination, 5) aquifer storage and recovery, 6) brush control, and 7) precipitation enhancement.

The potentially feasible strategy types that determined not viable for long-term water supply for the PWPA and are not discussed further include water right cancellation, interbasin transfers, and emergency transfers of water. Water right cancellation and interbasin transfers are surface water strategies. There is little existing surface in the region and little to no unappropriated surface water. Neither of these strategies would provide reliable long-term supplies. Emergency transfers of water is a strategy typically employed during an emergency situation and is not considered a sustainable strategy for long-term water needs.

The sections below include a brief discussion of each of the strategy types considered for the PWPA and the specific application to the users in the region.

5A.1.1 Water Conservation and Drought Management

Water conservation is defined as methods and practices that reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses. Water conservation is typically viewed as long-term changes in water use that are incorporated into daily activities. Conversely, drought management is the temporary reduction in water use in direct response to a drought or water supply emergency. It is typically short-term and does not result in lasting changes. If drought management measures are used as water management strategies, there is little or no flexibility remaining should the drought exceed the previous drought of record conditions.

Water conservation is a valued water management strategy in the PWPA because it helps prolong the limited water resources in the region. It is recommended for municipal (only County-Other users with needs have conservation savings applied, all other municipal water user groups have conservation savings applied) and irrigation water users, whether the user has a defined need or not, and it is encouraged for all other users. Drought management is not a recommended strategy in the PWPA because it does not provide a long-term solution to water needs. This strategy is still an important option to water users for times when existing water supplies are threatened during drought and entities should develop drought contingency plans in accordance with Texas Administrative Code, Chapter 288 rules.

5A.1.2 Wastewater Reuse

Wastewater reuse utilizes treated wastewater effluent as either a replacement for a potable water supply (potable reuse) or utilizes treated wastewater that has been returned to a water supply resource (indirect reuse). Wastewater reuse is currently heavily utilized by industries that purchases wastewater effluent from larger municipalities. It is also used for limited agricultural irrigation. The largest producers of wastewater effluent are the larger cities, including Amarillo, Borger, Canyon, Dumas and Pampa. Currently, Amarillo sells most of its treated wastewater to Xcel Energy for cooling water. Borger also sells its wastewater to industrial customers. There may be potential to expand wastewater reuse in the PWPA, but the amounts may be limited due to the current level of use.

5A.1.3 Expanded Use of Existing Supplies

Expanded use of existing supplies includes seven subcategories ranging from selling developed water that is not currently used to enhancing existing supplies through operations, storage, treatment or other means. In the PWPA, three of the seven subcategories were determined potentially feasible. These include conjunctive use of groundwater and surface water, voluntary transfer (sales or contracts for developed water), and water quality improvements.

5A.1.4 Conjunctive Use of Groundwater and Surface Water

Conjunctive use is the operation of multiple sources of water to optimize the water resources for additional supply. In the PWPA, there are two MWPs that own and operate both surface water and groundwater sources: CRMWA and Greenbelt MIWA. Both of these entities intend to conjunctively use the surface water when available to meet demands and use additional groundwater to supplement surface water supplies during drought. This will help reduce evaporative losses associated with the surface water reservoirs, while still meeting demands with groundwater when less or no surface water is available. Generally, this is a recognized operational approach for current and future supplies.

5A.1.5 Voluntary Transfer

Voluntary transfer is redistribution of existing water supplies from one user to another through sales, leases, contracts, options, subordination or other similar types of agreements. Typically, the entity providing the water has determined that it does not need the water for the duration of the transfer. The transfer of water could be for a set period of years or a permanent transfer. Redistribution of water makes use of existing resources and provides a more immediate source of water. In the PWPA, there is little to no developed water that is available for redistribution without the development of additional strategies. This strategy is used to represent sales and contracts between a water provider and its customers. It can include current contractual obligations and potential future customers.

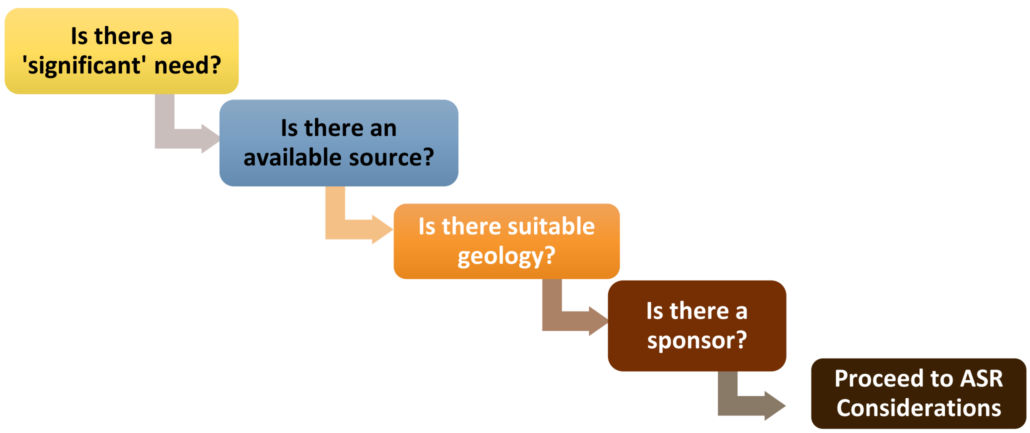
5A.1.6 Water Quality Improvements

Water quality improvements allow for the use of impaired water for municipal or other uses. In PWPA, there are areas with impaired water quality, specifically elevated nitrates and salts. Water quality improvement for these sources are typically accomplished through desalination. Nitrates can also be treated using ion exchange. This strategy type would apply to treatment of other water quality parameters. This strategy is considered for users with sufficient water quantity, but impaired water quality.

5A.1.7 Aquifer Storage and Recovery (ASR)

Aquifer storage and recovery is a type of strategy that utilizes suitable geologic formations to store water until needed. The water to be stored can be introduced through enhanced recharge or more commonly injected through a well into the aquifer. If an injection well is used, Texas law requires that the water be treated to the same quality of the receiving aquifer. Source water for ASR can include excess surface water, treated wastewater, or groundwater from another aquifer. The benefit of this strategy in the PWPA is that it can better utilize available infrastructure (transmission and/or treatment) during low demand periods and store the water to minimize evaporation. This strategy requires the availability of a suitable geologic formation for storage of the water and the infrastructure to place the water into the aquifer and then recover the water when needed. This strategy must be considered water users with a significant need as defined by the PWPG. For the PWPA, 5,000 acre-feet per year is used as the threshold for significant need. Two major water providers, CRMWA and Amarillo, meet this threshold. ASR is considered for CRMWA and Amarillo. As part of the CRMWA ASR strategy, the city of Pampa is considered as a participant in the ASR project.

ASR Decision Matrix



5A.1.8 New Groundwater Development

Groundwater accounted for approximately 98 percent of the total water use in the PWPA in 2016. Over much of the region, there is available groundwater for future development. Towards the southeast portion of the region, groundwater resources become more limited and there are water quality concerns. Even with these limitations, groundwater is a viable and cost-effective supply source for the PWPA. Most of municipal water users with a need during the planning period are expected to expand their current groundwater use or develop new groundwater supplies. Table 5A-1 shows the amount of groundwater that is available for new groundwater development by aquifer. There are areas within the PWPA that have limited groundwater sources or are heavily using these sources. Counties that are near capacity in utilizing the fresh groundwater resources are Childress, Collingsworth, Hall, and Hutchinson County. Also, there is little groundwater available for future development in the heavily irrigated areas in Dallam, Hartley, Moore, and Sherman County. Potential users of new or expanded groundwater is presented by aquifer and county in Table 5A-2.

Table 5A-1: Available Groundwater Supplies for Strategies

Aquifer	Unallocated Supplies[1] (acre feet)
Ogallala Aquifer/ Rita Blanca	1,682,229
Seymour Aquifer	5,820
Blaine Aquifer	17,291
Dockum Aquifer	232,449
Other Aquifer	436

[1] This is the amount of groundwater that is available for strategies in 2020.

Table 5A-2: Potential Users of New Groundwater

Source County	Ogallala/Rita Blanca	Dockum	Seymour
Armstrong	Claude		
Carson	Panhandle, Amarillo		
Childress			
Collingsworth			Wellington
Dallam	Dalhart, Texline		
Donley	Memphis, GMIWA		
Gray	McLean, Pampa		
Hall			Lakeview
Hansford	Gruver, Spearman		
Hartley			
Hemphill			
Hutchinson	Borger, Stinnett, TCW Supply		
Lipscomb	Booker		
Moore	Cactus, Dumas, Sunray		
Ochiltree	Perryton		
Oldham			
Potter	Amarillo, County-Other	County-Other	
Randall	Canyon, Lake Tanglewood, County-Other	Canyon, County-Other	
Roberts	CRMWA, Amarillo		
Sherman			
Wheeler	Wheeler		

5A.1.10 Desalination

Desalination of brackish groundwater was considered potentially feasible, but due to the availability of non-brackish groundwater for users with a need, it was not considered for any user in the PWPA. Seawater desalination is not feasible because the PWPA is located more than 500 miles from the coast.

5A.1.11 Brush Control

In 1985, the Texas Legislature authorized the Texas State Soil and Water Conservation Board (TSSWCB) to conduct a program for the "selective control, removal, or reduction of brush species that consume water to a degree that is detrimental to water conservation." In 1999 the TSSWCB began the Brush Control Program. In 2011, the 82nd legislature replaced the Brush Control Program with the Water Supply Enhancement Program (WSEP). The WSEP's purpose is to increase available surface and groundwater supplies through the selective control of brush species that are detrimental to water conservation. WSEP considers priority watersheds across the state, the need for conservation within the territory of a proposed projection based on the State Water Plan and if the Regional Water Planning Group has identified brush control as a strategy in the State Water Plan as part of their competitive grant, cost sharing program. However, this program is currently not funded. There are three primary species of brush in the PWPA that are eligible for funding from the WSEP as shown in Table 5A-3.

The Lake Meredith watershed is a priority watershed for brush control. In 2000, the State sponsored a feasibility study of brush removal in the Canadian River downstream from Ute Reservoir to Lake Meredith, which indicated potential significant reductions in water loss from brush. Since then, CRMWA has helped sponsor brush removal in the Lake Meredith watershed. However, brush management must be an on-going strategy to continue to realize water savings. This strategy is a potentially feasible strategy for CRMWA and users of Lake Meredith.

Table 5A-3: Plant Water Use Rates

Plant	Water Use Per Tree (gallons/tree/day)	Water Savings (ac ft/ac/yr)
Juniper	46.8	0.14 – 0.33
Mesquite	44	0.05
Salt cedar	0.1 – 15	2 – 5

Source: Texas State Soil and Water Conservation Board Brush Control Program, 2010 Annual Report

5A.1.12 Precipitation Enhancement

Precipitation enhancement introduces seeding agents to stimulate clouds to generate more rainfall. This process is also commonly known as cloud seeding or weather modification. There is one active precipitation enhancement program in the PWPA. This program covers most of the counties in the Panhandle GCD. The benefits from increased rainfall through precipitation enhancement projects include increased agricultural production, decreased irrigation use, increased reservoir levels, increased and higher quality forage for livestock and wildlife, and fire and hail suppression. Due to its primary use for agricultural benefits in the PWPA, this strategy is considered as part of the irrigation conservation strategies and discussed in Chapter 5B.

5A.2 Evaluation Procedures

The consideration and selection of water management strategies for water user groups with needs followed TWDB guidelines and were conducted in open meetings within the PWPA. The PWPA consistently endorsed the highest level of conservation achievable for all water uses in the region. In addition, environmental impacts and the protection of the region's resources were a priority in the selection process. In the development of the water management strategies, existing water rights, water contracts, and option agreements are recognized and fully protected.

The potentially feasible strategies were evaluated in accordance with state guidance and evaluation criteria. Some considerations listed in TAC 357.7(a), such as inter-basin transfers and third party impacts due to re-distribution of water rights, were not specifically reviewed because they were not applicable to strategies identified for the PWPA needs.

The definition of quantity is the amount of water the strategy would provide to the respective user group in acre-feet per year. This amount is considered with respect to the user's short-term and long-term needs. Reliability is an assessment of the availability of the specified water quantity to the user over time. If the quantity of water is available to the user all the time, then the strategy has a high reliability. If the quantity of water is contingent on other factors, reliability will be lower.

The assessment of cost for each strategy is expressed in dollars per acre-foot per year for water delivered and treated for the end user requirements. Calculations of these costs follow the Texas Water Development Board's guidelines for cost considerations and identify capital and annual costs by decade. Project capital costs are based on September 2018 price levels and include construction costs, engineering, land acquisition, mitigation, right-of-way, contingencies, and other project costs associated with the respective strategy. Annual costs include power costs associated with transmission, water treatment costs, water purchase (if applicable), operation and maintenance, and other project-specific costs. Debt service for capital improvements was calculated over 20 years at a 3.5 percent interest rate. In the case of Municipal and County-Other water needs, the cost estimates are only for development of the supply and delivery to the water utility's distribution system. There may be additional costs to distribute the water to the end users that are not represented in these estimates.

Evaluation Considerations

- Quantity, reliability, and cost
- Environmental factors, including effects on environmental water needs, wildlife habitat and cultural resources
- Impacts on water resources, such as playas and other water management strategies
- Impacts on agriculture and natural resources
- Other relevant factors

Potential impacts to sensitive environmental factors were considered for each strategy. Sensitive environmental factors may include wetlands, threatened and endangered species, unique wildlife habitats, and cultural resources. In most cases, a detailed evaluation could not be completed because a specific location for groundwater rights was not available. Therefore, a more detailed environmental assessment will be required before a strategy is implemented.

The impact on water resources considers the effects of the strategy on water quantity, quality, and use of the water resource. This review also evaluated whether the strategy would impact the water quantity and quality of other water management strategies identified.

A water management strategy could potentially impact agricultural production or local natural resources. Impacts to agriculture may include reduction in agricultural acreage, reduced water supply for irrigation, or impacts to water quality as it affects crop production. Various strategies may improve water quality, while others may have a negative impact. The impacts to natural resources may consider inundation of parklands, impacts to exploitable natural resources, recreational use of a natural resource, and other strategy-specific factors.

Other relevant factors include regulatory requirements, political and local issues, amount of time required to implement the strategy, recreational impacts of the strategy, and other socio-economic benefits or impacts.

Municipal and manufacturing strategies were developed to provide water of sufficient quantity and quality that is acceptable for its end use. Water quality affects water use options and treatment requirements. For the evaluations of the strategies, it was assumed that the water would meet existing state water quality requirements for the specified use. For example, a strategy that provided water for municipal supply would meet existing drinking water standards, while water used for mining may have a lower quality.

The evaluation of each strategy is quantified based on available data and given an overall evaluation score. This evaluation is documented in the evaluation matrices contained in Attachment 5-2.

5A.2.1 Strategy Development Assumptions

Strategies were developed for water user groups in the context of their current supply sources, previous supply studies and available supply within reasonable vicinity of the need. As previously discussed, most of the water supply in the PWPA is from groundwater. For many of the identified needs, the potentially feasible strategies included development of new groundwater supplies or further development of an existing well field. Site-specific data were used when available. When specific well fields could not be identified, assumptions regarding the source aquifer, well capacity, depth of well, and relative distance to the user were developed. Other strategy assumptions were developed with the input of the strategy sponsor.

While the development of the strategies considered acquisition of water rights when needed, the implementation of any groundwater strategy will need to ensure an adequate quantity of groundwater rights while complying with all applicable water conservation district rules. For this plan, strategy supplies could not exceed the MAG. This results in some strategies with less water than originally intended by the sponsor. If the MAGs increase in future rounds of planning, the supplies for these strategies may be adjusted.

Water transmission lines were assumed to take the shortest route, following existing highways or roads where possible. For new well fields that are not specifically identified, an average transmission distance was assumed. Pipes were sized to deliver peak-day flows within reasonable pressure and velocity ranges. Water losses of 25 percent were included for strategies requiring reverse osmosis (RO) treatment (potable reuse or nitrate removal). Water losses associated with transmission were assumed to be negligible for regional planning purposes.

Process to Identify and Evaluate Water Management Strategies

5A.2.2 Strategy Costs

The cost estimates for water management strategies identify both capital and annual costs. Capital costs are based on standard unit costs provided by the TWDB for installed pipe, pump stations and standard treatment facilities developed from experience with similar projects throughout the State of Texas. If a project had more detailed costs, these costs were used. Assumptions for groundwater strategies include project location, well depth, and well capacity.

A more detailed explanation of the cost assumptions and summaries of the costs developed for each strategy are included in Appendix D.

5B WATER CONSERVATION

Water conservation is a demand management strategy that proactively reduces future water needs. Conservation facilitates more efficient use of existing water supplies and may delay the need to develop new water supplies. An expected level of conservation is included in the municipal demand projections from the Texas Water Development Board (TWDB) due to the natural replacement of less efficient plumbing fixtures with low flow fixtures, as mandated under the Plumbing Code. Irrigation water demands also include a declining demand over the planning horizon due to expected reduced use associated with more efficient water use, declining groundwater levels, and the transfers of water rights to other uses.

Water conservation strategies must be considered for all water users with a need. In the PWPA, this includes municipal, manufacturing and irrigation water users. All of the manufacturing water needs are associated with needs of a municipal water provider. Conservation strategies to reduce manufacturing water use are typically industry and process-specific and cannot be specified to meet county-wide needs. Wastewater reuse is a more general strategy that can be utilized by various industries for process water, and this strategy will be considered where appropriate. For municipal and irrigation users, additional conservation savings can potentially be achieved in the region through the implementation of conservation best management practices (BMPs). These additional conservation measures were considered for municipal (only County-Other users with needs were evaluated, all other municipal water user groups were evaluated) and irrigation water user groups in the Panhandle Water Planning Area (PWPA). The PWPA recognizes that it has no authority to implement, enforce, or regulate water conservation practices. These water conservation practices are intended to be guidelines. Water conservation strategies determined and implemented by the individual water user group supersede the recommendations in the Regional Water Plan (Plan) and are considered to meet regulatory requirements for consistency with the Plan.

Definitions

Conservation: "The development of water resources; and those practices, techniques, and technologies that will reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses. TAC §11.002(8)

Drought/Emergency Management: Temporary measures that are implemented when certain criteria are met and are terminated when these criteria are no longer met.

Best Management Practice: "Conservation measure or series of measures that is useful, proven, cost effective, and generally accepted among conservation experts. In Texas, conservation BMPs are designed…as one alternative to meet future water needs." TWDB

5B.1 Municipal Conservation

Each public water supplier with 3,300 connections or holding a water right greater than 1,000 acre-feet per year is required to update and submit a Water Conservation Plan (WCP) to the Texas Commission on Environmental Quality (TCEQ) every five years. Also, entities with a financial obligation with the TWDB greater than $500,000 are also required to submit a water conservation plan to the TWDB These plans are also to be submitted to the respective regional water planning group. In the PWPA, two WCPs were submitted to the region as part of the required 2019 update. Three additional WCPs were previously submitted and considered in this round of planning. If a public water supplier serves over 5,000 people, they are additionally required to report water loss from the supply and distributions systems.

Both the water conservation plans and water loss audit reports for water suppliers in the PWPA were reviewed to help identify appropriate municipal water conservation measures. The data from the water loss audit reports for PWPA water providers are discussed in more detail in Chapter 1 of this plan.

Seven water providers in the PWPA submitted water loss audits in 2017. Based on these reports, the percentage of real water loss for the PWPA is approximately 19 percent, which is slightly greater than the accepted range of water loss (less than or equal to 12 percent). This is likely due to the large service areas with low population densities characteristic of rural water supply corporations. For the water suppliers that fall under the water supply corporation category, there may be few cost-effective options in reducing water loss.

5B.1.1 Identification of Potentially Feasible Conservation BMPs

To assess the appropriateness of additional conservation BMPs for the PWPA, 68 potential strategies were identified, and a screening level evaluation was conducted. Due to difference in the water needs and available resources between the larger municipalities and smaller rural areas, the screening evaluation was performed both for entities with populations less than 20,000 people and entities with population great than 20,000. In the PWPA, there are four entities that have populations greater than 20,000 during the planning period: Amarillo, Canyon, Dumas and Pampa.

The evaluation considered six criteria:

- Cost
- Potential Water Savings
- Time to Implement
- Public Acceptance
- Technical Feasibility
- Staff Resources

Each criterion was scored from 1 to 5 with 5 being the most favorable. Scores for all the criteria were then added to create a composite score. The strategies were then ranked and selected based on their composite score.

Selected Strategies for Entities under 20,000

Based on the screening level evaluation and requirements from the TCEQ, the following strategies were selected for consideration for entities in the PWPA with less than 20,000 people during every decade of the planning period:

- Education and Outreach
- Water Audits and Leak Repair
- Conservation – Oriented Rate Structure
- Water Waste Ordinance

Selected Strategies for Entities over 20,000
Based on the screening level evaluation and requirements from the TCEQ, the following strategies were selected for consideration for entities in the PWPA with more than 20,000 people during any decade of the planning period:

- Education and Outreach
- Water Audits and Leak Repair
- Conservation – Oriented Rate Structure
- Water Waste Ordinance
- Time of Day Watering Limit

Each of the selected strategies above were considered and evaluated for the appropriate water user groups (greater than or less than 20,000). Landscape Ordinance was not considered because of the high unit costs of implementation for small to medium communities. For the purposes of strategy evaluation, each household was assumed to have an average of three people. Additional assumptions were developed and used in the evaluation of the selected municipal conservation measures as described in Section 5B.1.2.

5B.1.2 Recommended Municipal Conservation Strategies

Published reports and previous studies were used to refine the description for the selected BMPs, including the potential water savings and costs. Water savings for some BMPs are difficult to estimate since there is little data for an extended time period. Also, most entities tend to implement a suite of strategies at the same time, which makes it difficult to estimate the individual water savings. These factors were considered in developing the assumptions defined below for each BMP. As more data become available through more rigorous water use tracking, the ability to estimate water conservation savings will improve.

Municipal Conservation Package

- Education and Outreach
- Water Audits and Leak Repair
- Conservation Oriented Rate Structure
- Water Waste Ordinance
- Time of Day Watering Limit (Cities> 20,000 population)

Education and Outreach
Local officials would offer water conservation education to schools, civic associations, include information in water bills, provide pamphlets and other materials as appropriate. It was assumed that the education outreach programs would be needed throughout the planning period to maintain the water savings. It was assumed that education and outreach would save 5,000 gallons per household per year with a 30 percent adoption rate, i.e., assume that 30 percent of the customers respond to this measure by reducing water use. Per person costs were based on data obtained from municipalities and water providers. The costs for entities with populations less than 20,000 are greater on a per person basis than for the larger cities. In this case, education and outreach were assumed to cost $2.75 per person per year with a maximum cost of $15,000 for entities with populations less than 20,000. In contrast, education and outreach were assumed to cost $1.80 per person per year for entities with populations greater than 20,000.

Water Audits and Leak Repair
Local officials would perform a water audit system wide and create a program of leak detection and repair including infrastructure replacement as necessary. It was assumed that 20 percent of an entity's losses could

be recovered through a water audit and leak repair program, and that the leak detection and repair program is an on-going activity to maintain the level of water loss reductions. This strategy was considered for all cities with greater than or equal to 15 percent losses and WSCs with losses greater than or equal to 25 percent. If no water loss data was available, this strategy was not considered.

Water Loss data was available for six WUGs in the PWPA, with five WUGs meeting the requirements for implementation of Water Audits and Leak Repair BMP (Amarillo, Canyon, Higgins, Turkey, and Dumas). Costs were estimated at $10 per person per year. If an entity's population was less than 20,000, then an estimated base cost of $5,000 was added to the total cost.

Rate Structure

Local officials would implement an increasing block rate structure where the unit cost of water increases as consumption increases. Increasing block rate structures discourage the inefficient use or waste of water. Many cities already have a non-promotional rate structure. This strategy assumes that the entity adopts a higher level of a non-promotional rate structure. It is assumed that increasing block rates would save 6,000 gallons per household per year and that 10 percent of the households would respond to this measure by reducing water use. Since it is likely that the entity would conduct the rate structure modifications themselves, this BMP has no additional costs to the water provider.

Water Waste Ordinance

Local officials would implement an ordinance prohibiting water waste such as watering of sidewalks and driveways or runoff into public streets. A water waste ordinance saves about 3,000 gallons per household per year. It is assumed that 50 percent of the households in entities with over 20,000 people and 30 percent of households in entities with less than 20,000 people would respond to this measure by not wasting water. Costs for this strategy would be those costs associated with enforcement. In this case, the costs associated with enforcement was estimated to be $10,000 in entities with over 20,000 people and $2,500 in entities with less than 20,000 people.

Time of Day Watering Limit (Population over 20,000)

Local officials would implement an ordinance prohibiting outdoor watering during the hottest part of the day when most of that water is lost (wasted) through evaporation. Many ordinances limit outdoor watering to between 6 p.m. and 10 a.m. on a year-round basis. It is assumed that time of day watering limits saves 1,000 gallons per household per year and 75 percent of the population would realize these savings (the other 25 percent is either not irrigating or already abide by this practice). Costs for this strategy would be those costs associated with enforcement, which were estimated to be $10,000.

5B.1.3 Evaluation of Municipal Conservation Strategies

Time Intended to Complete

This strategy is assumed to initially implemented by the respective municipal WUG by 2023 (2020 decade). To maintain the projected water savings, continued effort and funding will be required.

Quantity, Reliability and Cost

The water savings associated with municipal conservation vary depending on the potential of the entity's customers to reduce water use. For most water users in the PWPA, water that is conserved (i.e., not consumed) will further protect the natural resources for future use. The reliability is moderate because this strategy relies on actions of others (customers) and the willingness to change daily behaviors. The suite of recommended strategies focuses on the actions of the water provider, which have shown to be successful in reducing water consumption. The costs are low to moderate for larger entities and high for smaller entities. The capital costs are associated with the leak detection and repair strategy. For smaller entities, this strategy may not be cost effective. Table 5B-1 shows the total water savings by provider and associated costs for each decade.

Environmental Factors

Potential environmental impacts associated with municipal conservation should be neutral to positive. Reductions in water use will preserve water for other uses, including potential environmental purposes.

Impacts to Agricultural and Natural Resources

Impacts to agricultural and rural areas should be neutral to positive. Conserved water by cities could provide additional supplies to agricultural and rural areas. Impacts to natural resources should be neutral to positive. Conserved water by cities would protect limited groundwater supplies for future use. If the water remains in the original source and is not used for other purposes, municipal conservation could help maintain existing water quality of these resources. High use of some water sources can possibly degrade water quality over time.

Impacts to Other Water Resources and Management Strategies

There are no known impacts to other water resources and management strategies.

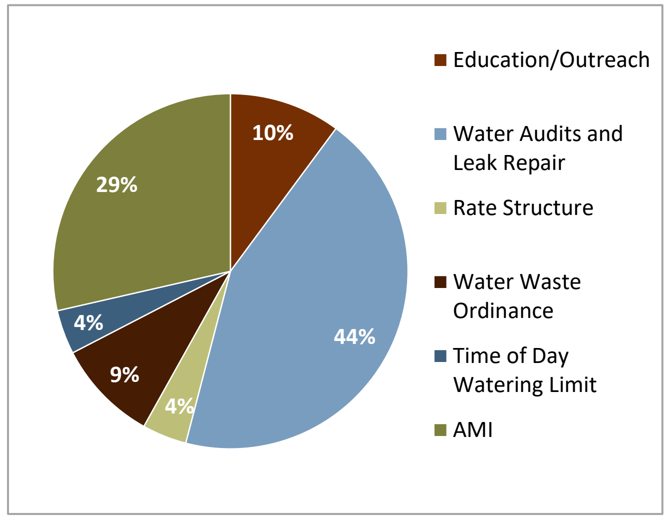
5B.1.4 GPCD Goals

As part of House Bill (HB) 807, the regional planning groups are required to "set one or more specific goals for gallons water use per capita per day (gpcd) in each decade of the period covered by the plan for the municipal water user groups in the regional water planning area." It should be noted that these goals are different than the goals set by utilities as part of their TCEQ Water Conservation Plans (WCP). WCP goals are often based on multi-year averages. Per capita goals in this plan are intended as goals for dry year use, and thus, will generally be higher than the gpcd goal shown in an entity's WCP. The recommended goals are the dry year gpcd used for this Plan, after incorporating the recommended conservation savings. The gpcd goals for each municipal user in the PWPA are included as Attachment 5-3 at the end of Chapter 5.

5B.1.5 Municipal Conservation Summary

It is estimated that the municipal conservation strategy outlined in this memorandum will save, on a regional basis, nearly 5,300 acre-feet per year in 2020 and nearly 8,400 acre-feet per year in 2070. The unit costs vary considerably between water user groups depending on the population size, and implementation of a water audit and leak repair program for entities with high water losses. Generally, conservation programs are funded through a city's annual operating budget and are not capitalized. However, in some cases, an entity may choose to capitalize a portion or all of their program. These kinds of costs are difficult to estimate for each individual entity due to the wide variety of factors at play. For this plan, it is assumed that only water audits and leak repairs and Advanced Metering Infrastructure (AMI) are capitalized. However, all capital expenditures for conservation are considered consistent with the Panhandle Water Plan.

Estimates of municipal conservation savings (to include AMI and water audits and leak repairs) for PWPA water users are shown in Table 5B-1. This table shows the amount of water savings that are estimated through conservation water management strategies, which is above the amount assumed to be achieved through the Plumbing Act (see Table 2-2). Table 5B-2 shows the estimated costs for municipal conservation (excluding AMI and water audits and leak repairs). The savings and costs associated with water audits and leak repairs are shown separately in Table 5B-3 and those for AMI are shown on Table 5B-4.



Municipal BMPs

Although water conservation is part of the culture of the region, the challenge for future water conservation activities in the PWPA will be the development of water conservation programs that are cost-effective, meet state mandates, and result in permanent real reductions in water use. Development of water conservation programs will be a particular challenge for smaller communities, which lack the financial and technical resources needed to develop and implement the programs. Any water conservation activities should consider the potential adverse impacts of lost revenues from water sales and the ability of communities to find alternative sources for those revenues. State financial and technical assistance will be required to meet state mandates for these communities.

Table 5B-1: Estimated Water Savings from Municipal Conservation (acre-feet per year)

Water User Group	2020	2030	2040	2050	2060	2070
Amarillo[1]	4,538	5,010	5,505	6,018	6,585	7,182
Booker	5	6	6	7	7	8
Borger	41	43	43	43	43	43
Cactus Municipal Water System	13	15	17	19	21	23
Canadian	10	11	12	13	14	15
Canyon	219	242	264	316	347	378
Childress	19	20	21	21	22	22
Clarendon	6	6	6	6	6	6
Claude Municipal Water System	4	4	4	4	4	4
Dalhart	27	30	32	35	37	40
Darrouzett	1	1	1	2	2	2
Dumas	168	188	240	268	297	326
Follett	1	1	1	2	2	2
Fritch	9	9	10	10	10	10
Groom Municipal Water System	2	2	2	2	2	2
Gruver	5	5	5	6	6	7
Happy[2]	0	0	0	0	0	0
Hartley WSC	2	2	2	2	2	2
Higgins Municipal Water System	9	10	10	12	12	12
Lake Tanglewood	3	3	3	3	3	3
McLean Municipal Water System	3	3	3	4	4	4
Memphis	7	7	7	7	7	7
Miami	2	2	2	2	2	2
Moore County-Other	7	8	9	10	11	12
Pampa Municipal Water System	59	95	106	121	132	144
Panhandle Municipal Water System	8	8	8	8	8	8
Perryton Municipal Water System	28	31	33	35	38	41
Red River Authority of Texas	9	9	10	11	11	12
Shamrock Municipal Water System	6	6	7	7	7	7
Spearman Municipal Water System	11	11	12	12	12	13
Stinnett	6	6	6	6	6	6
Stratford	7	8	8	8	9	9
Sunray	6	6	6	7	7	7
TCW Supply	6	6	6	6	6	6
Texhoma	1	1	1	1	1	1
Texline	2	2	2	2	2	2
Turkey Municipal Water System	5	5	5	5	5	5
Vega	3	3	3	3	3	3
Wellington Municipal Water System	7	7	8	8	8	8
Wheeler	5	5	5	5	6	6
White Deer	4	4	4	4	4	4
Total	**5,275**	**5,845**	**6,440**	**7,061**	**7,712**	**8,394**

[1] Includes estimated savings from Advanced Metering Infrastructure (AMI).

[2] Happy was not evaluated in this analysis because its primary region is Region O.

Table 5B-2: Estimated Costs for Municipal Conservation

	2020	2030	2040	2050	2060	2070
PWPA Annual Cost	$763,000	$859,000	$959,000	$1,061,000	$1,129,000	$1,200,000
Annual Cost per acre-foot	$540	$540	$541	$540	$529	$520
Annual Cost per 1,000 gal	$1.66	$1.66	$1.66	$1.66	$1.62	$1.59

Table 5B-3: Estimated Costs and Water Savings from Water Audits and Leak Repairs

Water User Group	2020 Capital Cost	2040 Capital Cost	2060 Capital Cost	2020	2030	2040	2050	2060	2070
Amarillo	$46,356,000	$56,653,000	$67,841,000	2,077	2,268	2,472	2,692	2,943	3,209
Canyon	$3,235,000	$3,890,000	$4,600,000	174	191	208	227	249	271
Dumas	$3,762,000	$4,671,000	$5,746,000	115	128	142	158	175	192
Higgins Municipal	$190,000	$199,000	$206,000	8	9	9	10	10	10
Turkey Municipal	$183,000	$184,000	$184,000	4	4	4	4	4	4
Total	**$53,726,000**	**$65,597,000**	**$78,577,000**	**2,378**	**2,600**	**2,835**	**3,091**	**3,381**	**3,686**

Table 5B-4: Estimated Costs and Water Savings for AMI

	Capital Cost	2020	2030	2040	2050	2060	2070
Amarillo	$31,000,000	1,485	1,655	1,831	2,008	2,198	2,398

5B.2 Agricultural Water Conservation

Agriculture is the largest user of water in the PWPA and accounted for 92 percent of the total water use in the PWPA in 2016 and is projected to account for approximately the same percentage in 2020. Most of the counties in the PWPA can meet the agricultural demands. There are seven counties showing needs in irrigation: Collingsworth, Dallam, Gray, Hall, Hartley, Moore and Sherman. These needs are projected to reach 146,064 acre-feet per year in 2020 and more than double (310,602 acre-feet per year) by 2070. Given the limited renewability of aquifers in the area, there is no readily available water supply in or near the high demand irrigation counties that could be developed to fully meet these needs. Water management strategies for reducing irrigation demands in the Ogallala Aquifer for all 21 counties were examined by the PWPG Agricultural Demands and Projections Committee. The primary strategies identified to address irrigation needs are demand reduction strategies (conservation). The seven agricultural water conservation strategies considered include irrigation scheduling, irrigation equipment changes, soil management, advances in plant breeding, conversion to dryland farming and changes to crop types and crop varieties that use less water. Precipitation enhancement was evaluated as a strategy and ultimately determined to be used as an alternate strategy. These strategies (and the recommended combination of strategies) are summarized in Section 5B.2.1 and evaluated in detail in Appendix C. While each of these strategies does not specifically address conservation education, conservation education can enhance the adoption of such strategies. There are no identified conservation strategies for livestock water use.

Precipitation enhancement is considered a limited use alternate strategy since it cannot be implemented by an individual producer and little interest has been shown in implementing this strategy by ground water districts in the region with the exception of the Panhandle Groundwater Conservation District.

A list of the potentially feasible irrigation strategies is shown in Table 5B-5. A synopsis of the potential water savings associated with all seven strategies is presented in Section 5B.2.2 for PWPA and each county with an irrigation need. County evaluations for each strategy are found in Appendix C.

5B.2.1 Irrigation Strategies

Irrigation Scheduling

Irrigation scheduling refers to the process of allocating irrigation water according to crop requirements based on meteorological demands and field conditions with the intent to manage and conserve water, control disease infestations, and maximize farm profit. Proper and accurate irrigation scheduling is critical to ensure profitable agricultural production and conservation of the existing water resources. Soil water measurement-based methods, plant stress sensing-based methods, and weather-based methods are the common irrigation scheduling tools. The prevalent soil-based irrigation scheduling method utilized in the region today employs soil moisture probes that estimate soil moisture at different depths to schedule irrigation. Irrigation scheduling based on crop evapotranspiration reported by ET networks in the region is also an important weather-based irrigation scheduling method since this data references the climatic demand, which varies annually and can vary substantially within the season. Plant stress-based irrigation scheduling techniques using thermal sensors are also a developing irrigation scheduling strategy but are not yet widespread in use. The soil moisture probe and thermal sensor methods can allow for automation of irrigation scheduling by wireless connection of the sensors to respective irrigation systems. Proper and accurate irrigation scheduling can save up to 2 to 3 acre-inches of irrigation per year for corn. In this analysis, the water savings from this strategy is assumed to be 10 percent of the water applied for each crop seasonally.

Agricultural Water Conservation Strategies Considered in Region A

- Irrigation Scheduling
- Irrigation Equipment Changes
- Soil Management
- Advances in Plant Breeding
- Conversion to Dryland Farming
- Changes to Crop Type
- Changes to Crop Variety

The cost of irrigation scheduling can vary significantly depending on several factors including the level of service, equipment costs, and area served. More money tends to be invested in irrigation scheduling of higher value crops. A range of $6.50 to

$12.00 per acre for irrigation scheduling was identified based on discussions with industry representatives, depending on the level of service. In this analysis, a $9.25 per acre annual cost was assumed for irrigation scheduling.

Change in Crop Variety

The evaporative demand for short season varieties can be significantly lower than that for long season varieties. Converting from long season varieties to short season varieties of corn and grain sorghum can be a useful water conservation strategy as they use less water than the conventional longer season varieties. Water savings may be enhanced by planting a short-season hybrid outside the normal production window, which can also help avoid high evaporative demand periods such as during the pollination period. In this planning cycle, a panel of industry and university experts was utilized to update this strategy given the rapidly changing seed industry. Analysis of the estimates provided by the panel indicated that moving to short-season corn from full/mid-season varieties could save 3.7 ac-in per acre but would result in an estimated 18 percent yield loss. Changing to a short-season sorghum variety from full/mid-season varieties was estimated to save 6.2 ac-in but would result in a 32 percent yield reduction. It was estimated that 10 percent of both corn and sorghum acreage is currently planted to short-season varieties, which is expected to reach an adoption level of 25 percent by 2070.

The implementation cost of this water conservation strategy was assumed to be the compensation needed to account for the loss in yield. A partial budget analysis was conducted using the 2018 Texas A&M AgriLife Crop and Livestock Budgets for the region. Results of the partial budgets indicate a net loss to producers (to include the savings in seed cost, pumping cost, fertilizer and harvest expense) of $40.05 per acre for corn and $44.76 per acre for sorghum for transition to short-season varieties. However, taking into consideration the different levels of water savings per acre, the cost per acre-foot saved is $131.06 and $86.32 for corn and sorghum, respectively.

Irrigation Equipment Changes

Current irrigation methods practiced in the Texas Panhandle include center pivot irrigation (MESA: Mid Elevation Spray Application, LESA: Low Elevation Spray Application, and LEPA: Low Elevation Precision Application) and subsurface drip irrigation (SDI).The average application efficiency of MESA, LESA, LEPA, and SDI is 78, 88, 95, and 97 percent, respectively (Amosson et al., 2011). These application efficiencies are the percentage of irrigation water applied that is used by the crop with the remainder being lost to runoff, evaporation or deep percolation. Switching from low efficiency irrigation systems such as CF and MESA to more efficient irrigation systems such as LEPA and SDI improves the efficiency of irrigation system water use and can help conserve groundwater resources. Switching irrigation systems can be a costly strategy to conserve irrigation water, but that expense can be partially offset by the decrease in pumping cost. The water conservation strategy of changing irrigation equipment includes converting MESA and LESA to LEPA or SDI to improve application efficiency. Establishing MESA, LESA, LEPA, or SDI systems requires a major investment, while converting MESA and LESA to LEPA using conversion kits are comparatively less expensive. The regional water savings estimate in 2020 from this strategy is 1.51 acre-inches in water savings per acre for conversion of MESA/LESA to LEPA.

Results of the NPGCD Master Irrigator surveys indicate that 25 percent of the irrigation systems currently are either LEPA or SDI and 75 percent are either LESA or MESA. The PWPG-AG anticipates with appropriate incentives the conversion of LESA or MESA center pivots to more efficient systems could increase incrementally 5 percent per decade reaching 55 percent by 2070.

Since 96 percent of the high-efficiency irrigation systems are LEPA, the cost for implementing this strategy was assumed to be the cost of converting MESA or LESA systems to LEPA. The implementation cost of this strategy is estimated using the costs associated with the change in irrigation equipment required for each of the systems and their respective adoption rate. Currently, the most popular spacing of drops is 30 inches for conversions. The cost of replacing an existing 125-acre system with 60-inch spacing was estimated at $18,900 or $151.20 per acre (Personal communication. T-L Irrigation). This included replumbing, new hoses, heads, weights and labor. The cost of converting an existing 125-acre system that had 30-inch spacing was estimated to be $44 per acre, which included replacing heads, adding weights and installation labor (Personal communication, Senninger Irrigation). It was assumed that 80 percent of the conversions would require total replacement, resulting in an average cost of conversion of $129.76 per acre.

Change in Crop Type

Incorporation of crops with lower water requirements can be an effective water conservation strategy. Corn, cotton, wheat, and grain sorghum are the four major crops in the Panhandle region accounting for about 90 percent of the irrigated acreage. Corn has one of the highest water requirements of any irrigated crop grown in the Texas High Plains because of a longer growing season than most other spring crops, which can adversely affect yield in limited moisture situations (Howell et al., 1996). The seasonal evaporative demand for corn is 28 to 32 inches, for wheat is 26 to 28 inches, for cotton is 13 to 27 inches, and for grain sorghum is 13 to 24 inches. To date, the majority of water used for irrigation has been applied to high water use crops such as corn. On the other hand, cotton, wheat, and grain sorghum can tolerate lower moisture availability and are more suited to deficit irrigation practices. Considerable amounts of irrigation water can be saved by shifting from high water use crops like corn to lower water use crops like cotton, wheat or grain sorghum.

Irrigated cotton acreage has increased more than 180,000 acres in the region since the 2016 Plan largely at the expense of irrigated wheat and to a lesser extent irrigated sorghum acreage, suggesting that cotton is the preferred low water use crop. This is also supported by the construction in the region of the world's largest cotton gin. A survey of 25 producers and crop consultants was conducted to determine/validate actual water use per acre of corn and cotton during the 2016 to 2018 time period. The survey indicated the application of 20.6 ac-in to corn and 9.9 ac-in to cotton per acre. A conservative average of 10 ac-in was utilized to estimate water savings for this strategy with implementation of cotton production reaching 30 percent by 2070.

The cost of implementing this water conservation strategy is evaluated in terms of an "opportunity cost" expressed by the reduced land values which reflect the water availability required to produce crops. Land that has "good" water availability to support corn production is worth more compared to the land with "fair" availability of water that can support cotton, wheat, or grain sorghum. Hence the cost of adoption of this strategy for one acre of land is estimated as the difference between the average land value in the region for irrigated cropland with good water availability ($3,400 per acre) and that of irrigated cropland with average water availability ($2,300 per acre) (ASFMRA, 2018). Therefore, $1,100 per acre was assumed to be a one-time cost for implementation of this strategy.

Soil Management

Effective soil management practices can increase the efficiency of both irrigation and rainfall events, increase soil infiltration, reduce runoff, reduce evaporative loss, and conserve moisture available within the soil profile. Thus, these practices promote efficient use of the available water and enhance crop production and sustainability of the region's natural resources. Conservation tillage practices, furrow diking, and introduction of fallow and low water use crops in the crop rotation are the most important land management practices that can lead to water conservation within the region.

Conservation tillage is defined as tillage practices that minimize soil and water loss by maintaining a surface residue cover of more than 30 percent on the soil surface (CTIC, 2014). Conservation tillage can reduce evaporation, increase rainfall infiltration, enhance soil profile water storage, soil moisture conservation, and water use efficiency. Conservation tillage systems are also reported to have economic advantages as it reduces machinery, fuel, and labor costs. Conservation tillage is a term covering a wide range of tillage practices with the common characteristic of reduced soil and water loss. In this analysis, the water savings from adopting effective soil management strategy is assumed to be 1.75 acre-inches per acre.

Results of the NPGCD Master Irrigator surveys indicate conservation tillage in some form (minimum till, strip till or no-till) is practiced on 84 percent of the irrigated land in the region. Initially, the PWPG-AC projects a decadal increase of 2.5 percent slowing in later years of the planning horizon until 95 percent of all irrigated acreage practices some sort of conservation tillage.

In this analysis the annualized cost difference between conventional and conservation tillage is assumed to be zero. A study by Epplin et al. appears to validate this assumption. Their analysis of Oklahoma wheat farms indicates a slight cost advantage to conventional tillage in small wheat farms (less than 700 acres) while there was a small cost advantage to no-till operations in large farms. While there is little to no difference in the annualized cost, it should be noted that the necessary chemical control costs and change in equipment such as the additional purchase of a strip tiller or no-till planter can impede the adoption process.

Conversion from Irrigated to Dryland Crops

Converting from an irrigated to dryland cropping system may be a viable economic alternative for some producers in the Panhandle on marginally irrigated lands or as a regional strategy to conserve water reserves. The primary dryland crops grown in the area are winter wheat, grain sorghum, and cotton. Conversion programs that provide incentives for dryland conversion, identifying and adopting crops that perform well in the region under rain fed conditions, and developing higher yielding heat- and drought-tolerant varieties will be critical in implementing this strategy. This analysis assumes 15.8 acre-inches per acre water savings by the adoption of this strategy over the entire region; however, the amount varies by county depending on crop composition.

Since the conversion of irrigated acreage to dryland production is measured from the baseline acreage (2016-2018 average), the 2018 baseline adoption rate was assumed to be 0 percent. Conversion of irrigated land to dryland was viewed by the PWPG-AC as a limited-use strategy given the economic base and grain deficit nature of the region. It was assumed a maximum of 5 percent total of the regional acreage would be converted by the end of the time horizon.

The cost of implementing this water conservation strategy is evaluated in terms of reduced land values and was estimated as the difference between the average land values across all water availability categories for irrigated cropland at $2,450 per acre and that of dryland at $925 per acre (ASFMRA, 2018). Therefore, the implementation cost to retire an acre of irrigated land was $1,525 ($2,450-$925) assuming the land would be suitable for dryland production. It should be noted, the amount of compensation required for this strategy would need to vary considerably depending on the water availability on a specific piece of land and the value of the dryland acreage in that part of the region. Also, implementing this strategy would be detrimental to the regional economy because of the reduced production and decrease in inputs used.

Advances in Plant Breeding

Plant breeding has played a major role in increasing crop productivity and enhancing the efficiency of input such as irrigation. The adoption of drought resistant varieties with high water use efficiency can be a potential water conservation strategy. The first wave of drought resistant varieties for corn, cotton, and soybeans are expected to be released by 2020 followed by a second wave in 2040 that will improve drought and heat tolerance even more. This analysis assumes that the first round of drought resistant varieties will reduce water use by 15 percent and the second round of varieties will reduce the water use an additional 15 percent compared to current varieties. It is also assumed that drought tolerant varieties of wheat and grain sorghum will be available by 2030 and will reduce the water use by 12 percent.

The new drought tolerant varieties have yet to hit the market; therefore, the 2018 baseline adoption rate was assumed to be 0 percent. The adoption rate was projected to be 50 percent in the first decade of market deployment (2020 for corn, soybeans and cotton; 2030 for wheat and sorghum) and escalate to 95 percent by the end of the planning horizon, assuming new varieties are cost effective.

The implementation cost of this strategy assumed an additional cost of drought resistant seed estimated at a dollar for every one percent reduction in water use. It was assumed a 15 percent reduction in water use will cost $15 per acre and a 30 percent reduction will cost $30 per acre. Cost estimates were made after consultation with industry personnel and researchers working in the area. These costs were then multiplied with the annual total acreage for corn, cotton and soybeans, affected by incorporation of this strategy. It is also assumed that drought tolerant varieties of wheat and grain sorghum will cost $12/acre for a 12 percent reduction in water use.

The estimated water savings and implementation schedule used in the 2021 planning effort for each of the strategies is presented in Table 5B-5.

Table 5B-5: Possible Water Management Strategies for Reducing Irrigation Demands

Water Management Strategy	Annual Regional Water Savings (ac-in/ac/yr)	Assumed Baseline Use 2018	Goal for Adoption 2020	Goal for Adoption 2030	Goal for Adoption 2040	Goal for Adoption 2050	Goal for Adoption 2060	Goal for Adoption 2070
Irrigation Scheduling	10%	65%	70%	75%	80%	85%	90%	95%
Irrigation Equipment Changes	MESA or LESA to LEPA or SDI 1.51	75%	80%	85%	90%	95%	100%	100%
Change in Crop Type	10.0	0%	5%	10%	15%	20%	25%	30%
Change in Crop Variety	3.7 (corn) 6.2 (sorghum)	10%	12.5%	15%	17.5%	20%	22.5%	25%
Conversion to Dryland	15.8	0%	0%	1.5%	3%	5%	5%	5%
Soil Management	1.75	84%	86.5%	89%	91.5%	94%	95%	95%
Advances in Plant Breeding	Corn, cotton, and soybean 15% (2020-2030); 30% starting in 2040	0%	50%	75%	85%	95%	95%	95%
	Wheat and sorghum 12% starting in 2030	0%	0%	50%	75%	85%	95%	95%

5B.2.2 Methodology

Water savings, implementation cost, savings from reduced pumping and the impact on gross crop receipts were estimated for each proposed water management strategy evaluated in the planning effort and described in Section 5B.2.1. The year 2018 was selected as the baseline for evaluating strategies. Baseline adoption rates for strategies were estimated using secondary data sources. Producer surveys (2016-2019) conducted as a part of the North Plains GCD Master Irrigator project that encompassed more than 295,000 irrigated acres were invaluable in estimating baseline values for irrigation scheduling, irrigation systems and soil management strategies. Future adoption rates (2020 – 2070) were identified under the guidance of the PWPG-AC, Table 5B-5. The water savings and direct cost of all strategies were evaluated over a 50-year planning horizon. The region has dramatically increased irrigated cotton acreage and a corresponding increase in cotton specific

Counties in PWPA with an Irrigation Need:

- Collingsworth
- Dallam
- Gray
- Hall
- Hartley
- Moore
- Sherman

equipment and processing infrastructure within the last few years. Given these changing conditions, a three-year average (2016–2018) of the FSA irrigated acreage was calculated to establish the 2018 baseline acreage by county and by crop. The three-year average dampened distortions resulting from acreage shifts between crops caused by volatile crop prices. Baseline acreage estimates were adjusted to account for irrigated acreage by known producers who choose not to report to FSA. Irrigated acreage and water availability were assumed to remain constant in measuring the impact of the various water conservation strategies.

In addition, the Agricultural subcommittee identified three combinations of the previously mentioned strategies that may likely be employed in irrigation deficit counties. The combinations of strategies were:

- changes in crop type, irrigation scheduling, and changes in irrigation equipment
- changes in crop variety, irrigation scheduling, and changes in irrigation equipment
- changes in crop type, advances in plant breeding, irrigation scheduling, and changes in irrigation equipment

When implementing multiple strategies, the impact on potential water savings are not additive in most instances. The cumulative water savings from use of multiple strategies was estimated using a stepwise procedure; first revising water use after implementing one strategy and then using the revised water use as the base before introducing the second strategy and repeating the process for the third and fourth strategy. For example, the impact of changing crop type on water use was estimated, then based on the revised water use, the impact of scheduling was identified and water use revised again, and based on this estimate, the effectiveness of changes in irrigation equipment was made. The water savings of the three combinations of strategies considered was done for the three large irrigation counties (Dallam, Hartley, and Moore) and the region as a whole. In examining the cost effectiveness of the strategy combinations (done on a regional basis), it was assumed the cost was additive.

Implementation costs were defined as the costs that could be borne by producers and/or the government associated with implementing a strategy. The savings in pumping cost takes into the account the variable cost savings from the reduced irrigation. The variable cost of irrigation is assumed be $8.35 per acre-inch (Texas A&M AgriLife Crop and Livestock Budgets, 2018). All costs were evaluated in 2018 dollars.

Several caveats to this analysis need to be mentioned. First, the associated water savings with these strategies are “potential” water savings. In the absence of water use constraints, most of the strategies considered will simply increase gross receipts. In fact, the improved water use efficiencies generated from some of these strategies may actually increase the depletion rate of the Ogallala aquifer. Second, potential water savings may be overestimated when combinations of strategies are implemented. For example, the savings associated with the implementation of irrigation equipment changes cannot be applied to irrigated land that is converted to dryland farming. To address this potential conflict, the decrease in water savings from using multiple conservation strategies is estimated for three combinations. Table 5B-6 shows the total estimated water savings and costs associated with proposed individual irrigation water conservation strategies and the three potential combinations for the region.

Table 5B-6: Possible Water Management Strategies for Reducing Irrigation Demands

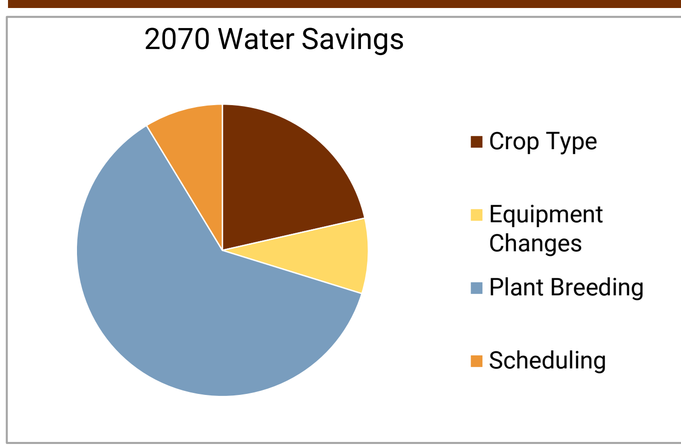
Water Management Strategy	Cumulative Water Savings (WS) acre feet	Capital Cost $1,000	Operational Cost $1,000	Total Implementation Cost (IC) $1,000	IC/WS $/acre foot
Irrigation Scheduling	1,439,303	-	$101,159	$101,159	$70.28
Change in Crop Variety	797,448	-	$97,965	$97,965	$122.85
Irrigation Equipment Changes	1,376,201	$47,302	-	$47,302	$34.37
Change in Crop Type	3,550,271	-	$156,212	$156,212	$44.00
Soil Management	765,524	-	-	-	-
Conversion to Dryland	2,782,652	-	$111,183	$111,183	$39.96
Advances in Plant Breeding	14,363,673	-	$1,048,090	$1,048,090	$72.97
Combinations					
Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	6,275,456	$47,302	$257,370	$304,673	$48.55
Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	3,573,101	$47,302	$199,123	$246,425	$68.97
Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	20,380,949	$47,302	$1,305,461	$1,352,763	$66.37

5B.2.3 Recommended Combination

For the purposes of planning, the recommended combination will provide the greatest level of irrigation conservation for counties with water needs. The recommended combination for counties with a need includes changes in crop type, advances in plant breeding, irrigation scheduling, and changes in irrigation equipment. Since the PWPG advocates conservation for all irrigators, counties without a need are recommended to adopt conservation measures of change in crop type, advances in plant breeding, irrigation scheduling, and changes in irrigation equipment. The savings for individual strategies by county are included in Appendix C. The combined strategies show a total supply that is less than the sum of the individual strategies. This is to account

PWPA Recommended Combination:

- Change in Crop Type
- Advances in Plant Breeding
- Irrigation Scheduling
- Changes in Irrigation Equipment



for potential overestimation of water savings when multiple strategies are implemented. The analysis further adjusts the savings for counties with declining irrigation water demands due to declining groundwater levels. These counties include Collingsworth, Dallam, Hartley, Moore, and Sherman. It is assumed that some of the savings estimated from the individual strategies would be implemented to achieve the lower irrigation demands. These adjustments reduce potential double counting of the irrigation savings. Table 5B-7 shows the savings associated with the recommended combination of strategies. Table 5B-8 shows the cost of the recommended combination by county. On a regional basis in 2070, the PWPA is projected to save approximately 565,000 acre-feet per year at a cost of $34.7 million per year. Over the 50-year period of implementation, the total cost could exceed $1.3 billion if each county implemented all four strategies to the level assumed in this analysis.

Weather modification (Precipitation Enhancement) is not a specific recommended strategy, but it is an on-going strategy for counties within the Panhandle GCD, which include Carson, Donley, Gray, Roberts, Wheeler and parts of Armstrong, Hutchinson, and Potter County. The benefits of weather modification are currently being realized today by these counties and the PWPG supports continued activities for precipitation enhancement within this area and any other areas within the PWPA that undertake such activities.

While these selected strategies are recommended by the PWPG, all irrigation conservation strategies are recognized and encouraged with the PWPA, and such strategies are considered consistent with this plan. Specifically, it is recommended that conservation education, such as demonstration events, be incorporated into an irrigation conservation program to enhance the adoption of the recommended practices.

Table 5B-7: Estimated Water Savings from Recommended Combination by County

County	Water Savings from Recommended Combination (ac ft/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	290	542	1,014	1,200	1,314	1,415
Carson	0	7,290	12,416	24,597	28,628	30,535	32,317
Childress	0	655	1,095	2,194	2,547	2,704	2,854
Collingsworth	0	2,610	3,966	7,955	9,658	9,419	9,757
Dallam	0	24,329	43,270	80,019	87,678	80,502	83,654
Donley	0	1,115	1,888	3,636	4,301	4,681	5,054
Gray	0	2,222	3,766	7,320	8,612	9,308	9,981
Hall	0	1,898	3,025	6,317	7,232	7,518	7,796
Hansford	0	14,572	25,101	49,532	57,670	61,580	65,189
Hartley	0	27,160	48,052	89,129	99,463	94,245	99,380
Hemphill	0	97	194	294	387	478	569
Hutchinson	0	4,432	7,624	15,285	17,656	18,663	19,562
Lipscomb	0	2,167	3,768	7,135	8,478	9,291	10,074
Moore	0	16,630	29,092	57,177	64,138	59,240	60,841
Ochiltree	0	7,080	12,160	23,955	27,927	29,865	31,668
Oldham	0	255	495	916	1,085	1,191	1,284
Potter	0	120	272	505	585	631	661
Randall	0	1,003	2,027	3,820	4,454	4,810	5,089
Roberts	0	683	1,158	2,283	2,666	2,855	3,034
Sherman	0	25,895	45,383	88,429	103,368	104,313	111,300
Wheeler	0	895	1,505	3,008	3,493	3,712	3,918
Total	**0**	**141,398**	**246,799**	**474,520**	**541,226**	**536,855**	**565,397**

[1] The recommended irrigation combination for Collingsworth, Dallam, Hartley, Moore and Sherman Counties includes the adjusted savings.

Table 5B-8: Estimated Cost for the Recommended Combination by County in the PWPA

County	Cost for Recommended Combination[1] ($/yr)					
	2020	2030	2040	2050	2060	2070
Armstrong	$32,929	$58,455	$106,886	$120,568	$125,961	$128,912
Carson	$660,199	$1,009,934	$1,921,466	$2,150,641	$2,205,554	$2,062,898
Childress	$82,920	$133,807	$272,348	$307,670	$316,358	$290,513
Collingsworth	$237,078	$381,844	$781,816	$883,188	$907,342	$834,816
Dallam	$1,915,384	$3,039,506	$5,354,341	$5,979,577	$6,193,868	$5,732,853
Donley	$130,273	$206,027	$399,185	$451,365	$467,404	$417,788
Gray	$220,354	$340,969	$633,177	$709,447	$731,205	$674,891
Hall	$170,334	$267,866	$557,364	$628,892	$643,471	$596,921
Hansford	$1,217,273	$1,914,925	$3,555,038	$3,977,296	$4,094,711	$3,824,233
Hartley	$2,158,937	$3,336,740	$5,865,087	$6,544,446	$6,769,222	$6,254,916
Hemphill	$13,119	$28,970	$41,853	$49,318	$56,161	$37,018
Hutchinson	$274,146	$440,916	$813,977	$911,649	$941,087	$875,375
Lipscomb	$201,975	$315,781	$558,337	$626,188	$650,970	$587,031
Moore	$1,214,587	$1,915,606	$3,458,633	$3,862,924	$3,986,200	$3,719,572
Ochiltree	$593,425	$936,170	$1,726,505	$1,931,331	$1,989,792	$1,856,286
Oldham	$23,135	$42,751	$72,952	$82,018	$86,386	$78,290
Potter	$4,494	$11,103	$17,560	$19,902	$21,555	$19,037
Randall	$74,978	$156,075	$268,983	$303,417	$321,174	$292,640
Roberts	$54,377	$84,249	$153,630	$171,752	$177,059	$164,376
Sherman	$2,024,757	$3,117,838	$5,592,463	$6,236,395	$6,425,691	$6,003,997
Wheeler	$75,997	$129,935	$247,374	$278,865	$289,151	$265,152
Total	**$11,380,671**	**$17,869,467**	**$32,398,977**	**$36,226,850**	**$37,400,323**	**$34,717,514**

5B.2.4 Additional Irrigation Supply from Groundwater Wells

While the PWPG does not recommend new groundwater wells as a strategy to meet future irrigation needs during the planning period because of declining water levels, drilling of new wells is an option for individual producers who have not fully developed their water rights. Approximate cost estimates were developed to determine the expense associated with installing irrigation wells. Table 5B-9 summarizes two scenarios: a pumping rate of less than and greater than 500 gallons per minute.

Table 5B-9: Estimated Costs of Irrigation Wells in the PWPA

Pumping Rate (gpm)	Well Depth (ft.)	Well Casing Diameter (in.)	Pumping Unit Diameter (in.)	Well Cost	Pumping Equipment Cost	Total Cost
Less than 500	375	12¾	4 - 6	$33,750	$25,500	$59,250
Greater than 500	500	16	8	$55,000	$54,500 [1]	$109,500
				$55,000	$61,000 [2]	$116,000

[1] Assumes submersible pump and associated equipment
[2] Assumes electric turbine and associated equipment

5B.3 Water Conservation Plans

Each public water supplier is required to update and submit a Water Conservation Plan (WCP) to the Texas Commission on Environmental Quality (TCEQ) every five years. Per Title 30, Part 1, Chapter 288, Subchapter A, Rule 288.2 of the Texas Administrative Code, some specific conservation strategies are required to be included as part of a water conservation plan. At a minimum each plan must include:

- Utility Profile that describes the entity, water system and water use data;
- Record management system that is capable of recording water use by different types of users;
- Quantified five-year and ten-year water savings goals;
- Metering device with a 5 percent accuracy to measure the amount of water diverted from the source of supply;
- A program for universal metering;
- Measures to determine and control water loss;
- A program of continuing public education and information regarding water conservation;
- A non-promotional water rate structure;
- A reservoir systems operation plan (if applicable);
- Means of implementation and enforcement, as evidenced by: a document indicating the adoption of the WCP, and a description of the authority where the water supplier will implement and enforce the WCP;
- Documentation of coordination with the regional water planning group.

If a public water supplier serves over 5,000 people, they are additionally required to have a conservation-oriented rate structure and a program of leak detection, repair, and water loss accounting for the water transmission, delivery, and distribution system.

The TCEQ also requires water conservation plans for all municipal and industrial water users with surface water rights of 1,000 acre-feet per year or more and irrigation water users with surface water rights of 10,000 acre-feet per year or more, and for all water users applying for a State water right. Water conservation plans may also be required for entities seeking State funding for water supply projects. Legislation passed in 2003 requires all conservation plans to specify quantifiable 5-year and 10-year conservation goals and targets. While these goals are not enforceable, they must be identified. In 2007 legislation was passed that requires all public water suppliers with greater than 3,300 connections to submit a conservation plan to the TCEQ. All updated water conservation plans were to be submitted to the Executive Director of the TCEQ by May 1, 2019.

In the PWPA, six water suppliers hold municipal or industrial surface water rights in excess of 1,000 acre-feet per year or have more than 3,300 connections. There are no entities with surface irrigation water rights greater than 10,000 acre-feet per year. Each of these entities is required to develop and submit to the TCEQ a water conservation plan. Several water users have contracts with regional water providers for water of 1,000 acre-feet per year or more. Those wholesale providers are required to include a provision in their wholesale contracts that each wholesale customer develop and implement a water conservation plan. A list of the users in the PWPG required to submit water conservation plans is shown in Table 5B-10.

Table 5B-10: Water Users in the PWPA Required to Prepare Water Conservation Plans

Municipal and Industrial Water Users	Irrigation Water Users
City of Amarillo	None in PWPA
Canadian River Municipal Water Authority	
Greenbelt Municipal Water Authority	
Palo Duro River Authority	
Borger	
Canyon	
Dumas	
Pampa	

There are numerous irrigation users pumping groundwater in excess of 10,000 acre-feet per year and these users are usually regulated through the local GCD which will issue well permits to the irrigators. The GCD is required to submit a groundwater management plan to the TWDB for approval. A groundwater management plan is a 10-year plan that describes a district's groundwater management goals. These goals include providing the most efficient use of groundwater, controlling and preventing waste of groundwater, controlling and preventing subsidence, addressing conjunctive surface water management issues, addressing natural resource issues, addressing drought conditions, and addressing conservation (§356.5 and §356.6, Texas Administrative Code, relating to Management Plan and Plan Submittal, respectively).

To assist entities in the PWPA with developing water conservation plans, model plans for municipal water users (wholesale or retail public water suppliers), industrial users and irrigation districts were developed considering the region's unique water issues. Each of these model plans address the latest TCEQ requirements and is intended to be modified by each user to best reflect the activities appropriate to the entity. These plans can be accessed through the PWPA website at www.panhandlewater.org. General model water conservation plan forms are also available from TCEQ in Microsoft Word and PDF formats. A printed copy of the form from TCEQ can be obtained by calling TCEQ at 512-239-4691 or by email to wras@tceq.state.tx.us .

The focus of the conservation activities for municipal water users in the PWPA are:

- Education and public awareness programs,
- Reduction of unaccounted for water through water audits and maintenance of water systems,
- Water rate structures and ordinances that discourage water waste.

Industrial water users include manufacturing and processing industries as well as smaller local manufacturers. Conservation activities associated with industries are site and industry-specific. Some industries can utilize brackish water supplies or wastewater effluent while others require only potable water. It is important in evaluating conservation strategies for industries to balance the water savings from conservation to economic benefits to the industry and the region.

The focus of the conservation activities for industrial users is:

- Evaluation of water saving equipment and processes, and
- Water rate structures that discourage water waste

5B.4 Other Conservation Recommendations

The PWPG encourages all water user groups to practice advanced conservation efforts to reduce water demand, not only during drought conditions, but as a goal in maintaining future supplies. This includes municipal, industrial and agricultural water users. As appropriate, municipal users should strive to reduce per capita water use to achieve the State-recommended goal of 140 gpcd use. The PWPG recognizes that some cities and rural communities may not achieve this level of reductions, but many communities have the opportunity to increase their water savings.

With irrigated agriculture being the largest water user in the PWPA, this sector has the greatest opportunities for water reductions due to conservation. The plan recommends strategies that would reduce the estimated irrigation water use by approximately 565,000 acre-feet per year by 2070. This represents a reduction of 42 percent of the projected demands. These strategies are specific to the region, but there may be additional strategies that are appropriate for selected crop type or irrigation practices. The PWPG supports the implementation of any and all measures that effectively reduce water for agricultural purposes.

The PWPG supports and encourages the collaboration of multiple entities across the region to promote water conservation. This could be accomplished with the assistance of regional organizations, such as the PRPC and GCDs. Consistent messaging is important in continuing to maintain and/or increase conservation levels in the region.

The TWDB provides a significant amount of information and services pertaining to water conservation that can be accessed at:

http://www.twdb.texas.gov/conservation/

5C WATER MANAGEMENT STRATEGIES FOR MAJOR WATER PROVIDERS

There are five major water providers located in the PWPA: CRMWA, Amarillo, Borger, Cactus and Greenbelt MIWA. Each of these entities is projected to have needs within the planning period. With the on-going drought, the reliability of its current supplies could be further impacted. Discussion of the water needs and recommended water management strategies for each of the major water providers follows.

5C.1 Canadian River Municipal Water Authority (CRMWA)

The CRMWA provides groundwater from Roberts County and surface water from Lake Meredith to users in the PWPA and entities in the Llano Estacado Region. The total available safe supply from the CRMWA system is 89,670 acre-feet per year in 2020, decreasing to 74,330 acre-feet per year by 2070 as groundwater becomes depleted within CRMWA's current well fields. Current demands on CRMWA are estimated at approximately 101,000 acre-feet per year in 2020 and increase to over 121,600 acre-feet per year by 2070. This results in near-term needs of 11,400 acre-feet per year and long-term needs of about 47,260 acre-feet per year. Table 5C-1 lists the demands by customer, current supplies, and projected needs for CRMWA.

The potentially feasible strategies considered for CRMWA to meet these needs include:

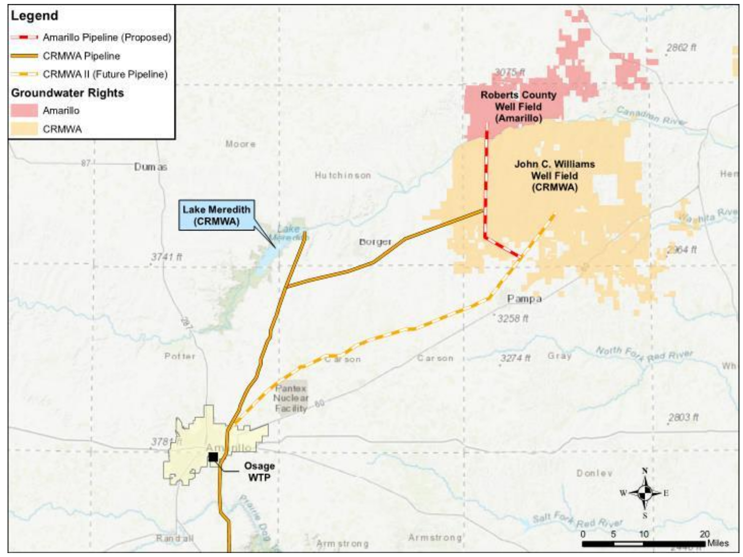
- Conservation of wholesale customers
- Expanded development of Roberts County well field with additional transmission
- Aquifer storage and recovery
- Brush control in Lake Meredith watershed
- Advanced treatment of Lake Meredith water

Table 5C-1: Summary of Demands, Supplies, and Projected Needs for CRMWA

Customers	Demands (Ac Ft/Yr)					
	2020	2030	2040	2050	2060	2070
PWPA						
City of Pampa	2,361	2,833	3,196	3,989	4,628	4,680
City of Borger	7,054	7,091	7,072	7,068	7,064	7,063
City of Amarillo	46,000	50,000	50,000	50,000	50,000	50,000
Region O:						
City of Lamesa	1,750	1,950	2,300	2,750	2,750	2,750
City of O'Donnell	124	125	123	123	128	132
City of Plainview	2,500	3,000	3,250	3,500	3,500	3,500
City of Levelland	2,301	2,400	2,500	2,588	2,671	2,743
City of Lubbock	35,600	39,000	43,500	47,000	47,000	47,000
City of Slaton	1,405	1,430	1,455	1,479	1,477	1,477
City of Tahoka	476	486	477	470	492	503
City of Brownfield	1,500	1,550	1,650	1,750	1,750	1,750
Total	**101,071**	**109,865**	**115,523**	**120,717**	**121,460**	**121,598**
Sources	**Current Water Supply (Ac Ft/Yr)**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Lake Meredith	24,669	24,635	24,602	24,568	24,534	24,501
Roberts County Groundwater	65,000	65,000	60,674	55,476	49,833	49,833
Total Current Supply	**89,669**	**89,635**	**85,276**	**80,044**	**74,367**	**74,334**
	Surplus or (Need) (Ac Ft/Yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
	(11,402)	(20,230)	(30,247)	(40,673)	(47,093)	(47,264)

Four strategies identified for CRMWA are recommended for implementation: conservation by wholesale customers, replacement of well capacity, increased groundwater supplies and transmission capacity from Roberts County well field, and brush control within the Lake Meredith watershed. Advanced treatment of Lake Meredith water is an alternate strategy. Conservation measures and associated savings for the wholesale customers that are in the PWPA are discussed in Chapter 5B. The savings associated with customers in Region O (Llano Estacado Region) are discussed in the Llano Estacado water plan and are included in the total wholesale customer conservation savings for CRMWA in Table 5C-2. A brief description of each of the other strategies is presented below.

Expanded Development of Roberts County Well Field



Groundwater is an important water resource for CRMWA. It is used during times when water is limited from Lake Meredith due to the lack of inflows or impaired water quality. Water from Roberts County is blended with Lake Meredith water to provide supplies that can be treated through conventional treatment. With these uncertainties for Lake Meredith, CRMWA is proceeding to expand their groundwater production and delivery capacity to be able to provide all necessary supplies from groundwater if needed. CRMWA holds water rights to 456,993 acres in Roberts and adjacent counties. Presently, only a fraction of these rights is developed. The current capacity of the transmission system (CRMWA I) from the Roberts County well field is 65 MGD and CRMWA can deliver up to 69,000 acre-feet per year. The existing well field capacity is 84 MGD, and CRMWA is experiencing a reduction of about 1 MGD per year. This reduction is expected to slow down but over the course of the planning period, CRMWA will need to construct additional wells to replace lost groundwater supplies for the existing transmission system. It will also need to develop additional groundwater supplies and transmission capacity from the Roberts County well field to meet its projected needs. There are also on-going discussions with the City of Amarillo to provide transmission capacity to move water from a future Amarillo Roberts County well field. Based on these discussions, CRMWA plans to develop a second pipeline with a capacity of 85 MGD. This capacity includes 20 MGD of transmission capacity for Amarillo's Roberts County well field, which is expected to be online by 2065. This second pipeline, also called the CRMWA II pipeline, would have the ability to deliver about 69,000 acre-feet per year to CRMWA and 20,000 acre-feet per year to Amarillo. For planning purposes, the CRMWA II pipeline would likely provide 65,000 acre-feet per year without additional local storage during the lower demand months (assumes a peaking factor of 1.15). Some years, less water will be delivered from the well field as more water from Lake Meredith is used. With this project the total capacity from the Roberts County for CRMWA is increased to 130 MGD. It is assumed that a new 57-mile 72-inch pipeline (CRMWA II) would be constructed from Roberts County to the terminal storage reservoir northeast of Amarillo. For CRMWA, an additional 10-mile 66-inch pipeline will connect the CRMWA wellfield in Roberts County to the 78-inch CRMWA II pipeline being shared with Amarillo. Infrastructure needed to develop the water and transmission is detailed in the cost estimates in Appendix D.

Time Intended to Complete

Continued expansion of the Roberts County well field to fully utilize the existing transmission capacity is needed by 2020 and would be on-going through the planning period. The planning and design of CRMWA II transmission system is expected to begin by 2025 with the transmission system online by 2027. Additional wells are assumed to be needed over time to maintain the full capacities of the system.

Quantity, Reliability and Cost

The total quantity of water provided by this strategy would be about 80,000 acre-feet per year. This includes the development of 15,000 acre-feet per year of new groundwater supply for the existing pipeline and an additional 65,000 acre-feet per year for the new pipeline. Reliability of Ogallala supplies is moderate to high. There are significant quantities of untapped water supplies in Roberts County, but the availability of this water also depends on other water users. Costs to expand the Roberts County well field is estimated at $454 million. This represents CRMWA's share of the CRMWA II pipeline, new wells to provide 80,000 acre-feet per year of supply, and well field piping.

Environmental Issues

The environmental issues associated with this water management strategy are for pipeline rights-of-way and sites for pumping plants and storage facilities. Since routes and sites can be selected to avoid sensitive wildlife habitat and cultural resources, there would be very little, if any, environmental issues of significant concern.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. There are other users that may compete for groundwater supplies, but there is sufficient water in Roberts County to support these demands.

Impact on Agriculture and Natural Resources

The expansion of the Roberts County well field and maintenance of the existing well field are expected to have minimal impacts on the agriculture and other natural resources. A small amount of agricultural lands may be affected by the transmission system associated with the well field, depending on the final transmission route.

Other Relevant Factors

There are no other identified relevant factors.

Aquifer Storage and Recovery

CRMWA currently has 65 MGD of capacity in the existing transmission system from the Roberts County Well Field. As CRMWA develops additional well field capacity in Roberts County and constructs the new CRMWA II pipeline, the maximum quantity of water that can be transported from the well field will increase to 130 MGD. The average annual supply from this system (including CRMWA II) is estimated at 113,000 acre-feet per year, based on system peaking factor of 1.15. This results in an average delivery of 101 MGD.

During non-peak periods, the capacity of the CRMWA transmission system is underutilized; yet during peak demand months, the ability to meet all CRMWA's customers' future peak demands may be limited. To address the need for increased peaking capacity in CRMWA's delivery system, available water from CRMWA's sources (Lake Meredith and/or Roberts County Well Field) could be treated and stored by the member cities during non-peak periods for future use during peak times. This strategy proposes to store excess non-peak water through an Aquifer Storage and Recovery program (ASR) that will utilize existing well fields and infrastructure. CRMWA will be conducting a feasibility study to further evaluate this strategy for all member cities.

For the purposes of this strategy it is assumed that the cities of Amarillo and

Pampa will develop an ASR project at one of their well fields using water from CRMWA and possibly other sources. Each of these projects are discussed under Amarillo and Pampa, respectively. For CRMWA's customers in the Llano-Estacado regions, CRMWA will assist in sponsoring an ASR project. Water from this project could be used by all eight member cities in the Llano-Estacado region. Until the feasibility study is completed, it is assumed that the cities of Lamesa, Plainview, Levelland, Lubbock, and Brownfield would receive water from the ASR project. The water would be treated at the Lubbock water treatment plant and stored at a nearby ASR site developed by CRMWA. Alternatively, each member city could utilize their existing well fields and treatment capacity. The cost components of this strategy assume a new ASR well field, which includes 14 injection wells and 13 recovery wells. Some of the injection wells may also be used for recovery. The strategy will also include transmission from the treatment plant to the ASR well field. Since this well field has not been sited, a 5-mile transmission line has been assumed as a placeholder. Defined improvements will be determined during the feasibility study sponsored by CRMWA. It should be noted that the City of Lubbock has developed a more detailed ASR strategy that will utilize water from CRMWA. However, the supplies for Lubbock's ASR strategy are based on the average annual supply from CRMWA's system with the assumed peaking factor. Additional water may become available to Lubbock with CRMWA's sponsored ASR project. The quantities and recipients will be refined during CRMWA's feasibility study.

Time to Implement

Supply will be available for the ASR project after CRMWA II is online in 2030.

Quantity, Reliability and Cost

The quantity will vary from year to year depending on the demand from the member cities and capacities of ASR well fields. The quantity of water that could be made available annually from the CRMWA-sponsored ASR project is 10,000 acre-feet per year. (Another 7,000 acre-feet per year of water from CRMWA would be available for ASR to users in the PWPA. These strategies are evaluated separately, but the total quantity of water supplied by this operation is shown with CRMWA.) If the water is stored over multiple years, additional supply may be available during drought. For purposes of this analysis, it is assumed that the water is stored and retrieved over one year. The source of this water would be Lake Meredith and/or the Ogallala aquifer in Roberts County. The actual amounts used from each source will vary by year based on demands and available supply in Lake Meredith.

Successful ASR development is highly reliable. It is possible to achieve 90-95% recovery efficiency, depending upon the natural hydraulic gradient of the receiving aquifer and competition from adjacent groundwater users. If the water is recharged and recovered over a relatively short period (e.g., one year), the likelihood of reduced reliability is low. The ASR project will increase the reliability of existing supplies by allowing storage of the supply during periods of low demand to meet high demands at a later time.

The quality of water is expected to be good. The ASR regulations for Texas specify that the quality of the recharge water must not degrade the quality of the receiving aquifer, which is generally good. The recovered ASR water would be treated to standards required by the end use. When recharge water is treated to meet drinking water standards prior to storage, the recovered water will only need simple re-disinfection prior to being distributed to end-users.

Cost estimates were developed for the application of ASR a single well field. A total of 27 wells for injection and recovery and 20,000 feet of well field piping were assumed for this strategy. No additional transmission costs to the end users are included in the strategy cost. If possible, existing infrastructure would be used to deliver the stored water. The feasibility study, when completed, would identify additional project components if needed. The strategy is estimated to cost $28 million.

Environmental Issues

Environmental impacts are expected to be low. The transmission system and the ASR facilities can be designed to avoid environmentally sensitive areas. As previously mentioned, the recharge water must not degrade the quality of the groundwater in the receiving aquifer. Therefore, environmental impacts to the receiving aquifer are expected to be minimal to none.

Impact on Water Resources and Other Management Strategies

This strategy should have a positive impact on other water management strategies by increasing reliability.

Impact on Agriculture and Natural Resources

The project should have no impact to agriculture or natural resources since it is utilizing existing water sources and existing infrastructure.

Other Relevant Factors

There are no other identified relevant factors.

Brush Control in Lake Meredith Watershed

CRMWA has an active salt cedar control program in the Lake Meredith watershed. The purpose of the program is to increase flow in the Canadian River, improve water quality and improve the habitat for the federally listed Arkansas River Shiner, which is known to inhabit this area. CRMWA has treated approximately 27,000 acres of salt cedar, which accounts for about 95 percent of the total salt cedar in the Lake Meredith watershed. Since 2004, over $3.5 million has been spent on brush control, with CRMWA contributing most of the funds. The salt cedar beetle was introduced into the Lake Meredith watershed several years ago and is becoming established. And could help control re-infestation. However, retreatment will likely still be needed. CRMWA is now in the on-going maintenance phase, which requires retreating of areas to control the growth and potential re-infestation of salt cedar. CRMWA is currently treating 500 acres each year. This strategy recommends that CRMWA continue with its program to control salt cedar in the Lake Meredith watershed and work with the State Water Supply Enhancement Program when this program is funded by the Legislature.

Time Intended to Complete

This strategy is on-going and would be implemented throughout the planning period.

Quantity, Reliability and Cost

The amount of water developed from brush control is difficult to estimate since there are so many factors that affect reservoir inflows, and Lake Meredith is benefiting from brush control that has been completed. For this plan, it is assumed that the amount of water made available from continuing treatment of brush is estimated at 5 acre-feet per year per acre of treatment for a total quantity of 2,500 acre-feet per year. This water would be realized through available supply in Lake Meredith and optimized with conjunctive use CRMWA's groundwater sources. The reliability during drought is low. The annual costs are estimated at $150,000.

Environmental Issues

There is concern about the removal of brush for wildlife. However, with increased runoff to streams and lakes, this strategy would provide additional water for wildlife.

Impact on Water Resources and Other Management Strategies

This strategy should have a positive impact to Lake Meredith, and ultimately to CRMWA's available supplies.

Impact on Agriculture and Natural Resources

The removal of invasive brush will allow for the development of native grasslands and other agricultural uses. It should have a positive impact on natural resources.

Other Relevant Factors

There are no other identified relevant factors.

Advanced Treatment of Lake Meredith Supplies

This strategy assumes an advanced treatment facility that would produce 10,000 acre-feet of treated supplies would be located near the intake of Lake Meredith to treat elevated chlorides and total dissolved solids. The waste stream would be piped about 10 miles upstream and discharged back into Lake Meredith. Alternatively, the waste stream could be injected in a brackish formation. Lake Meredith is located in an area where there is little potable groundwater (Canadian breaks).

Time Intended to Complete

This strategy is an alternate strategy. This strategy could be implemented as early 2030 or later in the planning cycle, depending upon future impacts to supplies in Lake Meredith.

Quantity, Reliability and Cost

This strategy would not provide additional supplies, but rather increase the reliability of CRMWA's existing supplies during times when water quality impairments limited the amount of water available from Lake Meredith. It also preserves groundwater supplies in Roberts County if more surface water is useable. The capital costs for this strategy are $100 million.

Environmental Issues

There is concern about the waste discharge stream from the advanced treatment process. As conceived, the salt stream would be discharged upstream into Lake Meredith. The discharge stream must not further impair the water quality of the stream segment.

Impact on Water Resources and Other Management Strategies

This strategy could increase salinity in Lake Meredith during very low inflow periods, however, the salts in the lake water would concentrate without this project due to evaporation. Lower salinity water to CRMWA's customers would improve the water quality and potentially reduce the required amount of groundwater needed for blending.

Impact on Agriculture and Natural Resources

The lower salinity source water could reduce the salinity in the wastewater effluent that is land applied for irrigation.

Other Relevant Factors

There are no other identified relevant factors.

Summary for CRMWA

The recommended strategies for CRMWA would provide up to 85,688 acre-feet per year (including conservation from PWPA customers). CRMWA is planning to initiate transmission expansion (CRMWA II) by 2027 and well capacity replacement for CRMWA I and II before 2040. Based on this timing, CRMWA may not be able to fully meet contractual demands until after the CRMWA II pipeline from Roberts County well field is completed. The recommended strategies and quantities are shown in Table 5C-2. The costs for the strategies are summarized in Table 5C-3.

Table 5C-2: Recommended Water Management Strategies for CRMWA (Ac-Ft/Yr)

	2020	2030	2040	2050	2060	2070
Need	(11,402)	(20,230)	(30,247)	(40,673)	(47,093)	(47,264)
Recommended Strategies	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
PWPA Customer Conservation	2,541	2,814	2,866	2,913	2,988	3,021
Replace Well Capacity for CRMWA I and II[1]	0	0	4,326	9,524	19,493	24,691
Expand GW and delivery capacity (CRMWA II) [1]	0	65,000	65,000	65,000	60,674	55,476
ASR[2]	0	17,000	17,000	17,000	17,000	17,000
Brush Control	2,500	2,500	2,500	2,500	2,500	2,500
Total from Strategies	5,041	70,314	74,692	79,937	85,655	85,688
Alternate Strategy	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Advanced Treatment of Lake Meredith Supplies		10,000	10,000	10,000	10,000	10,000

[1] This is part of the Expanded Development of Roberts County Well Field strategy.

[2]. Supply from ASR uses water developed from other strategies and is not included in the total.

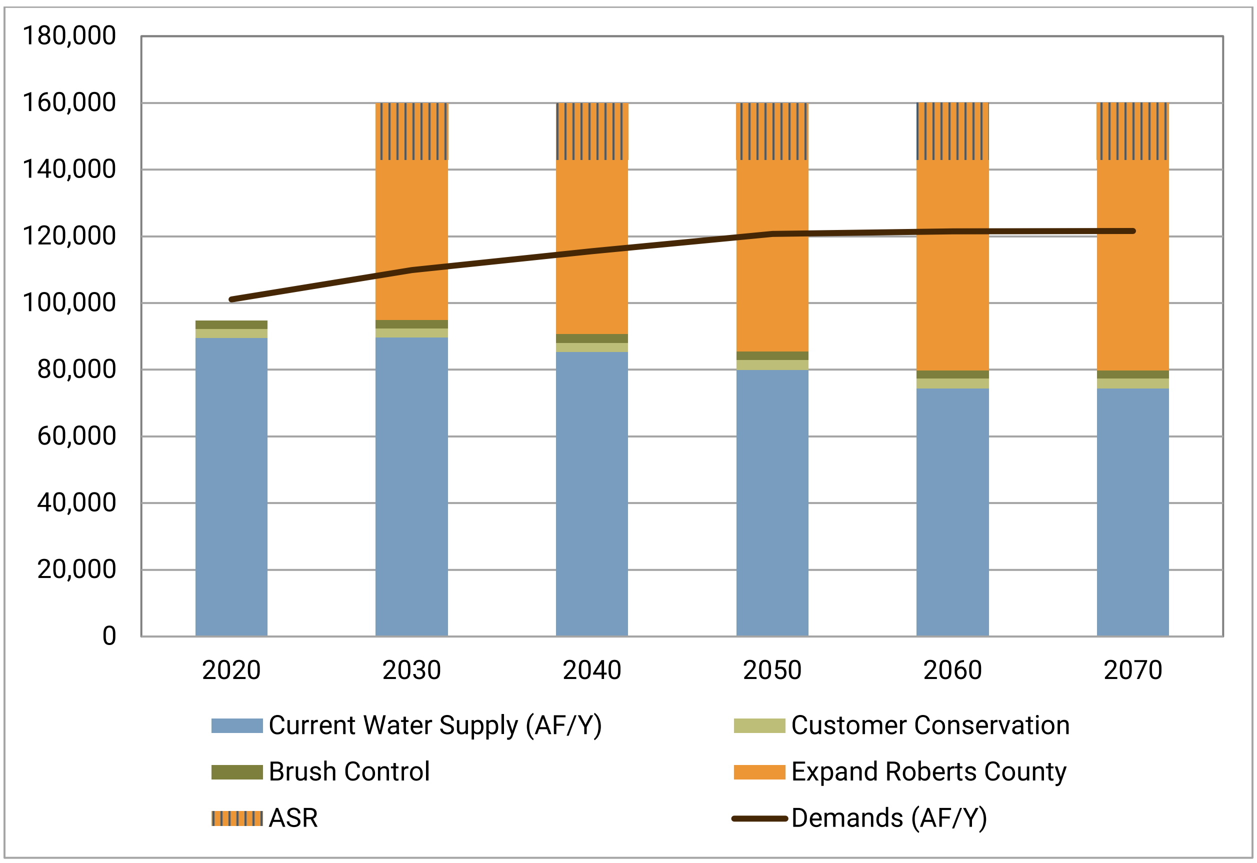


Figure 5C-1: Recommended Strategies for CRMWA

Table 5C-3: Summary of Costs for CRMWA's Recommended Strategies

Recommended Strategies	Capital Cost ($ Millions)	Annual Costs ($ Million) 2020	2030	2040	2050	2060	2070
Replace Well Capacity for CRMWA I	$30.9	$0.0	$0.0	$2.4	$2.4	$3.7	$3.7
Expand GW and delivery capacity (CRMWA II) [1]	$468.5	$0.0	$53.8	$53.8	$20.9	$20.9	$20.9
Aquifer Storage and Recovery	$27.8	$0.0	$0.0	$3.6	$3.6	$1.6	$1.6
Brush Control	$0.0	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
Total from Strategies	**$527.3**	**$0.2**	**$54.0**	**$59.9**	**$27.0**	**$26.3**	**$26.3**

[1.] Capital and annual costs for the shared pipeline with CRMWA are shown with CRMWA. Amarillo would be responsible for 24% of these costs; however, the details of the cost sharing agreement have not been finalized. Costs presented here include the well field and all infrastructure necessary to transport the water to CRMWA's service area.

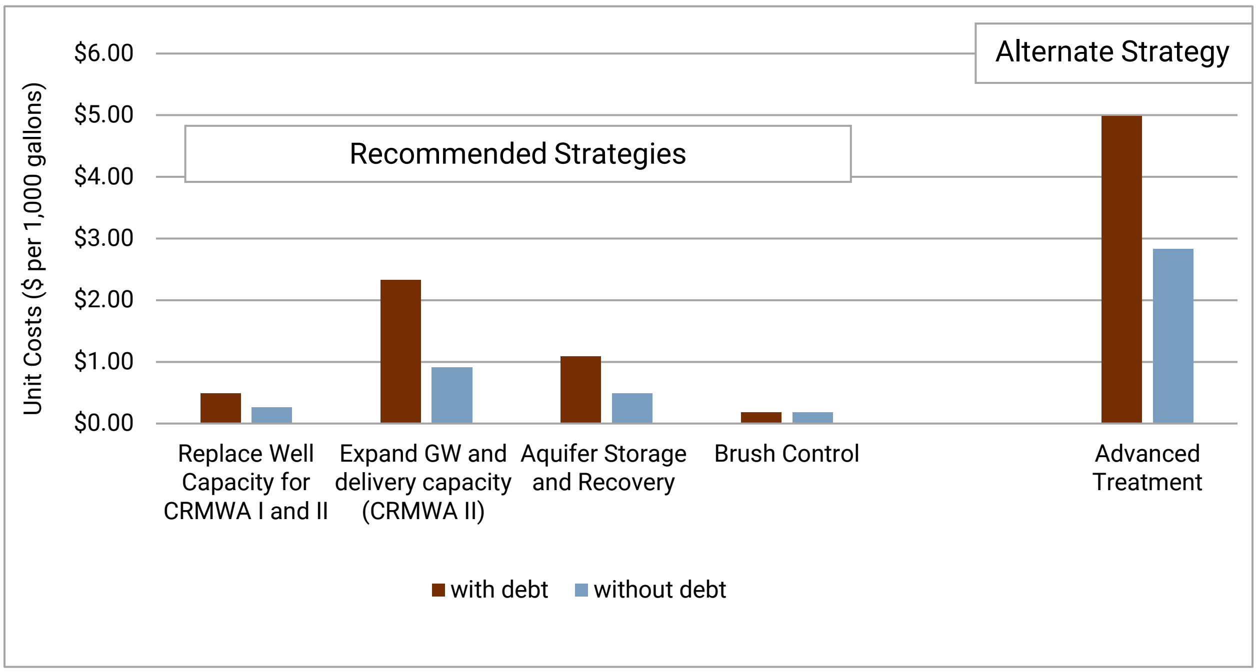


Figure 5C-2: Unit Costs for CRMWA Recommended and Alternate Strategies

5C.2 City of Amarillo

The City of Amarillo provides municipal water to city customers in Randall and Potter County, the City of Canyon, and Palo Duro State Park. It also provides most of the manufacturing water needs in Potter County with a small amount to manufacturing demands in Randall County. The City also has a contract to sell Xcel Energy treated wastewater effluent.

Amarillo owns water rights in Randall, Potter, Carson, Deaf Smith, Lipscomb, Ochiltree and Roberts County, but only a portion of these groundwater rights are developed. In addition, the City has a contract with CRMWA for water from Lake Meredith and Roberts County groundwater. The current delivery capacity for water from CRMWA is 42,987 acre-feet per year. CRMWA intends to increase this delivery capacity through the construction of its CRMWA II pipeline from Roberts County. Considering supplies from CRMWA and Amarillo's existing groundwater, the total estimated current supply for the City is 58,577 acre-feet per year of potable water and 21,992 acre-feet of treated wastewater effluent. Potable water supplies are projected to decrease to 41,486 acre-feet per year as groundwater supplies decline. Treated effluent is expected to increase over time and is currently supplied to Xcel Energy for steam electric power use and instream flow to Lake Tanglewood.

Table 5C-4 lists the projected demands by customer, the current sources of supply available, and the projected water needs. The projected needs are expected to begin in 2030 with a shortfall of about 6,500 acre-feet per year and increasing to nearly 42,000 acre-feet per year by 2070. Some of this need will be met when CRMWA develops additional groundwater in Roberts County to fully meet Amarillo's contractual demands. However, the City would still need to develop about 22,000 acre-feet of new water.

The City of Amarillo considered a wide array of strategies to meet the increased demands. The City realizes that it is important to be proactive and consider all potential sources of supplies. Potential sources include development and expansion of its existing groundwater rights holdings in Potter/Carson Counties and Roberts/Ochiltree Counties. Amarillo has been in discussions with CRMWA on participation with the CRMWA II pipeline to move water from its Roberts County well field. The City is also looking to develop an aquifer storage and recovery project that will store water delivered from CRMWA and treated effluent. Other potential sources of new supply for Amarillo include the use of water collected in playa lakes. This water could be used for non-potable use, but it would have low reliability and water quality could be a concern. At this time, it was decided not to include water from playa lakes as a potentially feasible strategy.

The recommended water management strategies for Amarillo include conservation strategies, obtain contractual supply from CRMWA, expansion of their Potter County well field, aquifer storage and recovery using reuse and CRMWA supplies, and development of the Roberts County Well Field.

Recommended Strategies

- Implement conservation strategies (See Section 5B.1)
- Obtain contractual supplies from CRMWA (this is evaluated with CRMWA strategies)
- Develop Phase II of the Potter/Carson County Well Field (Ogallala aquifer)
- Develop Roberts County Well Field (Ogallala aquifer)
- Aquifer Storage and Recovery (ASR) using CRMWA supplies and wastewater reuse

Table 5C-4: Summary of Demands, Supplies, and Projected Needs for Amarillo

Customers	Demands (Ac Ft/Yr) 2020	2030	2040	2050	2060	2070
City of Amarillo	49,454	53,992	58,861	64,093	70,074	76,402
Manufacturing - Potter County	5,527	6,118	6,118	6,118	6,118	6,118
City of Canyon	1,000	1,000	1,000	1,000	0	0
Manufacturing - Randall County	576	576	576	576	576	576
Palo Duro State Park	25	25	25	25	25	25
Steam Electric Power–Potter County	18,554	18,554	18,554	18,554	18,554	18,554
Instream Flows to Lake Tanglewood	1,682	1,682	1,682	1,682	1,682	1,682
Total Potable Demand	**56,582**	**61,711**	**66,580**	**71,812**	**76,793**	**83,121**
Total Non-Potable Demand	**20,236**	**20,236**	**20,236**	**20,236**	**20,236**	**20,236**
	Current Water Supply (Ac Ft/Yr)					
Sources	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Randall County	1,689	1,304	985	763	641	641
Ogallala - Potter County	5,188	3,295	3,201	3,071	2,895	2,895
Ogallala - Carson County	12,300	11,260	9,826	8,490	7,384	7,384
CRMWA	39,300	39,270	36,907	33,154	30,614	30,566
Ogallala - Deaf Smith	100	100	100	100	50	0
Reuse	21,992	24,044	25,992	28,084	30,477	33,008
Total Potable Supply	**58,577**	**55,229**	**51,019**	**45,578**	**41,584**	**41,486**
Total Reuse Supply	**21,992**	**24,044**	**25,992**	**28,084**	**30,477**	**33,008**
	Surplus or (Need) (Ac Ft/Yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Potable	**1,994**	**(6,482)**	**(15,561)**	**(26,234)**	**(35,209)**	**(41,635)**
Non-Potable	**1,757**	**3,809**	**5,757**	**7,849**	**10,242**	**12,773**

[1] The amount CRMWA sells to other Major Water Providers is included in the supplies reported for CRMWA.
[2] Reuse supply is only available to steam electric users in Potter County.

Develop Phase II of the Potter/Carson County Well Field (Ogallala aquifer)

The City of Amarillo has an existing well field in the Ogallala aquifer in Potter and Carson Counties. While Amarillo intends to develop this strategy over time in two 20 MGD phases, with each phase providing approximately 10,000 acre-feet per year. To provide this quantity of water, it is assumed that approximately 20 new wells will be drilled in Carson County and two new wells in Potter County (due to MAG limitations). The Carson County wells will be drilled to a depth of 450 feet and produce approximately 700 gallons per minute. The Potter County wells will be drilled to a depth of 600 feet and produce approximately 850 gallons per minute. This project includes 25 miles of well field piping ranging from 14- to 36-inches in diameter. It is assumed that an additional transmission pipeline will be needed to move the water the city's existing infrastructure. For this plan, 10-miles of 36-inch pipeline and associated pumping facilities upgrades are included in the cost estimates to connect to Amarillo's existing transmission system.

Time Intended to Complete

The first 20 MGD phase of this project will be online before 2030. The second phase would be online by 2050.

Quantity, Reliability and Cost

Approximately 20,000 acre-feet per year of additional water will be obtained from the Potter/Carson County well field. The reliability of Ogallala supplies is moderate since there is currently competition for this supply with irrigators. The total capital cost for the Potter/Carson County well field is $59.2 million.

Environmental Issues

The environmental impacts from groundwater development are expected to be low. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. There are other users that may compete for groundwater supplies in these counties including irrigation users that may be impacted by the development of this well field.

Impact on Agriculture and Natural Resources

The development of the proposed well fields is expected to have moderate impact on the agriculture and other natural resources. A small amount of agricultural lands may be affected by the transmission system associated with the well field, depending on the final transmission route.

Other Relevant Factors

There are no other identified relevant factors.

Develop Roberts County Well Field (Ogallala aquifer)

The City of Amarillo has unused groundwater rights in the Ogallala aquifer in Roberts and Ochiltree Counties. These rights are located the furthest from the city and will likely be developed after sources closer to Amarillo. As more supplies are needed, the city will develop its groundwater rights in Roberts County, followed by its rights in Ochiltree County. The strategy is referred to as the “Roberts County Well Field”, however, over time it will include water supplies from Ochiltree County. It is assumed that the Roberts County strategy will be implemented in two phases, with Phase 1 being developed by 2065 and Phase 2 developed after the regional water planning horizon. This well field strategy assumes that approximately 18 new wells will be drilled in Roberts County, north of CRMWA’s Roberts County water rights. The wells will be drilled to a depth of 600 feet and produce approximately 800 gallons per minute. This project includes well field piping ranging from 10- to 36-inches in diameter.

The City is currently negotiating with CRMWA for capacity in the CRMWA II pipeline for 20 MGD to transport the water to Amarillo. The CRMWA II pipeline strategy discussed in Section 5C.1.1 includes the added capacity for Amarillo. In addition, 27 miles of 36-inch pipeline is required to move the water to the CRMWA II pipeline. Alternatively, Amarillo could construct 75-miles of 36-inch pipeline to transport the water from Roberts County to Amarillo and not use the CRMWA II pipeline.

Time Intended to Complete

The Roberts County well field will be developed as additional supplies are needed. This is expected to occur by 2065. It is shown in the 2070 decade.

Quantity, Reliability and Cost

Approximately 11,200 acre-feet per year (20 MGD peak day) of additional water will be obtained from the Roberts County well field during the first phase. In Roberts County, the reliability of Ogallala supplies is moderate to high since there are large quantities of undeveloped supply in this county, though competing interests may be present. The total capital cost for the Roberts County well field is $143 million. These costs could potentially be more if Amarillo and CRMWA did not jointly develop additional transmission capacity from Roberts County.

Environmental Issues

The environmental impacts from groundwater development are expected to be low. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. There are other users that may compete for groundwater supplies, but there is sufficient water in Roberts County to support these demands.

Impact on Agriculture and Natural Resources

The development of the proposed well fields are expected to have minimal impact on the agriculture and other natural resources. A small amount of agricultural lands may be affected by the transmission system associated with the well field, depending on the final transmission route.

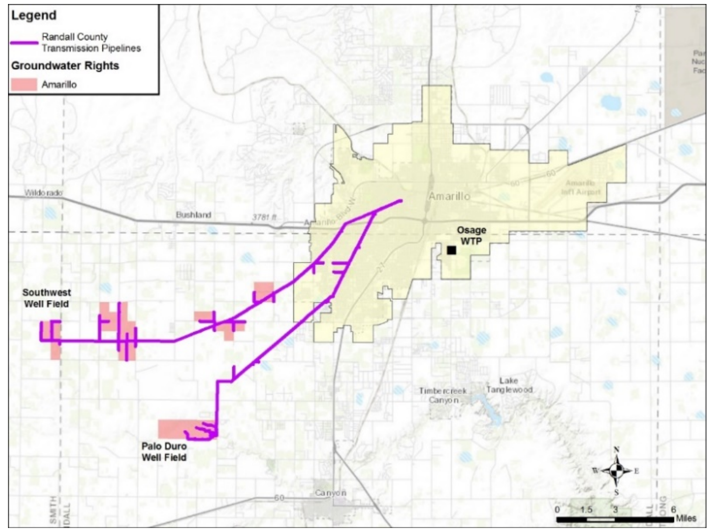
Other Relevant Factors

There are no other identified relevant factors.

Aquifer Storage and Recovery (ASR)

During non-peak periods, the capacity of Amarillo's transmission system is underutilized; yet during peak demand months, the ability to meet all of Amarillo's customers' future peak demands may be limited. To address the need for increased peaking capacity in the delivery system, available water from Amarillo's sources could be stored during non-peak periods for future use during peak times. This strategy proposes to store excess non-peak water through an Aquifer Storage and Recovery program (ASR) that will utilize existing well fields and infrastructure. Amarillo will be conducting a feasibility study to further evaluate this strategy.

For this strategy, it is assumed that the ASR project would be developed at Amarillo's Randall County well field. Amarillo currently has two existing 30-inch pipelines from the Randall County Well Fields to the City with a combined transmission capacity of 30 MGD; yet the City is only using a fraction of this capacity due to declining water levels. These lines could transport treated water from Amarillo's treatment plant to and from the well field. The cost components of this strategy include new well field piping, injection wells at the existing well fields, along with some pump improvements to move water to ASR injection wells.



This strategy assumes that sixteen 400-gpm 8-inch diameter wells will be required for ASR injection in Randall County. Existing wells would be used for recovery. It is assumed that no additional improvements are needed for the transmission system back to the City.

Time to Implement

Supply will be available for the ASR project by 2030.

Quantity, Reliability and Cost

The quantity will vary from year to year depending on demands and the capacities of ASR well fields. The quantity of water that would be made available from the ASR project is 10,000 acre-feet per year. The source of this water would be from CRMWA, which could include a combination of water from Lake Meredith and groundwater from Roberts County. Amarillo also may utilize treated wastewater for this strategy.

The ASR project will increase the reliability of existing supplies by allowing storage of the supply during periods of low demand to meet high demands at a later time. The strategy is estimated to cost $11.5 million.

Environmental Issues

Environmental impacts are expected to be low. Since the recharge water must not degrade the quality of the groundwater in the receiving aquifer, environmental impacts to the receiving aquifer are expected to be minimal to none. If all the source water is groundwater, pre-treatment of the water before injection and storage may not be needed.

Impact on Water Resources and Other Management Strategies

This strategy should have a positive impact on other water management strategies by increasing reliability.

Impact on Agriculture and Natural Resources

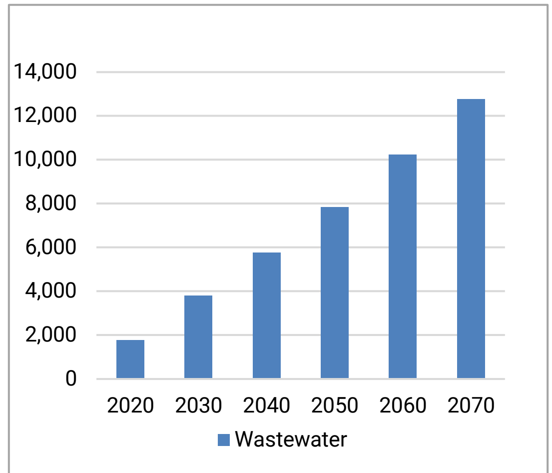
The project should have no impact to agriculture or natural resources since it is utilizing existing water sources and existing infrastructure.

Other Relevant Factors

There are no other identified relevant factors.

Direct Potable Reuse

The City of Amarillo is considering a project to treat their wastewater effluent to potable water status and then store the water in the ASR project discussed above. The strategy would treat between 3 and 5 MGD at the existing wastewater treatment plan with pre-treatment and reverse osmosis to produce 3,500 acre-feet per year of finished water. The water would then be transported to the Randall County well field using existing infrastructure (see Section 5C.2.2). The reject water from the treatment process would be discharged by a 7-mile pipeline to the Prairie Dog Town Fork of the Red River below.



Time Intended to Complete

This project is expected to be online by 2040, but it could be permitted and constructed earlier if needed.

Quantity, Reliability and Cost

Direct potable reuse would have moderate to high reliability. The capital cost for this project is approximately $51.3 million. If Amarillo is not able to discharge to a stream the cost for deep well injection could substantially increase the capital cost.

Environmental Issues

The greatest potential environmental impact is the quality of the discharge water. An initial review of the TDS stream standard for the Upper Prairie Dog Town Fork of the Red River is 2,000 mg/L. Additional studies would need to be conducted to determine the feasibility of discharging to the Prairie Dog Town Fork of the Red River.

Impact on Water Resources and Other Management Strategies

Amarillo is currently providing a significant amount of their direct reuse for steam electric cooling. Direct potable reuse could impact the amount of reuse available for steam electric power in Potter County; however, the demands for steam electric power cooling in Potter County are not expected to increase and additional reuse water will become available. This strategy is not expected to impact existing supplies or other water management strategies.

Impact on Agriculture and Natural Resources

Discharges to the Prairie Dog Town Fork of the Red River will need to be further evaluated to determine the impact to natural resources

Other Relevant Factors

This strategy would require extensive coordination with the TCEQ to obtain the necessary permits for use and discharge. It may also require a modification to the agreement with Xcel Energy for purchase of Amarillo's wastewater.

Summary of Recommended Strategies for Amarillo

The recommended strategies for Amarillo would provide over 60,000 acre-feet per year and fully meet the city's needs. Approximately 20,000 acre-feet per year will become available to Amarillo by 2030 after the CRMWA II pipeline is online and the city initiates Phase II of their Potter/Carson County Well Field. The recommended strategies and quantities are shown in Table 5C-5 and on Figure 5C-3. The total capital cost for Amarillo is $481 million and the annual costs for the strategies are summarized in Table 5C-6. Unit costs are shown on Figure 5C-4.

Table 5C-5: Recommended Water Management Strategies for Amarillo (Ac-Ft/Yr)

	2020	2030	2040	2050	2060	2070
Surplus or (Need) – Potable Supply	**1,994**	**(6,482)**	**(15,561)**	**(26,234)**	**(35,209)**	**(41,635)**
		Supply from Strategy (Ac Ft/Yr)				
Recommended Strategies	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Water Conservation	4,538	5,010	5,505	6,018	6,585	7,182
Supplies from CRMWA	0	10,732	13,093	16,846	19,386	19,435
Potter County Well Field – Phase 2		10,000	10,000	20,000	20,000	20,000
Roberts County Well Field						11,210
Aquifer Storage and Recovery (ASR)[1]		5,000	6,500	6,500	6,500	6,500
Direct Potable Reuse			3,500	3,500	3,500	3,500
Total from Strategies	**4,538**	**25,742**	**32,098**	**46,364**	**49,471**	**61,327**
Alternate Strategy	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Roberts County Well Field (independent transmission)						11,210

[1] The ASR strategy would use supplies from other strategies and is not included in the total water quantities.

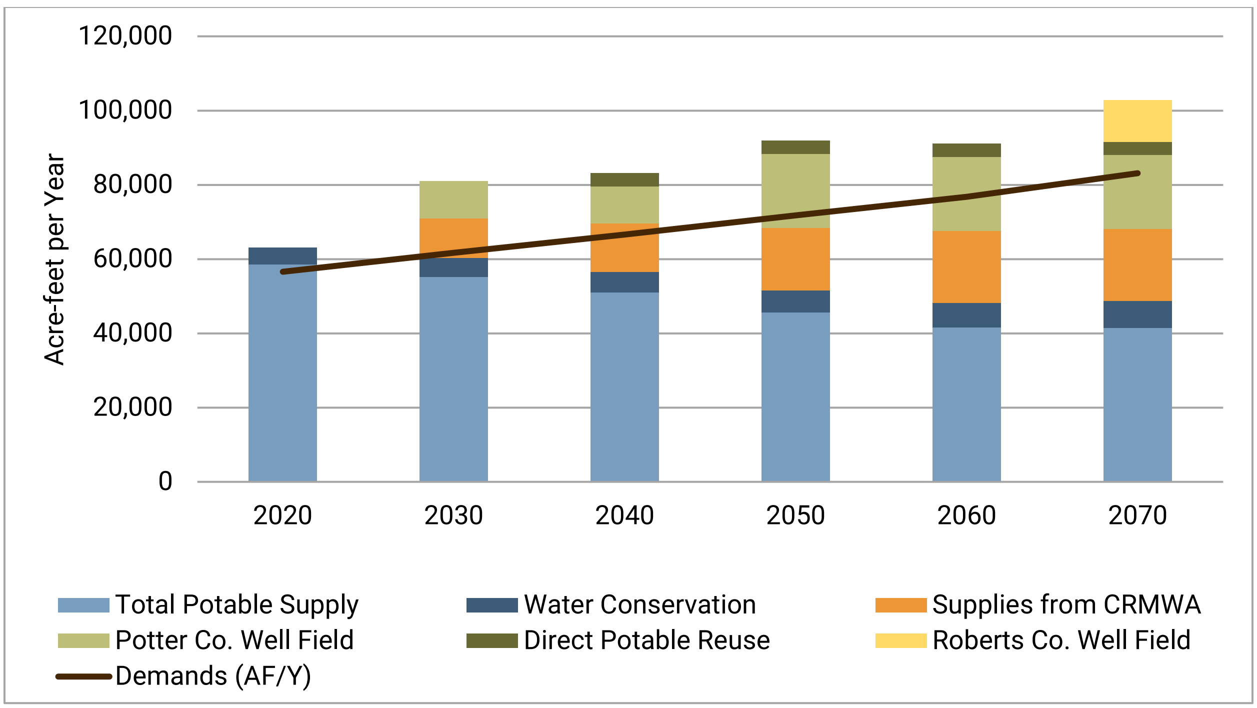


Figure 5C-3: Recommended Strategies for Amarillo

Table 5C-6: Summary of Costs for Recommended Strategies for Amarillo

Recommended Strategies	Capital Cost ($M)	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Water Conservation Package[1]	$201.8	$5.25	$5.30	$4.49	$4.54	$5.38	$5.43
Potter/Carson County Well Field – Phase 2	$59.2		$3.19	$3.19	$4.29	$4.29	$2.21
Roberts County Well Field (shared CRMWA II capacity)[2]	$113.1						$11.41
Aquifer Storage and Recovery (ASR)	$11.5		$1.69	$1.69	$0.88	$0.88	$0.88
Direct Potable Reuse	$51.3			$7.91	$7.91	$4.30	$4.30
Total from Strategies	**$436.9**	**$5.25**	**$10.18**	**$12.78**	**$13.08**	**$9.47**	**$18.80**

Alternate Strategy	Capital Cost ($M)	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Roberts County Well Field (independent transmission)	$276.2	$0.0	$0.0	$0.0	$0.0	$0.0	$25.3

[1] Includes the capital and O&M costs associated with conservation programs, AMI, and water audits and leak repair.

[2] Capital and annual costs for the shared pipeline with CRMWA are shown with CRMWA. Amarillo would be responsible for 24% of these costs; however, the details of the cost sharing agreement have not been finalized. Costs presented here include the well field and Amarillo only infrastructure.

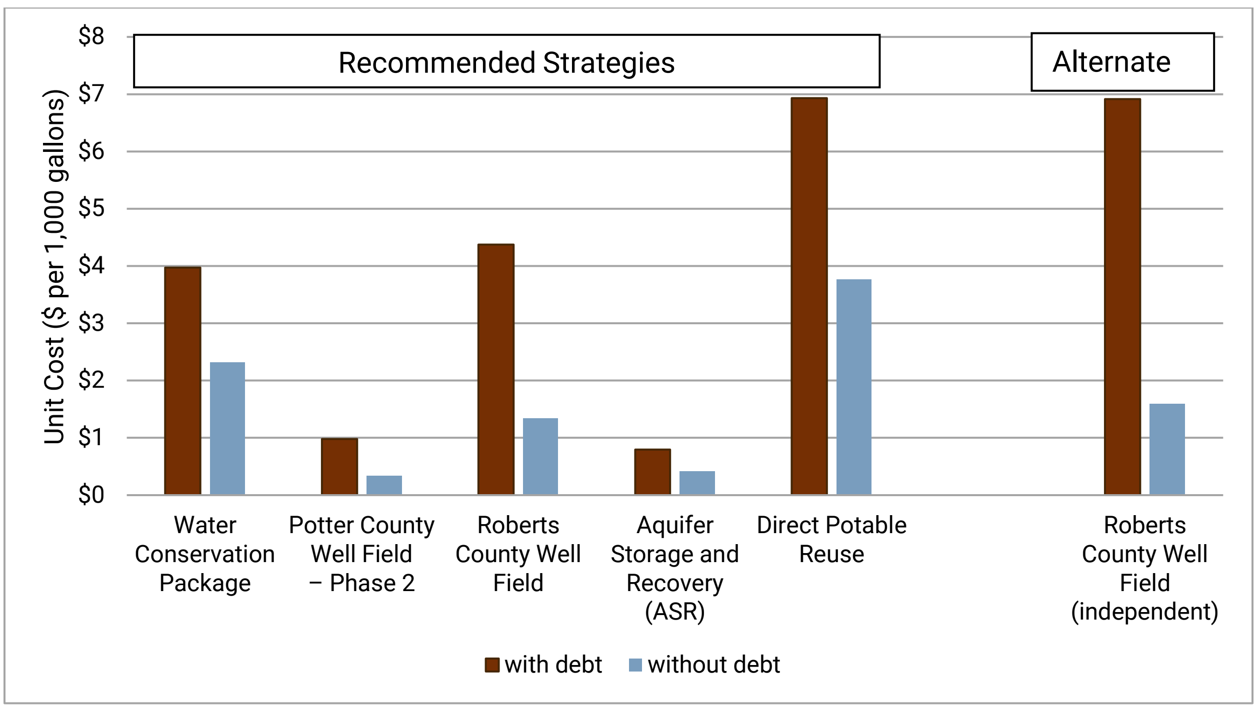


Figure 5C-4: Unit Costs for Amarillo Recommended and Alternate Strategies

5C.3 City of Borger

The City of Borger provides water to customers in Hutchinson County, and Hutchinson and Carson County manufacturing. The city receives water from CRMWA and operates wells in the Ogallala aquifer in Hutchison and Carson County. The city has a complex arrangement of trading water with several industries to most efficiently supply water to its customers. The city also sells treated wastewater to its manufacturing customers. Table 5C-7 lists the projected demands and supplies for the City of Borger and its customers.

Table 5C-7: Summary of Demands, Supplies and Needs for the City of Borger

	Demands (Ac Ft/Yr)					
Customers	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
City of Borger	3,163	3,201	3,182	3,177	3,172	3,172
Hutchinson County Manufacturing	7,342	7,834	7,834	7,834	7,834	7,834
Hutchinson County-Other	16	16	16	16	16	16
Total Demand	**10,521**	**11,051**	**11,032**	**11,027**	**11,022**	**11,022**
	Current Water Supply (Ac Ft/Yr)					
Sources	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Hutchinson Co.	6,499	5,841	5,456	5,149	4,890	4,890
Ogallala - Carson Co.	800	719	672	634	602	602
CRMWA[1]	5,558	5,423	5,220	4,686	4,325	4,318
Reuse[2]	1,100	1,100	1,100	1,100	1,100	1,100
Total Supply	**13,957**	**13,083**	**12,448**	**11,569**	**10,917**	**10,910**
	Surplus or (Need) (Ac Ft/Yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
	3,437	**2,032**	**1,416**	**542**	**(105)**	**(112)**

1 The sources of water from CRMWA are shown on Table 5C-1.

2 Reuse supply is only available to manufacturing users in Hutchinson County.

The recommended strategies include implementing conservation measures and obtaining contractual supplies from CRMWA. Table 5C-8 shows the amount of water supply associated with each of the recommended strategies.

Recommended Strategies

- Implement conservation strategies (See Section 5B.1)
- Obtain contractual supplies from CRMWA (this is evaluated with CRMWA strategies)

After the City of Borger implements conservation and water audits and leak repair and receives its full contracted amount of water from CRMWA, the City can fully meet its projected water demands.

Summary of Recommended Strategies for Borger

The recommended strategies for the City of Borger would provide up to 2,788 acre-feet per year by 2070. The City of Borger continues to add new wells to maintain capacities at their existing well fields. They recently completed an additional well field in Hutchinson County. With the ability to purchase additional water from CRMWA, the City of Borger should be able to fully meet demands once the CRMWA II pipeline from Roberts County well field is completed. The recommended strategies and quantities are shown in Table 5C-8 and on Figure 5C-5. The costs for the strategies are summarized in Table 5C-9.

Table 5C-8: Recommended Strategies for Borger (Ac-Ft/Yr)

	2020	2030	2040	2050	2060	2070
Surplus or (Need)	3,437	2,032	1,416	542	(105)	(112)
Recommended Strategies	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Municipal Conservation	41	43	43	43	43	43
Supplies from CRMWA	0	1,668	1,852	2,382	2,739	2,745
Total from Strategies	**41**	**1,711**	**1,895**	**2,425**	**2,782**	**2,788**

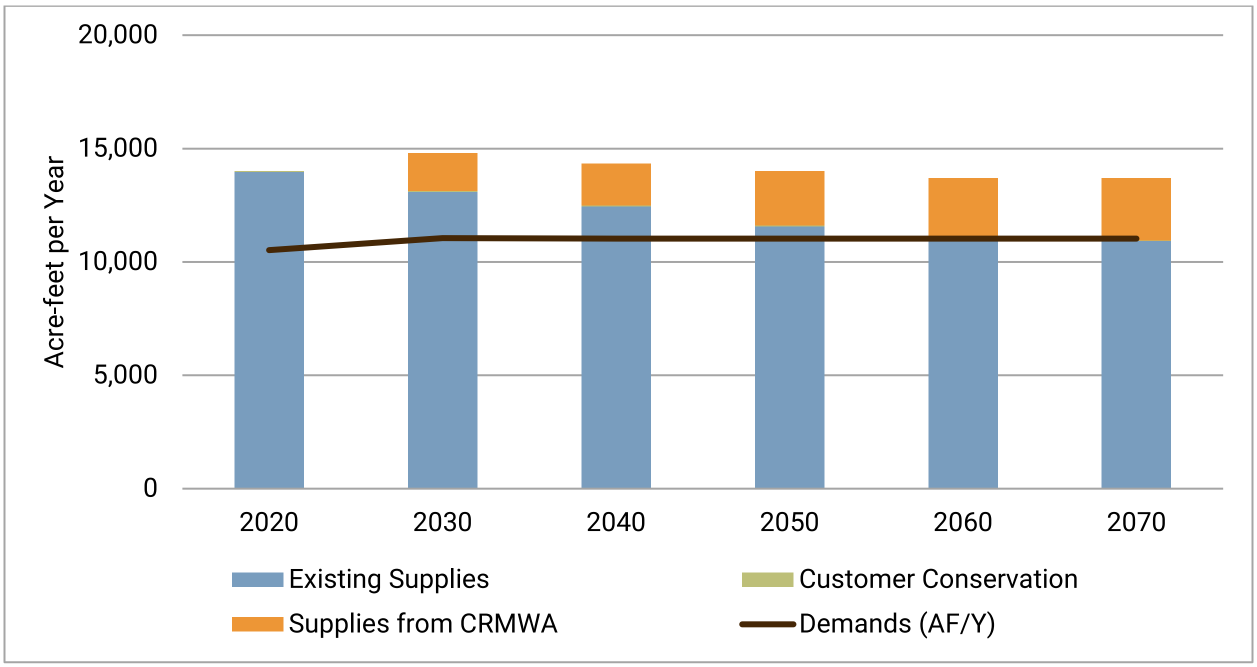


Figure 5C-5: Recommended Strategies for Borger

Table 5C-9: Summary of Costs for Recommended Strategies for Borger[1]

Recommended Strategies	Capital Cost ($ Million)	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Municipal Conservation	-	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02

1. Purchase of additional supplies from CRMWA does not include additional infrastructure and the purchase costs are already negotiated

5C.4 City of Cactus (Cactus Municipal Water System)

The Cactus Municipal Water System provides water to the City of Cactus and municipal and manufacturing customers in Moore County. Cactus MWS currently obtains all of its supplies from the Ogallala aquifer in Moore County. Cactus is also a member of the Palo Duro Water District (formerly Palo Duro River Authority). Table 5C-10 lists the projected demands by customer, current supplies, and projected water needs for Cactus MWS.

Table 5C-10: Summary of Demands, Supplies, and Needs for the Cactus MWS

	Demands (Ac Ft/Yr)					
Customers	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
City of Cactus	985	1,107	1,242	1,382	1,532	1,685
Moore County Manufacturing	3,247	3,370	3,370	3,370	3,370	3,370
Total Demand	**4,232**	**4,477**	**4,612**	**4,752**	**4,902**	**5,055**
	Current Water Supply (Ac Ft/Yr)					
Sources	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Moore County	2,918	2,122	1,572	1,071	769	769
Total Current Supply	**2,918**	**2,122**	**1,572**	**1,071**	**769**	**769**
	Surplus or (Need) (Ac Ft/Yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
	(1,314)	**(2,355)**	**(3,040)**	**(3,681)**	**(4,133)**	**(4,286)**

The recommended strategies for the City of Cactus include water conservation and water audits and leak repair, and the development of new wells in the Ogallala Aquifer in Moore County. At this time Palo Duro Reservoir is considered an alternate strategy.

Recommended Strategies

- Implement conservation strategies (see Section 5B.1)
- Develop new wells in the Ogallala aquifer in Moore County

Alternate Strategies

- Palo Duro Reservoir Transmission System

Develop New Wells in the Ogallala Aquifer in Moore County

This strategy includes developing new groundwater from the Ogallala aquifer in northwest Moore County with ten new wells producing approximately 750 gpm at a depth of 600 feet. The location of the new well field is unknown. For planning purposes, this strategy assumes 1.5 miles of various pipes ranging in size from 10-inch to 16-inch to connect to the existing City of Cactus ground storage tanks located within the City. Due to the large volume of water being delivered, it is anticipated that additional ground storage will be required at the delivery point. An increase in pumping capacity at the existing pump station may be required but that cost has not been included in this strategy.

Time Intended to Complete

Cactus will need to develop approximately 1,500 acre-feet of additional supplies by 2020 increasing to 4,300 by 2070. While the city may choose to implement the strategy in phases, it is included in the Panhandle Water Plan as one phase to be implemented in 2020.

Quantity, Reliability and Cost

The new wells are expected to provide up to 5,000 acre-feet per year. The quantity of water should be sufficient to meet the city's needs. Reliability of Ogallala supply is low to moderate since the aquifer is heavily used and availability depends on other water users. In order to obtain this quantity of water, agricultural producers would need to implement conservation measures. Otherwise there is insufficient quantity of water from this strategy. The total project cost for this strategy (including wells, piping and ground storage tank) is $16.6 million.

Environmental Issues

The environmental impacts from conservation and groundwater development are expected to be low. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of the Ogallala, other users will need to reduce their demands. This strategy may impact other groundwater development strategies in Moore County, as competition for available water supplies increase.

Impact on Agriculture and Natural Resources

The recommended strategies are expected to have moderate impact on the agriculture and other natural resources. This strategy may reduce the irrigated acreage for farming as additional water rights acreage is purchased. This acreage could be used for dry land farming if needed but may require crop changes.

Other Relevant Factors

There are no other identified relevant factors.

Summary of Recommended Strategies for Cactus

Recommended Strategies

The City of Cactus is expected to experience needs in 2020 of 1,500 acre-feet increasing to over 4,300 acre-feet by 2070. The recommended strategies of water conservation and development of a new well field in the Ogallala aquifer will be needed to meet these needs. Conservation is anticipated to provide approximately 50 acre-feet per year and the well field is sized to provide 5,000 acre-feet as shown in Table 5C-11 and Figure 5C-6. The total capital cost for the recommended strategies as shown in Table 5C-12 is $16.6 million. Unit costs are shown on Figure 5C-7.

Alternative Strategy

Cactus is one of the six member cities of the Palo Duro Water District (PDWD). As a member of the PDWD, Cactus may participate in developing a regional transmission system to use water from Palo Duro Reservoir, but the reliability of the water supply and costs make this strategy less desirable. The Palo Duro Reservoir transmission project is an alternative strategy for Cactus. The project would have very little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Cactus is expected to have a capital cost of $122.6 million associated with their portion of the project.

Table 5C-11: Recommended Water Management Strategies for Cactus (Ac-Ft/Yr)

	2020	2030	2040	2050	2060	2070
Surplus or (Need)	**(1,314)**	**(2,355)**	**(3,040)**	**(3,681)**	**(4,133)**	**(4,286)**
Recommended Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Water Conservation	13	15	17	19	21	23
New Well Field - Ogallala Aquifer	5,000	5,000	5,000	5,000	5,000	5,000
Total from Strategies	**5,013**	**5,015**	**5,017**	**5,019**	**5,021**	**5,023**
Alternate Strategy	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Palo Duro Reservoir Transmission System	0	0	1,744	1,744	1,744	1,744

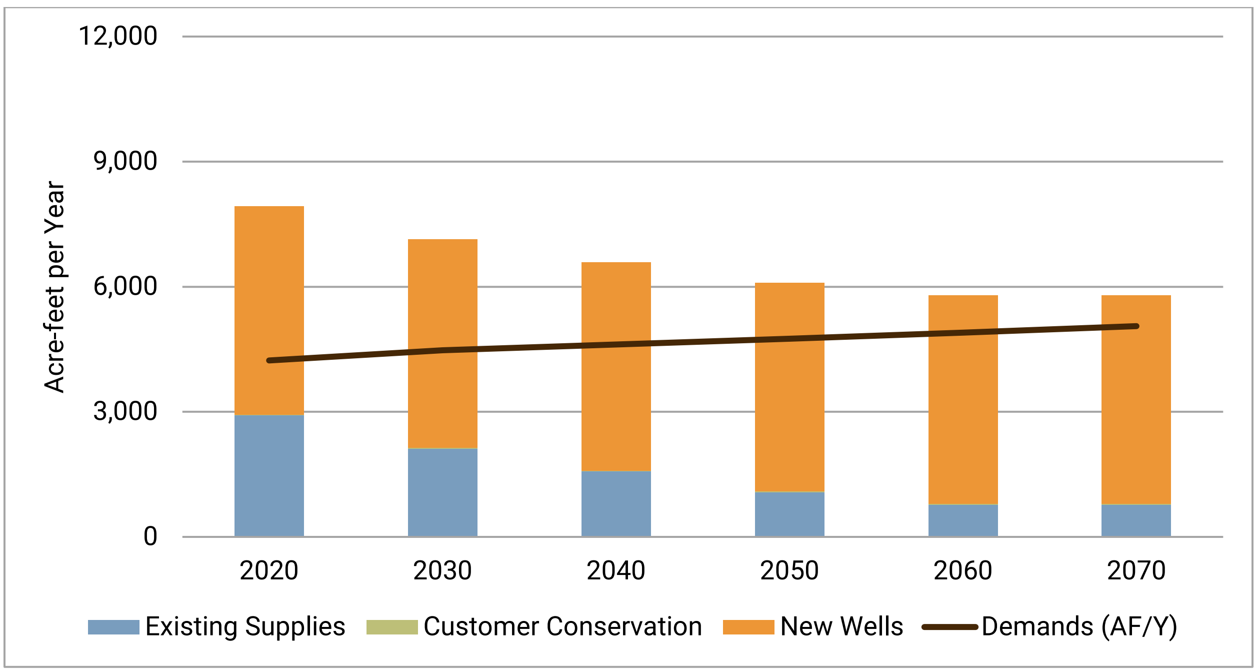


Figure 5C-6: Recommended Strategies for Cactus

Table 5C-12: Summary of Costs for Recommended Strategies for Cactus

Recommended Strategies	Capital Cost ($ Million)	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Water Conservation	-	$0.01	$0.02	$0.02	$0.02	$0.02	$0.02
New Well Field -Ogallala Aquifer	$16.6	$1.81	$1.81	$0.65	$0.65	$0.65	$0.65
Total from Strategies	**$16.6**	**$1.82**	**$1.83**	**$0.67**	**$0.67**	**$0.67**	**$0.67**
Alternate Strategy:							
Palo Duro Reservoir Transmission System	$122.6	-	-	$11.29	$11.29	$2.67	$2.67

Figure 5C-7: Unit Costs for Cactus Recommended and Alternate Strategies

5C.5 Greenbelt Municipal and Industrial Water Authority

Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA) owns and operates Greenbelt Reservoir on the Salt Fork of the Red River. The MIWA also recently developed local groundwater supplies from the Ogallala aquifer. The Greenbelt MIWA is located in Donley County and provides water to local municipalities through an extensive delivery system, including a 121-mile aqueduct. There are five member cities, including Clarendon, Hedley, and Childress in the PWPA and Quanah and Crowell in the Region B planning area. The Red River Authority is a non-voting member of the Greenbelt MIWA.

Greenbelt MIWA's primary water source is Greenbelt Reservoir. The estimated reliable supply from the reservoir is about 3,112 acre-feet per year in 2020 and declining to 2,256 acre-feet per year over the planning period. Groundwater supplies are estimated 1,900 acre-feet per year and are expected to decline to about half of this amount by 2070. Current projected demands on the MIWA are shown in Table 5C-13 and are not expected to exceed 3,900 acre-feet per year over the planning period. Considering both the reservoir supplies and local groundwater supplies, Greenbelt MIWA is not expected to have water needs until 2060.

Table 5C-13: Summary of Demands, Supplies and Needs for the Greenbelt MIWA

Customers	Demands (Ac Ft/Yr)					
	2020	2030	2040	2050	2060	2070
PWPA						
City of Childress	1,624	1,657	1,685	1,722	1,767	1,814
City of Clarendon	371	362	354	350	349	349
City of Hedley	56	56	56	56	56	56
City of Memphis	37	37	37	37	37	37
Red River Authority - Childress County	232	236	239	245	252	258
Red River Authority - Collingsworth County	16	16	16	16	16	16
Red River Authority - Donley County	30	30	30	30	30	30
Red River Authority - Hall County	100	100	100	100	100	100
Region B						
City of Chillicothe	40	40	40	40	40	40
City of Crowell	138	133	131	131	131	130
City of Quanah	396	391	387	394	397	400
Hardeman County Manufacturing	190	190	190	190	190	190
Red River Authority - Foard County	262	262	262	262	262	262
Red River Authority - Hardeman County	140	140	140	140	140	140
Total Demand	**3,631**	**3,649**	**3,666**	**3,712**	**3,766**	**3,821**

Sources	Current Water Supply (Ac Ft/Yr)					
	2020	2030	2040	2050	2060	2070
Ogallala - Donley County	1,900	1,615	1,373	1,167	992	843
Greenbelt Reservoir	3,112	2,941	2,770	2,599	2,428	2,256
Total Current Water Supply	**5,012**	**4,556**	**4,143**	**3,766**	**3,420**	**3,099**
	Surplus or (Need) (Ac Ft/Yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
	1,380	**907**	**477**	**54**	**(346)**	**(723)**

While the projections indicate Greenbelt MIWA can meet its projected demands until the 2060s, there are concerns regarding the reliability of the surface water supplies and the long-term reliability of the local groundwater. Greenbelt Reservoir is in current drought of record conditions. As the drought continues, the reliable supply may decrease. The on-going drought also increases the competition for local groundwater from nearby irrigators. With these uncertainties, Greenbelt is pursuing additional groundwater in northern Donley County. This additional supply will provide additional reliability to the Greenbelt MIWA's system. The recommended strategies for Greenbelt MIWA are shown below. Conservation measures and associated savings for the wholesale customers of the MIWA are discussed in Chapter 5B.

Recommended Strategies

- Conservation of wholesale customers
- Develop additional supplies from the Ogallala Aquifer in Donley County

Develop Additional Supplies from the Ogallala Aquifer in Donley County

In 2013, a feasibility study was developed for the Greenbelt MIWA. The recommended strategy included developing groundwater in North Donley County, transporting the water by a 16-inch pipeline approximately 16 miles to the Greenbelt Water Treatment Plant site. The strategy would include three 1000 gpm wells, a pump station and ground storage tank and associated electrical and instrumentation. The Greenbelt MIWA has purchased the groundwater rights necessary to provide 2,000 acre-feet annually. Greenbelt MIWA needs begin in 2060 and increase to 723 acre-feet per year in 2070.

Time Intended to Complete

The project is intended to be online by 2030. This project will supplement existing supplies for Greenbelt MIWA.

Quantity, Reliability and Cost

The quantity of water should be sufficient. Reliability of groundwater supply is moderate since there is competition for water from the Ogallala in Donley County. The capital cost is $17.9 million.

Environmental Issues

The environmental impacts from groundwater development are expected to be low. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The proposed wells are located north of Greenbelt Reservoir in an area with some competition for groundwater for irrigation.

The strategy should not significantly impact other water resources or management strategies.

Impact on Agriculture and Natural Resources

The recommended strategy is expected to have low impact on the agriculture and other natural resources.

Other Relevant Factors

Greenbelt MIWA will need to seek a groundwater permit from the Panhandle GCD.

Summary of Recommended Strategies for Greenbelt MIWA

Water conservation and water audits and leak repair by Greenbelt MIWA customers will provide approximately 40 acre-feet per year in 2020 increasing to approximately 90 acre-feet per year by 2070. New wells in the Ogallala aquifer can provide an additional 2,000 acre-feet per year and could be completed by 2030. Table 5C-14 shows the amount of supply from the recommended strategies. The total capital costs for the recommended strategies is $17.9 million as shown in Table 5C-15.

Table 5C-14: Recommended Water Management Strategies for Greenbelt MIWA (Ac-Ft/Yr)

	2020	2030	2040	2050	2060	2070
Surplus or (Need)	**1,380**	**907**	**477**	**54**	**(346)**	**(723)**
Recommended Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
PWPA Customer Conservation	34	36	37	38	39	41
Region B Customer Conservation	9	36	45	46	49	50
Donley County Groundwater	0	2,000	2,000	2,000	2,000	2,000
Total from Strategies	**43**	**2,072**	**2,082**	**2,084**	**2,088**	**2,091**

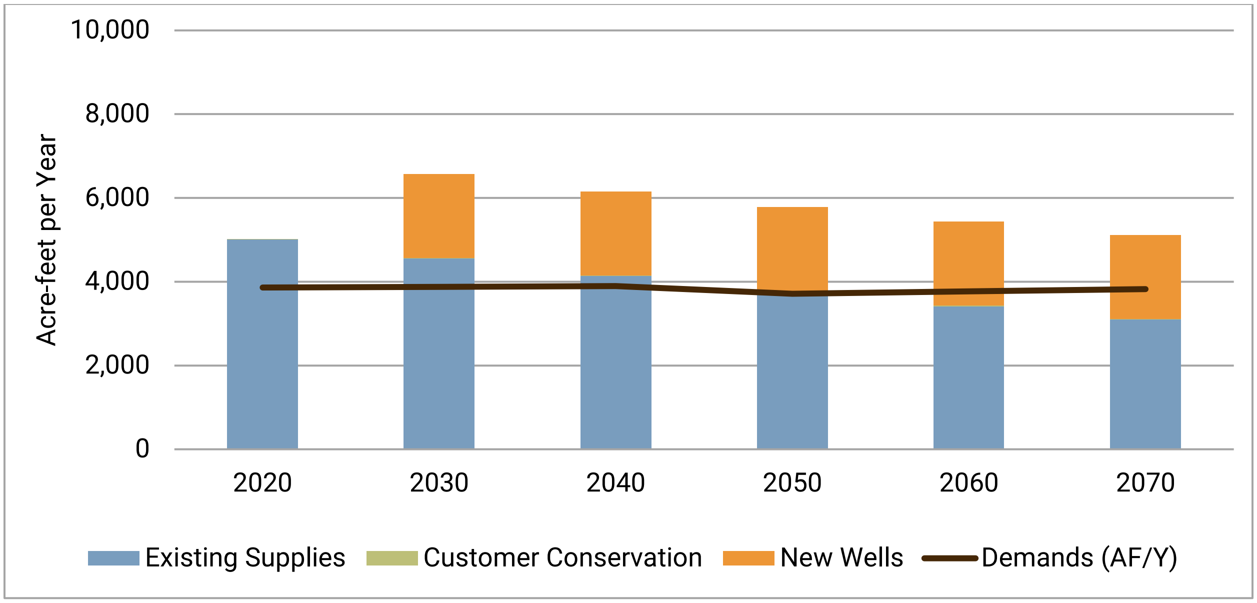
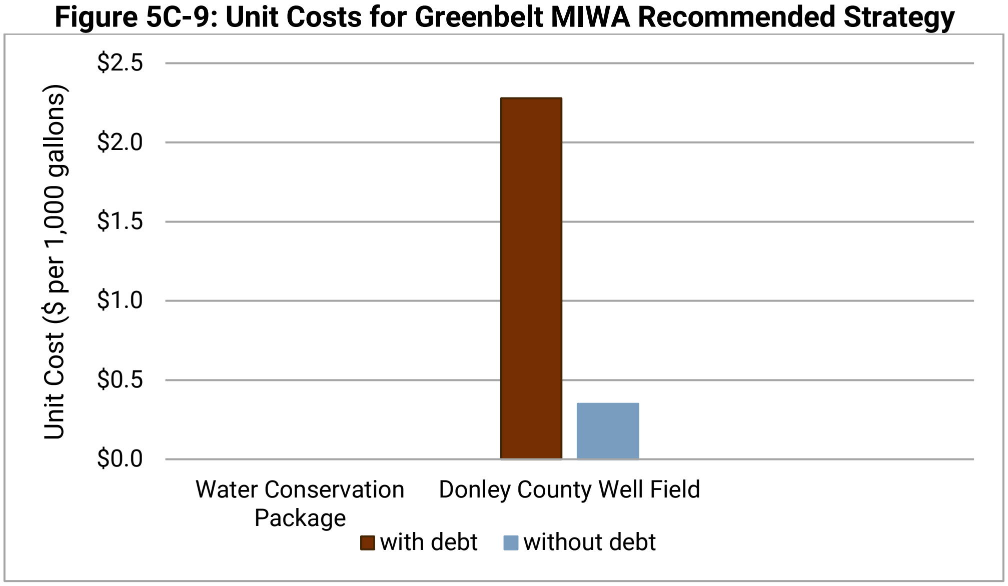


Figure 5C-8: Recommended Strategies for Greenbelt MIWA

Table 5C-15: Summary of Costs for Recommended Strategies for Greenbelt MIWA

Recommended Strategies	Capital Cost ($ million)	Annual Costs ($million)					
		2020	2030	2040	2050	2060	2070
Donley County Groundwater	$17.9	$0.00	$1.49	$1.49	$0.20	$0.20	$0.20
Total from Strategies	**$17.9**	**$0.00**	**$1.49**	**$1.49**	**$0.20**	**$0.20**	**$0.20**

Figure 5C-9: Unit Costs for Greenbelt MIWA Recommended Strategy



5C.6 Management Supply Factor

Based on TWDB regional planning guidance, a Management Supply Factor is to be provided for each major water provider. This management supply factor, commonly referred to as a safety factor, represents the margin of safety should supplies decrease or demands increase.

Management Supply Factor =

$$\frac{\text{Current Supplies + Strategies}}{\text{Total Demands}}$$

There are several factors that could affect the ability of a water provider to provide for projected needs, including:

- Climate change reduces the supply available from existing sources.
- The region experiences a drought more severe than the previous drought of record, which would reduce the supply available.
- One or more proposed management strategies cannot be developed or are developed more slowly than anticipated.
- Existing supplies become unusable due to invasive species, contamination or other factors.

The Management Supply Factors for the major water providers in the PWPA are shown on Table 5C-16.

Table 5C-16: Management Supply Factors for Major Water Providers

Major Provider		2020	2030	2040	2050	2060	2070
Amarillo	Potable	1.12	1.31	1.25	1.28	1.19	1.24
	Non-Potable	1.09	1.19	1.11	1.21	1.33	1.46
Borger	Both	1.33	1.34	1.30	1.27	1.24	1.24
Cactus	Potable	1.87	1.59	1.43	1.28	1.18	1.15
CRMWA	Potable	0.94	1.46	1.38	1.33	1.32	1.32
Greenbelt MIWA	Potable	1.39	1.82	1.70	1.58	1.46	1.36

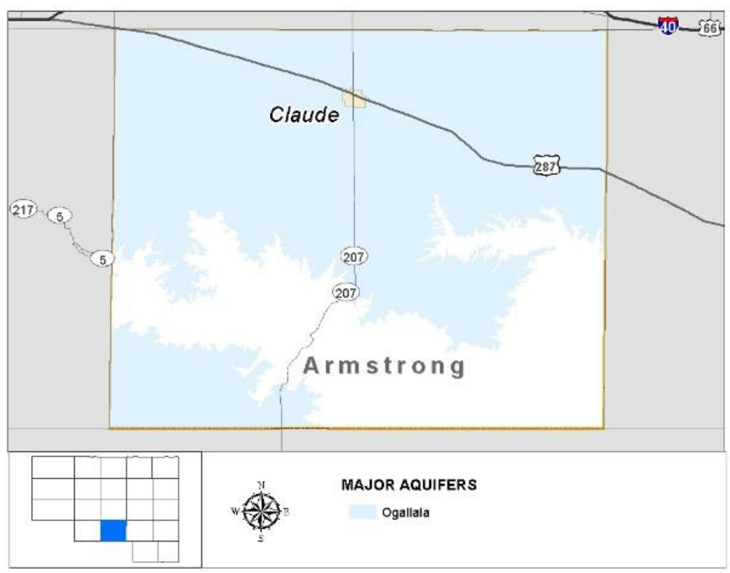
5D WATER MANAGEMENT STRATEGIES FOR WATER USERS BY COUNTY

There are twenty-one counties in the PWPA, of which six show no needs after Municipal Conservation and Irrigation Conservation water management strategies. Water conservation is recommended for all municipal water users (except County-Other users without a need) and irrigation water users, whether the user has a defined need or not, and it is encouraged for all other users. The description and evaluation of these strategies are in Chapter 5B. They are not discussed in detail in this subchapter but are included in the county summary sections.

This subchapter discusses the water issues of each county and outlines the proposed water management strategies to meet the identified needs. For some counties, there are projected needs that cannot be met through an economically viable project. These “unmet needs” are also identified, if present, by county. Descriptions of water management strategies that are developed by a Major Water Provider are discussed in Chapter 5C and included in the county summary tables for completeness, as appropriate. The detailed costs are presented in Appendix D and a summary evaluation matrix is included as Attachment 5-2.

5D.1 Armstrong County

Armstrong County is located along the southern edge of the Northern Ogallala aquifer. The City of Claude, with a 2017 population of 1,187, is the largest city in the county, and has a projected total demand of 360 acre-feet per year in 2020 and 347 acre-feet per year in 2070.



Water users in Armstrong County obtain their current water supplies from the Ogallala aquifer, with a small amount coming from the Dockum aquifer and local surface water supply for livestock.

There are no users in Armstrong County with a need.

5D.1.1 Armstrong County Summary

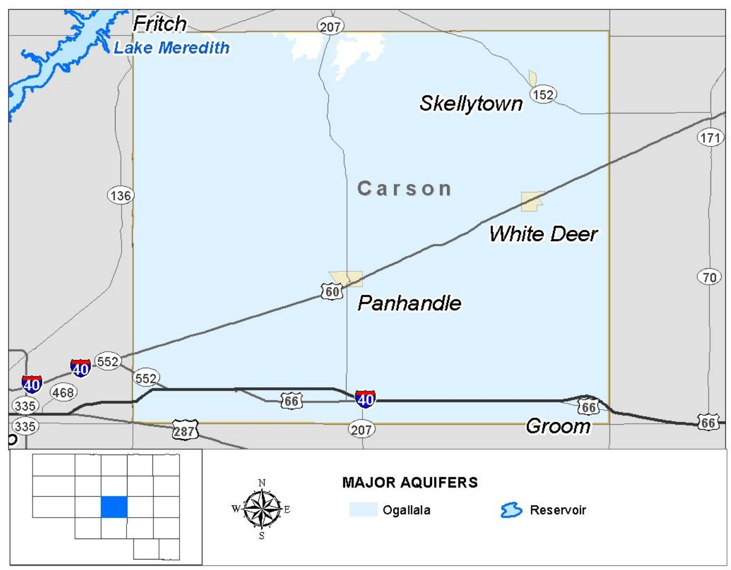
The primary source of water for Armstrong County is groundwater. These supplies have limited recharge and are generally finite in nature. To preserve these sources for future use, it is recommended that the City of Claude and local irrigators implement water conservation measures. A summary of the recommended water management plan for Armstrong County is shown in Table 5D-1.

Table 5D-1: Armstrong County Water Management Plan

Water User Group	Current Supplies	Need	Recommended Water Management Strategies
Claude	Ogallala aquifer	No	Municipal conservation
County-Other	Ogallala and Dockum aquifers	No	None
Irrigation	Ogallala and Dockum aquifers	No	Irrigation conservation
Livestock	Ogallala and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Steam Electric	None	-	-

5D.2 Carson County

Carson County is in the center of the PWPA. The City of Panhandle, with a 2017 population of nearly 2,500, is the largest city in the county, and has a projected total demand of approximately 600 acre-feet per year in 2020 and in 2070.



Most of the water supplies for Carson County is obtained from the Northern Ogallala aquifer. Small amounts of surface water and reuse supplies are used for irrigation and livestock. The City of Amarillo also operates a large well field in western Carson County and has plans for expansion.

Panhandle is the only entity shown to have a need over the planning period.

5D.2.1 Panhandle

The City of Panhandle is projected to have a water need beginning in 2030 and reaching a peak need of approximately 600 acre-feet per year by 2040. This need is due to declining water levels in the City’s current well field. The City of Panhandle is evaluating a groundwater source in the Ogallala aquifer to back up its current supplies.

The potential strategies for Panhandle are:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

City of Panhandle is to develop additional groundwater from the Ogallala aquifer with new wells and associated transmission. For planning purposes, it is assumed that that two new wells and associated well field piping will be necessary to meet the City's water needs. These two new wells will provide approximately 600 acre-feet per year and will produce water approximately 680 feet below the surface. Minimal treatment such as chlorine disinfection will be required.

Time Intended to Complete

This strategy would be completed by 2030. The City may elect to drill the wells in phases if needed, but the strategy costs and supplies are developed for one phase.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 475 gpm per well and provide up to 600 acre-feet per year. Reliability of Ogallala supplies is high to moderate. There is plenty of supply in Carson County, but there may be potential competing demands. The capital cost for the additional groundwater wells and collection piping is $1.8 million.

Environmental Issues

Long-term water quality of the Ogallala aquifer is unknown. Groundwater development from this source is expected to cause minimal environmental impacts.

Impact on Water Resources and Other Management Strategies

The quantity of water from this strategy is assumed to have a minimal impact on the Ogallala aquifer and other surrounding water resources.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategy.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-2: Recommended Water Strategies for Panhandle (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	461	586	581	580	580
Recommended Strategies							
Municipal Conservation	N/A	8	8	8	8	8	8
Drill Additional Groundwater Well(s)	$1.8	0	600	600	600	600	600
Total	**$1.8**	**8**	**608**	**608**	**608**	**608**	**608**

5D.2.2 Carson County Summary

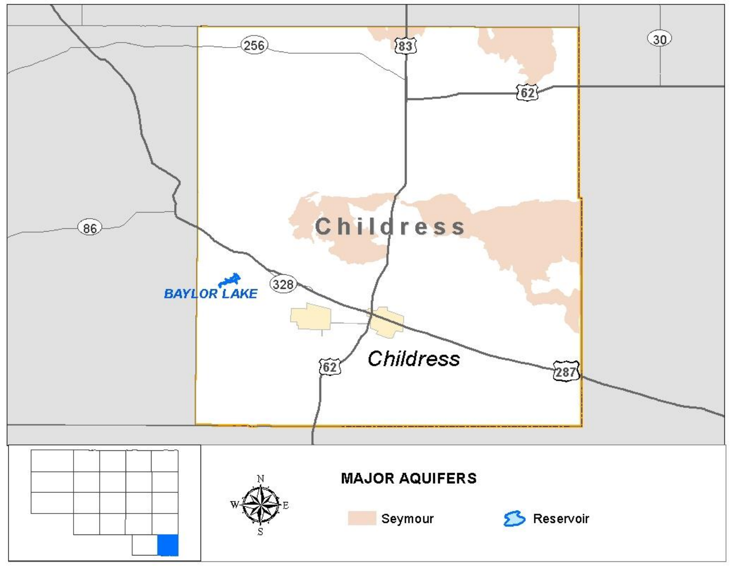
Carson County has a projected water need of 461 acre-feet per year in 2030 increasing to 580 acre-feet per year in 2070, all of which is associated with the City of Panhandle. The county's primary source of water, Ogallala aquifer has around 38,000 acre-feet per year of water that is not currently developed and could be used to meet water needs. Some of this water will be developed by Amarillo, but there are available supplies for Carson County. With development of additional Ogallala supplies, there are no needs.

Table 5D-3: Carson County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Groom	Ogallala aquifer	No	Municipal conservation
Irrigation	Ogallala aquifer, reuse and surface water	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None
Panhandle	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Steam Electric	None	-	-
White Deer	Ogallala aquifer	No	Municipal conservation

5D.3 Childress County

Childress County is in the far southeastern part of the PWPA. The City of Childress is the largest city in the county with a 2017 population of 6,076 and has a projected total demand of 1,624 acre-feet per year in 2020 growing to 1,814 acre-feet per year in 2070.



Groundwater sources in Childress County are limited. Municipal supplies are provided by the Greenbelt MIWA and small quantities of local groundwater. The Seymour and Blaine aquifers are the primary sources for agricultural use, along with small quantities from local surface water and reuse.

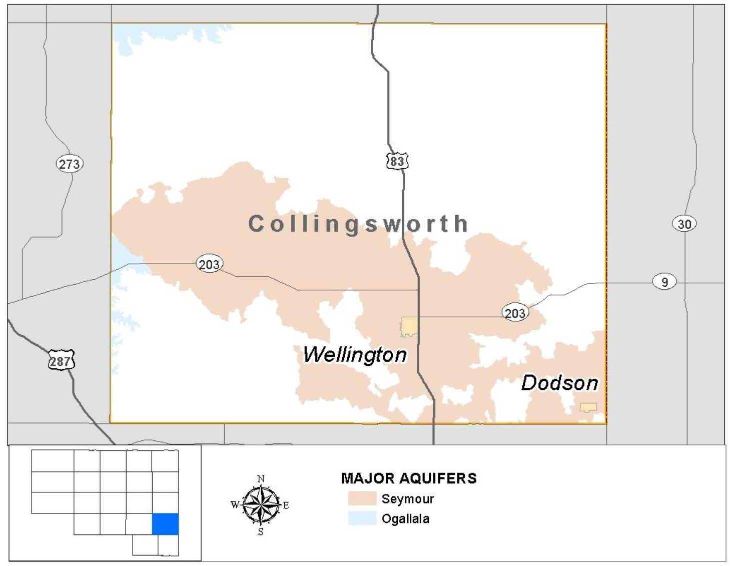
Childress County has two WUGs with needs during the planning horizon: City of Childress and Red River Authority of Texas. These needs will be met through strategies developed by Greenbelt MIWA and conservation.

A summary of the water plan for Childress County is shown in Table 5D-4.

Table 5D-4: Childress County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Childress	Greenbelt Reservoir and Ogallala aquifer	Yes	Municipal conservation
County-Other	Seymour and Other aquifer	No	None
Irrigation	Blaine, Seymour and Other aquifers, surface water, and reuse	No	Irrigation conservation
Livestock	Blaine and Seymour aquifers, and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Red River Authority of Texas	Greenbelt Reservoir and Ogallala aquifer	Yes	Municipal conservation
Steam Electric	None	-	-

5D.4 Collingsworth County



Collingsworth County is located on the southeastern border of the PWPA. The City of Wellington is the largest city in the county with a 2017 population of 2,129 and has a projected total demand of 524 acre-feet per year in 2020 growing to 595 acre-feet per year in 2070.

The primary source of water is groundwater from the Seymour and Blaine aquifers. Due to the poor water quality of the Blaine aquifer, most of the municipal supplies are obtained from the Seymour aquifer. Small amounts of groundwater are also obtained from undefined aquifers, known as Other Aquifer. Small quantities of surface water also are used in Collingsworth County for irrigation and livestock use.

Wellington has a projected need of approximately 500 to 600 acre-feet per year during the planning horizon due to impaired water quality. The City of Wellington is planning to construct a nitrate removal system and develop additional groundwater supplies to improve the reliability of its current sources. Collingsworth County has a projected irrigation need of approximately 7,000 acre-feet per year in 2020, increasing to approximately 9,000 acre-feet per year in 2070.

5D.4.1 Wellington

The City of Wellington currently obtains its water supply from the Seymour aquifer in Collingsworth County. Due to the elevated nitrates in the City's existing supplies, this supply is considered unavailable to Wellington for planning purposes. The City also has concerns from dropping water levels. The City is presently evaluating the Seymour aquifer for additional groundwater to back up its existing supply. Alternatively, the city would be receptive to receiving water from outside of the county if the opportunity arises.

For this plan, the potentially feasible water management strategies for Wellington are:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Nitrate Treatment of Seymour Aquifer Supplies

Drill Additional Groundwater Well(s)

This strategy includes 2 new wells and 1 mile of 6-inch diameter well field piping. In addition, 3 miles of 8-inch diameter will be constructed to transport the water to existing infrastructure. The 2 new wells would be drilled to provide approximately 100 acre-feet per year and is assumed to produce water approximately 160 feet below the surface. Due to the Seymour having high levels of nitrate and chloride throughout its extent, advanced treatment for municipal use may be required. Treatment for nitrates is evaluated as a separate strategy

Time Intended to Complete

The city is considering expanding its well field in the near future. For purposes of this plan, the strategy will be completed by 2020.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 100 gpm, which can produce an average annual amount of 100 acre-feet per year. Reliability of the supply is considered to be moderate to low due to water quality and competing demand. The capital cost for the additional groundwater wells, associated well field piping, and transmission pipeline is $1.5 million.

Environmental Issues

No significant environmental impact is expected for the recommended strategy. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

Increased demands on the Seymour aquifer will continue to deplete the storage. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

The recommended strategy is expected to have low impact on agriculture and other natural resources. This strategy may reduce the irrigated acreage for farming as additional water rights acreage is purchased. It is assumed that any purchase of water rights is on a willing buyer – willing seller basis.

Other Relevant Factors

There are no other identified relevant factors.

Nitrate Treatment

This strategy assumes the development of advanced treatment facilities to treat the City of Wellington's current and future groundwater from the Seymour aquifer. Currently, the city is experiencing elevated nitrate levels in its water source. This strategy assumes that half of the City's groundwater would be treated by reverse osmosis or other method and then blended with the remaining supplies to reduce nitrate concentrations. This strategy assumes that a 0.5 MGD treatment facility would be constructed and the waste stream from the facility could be discharged to a local tributary of the Salt Fork of the Red River.

Time Intended to Complete

The City is experiencing water quality issues now. To address these issues, the strategy will be completed by 2020.

Quantity, Reliability, and Cost

This strategy will provide 560 acre-feet per year of treated water that meets current drinking water standards. The capital cost is estimated at $8.3 million.

Environmental Issues

There may be environmental impacts with the discharge of the waste stream. This would need to be permitted by the State. At that time, environmental impacts would be assessed.

Impact on Water Resources and Other Management Strategies

There are no impacts on water resources or other management strategies.

Impact on Agriculture and Natural Resources

The strategy is expected to have no impact on agriculture and possible low impact to the receiving stream from the waste discharge. Any potential impacts of the waste discharge would be considered and mitigated during permitting.

Other Relevant Factors

There are no other identified relevant factors.

The recommended strategies for the City of Wellington are shown in Table 5D-5.

Table 5D-5: Recommended Strategies for Wellington (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		524	540	548	566	581	595
Recommended Strategies							
Municipal Conservation	N/A	7	7	8	8	8	8
Drill Additional Groundwater Well(s)	$1.5	0	100	100	100	100	100
Nitrate Treatment	$8.3	560	560	560	560	560	560
Total	**$9.8**	**567**	**667**	**668**	**668**	**668**	**668**

5D.4.2 Collingsworth County Irrigation

The irrigation needs in Collingsworth County peak at over 10,000 acre-feet per year over the planning period. A summary of the projected water needs and strategies for Collingsworth County Irrigation is shown in Table 5D-6. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-6: Recommended Water Strategies for Collingsworth County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		6,867	10,133	9,283	9,595	9,741	9,069
Recommended Strategies							
Irrigation Conservation	$1.3	2,610	3,966	7,955	9,658	9,419	9,757
Total	**$1.3**	**2,610**	**3,966**	**7,955**	**9,658**	**9,419**	**9,757**

5D.4.3 Collingsworth County Summary

Collingsworth County has projected needs associated with water quality impairments. Water users in the county are also experiencing water quantity issues during drought. To address these issues, additional groundwater development, advanced treatment and conservation are recommended for the City of Wellington. Conservation is also recommended for Red River Authority of Texas and Collingsworth County Irrigation. A summary of the water plan for Collingsworth County is shown in Table 5D-7.

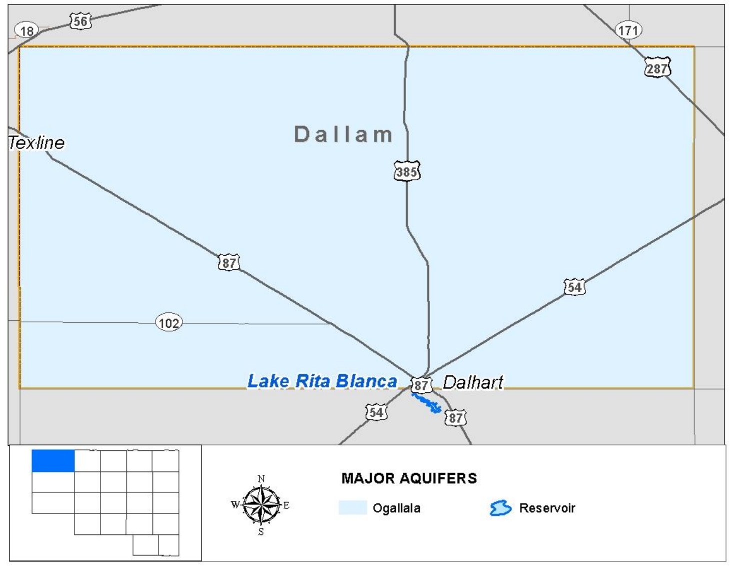
Table 5D-7: Collingsworth County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Blaine, Seymour and Other aquifers	No	None
Irrigation	Blaine, Seymour and Other aquifers, reuse and Red River water rights	Yes	Irrigation conservation
Livestock	Blaine, Seymour and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Red River Authority of Texas	Ogallala and Seymour aquifers, Greenbelt Reservoir	No	None
Steam Electric	None	-	-
Wellington	Seymour aquifer	Yes	Additional Seymour Aquifer, Nitrate Treatment, Municipal conservation

Table 5D-8: Unmet Water Needs in Collingsworth County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(4,817)	(6,727)	(1,888)	(497)	(882)	0

5D.5 Dallam County



Dallam County is in the far northwestern part of the PWPA. Dalhart is the largest city in Dallam County with a 2017 population of approximately 8,400, of which about two-thirds are located in Dallam County. The remaining population is in Hartley County. Dalhart's projected total demand is 2,667 acre-feet per year in 2020 (1,814 of which is based out of Dallam County) growing to 3,784 acre-feet per year in 2070 (2,877 of which is based out of Dallam County).

Dallam County is one of the larger irrigation water users in the region. The primary source of water in the county is the Ogallala aquifer. Smaller quantities of groundwater from the Dockum aquifer and local livestock supply are also used in the county.

There is plenty of water available from the Ogallala aquifer in Dallam County, but the use is concentrated in the heavily irrigated areas, which results in large water declines over time. Due to the geographic constraints imposed by the water supply allocation process, there are projected needs for the cities of Dalhart and Texline, and Dallam County Irrigation. The recommended strategies to meet the needs for Dallam County Irrigation is conservation, which is discussed in Chapter 5B. The potential strategies for Texline and Dalhart are discussed below.

5D.5.1 Dalhart

The City of Dalhart falls into two counties, Dallam and Hartley. Its current supplies are obtained from an existing well field in Dallam County. There is considerable competition for water from surrounding agricultural lands. As a result, the City of Dallam is expected to have a need beginning in 2020 and reaching 3,137 acre-feet per year by 2070. To meet this need, the strategies considered include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

The City of Dalhart is considering re-developing an existing well field in Hartley County that is located south-southwest of the city. The city plans on rehabilitating three existing wells and drilling two additional wells to develop the needed supply from the Ogallala aquifer. A new pump station and ground storage would be needed at the well field, along with a 2-mile pipeline from the pump station to the city's existing water line.

Time Intended to Complete

This strategy would be implemented by 2020. This strategy could be implemented in phases, but for planning purposes, the full strategy amount is shown.

Quantity, Reliability, and Cost

Assuming a similar well production as Dalhart's existing wells, this strategy could provide an average annual supply of 3,140 acre-feet per year. The reliability would be moderate due to the competition from other water users. The capital costs are estimated at $7.3 million.

Environmental Impacts

No significant environmental impact is expected for this strategy. The well field is already in place and the new infrastructure would be located within existing groundwater rights area.

Impact on Water Resources and Other Management Strategies

Increased demands on the Ogallala aquifer will continue to deplete the storage. There are no impacts to other water management strategies.

Impact on Agriculture and Natural Resources

This strategy is expected to have low to moderate impact on agriculture and other natural resources due to competition for water. This strategy would not impact any existing agricultural water rights since the water rights are already owned by Dalhart.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-9: Recommended Water Strategies for Dalhart (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		557	1,261	1,814	2,374	2,917	3,137
Recommended Strategies							
Municipal Conservation	N/A	27	30	32	35	37	40
Drill Additional Groundwater Well(s)	$7.3	3,140	3,140	3,140	3,140	3,140	3,140
Total	**$7.3**	**3,167**	**3,170**	**3,172**	**3,175**	**3,177**	**3,180**

5D.5.2 Texline

The City of Texline currently obtains its water supply from the Ogallala-Rita Blanca aquifer. The Rita Blanca aquifer underlies the Ogallala aquifer in the northwest corner of Dallam County and is hydraulically connected. The City is shown to have a small need beginning in 2060. The potential strategies to meet this need include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that one new well will be drilled near the City's existing wells. Well field piping will be installed to connect to the current collection system. The new well would be drilled to provide approximately 100 acre-feet per year and is assumed to produce water from approximately 350 feet below the surface. Minimal treatment such as chlorine disinfection will be required for municipal use. There is no transmission system associated with this strategy. It is assumed that the existing transmission system is sufficient.

Time Intended to Complete

This strategy would be implemented by 2050.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 200 gpm, which can provide an average annual supply of 100 acre-feet per year. Reliability of the supply is considered to be high due to large volumes of available water. In places where the Ogallala and Rita Blanca are hydraulically connected, the total thickness of water yielding formation is much greater. The capital cost for the additional groundwater well and well field piping is $0.5 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

This strategy is assumed to have a minimal impact on the Ogallala-Rita Blanca aquifer and other surrounding water resources. There are no impacts to other management strategies.

Impact on Agriculture and Natural Resources

It is uncertain whether Texline already holds sufficient groundwater rights or whether additional rights would need to be obtained. It is assumed if water rights are purchased from agricultural or rural water users, it would be on a willing buyer-willing seller basis. No significant impact on agricultural and natural resources is expected for this strategy.

Other Relevant Factors

There are no other relevant factors.

Table 5D-10: Recommended Water Strategies for Texline (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	0	12	28
Recommended Strategies							
Municipal Conservation	N/A	2	2	2	2	2	2
Drill Additional Groundwater Well(s)	$0.5	0	0	0	100	100	100
Total	**$0.5**	**2**	**2**	**2**	**102**	**102**	**102**

5D.5.3 Dallam County Irrigation

The irrigation needs in Dallam County peak at over 116,000 acre-feet per year over the planning period. These needs cannot be fully met through conservation in the early decades. A summary of the projected water needs and strategies for Dallam County Irrigation is shown in Table 5D-11. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-11: Recommended Water Strategies for Dallam County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		29,586	116,358	107,956	91,644	74,251	74,251
Recommended Strategies							
Irrigation Conservation	$8.1	24,329	43,270	80,019	87,678	80,502	83,654
Total	**$8.1**	**24,329**	**43,270**	**80,019**	**87,678**	**80,502**	**83,654**

5D.5.4 Dallam County Summary

Dallam County has a total projected water need of approximately 117,000 acre-feet per year in 2030 reducing to approximately 77,000 acre-feet per year in 2070. Much of this need is associated with irrigation, which can be partially met through conservation. The municipal needs are planned to be met through conservation and additional groundwater from the Ogallala aquifer. There is a projected unmet water need for Dallam County Irrigation of approximately 5,000 acre-feet per year in 2020, increasing to 73,000 acre-feet per year in 2030, and decreasing to zero by 2060. After 2060, there is potential water savings above the projected needs. This indicates potential aquifer storage depletions early in the planning period could be offset by water savings in later decades. The recommended water plan for Dallam County is shown in Table 5D-12. The unmet needs are shown in Table 5D-13.

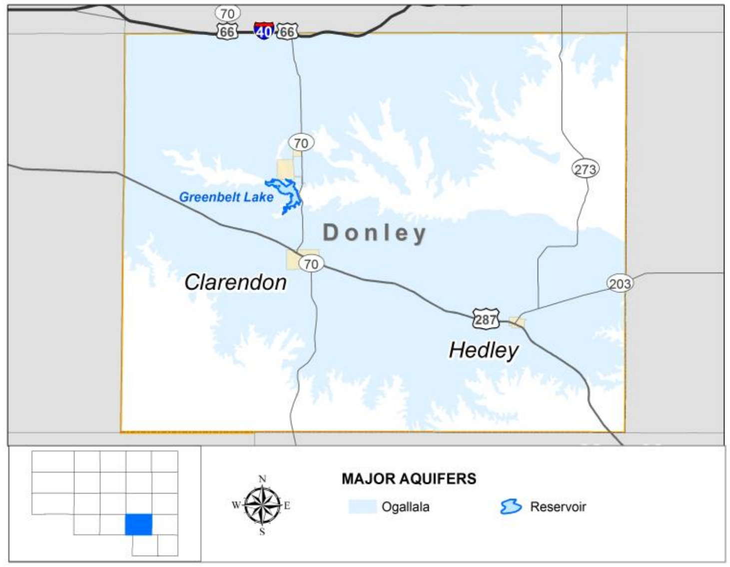
Table 5D-12: Dallam County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Dalhart	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Irrigation	Ogallala/Rita Blanca and Dockum aquifers	Yes	Irrigation conservation
Livestock	Ogallala/ Rita Blanca aquifer and local supply	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	None	-	-
Steam Electric	None	-	-
Texline	Ogallala aquifer	Yes	Drill additional groundwater well(s), Municipal conservation

Table 5D-13: Unmet Water Needs in Dallam County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(5,257)	(73,088)	(27,937)	(3,966)	0	0

5D.6 Donley County



Donley County lies on the southwestern edge of the Ogallala aquifer. It is also home to the Greenbelt Reservoir. The largest city in Donley County is Clarendon, which has a 2017 population of about 2,000 and has a projected total demand of 371 acre-feet per year in 2020 and 349 acre-feet per year in 2070.

The majority of the water supply for Donley County is obtained from the Ogallala aquifer, with some surface water being used for municipal and agricultural purposes.

Donley County has one WUG with needs during the planning horizon: City of Clarendon. Clarendon is a member city of Greenbelt MIWA. Water needs for Clarendon will be met through strategies developed by Greenbelt MIWA and municipal conservation. Conservation is also recommended for Donley County Irrigation, which is discussed in Section 5B.

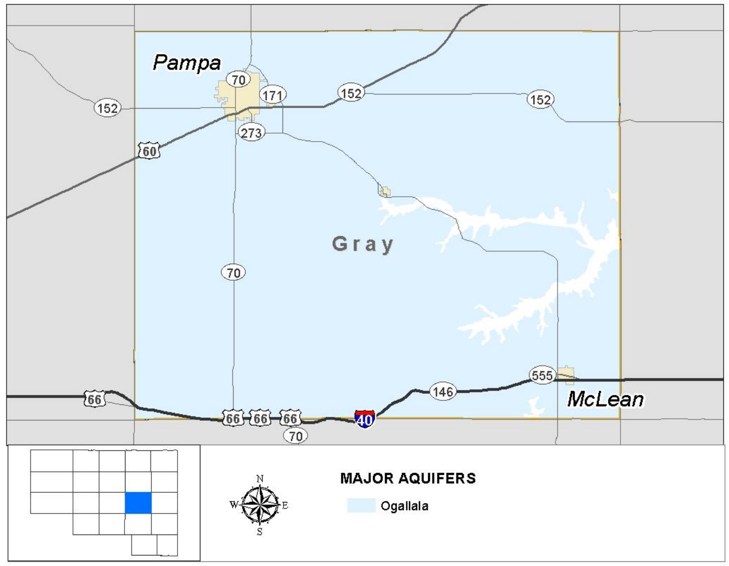
5D.6.1 Donley County Summary

Donley County has projected needs of 66 acre-feet per year in 2070, all associated with the City of Clarendon, which will be met through strategies developed by Greenbelt MIWA (see Section 5C.5). A summary of the water plan for Donley County is shown in Table 5D-14.

Table 5D-14: Donley County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Clarendon	Greenbelt Reservoir and Ogallala aquifer	Yes	Municipal conservation, Supplies from Greenbelt MIWA
County-Other	Ogallala aquifer and Greenbelt Reservoir	No	None
Irrigation	Ogallala aquifer and Red River water rights	No	Irrigation conservation
Livestock	Ogallala and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Red River Authority of Texas	Ogallala aquifer and Greenbelt Reservoir	No	None
Steam Electric	None	-	-

5D.7 Gray County



Gray County is located in the center of the PWPA. The Ogallala aquifer underlies most of Gray County. This water resource is the primary source for most users in the county. The largest city in the county is Pampa, with a 2017 population of 17,475 and a projected total demand of 3,685 acre-feet per year in 2020 growing to 5,815 acre-feet per year in 2070. The City of Pampa is a member city of CRMWA, which provides water from its Roberts County well field and Lake Meredith to Pampa. Pampa also receives water from its own well field.

Only about a third of the total available supply from the Ogallala in Gray County is currently developed. There are sufficient developed supplies to meet most of the demands in the county. Only McLean, Pampa and Gray County Irrigation are identified with projected water needs. Most of Pampa's need is associated with the need for CRMWA, which will be met through strategies developed by CRMWA (see Section 5C.1).

5D.7.1 McLean

The City of McLean is located in southwestern Gray County. Its current water supply is from the Ogallala aquifer. The city is projected to have a water supply need beginning in 2050 associated with declining water levels. However, due to the increased activities associated with mining and other construction and corresponding demands on the city, McLean is planning to develop a new well by 2030. The potentially feasible strategies for McLean include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes the city would drill one new well in the Ogallala aquifer near its existing well field. The well would be able to produce 150 gpm with well depths of about 150 feet. Only well field piping to connect to McLean's existing system is included in this strategy. If McLean develops new water in a different location, additional transmission would be needed, which will increase the costs in this plan.

Time Intended to Complete

The time to complete is 2030.

Quantity, Reliability, and Cost

This strategy would provide McLean with an additional 150 acre-feet per year of reliable supply. There is available water in the Ogallala and limited competition for the water. The capital cost of this strategy is $414,000, which provides a unit cost of $0.65 per thousand gallons.

Environmental Issues

There are no known environmental issues with this strategy.

Impact on Water Resources and Other Management Strategies

This strategy, at 150 acre-feet per year, is not expected to impact the Ogallala aquifer or other water management strategies.

Impact on Agriculture and Natural Resources

No impacts to agriculture or natural resources are anticipated. This strategy would improve the reliability of water supply to rural users.

Other Relevant Factors

There are no other relevant factors.

Table 5D-15: Recommended Water Strategies for McLean (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	40	88	115
Recommended Strategies							
Municipal Conservation	N/A	3	3	3	4	4	4
Drill Additional Groundwater Well(s)	$0.4	0	150	150	150	150	150
Total	**$0.4**	**3**	**153**	**153**	**154**	**154**	**154**

5D.7.2 Pampa

The City of Pampa provides water to customers in Gray County, including TDCJ, and Titan Specialties and other manufacturers. The city receives blended water from CRMWA and operates wells for groundwater from the Ogallala aquifer. The city also reuses treated wastewater to supply irrigation water to its municipal golf course. The city is able to meet its current water demands. However, a water need of 160 acre-feet per year is projected by 2030 and increasing to 2,241 acre-feet per year by 2070. Most of this need is associated with the need on CRMWA and will be met through strategies developed by CRMWA. Pampa is planning on further developing its own water supplies near the city. The potentially feasible strategies for Pampa include:

- Municipal Conservation (see Section 5B.1)
- Obtain contractual supplies from CRMWA (this is evaluated with CRMWA strategies in Section 5C.1)
- Drill Additional Groundwater Well(s)
- Aquifer Storage and Recovery

Drill Additional Groundwater Well(s)

This strategy includes two new wells and associated well field piping. The new wells would be drilled to provide 1,100 acre-feet per year and are assumed to produce water from approximately 555 feet below the surface. Minimal treatment such as chlorine disinfection will be required for municipal use. These wells are assumed to be located within three miles of the City.

Time Intended to Complete

The time to complete is 2040.

Quantity, Reliability, and Cost

The new wells will provide 1,100 acre-feet per year of good supply. These wells are expected to be reliable and there is limited competition for water near the city's existing well field. The capital cost for the wells and 3-mile transmission system is $4.1 million. The unit cost of this additional water is estimated at $1.09 per thousand gallons.

Environmental Issues

No significant environmental impact is expected for the recommended strategy. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed

Impact on Water Resources and Other Management Strategies

This strategy is assumed to have a minimal impact on the Ogallala aquifer and other surrounding water resources.

Impact on Agriculture and Natural Resources

There are no identified impacts to agricultural and natural resources.

Other Relevant Factors

There are no other relevant factors.

Aquifer Storage and Recovery

This strategy would use 500 acre-feet per year of water provided by CRMWA to Pampa in an effort to supplement supplies for member cities during high demand periods. The cost components of this strategy include new well field piping along with some pump improvements to move water to ASR injection wells. Depending on the source of water and its destination, water may be delivered directly from CRMWA's system to ASR wells in Pampa's existing well field. However, it is likely that the water will require treatment prior to injection and will be delivered from the Pampa water treatment plant. This strategy assumes that a minimum of two 870-gpm 10-inch diameter wells will be required for ASR injection in Pampa's well field.

Time to Implement

Supply will be available for the ASR project before 2030.

Quantity, Reliability and Cost

The quantity will vary from year to year depending on demands and the capacities of ASR well fields. The quantity of water that would be made available from the ASR project is 500 acre-feet per year. The source of this water would be from CRMWA's Ogallala aquifer well field in Roberts County and/or Lake Meredith.

The ASR project will increase the reliability of existing supplies by allowing storage of the supply during periods of low demand to meet high demands later. It was assumed that one-half mile of additional well field piping is needed along with pump improvements and injection wells. The strategy is estimated to cost $2.2 million.

Environmental Issues

Potential environmental impacts include water quality concerns for the receiving aquifer. Since not all source water is groundwater, pre-treatment of the water before injection and storage may be needed.

Impact on Water Resources and Other Management Strategies

This strategy should have a positive impact on other water management strategies by increasing reliability.

Impact on Agriculture and Natural Resources

The project should have no impact to agriculture or natural resources since it is utilizing existing water sources and existing infrastructure.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-16: Recommended Water Strategies for Pampa (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	160	836	1,344	1,794	2,241
Recommended Strategies							
Municipal Conservation	N/A	59	95	106	121	132	144
Drill Additional Groundwater Well(s)	$4.1	0	0	1,100	1,100	1,100	1,100
CRMWA Supplies[1]	N/A	0	468	837	1,344	1,794	1,819
ASR	$2.2	0	0	500	500	500	500
Total	**$6.3**	**59**	**563**	**2,043**	**2,565**	**3,026**	**3,063**

1 Supplies shown for ASR include water received from CRMWA. These supplies are not included in the totals.

5D.7.3 Gray County Irrigation

The irrigation needs in Gray County are minimal, at 2,632 acre-feet per year in 2060 and 2070. These needs are shown to be in the Canadian basin portion of the county and may be an artifact of the basin-split methodology. There is plenty of groundwater to meet the needs in the Red River basin portion of the county. The projected irrigation needs can be fully met through conservation. A summary of the projected water needs and strategies for Gray County Irrigation is shown in Table 5D-16. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-17: Recommended Water Strategies for Gray County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	0	2,632	2,632
Recommended Strategies							
Irrigation Conservation	$1.0	2,222	3,766	7,320	8,612	9,308	9,981
Total	**$1.0**	**2,222**	**3,766**	**7,320**	**8,612**	**9,308**	**9,981**

5D.7.4 Gray County Summary

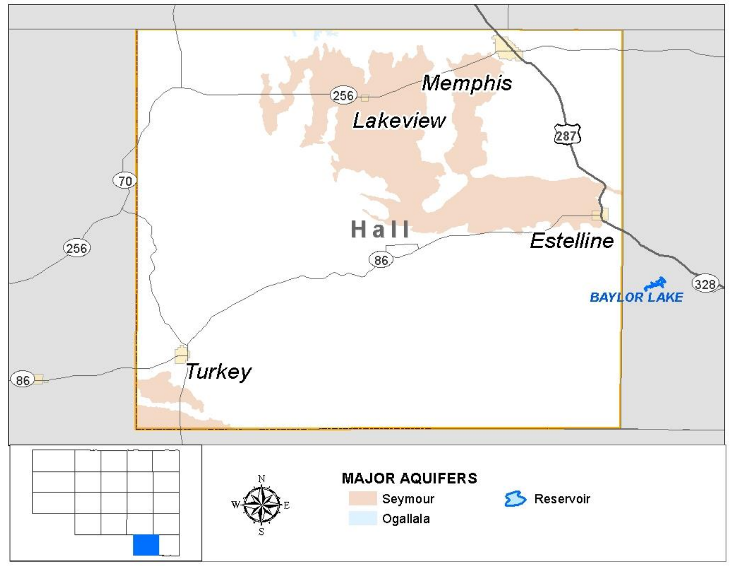
Gray County has a total projected need of nearly 5,000 acre-feet per year by 2070. Much of this need can be met through conservation. The municipal needs are planned to be met through conservation, aquifer storage and recovery, and additional groundwater from the Ogallala aquifer. The county's primary source of water, Ogallala aquifer has over 140,000 acre-feet per year of water that is not currently developed and could be used to meet water needs. The recommended water plan for Gray County is shown in Table 5D-17.

Table 5D-18: Gray County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer, run-of-river, and reuse	Yes	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
McLean	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Mining	Ogallala aquifer	No	None
Pampa	Ogallala aquifer and CRMWA system	Yes	Municipal conservation, new wells in Ogallala, ASR and contracted supplies from CRMWA
Steam Electric	None	-	-

5D.8 Hall County

Hall County is located in the southern end of the PWPA. The largest city in the county is Memphis, with a 2017 population of 2,089 and a projected total demand of 386 acre-feet per year in 2020 and 372 acre-feet per year in 2070.



Hall County has limited water sources. The primary sources of water are the Seymour and Blaine aquifers. Both of these sources have water quality concerns, which limits their use for municipal purposes. There is little surface water in the region. For this reason, Memphis obtains its water from Donley County. There is also about 1,000 acre-feet per year of water that is obtained from the Whitehorse formation, which is listed as Other Aquifer in this plan.

Hall County has two WUGs with needs during the planning horizon: City of Memphis and Hall County Irrigation.

5D.8.1 Memphis

The City of Memphis currently obtains its water supply from the Ogallala aquifer in Donley County and purchases treated surface water from Greenbelt MIWA as needed. Due to the limited groundwater in Donley County, Memphis is projected to have a need of 28 acre-feet per year by 2030, increasing to 146 acre-feet per year by 2070. To meet this need, Memphis is planning to develop additional groundwater in Donley County within its existing well field. The potential water management strategies for Memphis include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells will be drilled near the City's existing wells. Well field piping will be installed to connect to the current collection system. The new wells would be drilled to provide approximately 150 acre-feet per year and are assumed to produce water from approximately 150 feet below the surface. Minimal treatment such as chlorine disinfection will be required for municipal use. There is no transmission system associated with this strategy. It is assumed that the existing transmission system is sufficient.

Time Intended to Complete

This strategy would be implemented by 2030.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 150 gpm per well, which can provide an average annual supply of 150 acre-feet per year. Reliability of the supply is considered to be moderate due to thinner saturated thickness of the aquifer towards the southern edge. The capital cost for the additional groundwater wells and well field piping is $1.1 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

This strategy is assumed to have a minimal impact on the Ogallala-Rita Blanca aquifer and other surrounding water resources. There are no impacts to other management strategies.

Impact on Agriculture and Natural Resources

It is uncertain whether Memphis already holds sufficient groundwater rights or whether additional rights would need to be obtained. It is assumed if water rights are purchased from agricultural or rural water users, it would be on a willing buyer-willing seller basis. No significant impact on agricultural and natural resources is expected for this strategy.

Other Relevant Factors

There are no other relevant factors.

Table 5D-19: Recommended Water Strategies for Memphis (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	28	62	102	142	146
Recommended Strategies							
Municipal Conservation	N/A	7	7	7	7	7	7
Drill Additional Groundwater Well(s)	$1.1	0	150	150	150	150	150
Total	**$1.1**	**7**	**157**	**157**	**157**	**157**	**157**

5D.8.2 Turkey

The City of Turkey currently obtains its water from the Seymour Aquifer. The supply analysis indicates that Turkey does not have a need; however, the city is pursuing additional water supplies to increase the reliability of its existing sources. The strategies considered for Turkey include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well (Briscoe County)

Drill Additional Groundwater Well

Turkey has an Economically Distressed Areas Program project grant funded through TWDB to put in new wells in the Ogallala aquifer in Briscoe County, but they are still in the early stages of implementation. There is sufficient supply available for this project.

Time Intended to Complete

This strategy would be implemented by 2020.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to provide an average annual supply of 100 acre-feet per year. Reliability of the supply is considered to be moderate due to competition for water. The capital cost for the additional groundwater wells and transmission system is estimated at $1.6 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

This strategy is assumed to have a minimal impact on the Ogallala aquifer and other surrounding water resources. There are no impacts to other management strategies.

Impact on Agriculture and Natural Resources

It is assumed that Turkey holds sufficient groundwater rights for this project and there would be no significant impact on agricultural and natural resources for this strategy.

Other Relevant Factors

There are no other relevant factors.

Table 5D-20: Recommended Water Strategies for Turkey (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	3	1	0	0	0
Recommended Strategies							
Municipal Conservation[1]	$0.5	5	5	5	5	5	5
New Well (Briscoe)	$1.6	0	100	100	100	100	100
Total	**$2.1**	**5**	**105**	**105**	**105**	**105**	**105**

[1] Includes costs and water savings associated with Water Audits and Leak Repair

5D.8.3 Hall County – Other (Brice-Lesley, Estelline, Lakeview)

Two communities, Estelline and Lakeview, have been identified as having water quantity and quality concerns. Brice-Lesley WSC also is planning to expand their water supplies. Both Estelline and Brice-Lesley WSC obtain water from the Seymour aquifer in Hall County. The challenges with developing new supplies is that the local groundwater is fully utilized (no available supply under the MAG for the Seymour aquifer). Therefore, new development from the Seymour aquifer can only be an alternate strategy.

The potential strategies for Hall County-Other include.

- Drill Additional Groundwater Well (Brice-Lesley)
- Drill Additional Groundwater Well (Estelline)
- Water Quality Improvements (Lakeview)

Drill Additional Groundwater Well (Brice-Lesley)

This strategy assumes that one new well will be drilled near Brice-Lesley existing wells. Well field piping will be installed to connect to the current collection system. The new well would be drilled to provide approximately 50 acre-feet per year and is assumed to produce water from approximately 250 feet below the surface. Minimal treatment such as chlorine disinfection will be required for municipal use. There is no transmission system associated with this strategy. It is assumed that the existing transmission system is sufficient.

Time Intended to Complete

This strategy would be implemented by 2030.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 170 gpm per well, which can provide an average annual supply of more than 50 acre-feet per year. Reliability of the supply is considered to be low to moderate due to thinner saturated thickness of the aquifer towards the southern edge and competition for the supplies. The capital cost for the additional groundwater wells and well field piping is $0.4 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

This strategy is would exceed the MAG for the Seymour aquifer; therefore, it is considered an alternate strategy. Should the MAGs be modified, or supplies become available from other users, this strategy would then be recommended. There are no impacts to other management strategies.

Impact on Agriculture and Natural Resources

It is uncertain whether Brice-Lesley already holds sufficient groundwater rights or whether additional rights would need to be obtained. It is assumed if water rights are purchased from agricultural or rural water users, it would be on a willing buyer-willing seller basis. No significant impact on agricultural and natural resources is expected for this strategy.

Other Relevant Factors

There are no other relevant factors.

Drill Additional Groundwater Well (Estelline)

This strategy assumes that one new well will be drilled near Estelline's existing wells. Well field piping will be installed to connect to the current collection system. The new wells would be drilled to provide approximately 50 acre-feet per year and is assumed to produce water from approximately 150 feet below the surface. Minimal treatment such as chlorine disinfection will be required for municipal use. There is no transmission system associated with this strategy. It is assumed that the existing transmission system is sufficient.

Time Intended to Complete

This strategy would be implemented by 2020.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 75 gpm per well, which can provide an average annual supply of 50 acre-feet per year. Reliability of the supply is considered to be low to moderate due to thinner saturated thickness of the aquifer towards the southern edge and competition for the supplies. The capital cost for the additional groundwater wells and well field piping is $0.2 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

This strategy is would exceed the MAG for the Seymour aquifer; therefore, it is considered an alternate strategy. Should the MAGs be modified, or supplies become available from other users, this strategy would then be recommended. There are no impacts to other management strategies.

Impact on Agriculture and Natural Resources

It is uncertain whether Estelline already holds sufficient groundwater rights or whether additional rights would need to be obtained. It is assumed if water rights are purchased from agricultural or rural water users, it would be on a willing buyer-willing seller basis. No significant impact on agricultural and natural resources is expected for this strategy.

Other Relevant Factors

There are no other relevant factors.

Advanced Treatment (Nitrate Removal for Lakeview)

This strategy assumes the development of advanced treatment facilities to treat the City of Lakeview's current groundwater from the Seymour aquifer. Currently, the city is experiencing elevated nitrate levels in its water source. This strategy assumes that half of the city's groundwater would be treated by reverse osmosis or other method and then blended with the remaining supplies to reduce nitrate concentrations. This strategy assumes that a 0.1 MGD treatment facility would be constructed and the waste stream from the facility could be discharged to a local tributary of the Prairie Dog Town Fork of the Red River.

Time Intended to Complete

The City is experiencing water quality issues now. To address these issues, the strategy will be completed by 2030.

Quantity, Reliability, and Cost

This strategy will produce approximately 50 acre-feet per year. The capital cost is estimated at $2.6 million.

Environmental Issues

There may be environmental impacts with the discharge of the waste stream. This would need to be permitted by the State. At that time, environmental impacts would be assessed.

Impact on Water Resources and Other Management Strategies

With the losses associated with the treatment, the city would need to compensate by pumping additional groundwater to meet its needs.

Impact on Agriculture and Natural Resources

The strategy is expected to have low impact on agriculture and other natural resources.

Other Relevant Factors

There are no other identified relevant factors.

The recommended strategies for Hall County-Other are shown in Table 5D-20.

Table 5D-21: Alternate Water Strategies for Hall County-Other (Brice-Lesley, Estelline, Lakeview) (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	0	0	0
Alternate Strategies							
Advanced Treatment (Lakeview)	$2.6	0	50	50	50	50	50
New Well (Brice-Lesley)	$0.4	0	50	50	50	50	50
New Well (Estelline)	$0.2	0	50	50	50	50	50
Total	**$3.2**	**0**	**150**	**150**	**150**	**150**	**150**

[1]The need is shown for the aggregated water user. Needs for small rural communities may differ.

5D.8.4 Hall County Irrigation

The irrigation needs in Hall County begin at over 15,000 acre-feet per year in 2020 and reduce to 6,480 acre-feet per year in 2070. The recommended strategy to meet this need is conservation. A summary of the projected water needs and strategies for Hall County Irrigation is shown in Table 5D-21. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-22: Recommended Water Strategies for Hall County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		15,637	14,325	11,397	8,194	5,206	6,480
Recommended Strategies							
Irrigation Conservation	$0.8	1,898	3,025	6,317	7,232	7,518	7,796
Total	**$0.8**	**1,898**	**3,025**	**6,317**	**7,232**	**7,518**	**7,796**

5D.8.5 Hall County Summary

Hall County has a total projected need of over 15,000 acre-feet per year in 2020, reducing to 6,480 acre-feet per year in 2070. Much of this need can be met through conservation in the later decades, but there is an unmet need for irrigation in 2020 through 2050. The municipal needs are planned to be met through conservation and additional groundwater from the Seymour aquifer. The county's primary source of water, Seymour aquifer, has limited capacity (between 2,000 and 5,000 acre-feet per year above what is currently developed). It also has known water quality concerns. The recommended water plan for Hall County is shown in Table 5D-22.

Table 5D-23: Hall County Water Management Plan

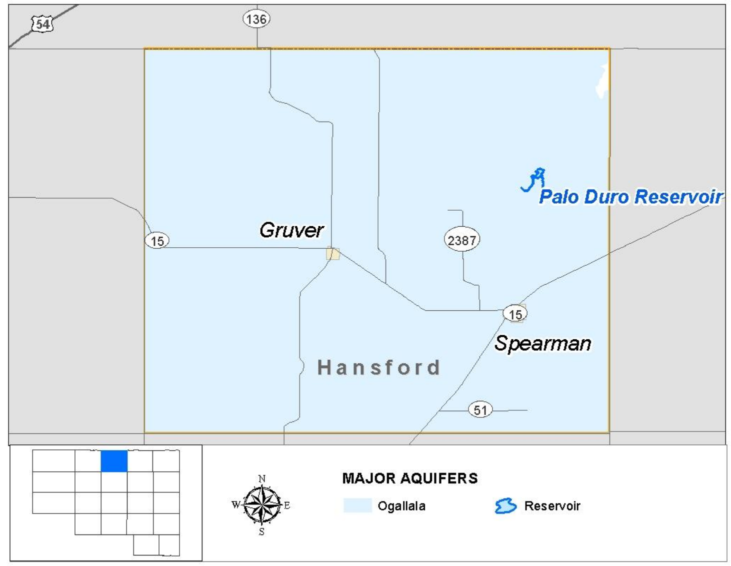
Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other[1]	Seymour aquifer	No	None
Irrigation	Seymour and Other aquifer, Red River water rights, and reuse	Yes	Irrigation conservation
Livestock	Seymour, Blaine and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Memphis	Ogallala aquifer and Greenbelt reservoir	Yes	Municipal conservation, Drill additional groundwater well(s)
Mining	None	-	-
Red River Authority of Texas	Ogallala and Seymour aquifers, and Greenbelt Reservoir	No	None
Steam Electric	None	-	-
Turkey Municipal Water System	Seymour aquifer	No	Municipal conservation, New wells in Briscoe County (Ogallala)

1. There are no strategies for Hall County-Other because there is insufficient groundwater availability. The considered strategies are alternate strategies.

Table 5D-24: Unmet Water Needs in Hall County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(13,739)	(11,300)	(5,080)	(962)	0	0

5D.9 Hansford County



Hansford County is located on the northern edge of the PWPA, along the border with Oklahoma. The largest city in the county is Spearman, with a 2017 population of 3,278 and a projected total demand of 670 acre-feet per year in 2020 increasing to 745 acre-feet per year in 2070.

Nearly all of the water supplies currently used in Hansford County are obtained from the Ogallala aquifer. The Palo Duro Reservoir is also located in Hansford County, but there is no infrastructure developed to transport the water. The larger municipalities include Spearman and Gruver. Both of these cities are member cities of the Palo Duro Water District (PDWD), but both currently obtain their water from the Ogallala aquifer.

There are sufficient supplies to meet most of the water demands in Hansford County. Both Gruver and Spearman have projected needs due to declining water levels within each city's existing well field.

5D.9.1 Gruver

The City of Gruver currently obtains its water supply from the Ogallala aquifer in Hansford County. Based on the availability of the City's current wells, Gruver will need to develop additional supplies before 2030. Projected needs for Gruver range from 20 acre-feet per year in 2030 to 280 acre-feet per year in 2070. The City owns approximately 1,000 acres of undeveloped water rights. These water rights may be sufficient to meet the projected needs, pending competition for water from other users. As a member of the PDWD, Gruver may be interested in developing a regional transmission system to use water from Palo Duro Reservoir, although this is considered an alternate strategy. The potential water management strategies for Gruver include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Develop PDWD Transmission System

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells will be drilled to provide approximately 280 acre-feet per year. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. These wells are assumed to be approximately 180 feet below the surface. The new wells will be drilled near the City's existing wells. Well field piping will be installed to connect to the current collection system. There is no additional transmission to the City.

Time Intended to Complete

The wells will be completed prior to 2030.

Quantity, Reliability and Cost

The quantity of water from this strategy should be able to produce 280 acre-feet per year with average well capacities of 265 gpm. Reliability of Ogallala supplies is moderate since availability depends on other water users. For cost purposes, it is assumed that the new wells would be located within the existing well field. The capital cost for the additional groundwater well is approximately $0.9 million.

Environmental Issues

No significant environmental impact is expected for this strategy. The City already owns the water rights and no transmission system is included in this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategies.

Other Relevant Factors

There are no other identified relevant factors.

Develop PDWD Transmission System

The Palo Duro Reservoir transmission project is an alternate strategy for Gruver. The project would have little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Gruver would expect to have a capital cost of $8.9 million associated with their portion of the project.

Table 5D-25: Recommended Water Strategies for Gruver (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	20	98	180	256	280
Recommended Strategies							
Municipal Conservation	N/A	5	5	5	6	6	7
Drill Additional Groundwater Well(s)	$0.9	0	280	280	280	280	280
Total	**$0.9**	**5**	**285**	**285**	**286**	**286**	**287**

5D.9.2 Spearman

The City of Spearman currently obtains its water supply from the Ogallala aquifer in Hansford County. Based on the availability of the city's current wells, Spearman will need to develop additional supplies by 2050 to replace lost production of its existing well field. The city will need 520 acre-feet per year by 2070. As a member of the PDWD, Spearman may be interested in developing a regional transmission system to use water from Palo Duro Reservoir, although this is considered an alternate strategy. The potential water management strategies for Spearman include:

- Municipal Conservation (See Section 5B.1)
- Drill Additional Groundwater Well(s)
- Develop PDWD Transmission System

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells will be drilled to provide approximately 520 acre-feet per year and are assumed to produce water approximately 180 feet below the surface. The additional wells are assumed to be located within 1 mile of the City. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. Well field piping will be installed to connect to the current collection system. The exact location of the additional wells is not known.

Time Intended to Complete

The wells will be completed prior to 2040.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 520 acre-feet per year with average well capacities of 618 gpm. Reliability of Ogallala supplies is moderate since availability depends on other water users. For costing purposes, the transmission system includes 200 feet of 14-inch pipeline and a well field pump station. The capital cost for the additional groundwater well is approximately $2.6 million.

Environmental Issues

No significant environmental impact is expected for this strategy. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected. Increased demands on the Ogallala aquifer will continue to deplete the storage. To prolong the life of this water resource, other users may need to reduce their demands.

Other Relevant Factors

There are no other identified relevant factors.

Develop PDWD Transmission System

The Palo Duro Reservoir transmission project is an alternate strategy for Spearman. The project would have little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Spearman would expect to have a capital cost of $9.1 million associated with their portion of the project.

Table 5D-26: Recommended Water Strategies for Spearman (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	229	495	517
Recommended Strategies							
Municipal Conservation	N/A	11	11	12	12	12	13
Drill Additional Groundwater Well(s)	$2.6	0	0	0	520	520	520
Total	**$2.6**	**11**	**11**	**12**	**532**	**532**	**533**

5D.9.3Hansford County Summary

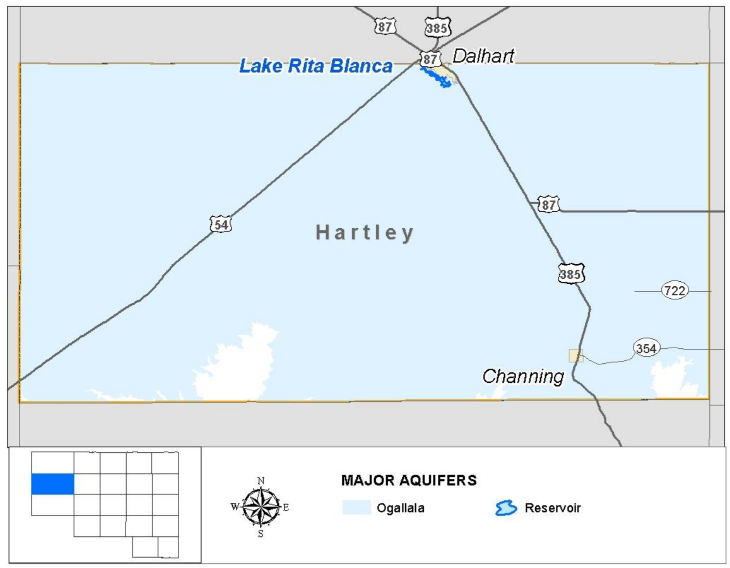
Hansford County has a total projected need of approximately 800 acre-feet per year by 2070. Much of this need can be met through conservation. The municipal needs are planned to be met through conservation and additional groundwater from the Ogallala aquifer. The county's primary source of water, Ogallala aquifer has nearly 100,000 acre-feet per year of water that is not currently developed and could be used to meet water needs. The recommended water plan for Hansford County is shown in Table 5D-26.

Table 5D-27: Hansford County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Gruver	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Irrigation	Ogallala aquifer, Canadian River water rights	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Spearman	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Steam Electric	None	-	-

5D.10 Hartley County



Hartley County is located in the far northwestern part of the PWPA. Dalhart is the largest city in Hartley County with a 2017 population of approximately 8,400, of which about one-third are located in Hartley County. The remaining population is in Dallam County.

Hartley County is one of the larger irrigation water users in the region. The primary source of water in the county is the Ogallala aquifer. Smaller quantities of groundwater from the Dockum aquifer and local livestock supply are also used in the county. There is plenty of water available from the Ogallala aquifer in Hartley County, but the use is concentrated in the heavily irrigated areas, which results in large water declines over time.

Due to the geographic constraints imposed by the water supply allocation process, there are projected needs for the City of Dalhart and Hartley County Irrigation. The recommended strategies to meet the needs for irrigation is conservation, which is discussed in Chapter 5B. The potential strategies for Dalhart are discussed in Section 5D.5, under Dallam County.

5D.10.1 Hartley County Irrigation

The irrigation needs in Hartley County peak at over 192,000 acre-feet per year over the planning period. These needs cannot be fully met through conservation in the early decades. A summary of the projected water needs and strategies for Hartley County Irrigation is shown in Table 5D-27. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-28: Recommended Water Strategies for Hartley County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		84,766	192,765	177,587	159,542	141,411	141,411
Recommended Strategies							
Irrigation Conservation	$9.0	27,160	48,052	89,129	99,463	94,245	99,380
Total	**$9.0**	**27,160**	**48,052**	**89,129**	**99,463**	**94,245**	**99,380**

5D.10.2 Hartley County Summary

Hartley County has a total projected water need of over 142,000 acre-feet per year by 2070. Much of this need can be met through conservation. The municipal needs are planned to be met through conservation and additional groundwater from the Ogallala aquifer. However, not all of the need for Hartley County Irrigation can be met through conservation. There is a projected unmet water need for Irrigation of approximately 58,000 acre-feet per year in 2020, which decreases to 42,000 acre-feet per year by 2050.The recommended water plan for Hartley County is shown in Table 5D-28. The unmet needs are shown in Table 5D-29.

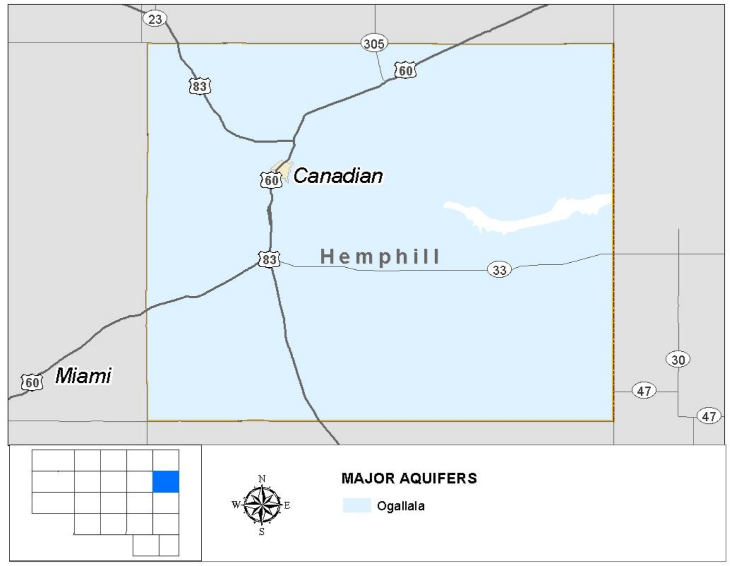
Table 5D-29: Hartley County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Dalhart	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s) (see Section 5D.5)
Hartley WSC	Ogallala aquifer	No	Municipal conservation
Irrigation	Ogallala and Dockum aquifers	Yes	Irrigation conservation
Livestock	Ogallala and Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

Table 5D-30: Unmet Water Needs in Hartley County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(57,606)	(144,713)	(88,458)	(60,079)	(47,166)	(42,031)

5D.11 Hemphill County



Hemphill County is located along the eastern edge of the PWPA. The City of Canadian, with a 2017 population of 2,800, is the largest city in the county and has a projected total demand of 823 acre-feet per year in 2020 increasing to 1,199 acre-feet per year in 2070.

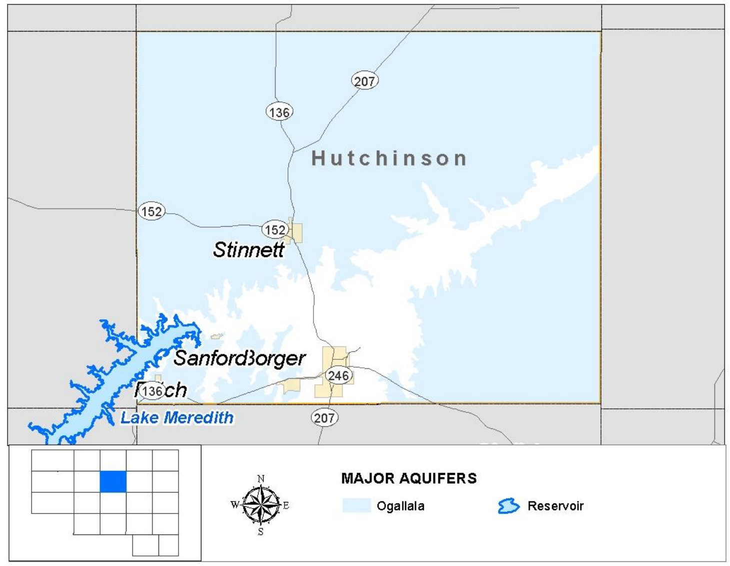
Water users in Hemphill County obtain their current water supplies from the Ogallala aquifer, with a small amount coming from the local supplies for livestock.

Current sources of supply in Hemphill County are shown to be adequate with no projected water need over the planning period. It is recommended that conservation be implemented for Canadian and irrigation to preserve supplies for future use. A summary of the recommended water plan for Hemphill County is shown in Table 5D-30.

Table 5D-31: Hemphill County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Canadian	Ogallala aquifer	No	Municipal conservation
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.12 Hutchinson County



Hutchinson County is located in the center of the PWPA along the Canadian River break, with Lake Meredith located in the southwestern part of the county. The Ogallala aquifer underlies most of the county. The largest city in Hutchinson county is Borger, with a 2017 population of 12,754 and a projected total demand of 3,163 acre-feet per year in 2020 and 3,172 acre-feet per year in 2070.

The entities in Hutchinson County obtain their water from the Ogallala aquifer and CRMWA. Borger receives water from CRMWA and is also a Major Water Provider because it provides considerable supplies to manufacturing water users. The water supply plan for Borger is discussed in Chapter 5C but is also included in the summary of this section for completeness.

Hutchinson County is projected to have a small need beginning in 2030 and increasing to nearly 4,000 acre-feet per year by 2070. Most of this need is associated with the City of Borger and its customers (manufacturing). The City of Stinnett and TCW Water Supply Corporation are also projected to have needs over the planning period.

5D.12.1 Borger

The City of Borger is a Major Water Provider. The city currently obtains water from CRMWA and multiple well fields. Borger provides a significant portion of the manufacturing supplies in Hutchinson County and some water to manufacturing users in Carson County. Borger has needs starting at 105 acre-feet per year in 2060, increasing to 112 acre-feet per year in 2070. Borger has recently developed additional groundwater to serve its retail and wholesale customers. With these new supplies Borger has sufficient water to meet the projected needs over the planning period. The recommended water management strategies for the City of Borger are water conservation and contractual supplies from CRMWA. Discussion of these strategies is found in Section 5C.3.

5D.12.2 Stinnett

The City of Stinnett currently obtains its water supply from the Ogallala aquifer. Due to declining well production of the city's current well field, Stinnett will need to develop additional supplies before 2060. Projected needs for Stinnett are 31 acre-feet per year in 2060 and 2070. These needs can be met through additional groundwater development to replace reductions in capacities. As a member of the PDWD, Stinnett may be interested in developing a regional transmission system to use water from Palo Duro Reservoir, although this is considered an alternate strategy.

The potential water management strategies for Stinnett include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Develop PDWD Transmission System

Drill Additional Groundwater Well(s)

This strategy assumes that one new well will be drilled to provide approximately 50 acre-feet per year. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. This well is assumed to be approximately 385 feet below the surface. It is assumed the new well would be drilled near the City's existing wells. Well field piping would be installed to connect to the current transmission system to the city. There is no additional transmission to the city.

Time Intended to Complete

The wells will be completed by 2050.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 50 acre-feet per year with average well capacities of 625 gpm. Reliability of Ogallala supplies is moderate since availability depends on other water users. For cost purposes, it is assumed that the new well would be located within the existing well field. The capital cost for the additional groundwater well is approximately $0.9 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategies.

Other Relevant Factors

There are no other identified relevant factors.

Develop PDWD Transmission System

The Palo Duro Reservoir transmission project is an alternate strategy for Stinnett. The project would have little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Stinnett would expect to have a capital cost of $12.1 million associated with their portion of the project.

The recommended strategies for Stinnett are shown in Table 5D-31.

Table 5D-32: Recommended Water Strategies for Stinnett (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	0	31	31
Recommended Strategies							
Municipal Conservation	N/A	6	6	6	6	6	6
Drill Additional Groundwater Well(s)	$0.9	0	0	0	50	50	50
Total	**$0.9**	**6**	**6**	**6**	**56**	**56**	**56**

5D.12.3 TCW Supply

The TCW Supply supplies water to the City of Sanford and currently obtains its water supply from the Ogallala aquifer in Hutchinson County. It also has an emergency connection with the city of Borger. Based on the availability of the TCW's current wells, the water provider will need to develop additional supplies by 2030. Projected needs for TCW Supply range from 132 acre-feet per year in 2030 to 383 acre-feet per year in 2070. To meet these needs, TCW Supply would need to expand its well field or purchase water from Borger. The potential water management strategies include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Purchase water from Borger

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells will be drilled to provide approximately 400 acre-feet per year. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. These wells are assumed to be approximately 575 feet below the surface. It is uncertain where the new wells will be located. For planning purposes, it is assumed that the wells would be located within two miles of TCW Supply's distribution system. A 6-inch transmission pipeline and pump station are included in this strategy.

Time Intended to Complete

The wells will be completed by 2030. It is likely that the wells may be installed in phases; however, for planning purposes, the costs and supplies are shown for the full strategy.

Quantity, Reliability and Cost

The quantity of water from this strategy should be able to produce 400 acre-feet per year with average well capacities of 360 gpm. Reliability of Ogallala supplies is moderate since availability depends on other water users. The capital cost for the additional groundwater well is approximately $3.9 million and includes the purchase of additional water rights. If TCW Supply can utilize its existing infrastructure, the costs would likely be less.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

It is uncertain whether TCW Supply already holds sufficient groundwater rights or whether additional rights would need to be obtained. It is assumed if water rights are purchased from agricultural or rural water users, it would be on a willing buyer-willing seller basis. No significant impact on agricultural and natural resources is expected for this strategy.

Other Relevant Factors

There are no other identified relevant factors.

Purchase Water from Borger

This strategy assumes TCW Supply would purchase the needed supply from the City of Borger. The water supplier has a connection to Borger's system and has purchased water from Borger in the past. This strategy could be implemented independently for the entire need or for a portion of TCW's projected need. Borger is planning to develop additional groundwater and has sufficient supplies to serve TCW Supply. (Borger's strategies are discussed in Chapter 5C.) It is uncertain whether infrastructure improvements would be required to provide the full amount of the projected need. For this plan, it is assumed that capital improvements would be needed at an estimated cost of $250,000. This is an alternate strategy for TCW Supply.

Table 5D-33: Recommended Water Strategies for TCW Supply (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	132	233	315	383	383
Recommended Strategies							
Municipal Conservation	N/A	6	6	6	6	6	6
Drill Additional Groundwater Well(s)	$3.9	0	400	400	400	400	400
Total	**$3.9**	**6**	**406**	**406**	**406**	**406**	**406**

5D.12.4 Hutchinson County Manufacturing

Hutchinson County manufacturers currently obtain water directly from the Ogallala aquifer in Hutchinson County and from the City of Borger, including direct reuse. Hutchinson County manufacturing users do not have a need. There is a small need for manufacturing supplies from Borger (31 acre-feet per year). As CRMWA develops strategies to meet its demands from Borger, the needs for manufacturing in Hutchinson County will be met. The strategies recommended for Borger are discussed in Section 5C.3.

5D.12.5 Hutchinson County Summary

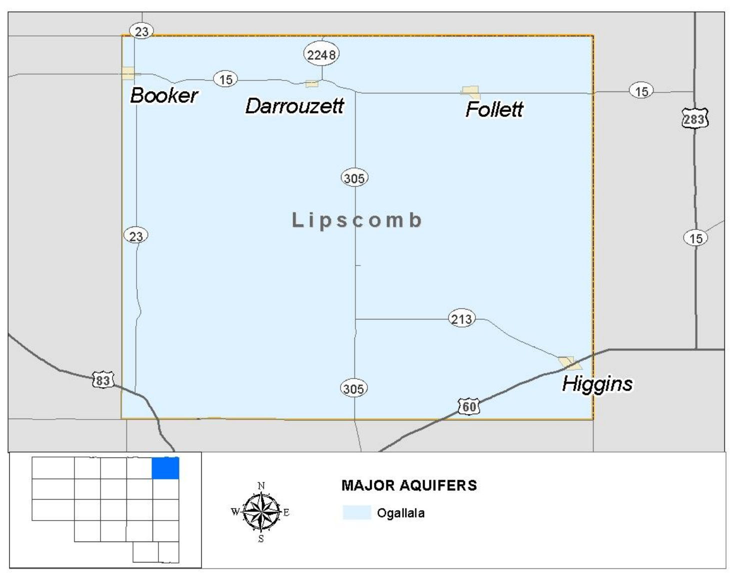
Hutchinson County can fully meet its projected needs through the development of water strategies by the Major Water Providers, Borger and CRMWA, the development of additional groundwater in the Ogallala, and conservation. While irrigation does not have a need over the planning period, it is recommended that conservation measures identified in Chapter 5B be implemented to preserve the groundwater supplies for future use. Table 5D-33 shows the recommended water plan for Hutchinson County.

Table 5D-34: Hutchinson County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Borger	Ogallala aquifer and CRMWA system	Yes	Municipal conservation and contractual supplies from CRMWA
County-Other	Ogallala aquifer	No	None
Fritch	Ogallala aquifer	No	Municipal conservation
Irrigation	Ogallala aquifer and Canadian River water rights	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer, reuse, CRMWA system, and Canadian River water rights	Yes	Purchase from Borger
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-
Stinnett	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
TCW Supply Inc.	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)

5D.13 Lipscomb County

Lipscomb County is located in the far northeastern corner of the PWPA. It is a predominantly rural county, with highest water demands associated with irrigated agriculture. The largest city in Lipscomb County is the City of Booker, with a 2017 population of 1,557. It lies on the county border with Ochiltree County and extends into Ochiltree County. Booker has a projected total demand of 502 acre-feet per year in 2020 (of which 99% is in Lipscomb County) increasing to 698 acre-feet per year in 2070.



The Ogallala aquifer is the primary source of water for entities in Lipscomb County. Small quantities of local surface water are used for agricultural purposes. There are large quantities of undeveloped water in the Ogallala aquifer in Lipscomb County. Several major water providers own water rights in this county, including CRMWA and Amarillo, but these rights are currently undeveloped.

The City of Booker and its customers (manufacturing) are shown to have a need beginning in 2040 due to declining well field production.

5D.13.1 Booker

The City of Booker lies in both Lipscomb and Ochiltree Counties. The City currently obtains its water supply from the Ogallala aquifer in Lipscomb County. The City sells water to its residents and manufacturing users in Lipscomb County. Based on the availability of the City's current wells, Booker will need to develop additional supplies before 2040. Projected needs for Booker (including customer sales to manufacturing) are 381 acre-feet per year by 2070. The potential water management strategies for Booker include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells will be drilled to provide approximately 400 acre-feet per year. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. These wells are assumed to be approximately 480 feet below the surface. The new wells will be drilled near the City's existing wells. Well field piping will be installed to connect to the current collection system. There is no additional transmission to the city.

Time Intended to Complete

The wells will be completed prior to 2040.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 400 acre-feet per year with average well capacities of 500 gpm. Reliability of Ogallala supplies is high since there is large quantities of undeveloped supplies. The capital cost for the additional groundwater wells is approximately $1.8 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer in the vicinity of the new wells. These impacts are expected to be minor.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategies. It is assumed that the new wells will be located near the city and not in agricultural areas.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-35: Recommended Water Strategies for Booker (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need (including sales)		0	0	98	245	351	381
Recommended Strategies							
Municipal Conservation	N/A	5	6	6	7	7	8
Drill Additional Groundwater Well(s)	$1.8	0	0	400	400	400	400
Total	**$1.8**	**5**	**6**	**406**	**407**	**407**	**408**

5D.13.2 Lipscomb County Manufacturing

Lipscomb County manufacturers currently get water supply from the Ogallala aquifer in Lipscomb County and from the City of Booker. The needs identified for manufacturing users in Lipscomb County are associated with the City of Booker. As Booker develops strategies to meet its demands, the needs for manufacturing in Lipscomb County will be met.

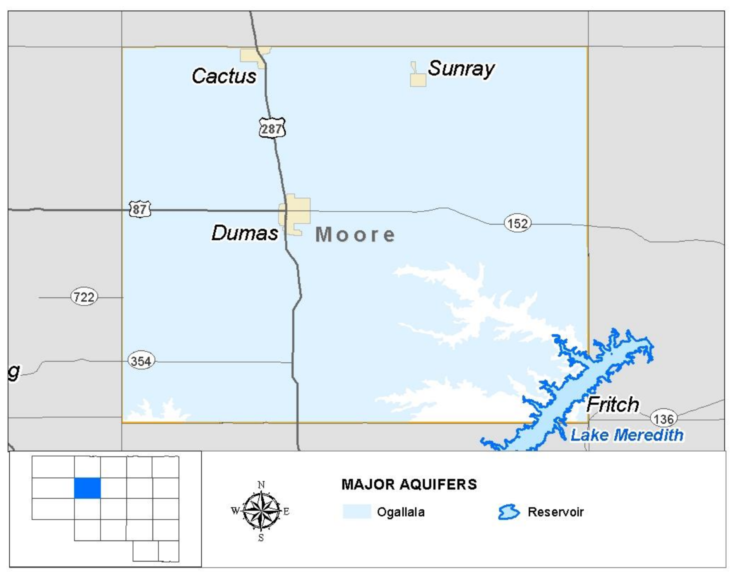
5D.13.3 Lipscomb County Summary

Lipscomb County has plenty of undeveloped water in the Ogallala aquifer. The needs identified for users in the county are associated with expected declines in production of existing wells. With further development of water from the Ogallala aquifer, Lipscomb County can fully meet its projected water needs. While irrigation does not have a need over the planning period, it is recommended that conservation measures identified in Chapter 5B be implemented to preserve the groundwater supplies for future use. Conservation is not recommended for County-Other because there is no specific sponsor. Table 5D-35 shows the recommended water plan for Lipscomb County.

Table 5D-36: Lipscomb County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Booker	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
County-Other	Ogallala aquifer	No	None
Darrouzett	Ogallala aquifer	No	Municipal conservation
Follett	Ogallala aquifer	No	Municipal conservation
Higgins Municipal Water System	Ogallala aquifer	No	Municipal conservation
Irrigation	Ogallala aquifer and Canadian River water rights	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds and irrigation)	No	None
Manufacturing	Ogallala aquifer	Yes	Purchase from Booker
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.14 Moore County



Moore County is located in the northwest portion of the PWPA. It is one of the four larger irrigation counties in the region. Agricultural water use accounts for 90 percent of the water used in the county. The largest city in Moore County is Dumas with a 2017 population of 14,785 and a projected total water demand of 3,584 acre-feet per year in 2020 increasing to 6,011 acre-feet per year in 2070.

The Ogallala aquifer provides nearly all of the water supplies in Moore County. The cities of Cactus, Dumas and Sunray are member cities of the PDWD, but they currently do not receive water from PDWD.

Due to the competition for water, Moore County is shown to have a need of 10,522 acre-feet per year in 2020 and increasing to 50,962 acre-feet per year by 2070. Irrigation and manufacturing are the uses with the largest needs, but municipal use also shows need beginning in 2020. Further development of the Ogallala in the later decades is contingent upon water saved in earlier decades.

5D.14.1 Cactus

The City of Cactus in Moore County is a member of the PDWD and a Major Water Provider to manufacturing users in Moore County. The current supply for Cactus is the Ogallala aquifer in Moore County. Cactus is expected to need additional water supplies beginning in 2020 to serve its municipal and industrial customers. The recommended water management strategies for the City of Cactus are water conservation and development of additional groundwater from the Ogallala. Discussion of these strategies is found in Section 5C.4.

5D.14.2 Dumas

The City of Dumas is located in Moore County and is the largest member city of the PDWD. Currently, Dumas obtains its water supply from its own wells in the Ogallala aquifer in Hartley and Moore County. Dumas is expected to need additional water to meet its demand throughout the planning period (2020-2070). By 2070, the projected needs for Dumas are 4,982 acre-feet per year. Dumas has approximately 27,800 acre-feet per year of undeveloped groundwater rights in Hartley County that will be used to meet its need. To provide the full 4,982 acre-feet per year by 2070, the city may need to acquire additional water rights. The city intends to fully meet its projected demands with groundwater. As an alternate, Dumas may participate in the Palo Duro transmission project.

The potential water management strategies for Dumas include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Develop PDWD Transmission System

Drill Additional Groundwater Well(s)

This strategy assumes that six new wells would be drilled to provide approximately 5,000 acre-feet per year and are assumed to produce water from approximately 440 feet below the surface. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. The new wells will be drilled near the City's existing wells in Hartley County. Well field piping will be installed to connect to the current collection system. It is assumed that the existing pipeline is sufficient to transport the water to the city, but a booster pump station may be needed.

Time Intended to Complete

Some of the additional wells will be completed by 2030. This project will likely be implemented in phases, with new wells coming online as needed. For this plan, the strategy is shown in two phases.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 5,000 acre-feet per year with average well capacities of 690 gpm. Reliability of Ogallala supplies is moderate to moderate-low since availability depends on other water users and the well field is located in heavily irrigated area. For cost purposes, it is assumed that the new wells would be located within the existing well field. The capital cost for the additional groundwater well is approximately $5.5 million.

Environmental Issues

No significant environmental impact is expected for this strategy. The City already owns the water rights and no transmission system is included in this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To be able to use this water resource, other users will need to reduce their demands. There is insufficient water available in Moore County in the later decades without the reduction in irrigation water use associated with irrigation conservation. This strategy may impact other strategies that plan to develop Ogallala aquifer supplies in Moore County.

Impact on Agriculture and Natural Resources

Moderate impacts to agricultural use due to competition for water in the later decades. No significant impact on natural resources is expected for the recommended strategy. If additional water rights are needed, this strategy may reduce the irrigated acreage for farming. It is assumed that any purchase of water rights would be on a willing buyer-willing seller basis.

Other Relevant Factors

There are no other identified relevant factors.

Develop PDWD Transmission System

As a member of the PDWD, Dumas may be interested in developing a regional transmission system to use water from Palo Duro Reservoir. The Palo Duro Reservoir transmission project is an alternate strategy for Dumas. The project would have very little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Dumas is expected to have a capital cost of $85.1 million associated with their portion of the project.

Table 5D-37: Recommended Water Strategies for Dumas (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	931	2,008	3,267	4,432	4,982
Recommended Strategies							
Municipal Conservation[1]	$14.2	168	188	240	268	297	326
Drill Additional Groundwater Well(s)	$5.5	0	5,000	5,000	5,000	5,000	5,000
Total	**$19.7**	**168**	**5,188**	**5,240**	**5,268**	**5,297**	**5,326**

[1] Includes costs and water savings associated with Water Audits and Leak Repair

5D.14.3 Sunray

The City of Sunray currently obtains its water supply from the Ogallala aquifer in Moore County, and is also a member of PDWD. The projected needs for Sunray are 110 acre-feet per year in 2030 and increasing to 485 acre-feet per year by 2070. To meet these needs Sunray will need to develop additional groundwater. Alternatively, the city could also participate in the PDWD transmission project to use water from Palo Duro Reservoir.

The potential water management strategies for Sunray include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)
- Develop PDWD Transmission System

Drill Additional Groundwater Well(s)

To fully meet its needs Sunray will need to develop additional supply totaling approximately 500 acre-feet of water per year. Presently, Sunray owns 764 acre-feet per year of water rights within one mile from the City. At this time, Sunray does not have intentions of acquiring additional water rights. However, this strategy assumes that Sunray will purchase additional water rights to account for water developed from this strategy.

This strategy assumes that two new wells will be drilled near the City's existing wells and will produce water approximately 355 feet below the surface. Two miles of well field piping 8-inches in diameter will be installed to connect to the current collection system. The strategy accounts for the construction of a new 0.2-million-gallon storage tank to increase Sunray's current storage capacity. Minimal treatment such as chlorine disinfection is required for municipal use.

Time Intended to Complete

At least one of the additional wells will be completed by 2030. This project will likely be implemented in phases, with new wells coming online as needed. For this plan, the strategy is shown in one phase.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 500 acre-feet per year with average well capacities of 470 gpm. Reliability of Ogallala supplies is moderate to moderate-low since availability depends on other water users. For cost purposes, it is assumed that the new wells would be located near the existing wells. The capital cost for the additional groundwater wells is approximately $4.5 million.

Environmental Issues

No significant environmental impact is expected for this strategy. There is no transmission system included in this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To provide sufficient quantities of water in the later planning decades, other users will need to reduce their demands. It is assumed that irrigation water savings associated with irrigation conservation makes sufficient water available for this strategy.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for this strategy based on the relative quantity. If additional water rights are needed, this strategy may reduce the irrigated acreage for farming. It is assumed that any purchase of water rights would be on a willing buyer-willing seller basis.

Other Relevant Factors

There are no other identified relevant factors.

Develop PDWD Transmission System

As a member of the PDWD, Sunray is interested in developing a regional transmission system to use water from Palo Duro Reservoir. The Palo Duro Reservoir transmission project is an alternate strategy for Sunray. The project would have very little impact on the environment, agricultural or other natural resources. Once the pipeline route is established, a more detailed analysis of the impacts should be considered. No interbasin transfer permits would be required for the Palo Duro transmission project. The use of this supply might decrease lake levels and impact recreation uses on the lake from time to time. No other impacts are expected from this project. Sunray is expected to have a capital cost of $17.1 million associated with their portion of the project.

Table 5D-38: Recommended Water Strategies for Sunray (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	110	336	415	470	485
Recommended Strategies							
Municipal Conservation	N/A	6	6	6	7	7	7
Drill Additional Groundwater Well(s)	$4.5	0	500	500	500	500	500
Total	**$4.5**	**6**	**506**	**506**	**507**	**507**	**507**

5D.14.4 Moore County-Other

Moore County-Other consists of rural water users that live outside of an incorporated town or in a town with a population of less than 500 people. Moore County-Other is shown to have a small need beginning in 2030. The maximum amount of the needs is 41 acre-feet per year. Some water is provided to County-Other users from the City of Dumas. The majority of Moore County-Other supply is from unincorporated rural wells in the Ogallala aquifer. The shortage shown for Moore County-Other is associated with the shortage on Dumas, which will be met by the strategies developed by Dumas.

Table 5D-39: Recommended Water Strategies for Moore County-Other (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	12	23	33	41	41
Recommended Strategies							
Municipal Conservation	N/A	7	8	9	10	11	12
Dumas contractual supplies	N/A	0	12	23	33	41	41
Total	**N/A**	**7**	**20**	**32**	**43**	**52**	**53**

5D.14.5 Moore County Manufacturing

The manufacturing needs in Moore County range from 1,008 acre-feet per year in 2020 to 5,785 acre-feet per year in 2070. Some of these needs are associated with needs for the City of Cactus, which will be met through the City of Cactus' water management strategies. The City of Cactus is a Major Water Provider and water management strategies for this entity are discussed in Section 5C.4. By 2030, manufacturing demands will exceed the supplies provided by the City of Cactus. It is assumed that these demands will be self-supplied through additional groundwater development.

The potential water management strategies for Moore County Manufacturing include:

- Purchase water from Cactus (see Section 5C.4)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that six new wells will be drilled near the location of need. There is limited groundwater available from the Ogallala aquifer in the later decades in Moore County. There is some available water from the Dockum aquifer. It is assumed that some of the new water for Manufacturing will be from the Ogallala and some from the Dockum. Since Manufacturing is an aggregated water user group, the number of wells and locations are difficult to assess. For purposes of this plan, the strategy has no transmission and minimal well field piping.

Time Intended to Complete

This strategy will likely be phased beginning in 2050, but the costs and quantities are developed in one phase.

Quantity, Reliability and Cost

The quantity of water from these wells should be able to produce a total of 3,000 acre-feet per year with average well capacities of 450 gpm. Reliability of Ogallala supplies is low to moderate since availability depends on other water users. It is assumed that that this strategy develops 1,000 acre-feet per year from the Ogallala aquifer and 2,000 acre-feet per year from the Dockum aquifer. The capital cost for the additional groundwater wells is approximately $3.6 million.

Environmental Issues

No significant environmental impact is expected for this strategy. There is no transmission system included in this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on groundwater will continue to deplete the storage in the aquifers. Competition for water in Moore County may impact other strategies. The MAG values were respected in developing these strategies, which should mitigate impacts.

Impact on Agriculture and Natural Resources

At the level of additional water development, no significant impact on agricultural or natural resources is expected for the recommended strategies.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-40: Recommended Water Strategies for Moore County Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		1,008	1,773	2,221	4,131	5,769	5,785
Recommended Strategies							
Purchase from Cactus	N/A	1,008	1,773	2,221	2,610	2,841	2,857
Drill Additional Groundwater Well(s) Ogallala	$3.6	0	0	0	1,000	1,000	1,000
Drill Additional Groundwater Well(s) Dockum		0	0	0	2,000	2,000	2,000
Total	**$3.6**	**1,008**	**1,773**	**2,221**	**5,610**	**5,841**	**5,857**

Moore County Irrigation

The irrigation needs in Moore County range from 9,208 acre-feet per year in 2020 to 38,281 acre-feet per year in 2070. These needs can be fully met through conservation, with the exception of 2030. A summary of the projected water needs and strategies for Moore County Irrigation is shown in Table 5D-40. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-41: Recommended Water Strategies for Moore County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		9,208	47,976	49,251	43,861	38,281	38,281
Recommended Strategies							
Irrigation Conservation	$4.7	16,630	29,092	57,177	64,138	59,240	60,841
Total	**$4.7**	**16,630**	**29,092**	**57,177**	**64,138**	**59,240**	**60,841**

5D.14.6 Moore County Summary

The preferred source of water for Moore County is the Ogallala aquifer. This source is heavily used by current users, such that by 2070, the undeveloped supply in the entire county is estimated at 2,000 acre-feet per year. This is not enough water to fully meet the county's projected needs. Conservation provides a means to balance the water supplies among users. Irrigation conservation can save over 60,000 acre-feet pear year of Ogallala water by 2070 in Moore County. Some of this water savings would become available to other users. Collectively, the municipal water users (including Cactus) are expected to develop approximately 13,000 acre-feet per year of new supplies from the Ogallala in Moore County. This water is proposed to come from the irrigation water conservation savings. With active conservation, Moore County can meet the projected water needs.

The water plan for Moore County is shown in Table 5D-41.

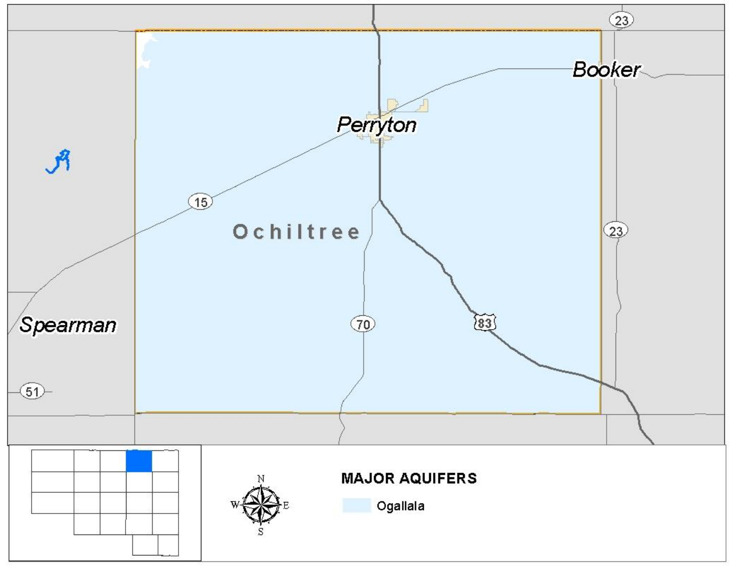
Table 5D-42: Moore County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Cactus	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
County-Other	Ogallala aquifer	Yes	Municipal conservation, Purchase from Dumas
Dumas	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Fritch	Ogallala aquifer	No	Municipal conservation (See Section 5D.12)
Irrigation	Ogallala and Dockum aquifers, Canadian River water rights	Yes	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	Yes	Purchase from Cactus, Drill additional groundwater well(s) in Ogallala and Dockum aquifers
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-
Sunray	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)

Table 5D-43: Unmet Water Needs in Moore County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	0	(23,884)	0	0	0	0

5D.15 Ochiltree County



Ochiltree County is located on the Texas-Oklahoma border in the northern part of the PWPA. The largest city in the county is Perryton, with a 2017 population of 8,683 and a projected total demand of 2,693 acre-feet per year in 2020 increasing to 3,734 acre-feet per year in 2070.

The primary source of water in Ochiltree County is the Ogallala aquifer. Only about 40 percent of the current available supply in the county has been developed.

Perryton Municipal Water System is shown to have a need starting in 2050 due to declining production of its well field, and City of Booker is shown to have a need starting in 2040. Note that Booker's strategies are summarized with Lipscomb County in Section 5D.13.

5D.15.1 Perryton Municipal Water System

Perryton Municipal Water System currently obtains its water from the Ogallala aquifer in Ochiltree County. Perryton is showing a need of 815 acre-feet per year by 2070. Some of this need may be able to be met through conservation, but Perryton will need to develop additional groundwater supplies. Perryton is developing additional supplies from the Ogallala aquifer to help meet the growing water demands and replace production losses of the existing well field. The potential water management strategies for Perryton include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that three new wells would be drilled to provide approximately 820 acre-feet per year, and the wells are assumed to produce water from approximately 530 feet below the surface. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. It is assumed that the new wells will be drilled near the city's existing wells in Ochiltree County, but the exact location is uncertain or if the city has sufficient water rights to expand its existing well field. For this plan, it is assumed that a new well field will be developed within ten miles of Perryton's existing infrastructure. The strategy includes a ten-mile 12-inch pipeline to transport the water to the city.

Time Intended to Complete

This project will likely be implemented in phases, with new wells coming on-line as needed. For this plan, the strategy is shown in one phase with an online date of 2050.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 820 acre-feet per year with average well capacities of 490 gpm. Reliability of Ogallala supplies is high. The capital cost for the additional groundwater well is approximately $9.1 million.

Environmental Issues

No significant environmental impact is expected for this strategy.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. There is sufficient undeveloped water in the Ogallala aquifer in Ochiltree County.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategies. If additional water rights are needed, this strategy may reduce the irrigated acreage for farming. It is assumed that any purchase of water rights would be on a willing buyer-willing seller basis.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-44: Recommended Water Strategies for Perryton (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	193	556	815
Recommended Strategies							
Municipal Conservation	N/A	28	31	33	35	38	41
Drill Additional Groundwater Well(s)	$9.1	0	0	0	820	820	820
Total	**$9.1**	**28**	**31**	**33**	**855**	**858**	**861**

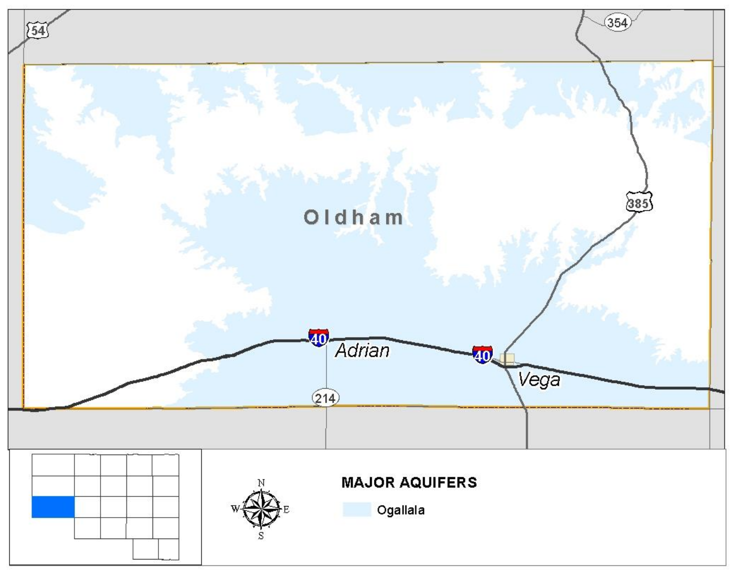
5D.15.2 Ochiltree County Summary

Ochiltree County has plenty of undeveloped water in the Ogallala aquifer. The needs identified for the City of Perryton are associated with expected declines in production of existing wells and increases in demands. With further development of water from the Ogallala aquifer, Ochiltree County can fully meet its projected water needs. While irrigation does not have a need over the planning period, it is recommended that conservation measures identified in Chapter 5B be implemented to preserve the groundwater supplies for future use. Conservation is not recommended for County-Other because there is no specific sponsor. Table 5D-44 shows the recommended water plan for Ochiltree County.

Table 5D-45: Ochiltree County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Booker	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s) (See Section 5D.13)
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None
Perryton	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)
Steam Electric	None	-	-

5D.16 Oldham County



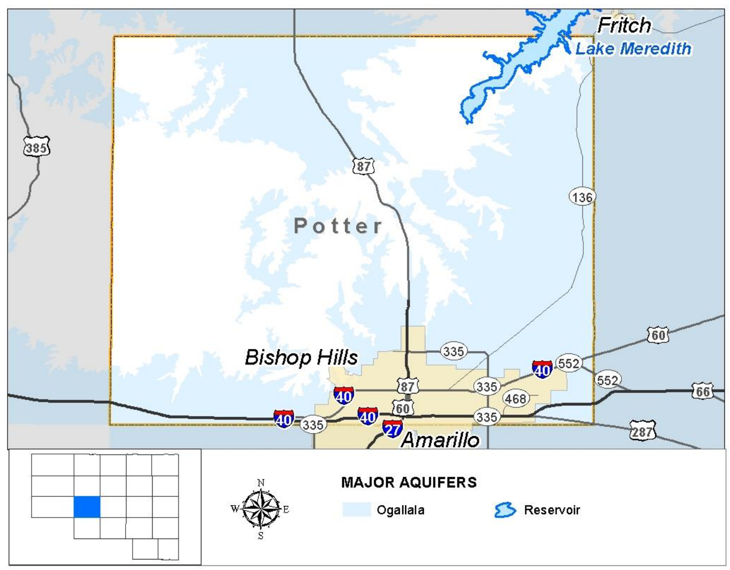
Oldham County is located in the far southwestern part of the region. The county borders New Mexico to the west and the Llano Estacado Region to the south. A geologic break in the Ogallala aquifer occurs in Oldham County, resulting in large non-productive areas in the county. The largest city in Oldham County is the City of Vega, with a 2017 population of less than 1,000, and a projected total demand of 292 acre-feet per year in 2020 and 282 acre-feet per year in 2070.

Most of the water supply in Oldham County is obtained from the Ogallala and Dockum aquifers. The county has sufficient supplies to meet the projected demands through the planning period. Conservation is recommended for the City of Vega and irrigation use. Water saved through these measures can be used for future needs. Conservation measures are discussed in Chapter 5B. Table 5D-45 shows the recommended water plan for Oldham County.

Table 5D-46: Oldham County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala and Dockum aquifers	No	None
Irrigation	Ogallala and Dockum aquifers	No	Irrigation conservation
Livestock	Ogallala and Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala and Dockum aquifers	No	None
Steam Electric	None	-	-
Vega	Ogallala aquifer	No	Municipal conservation

5D.17 Potter County



Potter County is located along the southern boundary of the Canadian River Basin. The Canadian River runs through Potter County and flows into Lake Meredith to the northeast. A geologic break in the Ogallala aquifer occurs in Potter County, resulting in large non-productive areas in the county. Amarillo is the largest city in Potter County with a 2017 population of over 200,000, of which slightly more than half is located in Potter County. The remaining population is in Randall County. Amarillo has a projected total demand of 49,454 acre-feet per year in 2020 (of which 27,293 is based out of Potter County), increasing to 76,402 acre-feet per year in 2070 (of which 42,033 is based out of Potter County).

Most of the demands in Potter County are associated with the City of Amarillo and Steam Electric Power. Amarillo obtains much of its water supplies from outside of the county through CRMWA and multiple well fields in Carson, Potter, Randall and Deaf Smith Counties. All of the Steam Electric Power demands are met from reuse from Amarillo. The remaining in-county water users obtain water from the Ogallala and Dockum aquifers. There is some additional reuse and local supplies used for irrigated agriculture, livestock use, and manufacturing.

Potter County is found to have a projected need of 24,263 acre-feet per year by 2070, most of which is associated with the City of Amarillo. Some manufacturing water use will not be served by Amarillo and strategies will need to be developed.

5D.17.1 Amarillo

The City of Amarillo is a water user group and a Major Water Provider in the PWPA. The current sources of water include well fields in the Ogallala aquifer, reuse, and purchasing surface water and groundwater from the Canadian River Municipal Water Authority (CRMWA). The recommended strategies for the City of Amarillo include water conservation, the development of Phase 2 of the Potter/ Carson County well field, developing reuse supplies, developing the Roberts County well field, and utilizing aquifer storage and recovery to more efficiently utilize their water sources. Additional information regarding Amarillo's recommended strategies is found in Section 5C.2.

5D.17.2 Potter County Manufacturing

The current supplies for manufacturing in Potter County include self-supplied Ogallala water, Dockum water, and water purchased from Amarillo. Much of the water for manufacturing is currently supplied by the City of Amarillo via contracts to Tyson and ASARCO, Inc. The projected needs for Potter County Manufacturing are 629 acre-feet per year in 2030, increasing to 3,209 acre-feet per year in 2070. Of these needs, Amarillo is expected to meet up to 3,064 acre-feet per year of the need through strategies developed by Amarillo. The remaining shortage would be met with new strategies. The quantity of need is less than 150 acre-feet per year. It is likely that this need would be met through additional groundwater development. The potential water management strategies for Potter County Manufacturing include:

- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

This strategy assumes that two new wells would be drilled to provide approximately 150 acre-feet per year, and the wells are assumed to produce water from approximately 335 feet below the surface. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. It is assumed that the new wells will be drilled proximal to the City of Amarillo, but the exact location is uncertain. This groundwater strategy assumes that additional water rights are already owned by the individual manufacturers. The strategy includes a 6-inch well field collection system.

Time Intended to Complete

This strategy would be completed by 2040. Manufacturers will likely develop these wells on a case by case basis as they are needed. However, for the purposes of this plan, this strategy and the costs were developed as one phase.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 150 acre-feet per year with average well capacities of 100 gpm. Reliability of Ogallala supplies is moderate since availability depends on competition from other water users. The capital cost for the additional groundwater wells is approximately $0.3 million.

Environmental Issues

No significant environmental impact is expected for the recommended strategies. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. There is sufficient undeveloped water in the Ogallala aquifer in Potter County.

Impact on Agriculture and Natural Resources

This strategy may reduce the irrigated acreage for farming if additional water rights acreage is purchased. This acreage could be used for dry land farming if needed but may require crop changes.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-47: Recommended Water Strategies for Potter County Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	629	1,471	2,327	2,951	3,209
Recommended Strategies							
Amarillo's existing contracts	N/A	0	643	1,430	2,235	2,805	3,064
Drill Additional Well(s)	$0.3	0	0	150	150	150	150
Total	**$0.3**	**0**	**643**	**1,580**	**2,385**	**2,955**	**3,214**

5D.17.3 Potter County Summary

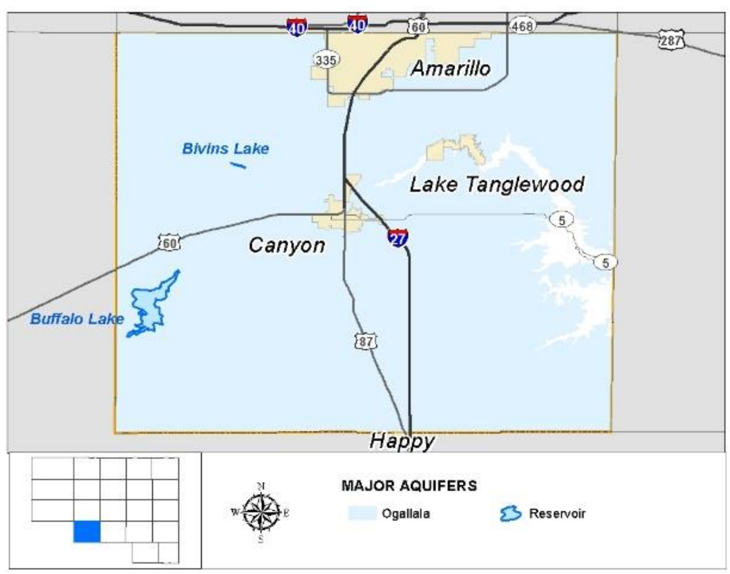
Potter County has a projected need of 24,263 acre-feet per year by 2070. Most of this need is associated with the City of Amarillo and will be met through their strategies which are discussed in Section 5C.2. The remainder of the need will be met by municipal conservation, drilling of additional wells and contractual supplies from CRMWA. Manufacturing needs will be met with purchases from Amarillo for potable and reuse supplies. While irrigation does not have a projected need, conservation is recommended. The recommended water plan for Potter County is shown in Table 5D-47.

Table 5D-48: Potter County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Amarillo	Ogallala aquifer and CRMWA system	Yes	Roberts and Potter/Carson Counties well fields, ASR, reuse, municipal conservation, and contracted supplies from CRMWA
County-Other	Ogallala and Dockum aquifers	No	None
Irrigation	Ogallala aquifer, local supply and reuse	No	Irrigation conservation
Livestock	Ogallala and Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	Ogallala and Dockum aquifers, reuse, and CRMWA system	Yes	Obtain contracted supplies from Amarillo and develop additional groundwater (Ogallala)
Mining	Ogallala aquifer	No	None
Steam Electric	Reuse	No	None

5D.18 Randall County

Randall County is located in the southern portion of the PWPA. Amarillo is a major population center for the County. Slightly less than half of Amarillo's 200,000 people reside in Randall County. The remaining portion of the population live in Potter County. Amarillo has a projected total demand of 49,454 acre-feet per year in 2020 (of which 22,161 is based out of Randall County), increasing to 76,402 acre-feet per year in 2070 (of which 34,369 is based out of Randall County). Other towns in Randall County include Canyon and Lake Tanglewood. A small portion of the City of Happy falls in Randall County but it is being planned for by the Llano Estacado Region, where it is primarily located.



Current sources of water include the Ogallala aquifer, Dockum aquifer, reuse, and supplies from CRMWA's system.

Several water users show needs over the planning period due to increasing demands and declining water levels over time within the user's existing well fields. Needs are projected for Amarillo, Canyon, and Randall County Manufacturing.

5D.18.1 Amarillo

The City of Amarillo is a water user group and a Major Water Provider in Region A. The current sources of water include well fields in the Ogallala aquifer, reuse, and purchasing surface water and groundwater from CRMWA. The recommended strategies for the City of Amarillo include water conservation, the development of the Potter County Phase II well field, expansion of Carson County well field, and development of the Roberts County well field. Additional information regarding Amarillo's recommended strategies is found in Section 5C.2.

5D.18.2 Canyon

Canyon currently buys water from the City of Amarillo, as well as using groundwater from its own wells in the Ogallala and Dockum aquifers. Canyon is shown to have needs beginning in 2030 with a projected need of 3,171 acre-feet per year by 2070. The potential water management strategies for Canyon include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

The City is in the process of expanding their existing Kim Road Well Field and developing the Rockwell Road Well Field at the writing of this plan. These wells will produce from the Dockum aquifer. It is estimated that seven wells will be drilled in the Dockum and Ogallala aquifers by 2070 to provide an estimated 3,000 acre-feet per year of additional water supply. This cost includes connection piping and a storage tank. The City, also, is currently actively pursuing additional groundwater rights.

Time Intended to Complete

The City is currently in the process of developing and constructing a significant portion of this supply now. For planning purposes, the strategy cost and supplies are developed in two phases, with the first phase online by 2030. However, the city may choose to drill the wells in multiple phases.

Quantity, Reliability, and Cost

The total quantity of water from this strategy is 3,000 acre-feet per year, which would be implemented in two equal phases and should be sufficient to meet the City's needs. The reliability of the additional supply from groundwater is moderate. There is competition for groundwater in Randall County which can impact the long-term reliability of this source. The capital cost for additional infrastructure is estimated at $9.5 million with a unit cost of water at $564 per acre-foot.

Environmental Issues

No significant environmental impacts are expected as a result of drilling the additional wells.

Impact on Water Resources and Other Management Strategies

Long-term water quality of the Ogallala and Dockum aquifer in Randall County is unknown. Throughout much of the aquifer, groundwater withdrawals exceed the amount of recharge, and water levels have declined consistently through time. This strategy will place additional demands on these sources, which will continue to deplete available storage. The strategy is not expected to have significant impacts on other management strategies.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategies.

Other Relevant Factors

There are no other relevant factors associated with these strategies.

Table 5D-49: Recommended Water Strategies for Canyon (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	54	696	1,364	2,578	3,171
Recommended Strategies							
Municipal Conservation[1]	$11.7	219	242	264	316	347	378
Contractual supplies from Amarillo	$0	0	105	234	365	0	0
Drill Additional Groundwater Well(s)	$9.5	0	1,500	1,500	1,500	3,000	3,000
Total	**$22.2**	**219**	**1,847**	**1,998**	**2,181**	**3,347**	**3,378**

[1] Includes costs and water savings associated with Water Audits and Leak Repair

5D.18.3 Randall County Manufacturing

Randall County manufacturers currently get water supply from the Ogallala aquifer in Randall County and from the City of Amarillo's supplies. Randall County manufacturing users have needs ranging from 151 to 379 acre-feet per year beginning in 2030 due to increasing demands and limited supplies from Amarillo. Through existing contracts, Amarillo is expected to provide most of this need. To meet the remaining 100 acre-feet per year need, the potentially feasible water management strategies considered for Randall County Manufacturing include:

- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

To meet the projected needs for manufacturing, groundwater wells will likely need to be expanded and/or improved to access additional water. This groundwater strategy assumes that additional water rights are already owned by the individual manufacturers and includes the development of two new wells in the Ogallala aquifer. The two new wells would be drilled to provide approximately 100 acre-feet per year and are assumed to produce water approximately 500 feet below the surface.

Time Intended to Complete

This strategy would be completed by 2030. Manufacturers will likely develop these wells on a case by case basis as they are needed. However, for the purposes of this plan, this strategy and the costs were developed as one phase.

Quantity, Reliability and Cost

The quantity of water from these strategies should be sufficient. Each well is estimated to produce 100 gpm. Reliability of Ogallala supplies is moderate since availability depends on competition from other water users. The capital cost for additional groundwater wells is approximately $0.4 million.

Environmental Issues

No significant environmental impact is expected for the recommended strategies. Once the specific locations of additional wells and alignments associated with infrastructure are identified, a detailed evaluation to determine environmental impacts, if any, will need to be performed.

Impact on Water Resources and Other Management Strategies

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. To prolong the life of this water resource, other users may need to reduce their demands.

Impact on Agriculture and Natural Resources

This strategy may reduce the irrigated acreage for farming if additional water rights acreage is purchased. This acreage could be used for dry land farming if needed but may require crop changes.

Other Relevant Factors

None identified.

Table 5D-50: Recommended Water Strategies for Randall County Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	151	225	300	354	379
Recommended Strategies							
Contractual supplies from Amarillo	N/A	0	61	135	210	264	289
Drill Additional Groundwater Well(s)	$0.4	0	100	100	100	100	100
Total	**$0.4**	**0**	**161**	**135**	**310**	**364**	**389**

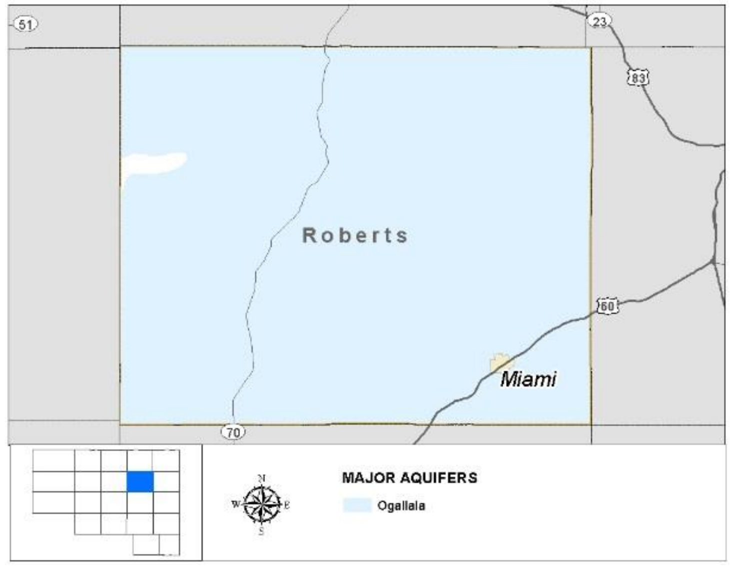
5D.18.4 Randall County Summary

Randall County has a projected need of over 20,000 acre-feet per year by 2070. Most of this need is associated with the City of Amarillo and will be met through their strategies which are discussed in Section 5C.2. The remainder of the need will be met by municipal conservation and drilling of additional wells in the Ogallala aquifer in Randall County. While irrigation does not have a projected need, conservation is recommended to reduce the demands on the limited resource in Randall County. The recommended water plan for Randall County is shown in Table 5D-50.

Table 5D-51: Randall County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Amarillo	Ogallala aquifer and CRMWA system	Yes	Roberts and Carson/Potter Counties well fields, ASR, reuse, municipal conservation, and contracted supplies from CRMWA
Canyon	Ogallala and Dockum aquifers, and CRMWA system	Yes	Drill additional groundwater well(s), Municipal conservation
County-Other	Ogallala aquifer and CRMWA system	No	None
Irrigation	Ogallala and Dockum aquifers, Red River water rights, and reuse	No	Irrigation conservation
Lake Tanglewood	Ogallala and Dockum aquifers	No	Municipal conservation
Livestock	Ogallala and Dockum aquifers, and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer & CRMWA system	Yes	Drill additional groundwater well(s), Contractual supplies from Amarillo
Mining	None	-	-
Steam Electric	None	-	-

5D.19 Roberts County



Roberts County is located in the northeastern portion of the PWPA. The population of Roberts County is about 1,000 people of which, 600 live in Miami. Miami has a projected total water demand of 225 acre-feet per year in 2020 and 223 acre-feet per year in 2070.

Nearly all of Roberts County's water supply is derived from the Ogallala aquifer. Small amounts of surface water are used from the Canadian Run-of-River for irrigation as well as small amounts from livestock local supplies for ranching operations.

Roberts County is water rich and has plenty of water in storage in the Ogallala aquifer to meet the County's water demands. In addition to demands stemming from within the county, groundwater from Roberts County is also used to supply customers of CRMWA including Amarillo. CRMWA holds a large quantity of water rights in Roberts County and plans to expand their existing well field. The City of Amarillo also holds unused water rights in Roberts County with the intention to develop these rights by 2065. Additional information on the Major Water Provider strategies in Roberts County can be found in Sections 5C.1.1 and 5C.2.2.

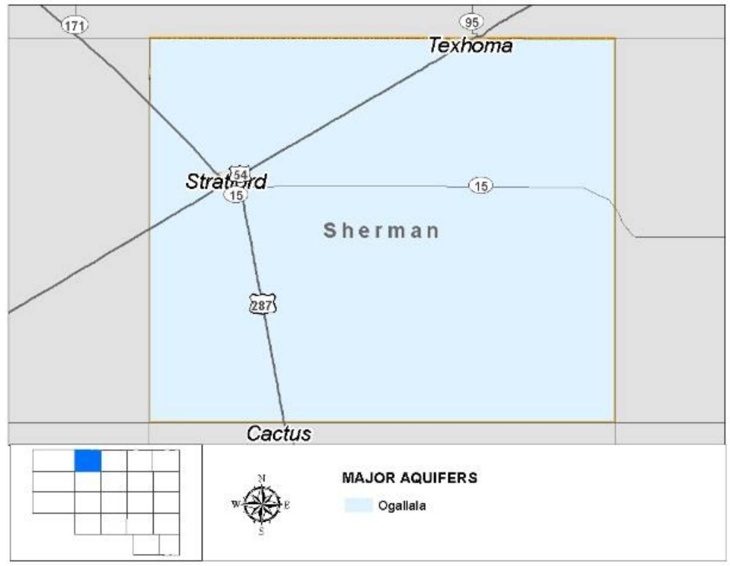
Roberts County has ample supply to support all current and future projected demands. The only strategy recommended for Roberts County is municipal and irrigation conservation.

Table 5D-52: Roberts County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer, Canadian River water rights, and reuse	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Miami	Ogallala aquifer	No	Municipal conservation
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.20 Sherman County

Sherman County is located in the northwestern part of the PWPA. Stratford is the largest city in Sherman County with a 2017 population of approximately 2,100, which accounts for about two thirds of the County's total population. Stratford has a projected total demand of 496 acre-feet per year in 2020, increasing to 577 acre-feet per year in 2070.



Sherman County is one of the larger irrigation water users in the region. The primary source of water in the county is the Ogallala aquifer. Smaller quantities of local Canadian Run-of-River and local livestock supply are also used in the county.

There is plenty of water available from the Ogallala aquifer in Sherman County, but the use is concentrated in the heavily irrigated areas, which may result in great competition and some water declines over time. Sherman County is projected to have needs of up to 38,000 acre-feet per year over the planning period, all attributed to Sherman County Irrigation. Irrigation conservation is recommended as a way to preserve water for future use.

5D.20.1 Sherman County Irrigation

The irrigation needs in Sherman County range from 29,567 acre-feet per year in 2040 to 38,423 acre-feet per year in 2070. These needs can be fully met through conservation. A summary of the projected water needs and strategies for Sherman County Irrigation is shown in Table 5D-52. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-53: Recommended Water Strategies for Sherman County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	29,567	38,831	38,207	38,423
Recommended Strategies							
Irrigation Conservation	$7.4	25,895	45,383	88,429	103,368	104,313	111,300
Total	**$7.4**	**25,895**	**45,383**	**88,429**	**103,368**	**104,313**	**111,300**

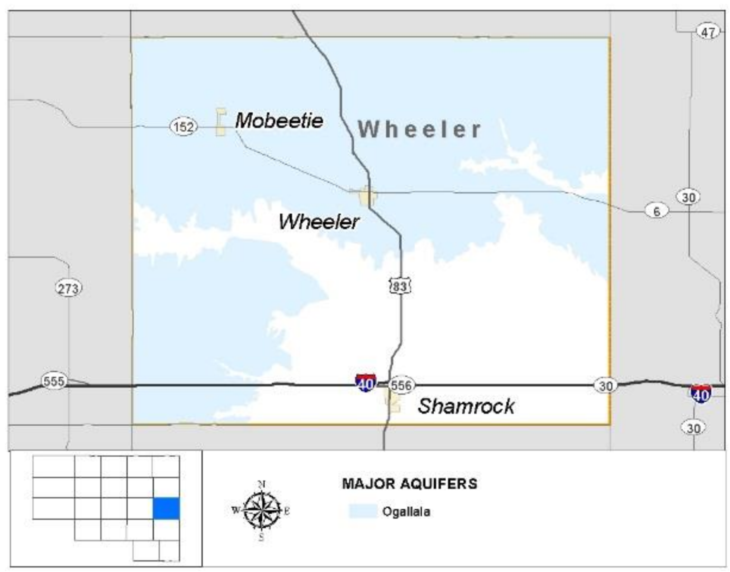
5D.20.2 Sherman County Summary

Sherman County has a projected need of over 38,000 acre-feet by 2070, all associated with Sherman County Irrigation. A summary of the water plan for Sherman County is shown in Table 5D-53.

Table 5D-54: Sherman County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala and Dockum aquifers, and Canadian River water rights	Yes	Irrigation conservation
Livestock	Ogallala aquifer and local supply (irrigation and stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-
Stratford	Ogallala aquifer	No	Municipal conservation
Texhoma	Ogallala aquifer	No	Municipal conservation

5D.21 Wheeler County



Wheeler County is located on the eastern edge of the PWPA. Shamrock is the largest city in Wheeler County, with a 2017 population of nearly 2,000 people and a projected total demand of 350 acre-feet per year in 2020 and 397 acre-feet per year in 2070.

Most of the water supplies for Wheeler County are derived from the Ogallala aquifer. However, the Blaine, as well as other undefined aquifers, also contribute to the water supply. A small amount of reuse water is used for irrigation. Irrigation demands in Wheeler County also use Red River supplies.

Shamrock shows no need over the planning period. The next largest city is Wheeler, with a 2017 population of approximately 1,600 people. Wheeler is the only entity to show a need in the county.

5D.21.1 Wheeler

The City of Wheeler is shown to have a water need beginning in 2050 and reaching a peak need of 153 acre-feet per year by 2070. This need is due to declining water levels in the City's current well field. The City of Wheeler is evaluating a groundwater source in the Ogallala aquifer to back up its current supplies.

The potential strategies for Wheeler are:

- Municipal Conservation (See Section 5B.1)
- Drill Additional Groundwater Well(s)

Drill Additional Groundwater Well(s)

City of Wheeler is to develop additional groundwater from the Ogallala aquifer with new wells and associated transmission. For planning purposes, it is assumed that two new wells and two miles of pipeline will be necessary to meet the City's water needs. These two new wells will provide approximately 160 acre-feet per year and will produce water approximately 150 feet below the surface. Minimal treatment such as chlorine disinfection will be required.

Time Intended to Complete

This strategy would be completed by 2050. The City may elect to drill the wells in phases if needed, but the strategy costs and supplies are developed for one phase.

Quantity, Reliability, and Cost

The quantity and reliability of water from this source is expected to be approximately 400 gpm and provide up to 160 acre-feet per year. Reliability of Ogallala supplies is high to moderate. There is plenty of supply in Wheeler County, but there may be potential competing demands. The capital cost for the additional groundwater wells and collection piping is $2.7 million.

Environmental Issues

Groundwater development from this source is expected to cause minimal environmental impacts.

Impact on Water Resources and Other Management Strategies

This strategy is assumed to have a minimal impact on the Ogallala aquifer and other surrounding water resources.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for the recommended strategy.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-55: Recommended Water Strategies for Wheeler (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	47	132	153
Recommended Strategies							
Municipal Conservation	N/A	5	5	5	5	6	6
Drill Additional Groundwater Well(s)	$2.7	0	0	0	160	160	160
Total	**$2.7**	**5**	**5**	**5**	**165**	**166**	**166**

5D.21.2 Wheeler County Summary

Wheeler County has a total projected water need of 153 acre-feet per year by 2070, all of which is associated with the City of Wheeler. The county's primary source of water, Ogallala aquifer has over 100,000 acre-feet per year of water that is not currently developed and could be used to meet water needs. With development of additional Ogallala supplies, there are no needs.

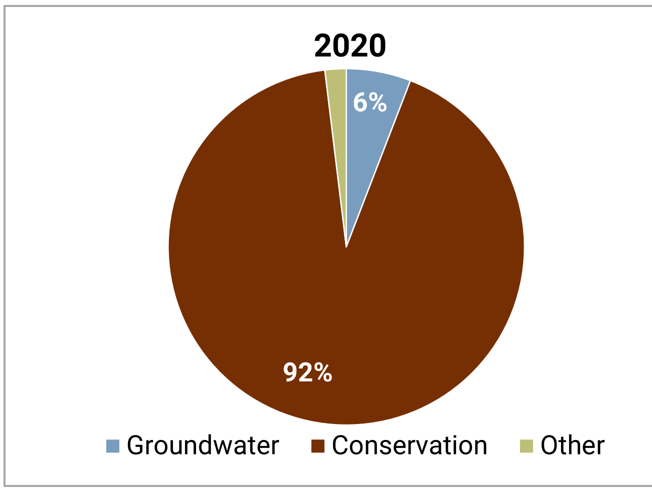
Table 5D-56: Wheeler County Water Management Plan

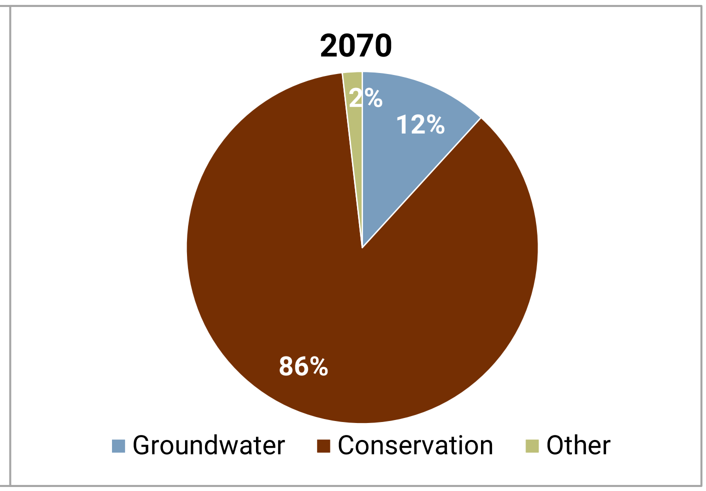
Water User Group	Current Supplies	Need	Proposed Water Management Strategies
County-Other	Ogallala, Blaine, and Other aquifers	No	None
Irrigation	Ogallala, Blaine, and Other aquifer, Red River water rights, and reuse	No	Irrigation conservation
Livestock	Ogallala, Blaine, and Other aquifers, and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
Shamrock	Ogallala aquifer	No	Municipal conservation
Steam Electric	None	-	-
Wheeler	Ogallala aquifer	Yes	Municipal conservation, Drill additional groundwater well(s)

5D.22 PWPA Water Management Strategies Summary

Conservation (both irrigation and municipal) is a crucial component to the viability of the PWPA. Water conservation is recommended for all municipal water users (except County-Other users without a need) and irrigation water users, whether the user has a defined need or not, and it is encouraged for all other users. In total, conservation accounts for nearly 147,000 acre-feet per year of water savings in 2020, growing to 574,000 acre-feet per year of water savings in 2070.

Groundwater development strategies represent an important part of the portfolio of PWPA strategies, with significant developments proposed by the major water providers and smaller expansions of groundwater use by water user groups. Other strategies recommended for implementation include Aquifer Storage and Recovery, Reuse, Brush Control, and Water Treatment.





The recommended strategies will meet the projected needs for all water users except for irrigation in five counties. The projected unmet needs for the PWPA is shown on Table 5D-56.

Table 5D-57: Unmet Water Needs in PWPA

County	WUG	2020	2030	2040	2050	2060	2070
Collingsworth	Irrigation	(4,817)	(6,727)	(1,888)	(497)	(882)	0
Dallam	Irrigation	(5,257)	(73,088)	(27,937)	(3,966)	0	0
Hall	Irrigation	(13,739)	(11,300)	(5,080)	(962)	0	0
Hartley	Irrigation	(57,606)	(144,713)	(88,458)	(60,079)	(47,166)	(42,031)
Moore	Irrigation	0	(23,884)	0	0	0	0
	Total	**(81,419)**	**(259,712)**	**(123,363)**	**(65,504)**	**(48,048)**	**(42,031)**

ATTACHMENT 5-1

WATER MANAGEMENT STRATEGIES CONSIDERED AND EVALUATED

MEMORANDUM

FREESE AND NICHOLS

Innovative approaches
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TO: Panhandle Water Planning Group

CC: File

FROM: Simone Kiel

SUBJECT: Methodology to Identify Potentially Feasible Water Management Strategies

DATE: March 16, 2018

PROJECT: PPC16440

The Regional Water Planning rules requires each region to develop and document the process to identify potentially feasible water management strategies (PFWMS). This process is in addition to the process set forth by the TWDB to evaluate each PFWMS. This memorandum presents the proposed process to be used by the Panhandle Water Planning Group (PWPG).

For the Panhandle Water Planning Area (PWPA), the identification process for PFWMS will follow the sequence below:

1. Identify entities with needs
2. Review recommended strategies in previous Regional Water Plan (RWP)
3. Review new studies/ reports
4. Determine if new or changed strategies are needed
5. Review strategy types appropriate for the PWPA
6. Contact entity for input
7. Contact PWPG representative for county-wide WUGs
8. Verify recommendations

As required by TWC §16.053(e)(3), and 31 TAC §357.34(c) the RWPG shall consider a specified list of strategy types. This list includes 24 water management strategy types that require screening as part of the process for identifying PFWMS.[1]

While the TWDB list is comprehensive, not each strategy type is appropriate for every need, and some strategy types may not be appropriate for PWPA water users. To determine whether a strategy is potentially feasible, the first considerations are:

- A strategy must use proven technology and must be technically feasible.
- A strategy should have an identifiable sponsor.
- A strategy must consider end use. This includes water quality, economics, geographic constraints, etc. For example, long transmission systems to move water for agricultural use is not economically feasible.
- A strategy must meet existing regulations.

[1] First Amended General Guidelines for Fifth Cycle of Regional Water Plan Development, April 2017. Exhibit C to Contract between TWDB and PRPC, executed June 14, 2017.

The second consideration is whether a strategy would provide sufficient water to meet a projected need or a sizeable portion of the need. Considerations at this juncture include:

- Is there available existing supply that is not already allocated to another user?
- Can new water be developed? If yes, identify the potential sources.
- Does the water quality meet the end use requirements? If not, can it be treated?
- Are there any technical considerations that would preclude the feasibility of the strategy type? For example, are there suitable geologic formations for aquifer storage and recovery?

Strategy types that will be reviewed for consideration as potentially feasible for the PWPA include:

- Water conservation
    - Review for applicability and consider for all WUGs with a need
    - Consider water conservation for all municipal WUGs
    - Consider water conservation for all irrigation WUGs
- Reuse
    - Consider for WUGs with needs that generate a waste stream. This includes municipal, manufacturing and mining WUGs.
- Management of existing water supplies/System optimization
    - Consider for WUGs/WWPs that operate multiple water supply sources
- Conjunctive use
    - Consider for WUGs/WWPs that use or will use both surface water and groundwater sources
- Acquisition of available existing water supplies
    - Includes purchase of surface water and groundwater rights
- Developing regional water supply facilities or providing regional management of water supply facilities
- Developing large-scale desalination facilities for brackish groundwater that serve local or regional brackish groundwater production zones identified and designated under TWC §16.060(b)(5)
    - Consider for WUGs/WWPs that intend to develop large scale brackish groundwater for municipal use
- Voluntary transfer of water within the region using, but not limited to, contracts, water marketing, regional water banks, sales, leases, options, subordination agreements, and financing agreements
- Emergency transfer of water under TWC §11.139
- Enhancements of yields.
    - This may be considered with other strategies, such as Brush Control and Precipitation Enhancement
- Improvements to water quality
- New groundwater supply
- Interbasin transfers of surface water
    - This would likely be considered as part of a voluntary transfer of water strategy
- Brush control
- Precipitation enhancement
    - Consider for areas with an existing precipitation enhancement program
- Aquifer storage and recovery

There are several strategy types that likely are not appropriate for PWPA water users. However, they may be considered if a project sponsor requests a specific strategy.

- <u>Drought management.</u> Drought management is an emergency measure and is generally not recommended for long-term supply.
- <u>New surface water supply.</u> There are limited opportunities to develop new surface water supplies in the PWPA.

- Reallocation of reservoir storage to new uses. There are limited opportunities for reservoir storage reallocation in the PWPA.

Three strategy types identified by the TWDB are not appropriate for the PWPA. These include:

- Developing large-scale desalination facilities for marine seawater that serve local or regional entities. The PWPA does not have access to seawater.
- Cancellation of water rights. The run-of-river water rights in the Canadian River Basin and upper Red River Basin have little supply. Cancellation of water rights in the PWPA would not provide additional water.
- Rainwater harvesting. The average rainfall over the PWPA from west to east ranges from 14 to 24 inches per year. During drought there is very little rainfall. This is not a reliable strategy for the PWPA.

List of Potentially Feasible Strategies

Entity Name	Potentially Feasible WMS
Multiple Entities	Municipal Conservation
Multiple Entities	Irrigation Conservation
Multiple Entities	Palo Duro Reservoir Transmission System
Amarillo	Potter/Carson County Well Field - Phase 2
Amarillo	Roberts/Ochiltree Counties Well Field - Phased With CRMWA 2 Pipeline
Amarillo	Roberts/Ochiltree Counties Well Field - Independent
Amarillo	Aquifer Storage And Recovery
Amarillo	Direct Potable Reuse
Amarillo	Contractual Supplies (CRMWA)*
Booker	Drill Additional Groundwater Well
Borger	Contractual Supplies (CRMWA)*
Cactus	Drill Additional Groundwater Well
Canadian River Municipal Water Authority	Expansion of Roberts County Well Field (CRMWA 2 Pipeline, Phased With Amarillo)
Canadian River Municipal Water Authority	Well Field Capacity Replacement
Canadian River Municipal Water Authority	Aquifer Storage and Recovery
Canadian River Municipal Water Authority	Brush Control
Canyon	Drill Additional Groundwater Well
Canyon	Contractual Supplies (Amarillo)*
Childress	Contractual Supplies (Greenbelt)*
Clarendon	Contractual Supplies (Greenbelt)*
County Other (Hall)	Water Quality Improvements
County Other (Hall)	Drill Additional Groundwater Well
County Other (Moore)	Contractual Supplies (Dumas)*
Dalhart	Drill Additional Groundwater Well
Dumas	Drill Additional Groundwater Well

* Supplies will be met through fulfillment of contract amount by provider.

List of Potentially Feasible Strategies

Entity Name	Potentially Feasible WMS
Greenbelt Municipal & Industrial Water Authority	Develop New Groundwater Wellfield
Gruver	Drill Additional Groundwater Well
Manufacturing (Hutchinson)	Contractual Supplies (Borger)*
Manufacturing (Lipscomb)	Contractual Supplies (Booker)*
Manufacturing (Moore)	Contractual Supplies (Cactus)*
Manufacturing (Moore)	Drill Additional Groundwater Well
Manufacturing (Potter)	Contractual Supplies (Amarillo)*
Manufacturing (Potter)	Drill Additional Groundwater Well
Manufacturing (Randall)	Contractual Supplies (Amarillo)*
Mclean	Drill Additional Groundwater Well
Memphis	Drill Additional Groundwater Well
Pampa	Drill Additional Groundwater Well
Pampa	Aquifer Storage and Recovery
Pampa	Contractual Supplies (CRMWA)*
Panhandle	Drill Additional Groundwater Well
Perryton	Drill Additional Groundwater Well
Red River Authority (Childress)	Contractual Supplies (Greenbelt)*
Red River Authority (Donley)	Contractual Supplies (Greenbelt)*
Spearman	Drill Additional Groundwater Well
Stinnett	Drill Additional Groundwater Well
Sunray	Drill Additional Groundwater Well
TCW Supply Inc	Drill Additional Groundwater Well
Texline	Drill Additional Groundwater Well
Turkey	Drill Additional Groundwater Well
Wellington	Water Treatment For Nitrates
Wheeler	Drill Additional Groundwater Well

* Supplies will be met through fulfillment of contract amount by provider.

Water Management Strategies Considered and Evaluated

County	Identified WUG Need		WMSs Required To be Considered													
	WUG	Maximum Need 2020-2070 (ac-ft/yr)	Conservation	Reuse	Reallocation of storage	Voluntary Transfers	Conjunctive Use	Expansion of Existing Supplies	New Supplies	Regional Water Supply	Improvement of Water Quality	System Optimization, Subordination, Enhancement	Brush Control	Precipitation Enhancement	Desalination	Aquifer Storage and Recovery
Lipscomb, Ochiltree	Booker	242	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Randall	Canyon	3,171	●	○	○	●	○	○	●	○	○	○	○	○	○	○
Childress	Childress	344	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Donley	Clarendon	66	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Moore	County-Other (Moore)	41	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Hall	County-Other (Hall)	0	○	○	○	○	○	●	○	○	●	○	○	○	○	○
Dallam, Hartley	Dalhart	3,137	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Moore	Dumas	4,982	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Hansford	Gruver	280	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Collingsworth	Collingsworth County Irrigation	10,133	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Dallam	Dallam County Irrigation	116,358	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Gray	Gray County Irrigation	2,687	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Hall	Hall County Irrigation	15,637	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Hartley	Hartley County Irrigation	192,765	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Moore	Moore County Irrigation	49,251	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Sherman	Sherman County Irrigation	38,831	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Hutchinson	Hutchinson County Manufacturing	0	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Lipscomb	Lipscomb County Manufacturing	139	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Moore	Moore County Manufacturing	5,785	○	○	○	●	○	○	●	○	○	○	○	○	○	○
Potter	Potter County Manufacturing	3,209	○	○	○	●	○	○	●	○	○	○	○	○	○	○
Randall	Randall County Manufacturing	379	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Gray	McLean Municipal Water System	115	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Hall	Memphis	146	●	○	○	○	○	○	●	○	○	○	○	○	○	○

Water Management Strategies Considered and Evaluated

	Identified WUG Need		WMSs Required To be Considered													
County	WUG	Maximum Need 2020-2070 (ac-ft/yr)	Conservation	Reuse	Reallocation of storage	Voluntary Transfers	Conjunctive Use	Expansion of Existing Supplies	New Supplies	Regional Water Supply	Improvement of Water Quality	System Optimization, Subordination, Enhancement	Brush Control	Precipitation Enhancement	Desalination	Aquifer Storage and Recovery
Multiple	Palo Duro Water District	0	○	○	○	○	○	○	○	●	○	○	○	○	○	○
Gray	Pampa Municipal Water System	2,241	●	○	○	●	○	○	●	○	○	○	○	○	○	●
Carson	Panhandle Municipal Water System	586	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Ochiltree	Perryton Municipal Water System	815	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Childress	Red River Authority of Texas	49	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Hansford	Spearman Municipal Water System	517	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Hutchinson	Stinnett	31	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Moore	Sunray	485	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Hutchinson	TCW Supply	383	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Dallam	Texline	28	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Hall	Turkey	0	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Collingsworth	Wellington Municipal Water System	595	●	○	○	○	○	○	○	○	●	○	○	○	○	○
Wheeler	Wheeler	153	●	○	○	○	○	○	●	○	○	○	○	○	○	○
	Major Water Providers:															
Potter, Randall	Amarillo	41,635	●	●	○	●	○	●	●	○	○	○	○	○	○	●
Hutchinson	Borger	112	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Moore	Cactus	4,286	●	○	○	○	○	○	●	○	○	○	○	○	○	○
Multiple	CRMWA	47,264	●	○	○	○	○	●	●	○	●	○	●	○	○	●
Multiple	Greenbelt MIWA	723	●	○	○	○	○	○	●	○	○	○	○	○	○	○

For purposes of this table, voluntary transfer also represents supplies developed by wholesale water providers to existing customers.

ATTACHMENT 5-2

STRATEGY EVALUATION MATRIX AND QUANTIFIED ENVIRONMENTAL IMPACT MATRIX

INTRODUCTION

In accordance with TWDB rules and guidelines, the Panhandle Water Planning Group has adopted a standard procedure for ranking potential water management strategies. This procedure classifies the strategies using the TWDB's standard categories developed for regional water planning.

The strategies are ranked based upon the following categories;

- Quantity
- Reliability
- Cost
- Environmental Factors
- Agricultural Resources/Rural Areas
- Other Natural Resources
- Key Water Quality Parameters

Each category is quantitatively assessed and assigned a ranking from 1 to 5. With the exception of the Environmental Factors category, Table 1 shows the correlation between the category and the ranking. The Environmental Factors score is taken directly from the Environmental Matrix and are discussed later in this document.

Table 1: Evaluation Matrix Category Ranking Correlation

Rank	Quantity	Cost per Ac Ft	Reliability	Remaining Strategy Impacts
1	Meets 0-25% Shortage	>$3,000	Low	High
2	Meets 25-50% Shortage	$2,000-$3,000	Low to Medium	Medium
3	Meets 50-75% of Shortage	$1,000-$2,000	Medium	Low
4	Meets 75-100% of Shortage	$500-$1,000	Medium to High	None
5	Exceeds Shortage	<$500	High	Positive Impact

Environmental Factors

The evaluation of Environmental Factors considers multiple aspects of the potential impacts of the project as it relates to habitats, stream flow, water quality, threatened and endangered species and cultural resources. Each of these contributing factors are assessed through the Environmental Matrix and the resultant score is recorded on the Evaluation Matrix. Details of these evaluations are discussed under the Environmental Matrix.

Agricultural Resources

Impacts to Agricultural Resources are quantified based on the permanent impacts to water supplies to irrigation users or direct impacts to irrigated acreage. Projects with only temporary impacts, such as pipeline projects, would be classified as low impacts. Specific assumptions include:

- If the location of the strategy is known and data is available, actual impacts to agricultural lands will be used.
- If a strategy is located in a rural area of a county with significant irrigation use (>50,000 ac-ft/yr), it is assumed that the strategy could potentially impact agricultural lands. Since most projects will avoid direct impacts to agricultural lands, the quantity of impacts is estimated to be no more than 10% of the total area for the strategy.
- If a strategy permanently impacts more than 2,000 acres of agricultural land, the impacts are classified as "high". If a strategy impacts no more than 50 acres of agricultural lands, the impacts are classified as "low".
- If a strategy will reduce the available water to an irrigation user (by county) by the greater of 10% current irrigation use or 5,000 ac-ft/yr, the strategy is determined to have "high" impacts. If a strategy will reduce the available water to an irrigation user (by county) by 1% of current irrigation use or 500 ac-ft/yr, the strategy is determined to have "low" impacts.
- If the entity already holds water rights for the strategy, the impacts would be "none".
- If the strategy does not impact any agricultural or rural user, "none" is selected.
- For strategies that provide water to agricultural and rural users, the strategy is rated as "positive impacts."

The quantified impacts are recorded in the Environmental Matrix table.

Other Natural Resources

Other Natural Resources include parks and public lands, energy and mining reserves, and other water resources not directly affected by the proposed strategy. This evaluation is qualitatively assessed and scored as shown on Table 1.

Key Water Quality Parameters

Impacts to key water quality parameters are discussed by strategy type in Chapter 6. These parameters may vary by project type. This parameter is qualitatively assessed and scored as shown on Table 1.

Environmental Matrix

The Environmental Matrix is used to determine the score of the ‘Environmental Factors’ category on the Evaluation Matrix.

The Environmental Matrix takes into consideration the following categories;

- Total Acres Impacted
- Total Wetland Acres Impacted
- Environmental Water Needs
- Habitat
- Threatened and Endangered Species
- Cultural Resources
- Bays & Estuaries
- Environmental Water Quality

Each category is quantitatively assessed and assigned a ranking from 1 to 5. The Overall Environmental Impacts column averages all of the rankings assigned to the strategy. This value is also illustrated in the Evaluation Matrix as the Environmental Factors rank. Table 2 shows the correlation between the rank assigned within each category.

Table 2: Environmental Matrix Category Ranking Correlation

Rank	Acres Impacted	Threatened and Endangered Species	All Remaining Categories
1	Greater than 5000 Acres and/or 500 Ac Wetlands	Greater than 50	High Impact
2	1000-5000 Acres and/or 100-500 Ac Wetlands	Between 30-50	Medium Impact
3	50-1000 Acres and/or 5-100 Ac Wetlands	Between 10-30 or ‘varies’	Low Impact
4	0-50 Acres	Between 0-10	No Impact or n/a
5	None	None or n/a	Positive

Acres Impacted

Acres Impacted refers to the total amount of area that will be impacted due to the implementation of a strategy.

The following conservative assumptions were made (unless more detailed information was available);

- Each well will impact approximately 1 acre of land
- The acres impacted for pipelines is equivalent to the right of way easements required
- Reservoirs will impact an area equal to their surface area
- A conventional water treatment plant will impact 5 acres
- Conservation, Precipitation Enhancement and Subordination strategies will have no impact on acres

Wetland Acres

Wetland Acres refers to how many acres that are classified as wetlands are impacted by implementation of the strategy. No strategies in the PWPA are expected to have an impact on wetlands. The total acreage was determined using the National Wetlands Inventory located at http://www.fws.gov/wetlands/Data/Mapper.html .

Environmental Water Needs

Environmental Water Needs refers to how the strategy will impact the area's overall environmental water needs. Water is vital to the environmental health of a region, and so it is important to take into account how strategies will impact the amount of water that will be available to the environment.

The following conservative assumptions were made (unless more detailed information was available);

- The majority of the strategies are associated with new groundwater development and will have a low impact on environmental water needs
- Reuse will also have a medium impact if the effluent was previously used for irrigation or discharged back into the water system. This will decrease the overall amount of water that is available to the environment by diverting the effluent and using it for another purpose
- Precipitation Enhancement and Brush Control will have a positive impact because both of these strategies increase the amount of water available to the environment.

Habitat

Habitat refers to how the strategy will impact the habitat of the local area. The more area that is impacted due to the implementation of the strategy, the more the area's habitat will be disrupted.

The following conservative assumptions were made (unless more detailed information was available);

- Strategies with less than 100 acres impacted will have a low impact
- Strategies above 100 acres impacted will have a medium impact

Threatened and Endangered Species

Threatened and endangered species refers to how the strategy will impact those species in the area once implemented.

The following conservative assumptions were made (unless more detailed information was available);

- Only applicable to strategies implementing infrastructure
- Rankings were based on the amount of State and federally threatened and endangered species located within the county. This amount was found using the Texas Parks and

Wildlife Database located at http://tpwd.texas.gov/gis/rtest/ and the U.S. Fish and Wildlife Service Database located at http://www.fws.gov/endangered/ .

- This ranking only includes threatened and endangered species as defined in the TWDB guidelines and does not include species without official protection such as those proposed for listing or species that are considered rare or otherwise of special concern.

Cultural Resources

Cultural Resources refers to how the strategy will impact cultural resources located within the area. Cultural resources are defined as the collective evidence of the past activities and accomplishments of people. Locations, buildings and features with scientific, cultural or historic value are considered to be cultural resources.

The following conservative assumptions were made (unless more detailed information was available);

- Only applicable to strategies implementing infrastructure
- All groundwater and transmission strategies will have a low impact on cultural resources because of the ability to avoid areas with high probably of cultural resources.

Bays and Estuaries

The PWPA is located too far away from and bays or estuaries to have a quantifiable impact. Therefore this category was assumed to be non-applicable for every strategy.

Environmental Water Quality

Environmental Water Quality refers to the impact that the implementation of the strategy will have on the area's applicable water quality. These ranks were assumed to be equivalent to those assigned previously to each strategy in the Evaluation Matrix.

Water Management Strategy Evaluation Matrix

Entity	County Used	Basin Used	Strategy	Quantity (Ac-Ft/Yr)	Maximum Need	Percentage of Max Need Met	Quantity Score	Reliability	Annual Cost ($/Ac-Ft)	Cost Score	Environmental Factors	Impacts of Strategy on: Agricultural Resources/ Rural Areas	Other Natural Resources	Key Water Quality Parameters	Overall Score (5 40)
Claude	Armstrong	Red	Conservation	4	0	N/A	5	3	$1,570	3	5	5	5	5	31
Irrigation	Armstrong	Red	Conservation	1,415	0	N/A	5	3	$66	5	5	5	5	5	33
Groom	Carson	Red	Conservation	2	0	N/A	5	3	$2,330	2	5	5	5	5	30
Irrigation	Carson	Canadian and Red	Conservation	32,317	0	N/A	5	3	$66	5	5	5	5	5	33
Panhandle	Carson	Red	Conservation	8	586	1%	1	3	$1,203	3	5	5	5	5	27
			New Well(s) (Ogallala Carson)	600		>100%	5	4	$390	5	4	4	4	4	30
White Deer	Carson	Canadian and Red	Conservation	4	0	N/A	5	3	$1,538	3	5	5	5	5	31
Childress	Childress	Red	Conservation	22	0	N/A	5	3	$779	4	5	5	5	5	32
Red River Authority of Texas	Childress	Red	Conservation	12	0	N/A	5	3	$1,107	3	5	5	5	5	31
Irrigation	Childress	Red	Conservation	2,854	0	N/A	5	3	$66	5	5	5	5	5	33
Wellington	Collingsworth	Red	Conservation	8	595	1%	1	3	$1,192	3	5	5	5	5	27
			New Well(s) (Seymour Collingsworth)	100		17%	1	4	$1,250	3	4	4	4	4	24
			Nitrate Treatment	560		94%	4	4	$2,116	2	3	4	5	3	25
Irrigation	Collingsworth	Red	Conservation	9,757	10,133	96%	4	3	$66	5	5	5	5	5	32
Dalhart	Dallam and Hartley	Canadian	Conservation	40	3,137	1%	1	3	$443	5	5	5	5	5	29
			New Well(s) (Ogallala Hartley)	3,140		100%	5	4	$507	4	4	4	4	4	29
Texline	Dallam	Canadian	Conservation	2	28	9%	1	3	$1,913	3	5	5	5	5	27
			New Well(s) (Ogallala Dallam)	100		>100%	5	4	$390	5	4	4	4	4	30
Irrigation	Dallam	Canadian	Conservation	83,654	116,358	72%	3	3	$66	5	5	5	5	5	31
Clarendon	Donley	Red	Conservation	6	0	N/A	5	3	$1,293	3	5	5	5	5	31
Irrigation	Donley	Red	Conservation	5,054	0	N/A	5	3	$66	5	5	5	5	5	33
McLean	Gray	Red	Conservation	4	115	4%	1	3	$1,459	3	5	5	5	5	27
			New Well(s) (Ogallala Gray)	150		>100%	5	5	$213	5	4	4	4	4	31
Pampa	Gray	Canadian	Conservation	144	422	34%	2	3	$544	4	5	5	5	5	29
			New Well(s) (Ogallala Gray)	1,100		261%	5	5	$354	5	4	4	4	4	31
Irrigation	Gray	Red and Canadian	Conservation	9,981	2,632	>100%	5	3	$66	5	5	5	5	5	33
Memphis	Hall	Red	Conservation	7	146	5%	1	3	$1,235	3	5	5	5	5	27
			New Well(s) (Ogallala Donley)	150		>100%	5	2	$1,107	3	4	4	3	4	25
Turkey	Hall	Red	New Well(s) (Ogallala Briscoe)	100	0	N/A	5	3	$1,280	3	4	4	4	4	27
Irrigation	Hall	Red	Conservation	7,796	15,637	50%	2	3	$66	5	5	5	5	5	30
County-Other	Hall	Red	Conservation	5	0	N/A	5	3	$2,429	2	5	5	5	5	30
			Advanced Treatment - Lakeview	50		N/A	5	4	$2,560	2	3	4	5	3	26
			New Well(s) - Estelline (Seymour Hall)	50		N/A	5	1	$320	5	4	4	4	4	27
			New Well(s) - Brice-Lesley (Seymour Hall)	50		N/A	5	1	$620	4	4	4	4	4	26
Gruver	Hansford	Canadian	Conservation	7	280	2%	1	3	$1,280	3	5	5	5	5	27
			New Well(s) (Ogallala Hansford)	280		100%	4	4	$286	5	4	4	4	4	29
Spearman	Hansford	Canadian	Conservation	13	517	2%	1	3	$1,094	3	5	5	5	5	27
			New Well(s) (Ogallala Hansford)	520		101%	5	4	$467	5	4	4	4	4	30
Irrigation	Hansford	Canadian	Conservation	65,189	0	N/A	5	3	$66	5	5	5	5	5	33
Hartley WSC	Hartley	Canadian	Conservation	2	0	N/A	5	3	$1,958	3	5	5	5	5	31
Irrigation	Hartley	Canadian	Conservation	99,380	192,765	52%	3	3	$66	5	5	5	5	5	31
Canadian	Hemphill	Canadian	Conservation	15	0	N/A	5	3	$1,067	3	5	5	5	5	31
Irrigation	Hemphill	Canadian and Red	Conservation	569	0	N/A	5	3	$66	5	5	5	5	5	33
Fritch	Hutchinson and Moore	Canadian	Conservation	10	0	N/A	5	3	$1,157	3	5	5	5	5	31
Stinnett	Hutchinson	Canadian	Conservation	6	31	21%	1	3	$1,288	3	5	5	5	5	27
			New Well(s) (Ogallala Hutchinson)	50		>100%	5	2	$1,320	3	4	4	4	4	26
TCW Supply	Hutchinson	Canadian	Conservation	6	383	2%	1	3	$1,281	3	5	5	5	5	27
			New Well(s) (Ogallala Hutchinson)	400		>100%	5	2	$868	4	4	4	4	4	27
Irrigation	Hutchinson	Canadian	Conservation	19,562	0	N/A	5	3	$66	5	5	5	5	5	33
Booker	Lipscomb and Ochiltree	Canadian	Conservation	8	381	2%	1	3	$1,218	3	5	5	5	5	27
			New Well(s) (Ogallala Lipscomb)	400		>100%	5	5	$1,268	3	4	4	4	4	29

Water Management Strategy Evaluation Matrix

Entity	County Used	Basin Used	Strategy	Quantity (Ac-Ft/Yr)	Maximum Need	Percentage of Max Need Met	Quantity Score	Reliability	Annual Cost ($/Ac-Ft)	Cost Score	Environmental Factors	Impacts of Strategy on: Agricultural Resources/ Rural Areas	Impacts of Strategy on: Other Natural Resources	Impacts of Strategy on: Key Water Quality Parameters	Overall Score (5 40)
Darrouzett	Lipscomb	Canadian	Conservation	2	0	N/A	5	3	$2,430	2	5	5	5	5	30
Follett	Lipscomb	Canadian	Conservation	2	0	N/A	5	3	$2,442	2	5	5	5	5	30
Higgins	Lipscomb	Canadian	Conservation	12	0	N/A	5	3	$1,232	3	5	5	5	5	31
Irrigation	Lipscomb	Canadian	Conservation	10,074	0	N/A	5	3	$66	5	5	5	5	5	33
Dumas	Moore	Canadian	Conservation	326	4,982	7%	1	3	$1,151	3	5	5	5	5	27
			New Well(s) (Ogallala Hartley)	5,000		100%	5	4	$134	5	4	4	4	4	30
Sunray	Moore	Canadian	Conservation	7	485	1%	1	3	$1,251	3	5	5	5	5	27
			New Well(s) (Ogallala Moore)	500		>100%	5	3	$1,254	3	4	4	4	4	27
County-Other	Moore	Canadian	Conservation	12	41	29%	2	3	$1,110	3	5	5	5	5	28
Irrigation	Moore	Canadian	Conservation	60,841	49,251	>100%	5	3	$66	5	5	5	5	5	33
Manufacturing	Moore	Canadian	New Well(s) (Ogallala/Dockum Moore)	3,000	5,785	52%	3	3	$142	5	4	4	3	4	26
Perryton	Ochiltree	Canadian	Conservation	41	815	5%	1	3	$430	5	5	5	5	5	29
			New Well(s) (Ogallala Ochiltree)	820		>100%	5	5	$955	4	4	4	4	4	30
Irrigation	Ochiltree	Canadian	Conservation	31,668	0	N/A	5	3	$66	5	5	5	5	5	33
Vega	Oldham	Canadian	Conservation	3	0	N/A	5	3	$1,682	3	5	5	5	5	31
Irrigation	Oldham	Canadian and Red	Conservation	1,284	0	N/A	5	3	$66	5	5	5	5	5	33
Irrigation	Potter	Canadian and Red	Conservation	661	0	N/A	5	3	$66	5	5	5	5	5	33
Manufacturing	Potter	Canadian and Red	New Well(s) (Ogallala Potter)	150	3,209	5%	1	2	$100	5	4	5	4	4	25
Canyon	Randall	Red	Conservation	378	3,171	12%	1	3	$803	4	5	5	5	5	28
			New Well(s) (Ogallala/Dockum Randall)	3,000		95%	4	3	$282	5	4	4	4	4	28
Lake Tanglewood	Randall	Red	Conservation	3	0	N/A	5	3	$1,618	3	5	5	5	5	31
Irrigation	Randall	Red	Conservation	5,089	0	N/A	5	3	$66	5	5	5	5	5	33
Manufacturing	Randall	Red	New Well(s) (Ogallala Randall)	100	379	26%	2	3	$400	5	4	4	4	4	26
Miami	Roberts	Canadian	Conservation	2	0	N/A	5	3	$2,193	2	5	5	5	5	30
Irrigation	Roberts	Canadian and Red	Conservation	3,034	0	N/A	5	3	$66	5	5	5	5	5	33
Stratford	Sherman	Canadian	Conservation	9	0	N/A	5	3	$1,184	3	5	5	5	5	31
Texhoma	Sherman	Canadian	Conservation	1	0	N/A	5	3	$2,817	2	5	5	5	5	30
Irrigation	Sherman	Canadian	Conservation	111,300	38,831	>100%	5	3	$66	5	5	5	5	5	33
Shamrock	Wheeler	Red	Conservation	7	0	N/A	5	3	$1,239	3	5	5	5	5	31
Wheeler	Wheeler	Red	Conservation	6	153	4%	1	3	$1,319	3	5	5	5	5	27
			New Well(s) (Ogallala Wheeler)	160		>100%	5	5	$1,463	3	4	4	4	4	29
Irrigation	Wheeler	Red	Conservation	3,918	0	N/A	5	3	$66	5	5	5	5	5	33
Major Water Providers:															
Amarillo	Potter and Randall	Red and Canadian	Conservation	7,182	41,635	17%	1	3	$1,157	3	5	5	5	5	27
			Potter/Carson Co. Well Field	20,000		48%	2	4	$319	5	4	4	3	4	26
			Roberts Co. Well Field (shared CRMWA II capacity)	11,210		27%	2	5	$1,425	3	4	4	4	4	26
			Aquifer Storage and Recovery	6,500		N/A	3	3	$260	5	5	4	4	4	28
			Direct Potable Reuse	3,500		8%	1	5	$2,258	2	4	4	2	4	22
Borger	Hutchinson	Canadian	Conservation	43	112	39%	2	3	$404	5	5	5	5	5	30
Cactus	Moore	Canadian	Conservation	23	4,286	1%	1	3	$766	4	5	5	5	5	28
			New Well(s) (Ogallala Moore)	5,000		>100%	5	4	$363	5	4	4	4	4	30
CRMWA			Replace Well Capacity for CRMWA I	30,334	47,264	64%	3	5	$159	5	4	4	4	4	29
			Expand Groundwater and Delivery Capacity (CRMWA II)	65,000		>100%	5	5	$799	4	4	4	4	4	30
			Brush Control	2,500		5%	1	2	$60	5	3	4	4	4	23
			Aquifer Storage and Recovery	17,000		N/A	5	3	$355	5	4	4	4	4	29
Greenbelt MIWA			Donley Co. Well Field	2,000	723	>100%	5	3	$743	4	4	4	4	4	28

Quantified Environmental Impact Matrix

Entity	County	Basin	Strategy	Acres Impacted	Wetland Acres	Acres Impacted Score	Envir Water Needs	Envir Water Needs Score	Habitat	Habitat Score	Threat and Endanger Species	Threat and Endanger Species Score	Cultural Resources	Cultural Resources Score	Bays & Estuaries	Bays & Estuaries Score	Envir Water Quality	Overall Environmental Impacts	Agricultural Impacts Temporary	Agricultural Impacts Permanent	Agricultural Impacts Score
											Quantity (Ac Ft/Yr)										
Claude	Armstrong	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Armstrong	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Groom	Carson	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Carson	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Panhandle	Carson	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Carson)	1	N/A	4	Low	3	None	4	5	4	Low	3	N/A	5	4	4	0	0	4
White Deer	Carson	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Childress	Childress	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Red River Authority of	Childress	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Childress	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Wellington	Collingsworth	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Seymour Collingsworth)	6	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	0	0	4
			Nitrate Treatment	2	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	3	4	0	0	4
Irrigation	Collingsworth	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Dalhart	Dallam and Hartley	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hartley)	28	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	3	0	4
Texline	Dallam	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Dallam)	2	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Dallam	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Clarendon	Donley	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Donley	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
McLean	Gray	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Gray)	2	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	0	0	4
Pampa	Gray	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Gray)	26	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Gray	Red and Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Memphis	Hall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Donley)	6	N/A	4	Low	3	None	4	6	4	Low	3	N/A	5	4	4	0	0	4
Turkey	Hall	Red	New Well(s) (Ogallala Briscoe)	1	N/A	4	Low	3	None	4	6	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Hall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
County-Other	Hall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			Advanced Treatment - Lakeview	2	N/A	4	Low	3	None	4	6	4	Low	3	N/A	5	3	4	0	0	4
			New Well(s) - Estelline (Seymour Hall)	1	N/A	4	Low	3	None	4	6	4	Low	3	N/A	5	4	4	0	0	4
			New Well(s) - Brice-Lesley (Seymour Hall)	1	N/A	4	Low	3	None	4	6	4	Low	3	N/A	5	4	4	0	0	4
Gruver	Hansford	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hansford)	1	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	0	0	4
Spearman	Hansford	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hansford)	12	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Hansford	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Hartley WSC	Hartley	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Hartley	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Canadian	Hemphill	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Hemphill	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Fritch	Hutchinson and Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Stinnett	Hutchinson	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hutchinson)	2	N/A	4	Low	3	None	4	5	4	Low	3	N/A	5	4	4	0	0	4
TCW Supply	Hutchinson	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hutchinson)	20	N/A	4	Low	3	None	4	5	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Hutchinson	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Booker	Lipscomb and Ochiltree	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Lipscomb)	4	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	0	0	4
Darrouzett	Lipscomb	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5

Quantified Environmental Impact Matrix

Entity	County	Basin	Strategy	Acres Impacted	Wetland Acres	Acres Impacted Score	Envir Water Needs	Envir Water Needs Score	Habitat	Habitat Score	Threat and Endanger Species	Threat and Endanger Species Score	Cultural Resources	Cultural Resources Score	Bays & Estuaries	Bays & Estuaries Score	Envir Water Quality	Overall Environmental Impacts	Agricultural Impacts: Temporary	Agricultural Impacts: Permanent	Agricultural Impacts: Score
											Quantity (Ac Ft/Yr)										
Follett	Lipscomb	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Higgins	Lipscomb	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Lipscomb	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Dumas	Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Hartley)	9	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	1	0	4
Sunray	Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Moore)	20	N/A	4	Low	3	None	4	2	4	Low	3	N/A	5	4	4	0	0	4
County-Other	Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Manufacturing	Moore	Canadian	New Well(s) (Ogallala/Dockum Moore)	4	N/A	4	Low	3	None	4	2	4	Low	3	N/A	5	4	4	0	0	4
Perryton	Ochiltree	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Ochiltree)	19	N/A	4	Low	3	None	4	3	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Ochiltree	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Vega	Oldham	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Oldham	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Potter	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Manufacturing	Potter	Canadian and Red	New Well(s) (Ogallala Potter)	1	N/A	4	Low	3	Low	3	6	4	Low	3	N/A	5	4	4	0	0	5
Canyon	Randall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala/Dockum Randall)	8	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	1	0	4
Lake Tanglewood	Randall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Randall	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Manufacturing	Randall	Red	New Well(s) (Ogallala Randall)	1	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	0	0	4
Miami	Roberts	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Roberts	Canadian and Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Stratford	Sherman	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Texhoma	Sherman	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Irrigation	Sherman	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Shamrock	Wheeler	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Wheeler	Wheeler	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Wheeler)	21	N/A	4	Low	3	None	4	4	4	Low	3	N/A	5	4	4	0	0	4
Irrigation	Wheeler	Red	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Amarillo	Potter and Randall	Red and Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			Potter/Carson Co. Well Field	301	N/A	3	None	4	Low	3	8	4	Low	3	N/A	5	4	4	30	0	4
			Roberts Co. Well Field (shared	502	N/A	3	None	4	Low	3	10	4	Low	3	N/A	5	4	4	50	0	4
			Aquifer Storage and Recovery	0	N/A	5	None	4	N/A	5	10	4	N/A	5	N/A	5	4	5	0	0	4
			Direct Potable Reuse	44	N/A	4	Low	3	None	4	N/A	5	Low	3	N/A	5	4	4	4	0	4
Borger	Hutchinson	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
Cactus	Moore	Canadian	Conservation	0	N/A	5	Positive	5	None	4	N/A	5	N/A	5	N/A	5	5	5	0	0	5
			New Well(s) (Ogallala Moore)	15	N/A	4	Low	3	None	4	2	4	Low	3	N/A	5	4	4	0	0	4
CRMWA			Replace Well Capacity for CRMWA I	15	N/A	4	Low	3	None	4	7	4	Low	3	N/A	5	4	4	2	0	4
			Expand Groundwater and Delivery Capacity (CRMWA II)	548	N/A	3	Low	3	Low	3	7	4	Low	3	N/A	5	4	4	55	0	4
			Brush Control	500	N/A	3	Low	3	Low	3	Varies	3	Low	3	N/A	5	4	3	50	0	4
			Aquifer Storage and Recovery	19	N/A	4	Low	3	None	4	Varies	3	Low	3	N/A	5	4	4	2	0	4
Greenbelt MIWA			Donley Co. Well Field	94	N/A	3	Low	3	Low	3	9	4	Low	3	N/A	5	4	4	9	0	4

ATTACHMENT 5-3

PER CAPITA WATER USE GOALS

Gallons per Capita per Day (GPCD) Goals

WUG	2020	2030	2040	2050	2060	2070
Amarillo	183	179	176	175	175	175
Booker	252	248	246	244	244	244
Borger	206	201	198	198	198	198
Cactus Municipal Water System	205	202	201	200	199	199
Canadian	230	226	223	222	221	222
Canyon	206	202	199	196	196	196
Childress	227	223	220	219	218	218
Clarendon	159	155	151	149	149	149
Claude Municipal Water System	263	259	255	253	253	253
Dalhart	268	264	261	260	260	260
Darrouzett	256	252	250	249	248	248
Dumas	178	174	170	169	169	169
Follett	268	265	263	261	261	262
Fritch	175	171	167	167	167	166
Groom Municipal Water System	275	271	268	266	266	266
Gruver	208	204	202	200	200	200
Hartley WSC	308	303	301	300	299	300
Higgins Municipal Water System	243	238	236	234	235	235
Lake Tanglewood	344	340	336	335	335	335
McLean Municipal Water Supply	213	208	206	204	204	203
Memphis	145	140	137	136	136	136
Miami	323	319	316	314	314	314
Moore County-Other	118	114	111	110	109	109
Pampa Municipal Water System	167	161	158	157	157	157
Pandhandle Municipal Water System	202	198	195	193	193	193
Perryton Municipal Water System	257	253	250	249	248	248
Red River Authority of Texas	217	213	210	208	208	208
Shamrock Municipal Water System	156	151	147	147	146	146
Spearman Municipal Water System	168	164	161	159	159	159
Stinnett	201	197	193	193	192	192
Stratford	188	184	181	180	179	179

Gallons per Capita per Day (GPCD) Goals

WUG	2020	2030	2040	2050	2060	2070
Sunray	200	196	193	191	191	191
TCW Supply	301	297	294	293	292	292
Texhoma	311	308	305	303	304	303
Texline	343	338	335	334	334	334
Turkey Municipal Water System	251	247	243	243	243	243
Vega	249	245	242	240	240	240
Wellington Municipal Water System	199	195	191	190	190	190
Wheeler	273	269	265	264	264	263
White Deer	191	186	183	182	182	182

6 IMPACTS OF THE REGIONAL WATER PLAN

The development of viable strategies to meet the demand for water while supporting the long-term protection of resources of the state is an important goal of regional planning. The purpose of this chapter is to describe the overall potential impacts of the recommended 2021 Panhandle Water Plan and document how the Water Plan is consistent with the long-term protection of the state's water resources, agricultural resources, and natural resources.

In accordance with 31 TAC Chapter 357.40, each regional water plan shall identify key parameters of water quality and describe how implementing the Water Plan could affect these parameters. The plans shall also discuss the potential impacts of moving water from agricultural and rural areas to other purposes, socio-economic impacts of not meeting the water needs and impacts on navigation.

This chapter presents an assessment of the water quality parameters that could be affected by the implementation of water management strategies for Region A. Based on this assessment, the key water quality parameters for each type of strategies are identified. From this determination, the specific water management strategies selected for PWPA were evaluated with respect to potential impacts to the key water quality parameters. These discussions are presented in Section 6.1.

The impacts of moving water from agricultural and rural areas to other purposes, socio-economic impacts of not meeting the water demands and impacts on navigation are discussed in Sections 6.2 through 6.4.

The requirement to evaluate the consistency of the regional water plan with protection of resources is found in 31 TAC Chapter 357.41, which states:

"RWPGs shall describe how RWPs are consistent with the long-term protection of the state's water resources, agricultural resources, and natural resources as embodied in the guidance principles in §358.3(4) and (8) of this title (relating to Guidance Principles)."

Sections 6.5 through 6.7 address this issue by providing general descriptions of how the plan is consistent with protection of water resources, agricultural resources, and natural resources. Additionally, the chapter will specifically address consistency of the 2021 Panhandle Water Plan with the state's water planning requirements. To demonstrate compliance with the state's requirements, a matrix has been developed and is included in Appendix E.

6.1 Potential Impacts of Water Management Strategies on Key Water Quality Parameters

Water quality plays an important role in determining the availability of water supplies to meet current and future water needs in the region. Evaluations of the potential impacts to water quality by each potential water management strategy are discussed in Chapter 5. This chapter describes the key water quality parameters for the surface water and groundwater sources in the region, identifies specific water quality concerns or issues, and discusses potential impacts on water quality associated with the recommended water management strategies.

The key water quality parameters to be evaluated are dependent on the water management strategy recommended. Strategies recommended for municipal use must meet drinking water standards, while water used for non-municipal purposes may not. Source water quality for strategies can have an impact on key water quality parameters of the region's water sources depending on potential use and/or discharge of the water.

Surface water sources in the PWPA include Greenbelt Reservoir and Lake Meredith. Water quality in these sources are generally good but can contain elevated total dissolved solids (TDS) when lake levels are low (including chlorides and sulphates). CRMWA has supplemented water from Lake Meredith with groundwater from Roberts County to improve the water quality of the water delivered from the lake. Lake Meredith is also included on the State of Texas Clean Water Act Section 303(d) list for mercury in fish. Elevated salt contents, expressed in TDS, is also prevalent in many of the local rivers and streams in the PWPA.

Groundwater resources in the Panhandle region are generally potable, although region-wide up to approximately thirteen percent of the groundwater may be brackish. Groundwater quality issues in the region are generally related to elevated concentrations of nitrate, chloride, and TDS. Sources of elevated nitrate include cultivation of soils and domestic and animal sources. Higher concentrations of nitrate are typically found near agricultural areas and outcrop areas of the aquifer. Elevated concentrations of chloride are due to dissolution of evaporite minerals and upwelling from underlying, more brackish groundwater formations. Elevated concentrations of TDS are primarily the result of the lack of sufficient recharge and restricted circulation. Together, these limit the flushing action of fresh water moving through the aquifers.

Groundwater sources with known elevated concentrations of nitrates include the Seymour aquifer in the southeastern part of the region and parts of the Ogallala and Dockum aquifers, specifically in the heavily irrigated counties. High TDS levels occur throughout the Blaine and Dockum aquifers. Also, much of the Whitehorse formation and Other aquifers have elevated TDS levels, which limits their use.

Table 6-1 summarizes the most pertinent water quality parameters in the PWPA for the types of strategies proposed in this plan.

Table 6-1: Key Water Quality Parameters by Water Management Strategy Type[1]

Water Quality Parameter	Water Conservation	Reuse	Voluntary Transfer	New or Expanded Groundwater	Brush Control	Conjunctive Use	Advanced Treatment
Total dissolved solids (TDS)	+	+ / -	+ / -		+ / -	+	-
Alkalinity	+					+	
Hardness	+					+	
Dissolved Oxygen (DO)	+	+ / -	+ / -		+ / -	+	
Nitrogen	+	+ / -	+ / -		+ / -	+	-
Phosphorus	+	+ / -	+ / -		+ / -	+	
Radionuclides				-			
Metals [2]		+	- [2]	- [2]			- [2]

[1] A positive sign (+) indicates a potential positive impact. A negative sign (-) indicates a potential negative impact. If both signs are shown, the strategy could have either a positive or negative impact. Water management strategies with no potential impacts to water quality are not shown in this table.
[2] Only for specific metals where there are significant discharges of the metal.

The implementation of specific strategies can potentially impact both the physical and chemical characteristics of water resources in the region. The following is an assessment of the characteristics of each strategy type that may affect water quality and an identification of the specific water quality parameters that could be affected based on those characteristics. This assessment found that the implementation of water management strategies recommended in Chapter 5 of the Panhandle Water Plan is not expected to have negative impact on native water quality and may actually improve water quality through conservation.

6.1.1 Water Conservation

Water conservation is a recommended strategy for irrigation and municipal water use in the PWPA. Recommended irrigation conservation measures include improvements in the efficiency of irrigation equipment, irrigation scheduling, change in crop type, and advances in plant breeding. These recommended strategies are not expected to affect water quality adversely. The results should be beneficial because the demand on surface and groundwater resources will be decreased. Municipal conservation should have similar beneficial effects, but at a smaller scale.

6.1.2 Reuse

In general, there are three possible water quality effects associated with the reuse of treated wastewaters:

- There can be a reduction in instream flow if treated wastewaters are not returned to the stream, which could affect TDS, nutrients, and DO concentrations of the receiving stream.

- Conversely, in some cases, reducing the volume of treated wastewater discharged to a stream could have a positive effect and improve levels of TDS, nutrients, DO, and possibly metals in the receiving stream.
- Reusing water multiple times and then discharging it can significantly increase the TDS concentration in the effluent and possibly the receiving stream.

These impacts will vary depending on the quality and quantity of treated wastewater that has historically been discharged to the stream and the existing quality and quantity of the receiving stream.

In the PWPA, only Amarillo has a reuse strategy. Currently Amarillo's treated effluent is sold to Xcel Energy for power generation and little, if any, wastewater is discharged to a stream.

6.1.3 Voluntary Transfers

Voluntary transfers are defined as new sales of water from one provider to another. In the PWPA, there are no new sales or increased contract amounts as recommended strategies. Sales to users under existing contracts are discussed with the respective project type.

6.1.4 New and/or Expanded Use of Groundwater Resources

Increased use of groundwater can decrease instream flows if the base flow is supported by spring flow. This is not expected to be a concern for the recommended water management strategies in the PWPA. Most new groundwater development is from relatively deep portions of aquifers that most likely do not have significant impact on surface flows, such as Roberts County. A previous study conducted by the Bureau of Economic Geology concluded that no identifiable relationship can be found at this time relating increased pumping of the Ogallala to the deterioration of water quality (Freese and Nichols, Inc., 2006).

Increased use of groundwater has the potential to increase TDS concentrations in area streams if the groundwater sources have higher concentrations of TDS or hardness than local surface water and are discharged as treated effluent. This is not the case in most areas in PWPA since all but two municipal strategies propose to use water from the Ogallala aquifer which has low to moderate levels of TDS. The City of Canyon is developing additional groundwater from the Ogallala and Dockum aquifers. The City of Wellington in Collingsworth County is recommended to develop additional groundwater in the Seymour aquifer. Both of these entities are in the Red River Basin, where naturally occurring salt seeps and high TDS waters are common and discharges of slightly elevated TDS water will not impact these streams. In general, the discharges of wastewater from groundwater sources is not expected to impact streams in the PWPA.

6.1.5 Brush Control

Brush control is a recommended strategy for the Lake Meredith watershed. Impacts to the water quality of area streams will depend upon the methods employed to control the brush. It is assumed that chemical spraying will not be used near water sources. Mechanical removal, prescribed burns and use of the salt cedar beetle are the preferred methods near water sources. With these assumptions, chemical contamination of the water source is very low. Increases in stream flow due to reduced evapotranspiration associated with the removed brush should improve water quality in the Lake Meredith watershed.

6.1.6 Conjunctive Use

Conjunctive use is not a recommended strategy but is actively employed in the PWPA. Both CRMWA and Greenbelt MIWA conjunctively use surface water and groundwater. As more groundwater supplies are developed, this would allow the water providers to operate their lakes in a manner that minimizes impacts to key water quality parameters while still being able to provide sufficient supplies to its customers from groundwater.

6.1.7 Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is a recommended strategy for CRMWA, Amarillo, and Pampa. This strategy proposes to treat surface water, reuse and/or groundwater to comparable aquifer quality and then store the water for future use. The water is typically stored during low use periods and later recovered from the aquifer for use during periods of high demand. This allows for optimal sizing of transmission systems and reduces evaporative losses associated with reservoir storage, preserving water resources for future use. ASR, as part of a conjunctive use operation, may allow a reservoir operator to minimize impacts to key water quality parameters while still providing users with sufficient supplies from stored groundwater. It also may reduce long-term demands on groundwater sources, which can reduce deterioration of water quality in the aquifer. ASR is expected to have minimal impacts on key water quality parameters of water in the receiving aquifer because the treated water being pumped into the aquifer will not degrade the existing quality of the aquifer.

6.1.8 Advanced Treatment

Advanced treatment is recommended for City of Wellington for nitrate removal. The waste stream from the advanced treatment would likely be discharged to a tributary of the Salt Fork of the Red River. The TCEQ would need to issue a discharge permit that would protect the water quality of the receiving stream. The small amount of proposed discharge is not expected to have significant impacts to key water quality parameters.

6.2 Impacts of Moving Water from Agricultural and Rural Areas

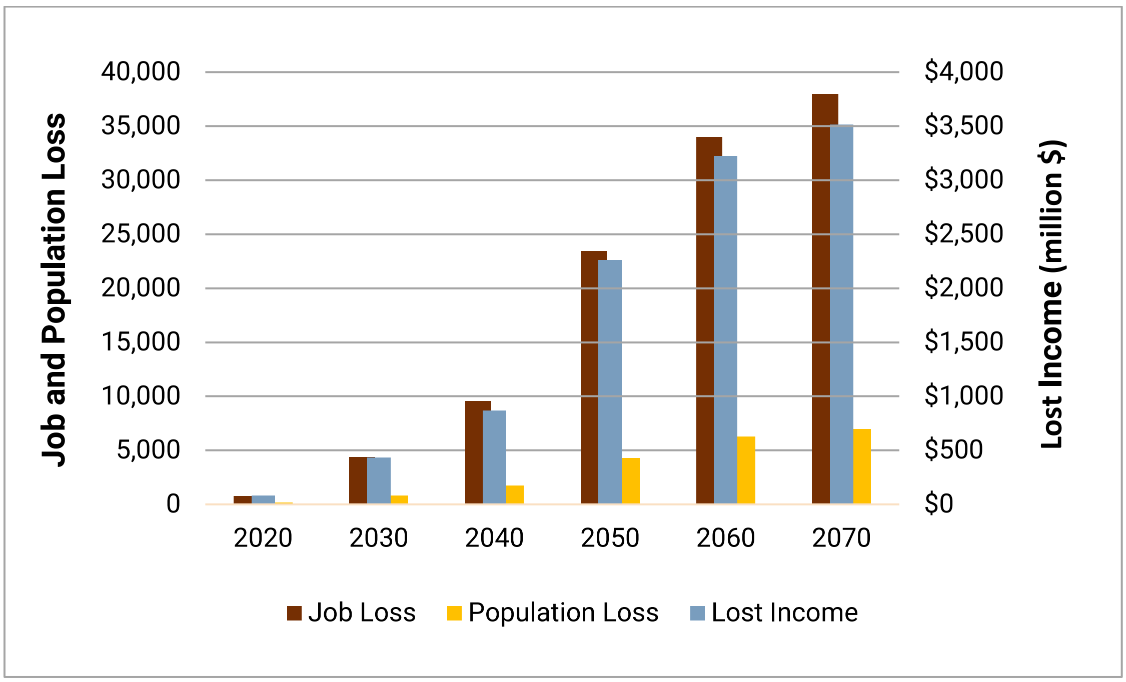
The implementation of water management strategies recommended in Chapter 5 of this regional plan is not expected to impact water supplies that are currently in use for agricultural purposes. The development of new groundwater that may include transfers of water from agricultural use to municipal use is predicated on a willing buyer, willing seller basis. Most of the recommended water management strategies for municipal water users rely on developing existing water rights. Most of the agricultural water use is from groundwater. The methodology for assessing the available supply from groundwater for this regional water plan respects current water use, which provides some protections to current agricultural and rural users.

6.3 Socio-Economic Impacts of Not Meeting Water Needs

The TWDB provided technical assistance to the PWPG in the development of socio-economic impacts of failing to meet projected water needs. The report, which can be found in Appendix F, details what would happen if identified water shortages in the region were to go unmet and no actions were taken to address these shortages. The report is based on regionally generated data that have been analyzed through the IMPLAN (Impact for Planning Analysis) model, an economic impact modeling software. The regional data is coupled with state-level multipliers to produce the impacts presented.

The TWDB's analysis calculated the impacts of a severe drought occurring in a single year at each decadal period in the PWPA. It was assumed that all of the projected shortage was attributed to drought. The TWDB's findings for not meeting needs can be summarized as follows:

- Combined lost income of approximately $80 million per year in 2020, increasing to $3.5 billion per year in 2070.
- In 2020, the region would lose approximately 800 jobs, and by 2070 job losses would increase to approximately 38,000.



This study was conducted for each water use type (economic sectors) and was designed to be consistent across the different water planning regions. In the PWPA, much of the projected water need is associated with the agricultural sector, which is comprised of irrigated agriculture and livestock. In addition, the agricultural sector is one of the economic drivers for other sectors (municipal and manufacturing) for many counties in the PWPA. There is concern that the socio-economic study conducted for the PWPA does not consider the impacts from these important interconnections to irrigated agriculture. For example, the reduction of grain production due to drought would impact livestock feed, potentially reducing livestock head. Consideration of these linkages would result in greater economic impacts in the region. The economic study did account for indirect effects and induced effects, such as changes in local spending among employees of the affected industries.

As required by statute, the socio-economic analysis considers only users with an identified water need (shortage). For irrigated agriculture, an extreme drought would impact counties with insufficient irrigation supply as well as counties with marginal supplies. These counties would not have the irrigation capacity to compensate during a drought worse than the drought of record. Consideration of all heavily irrigated counties would increase the potential economic impacts.

The PWPG recognizes that addressing these concerns is beyond the scope of this study. The methodology employed by the TWDB is defensible but may underestimate the losses associated with significantly reduced agricultural production due to drought. On the other hand, the projected losses in the future do not account for implementing water saving measures, insurance compensation or disaster payments, which will mitigate the economic loss. The economic elasticity function is critical in projecting future loss estimates. It is recommended that the TWDB periodically review the selection of the elasticity function for the different economic sectors to ensure its suitability for future studies. It is also recommended that the TWDB revise their methodology for the agricultural sector in future studies to include drought impacts not just on projected deficit counties but in all counties or at a minimum include those counties projected with marginal surpluses to more closely estimate the effects of a drought on the regional economy.

6.4 Other Potential Impacts

In accordance with Section 10 of the Rivers and Harbors Act of 1899, navigable waters are those waters that are subject to the ebb and flow of the tide and/or are presently being used, or have been used in the past for use to transport interstate or foreign commerce. In the PWPA, the major rivers include the Canadian and Red Rivers. Neither of these rivers are considered navigable within the PWPA. Therefore, the Panhandle Water Plan does not have an impact on navigation.

The Panhandle Water Plan protects existing water contracts and option agreements by reserving the contracted amount included in those agreements where those amounts were known. In some cases, there were insufficient supplies to meet existing contracts. In those cases, the supply amount was reduced proportionately for each contract holder. For entities with needs, water management strategies were recommended to meet deficits in contractual obligations.

6.5 Consistency with the Protection of Water Resources

Water resources in the PWPA include surface water from the Canadian and Red River Basins and groundwater from two major and three minor aquifers. The primary water resource in the region is the Ogallala aquifer. Approximately 92 percent of the current water used in the region is from the Ogallala aquifer. Of the recommended strategies, 86 percent of the new water supply in 2070 is associated with conservation with irrigation conservation accounting for the majority. The remaining 14 percent is from additional development of the PWPA groundwater resources and reuse.

The protections of water resources were considered through the supply allocation process and development of water management strategies. For surface water, the distribution of supplies does not exceed the safe yield of the reservoir. This provides some water in the lakes through the drought of record and provides some protections from future droughts. For groundwater, the desired future conditions (DFCs) adopted by the Groundwater Management Areas (GMAs) were honored for both currently developed supplies and potential future strategies.

To be consistent with the long-term protection of water resources, the plan must recommend strategies that minimize threats to the region's sources of water over the planning period. The water management strategies identified in Chapter 5 were evaluated for threats to water resources. The recommended strategies represent a comprehensive plan for meeting the needs of the region while effectively minimizing threats to water resources. Sections 6.5.1 to 6.5.9 describe the major strategies and the ways in which they minimize threats.

6.5.1 Water Conservation

Strategies for water conservation have been recommended that will reduce the demand for water, thereby reducing the impact on the region's groundwater and surface water sources. Water conservation practices are expected to save approximately 146,700 acre-feet of water annually by 2020, reducing impacts on both groundwater and surface water resources. By 2070, the recommended conservation strategies savings total 573,800 acre-feet per year. These savings are in addition to the water savings assumed in the demands. The total projected water savings from conservation for the PWPA by 2070 is over 586,000 acre-feet per year when including the plumbing code savings.

6.5.2 Wastewater Reuse

This strategy, developed by Amarillo, will provide high quality treated wastewater effluent to meet water needs in the region. This strategy will decrease the future demands on surface and groundwater sources and will not have a major impact on water resources.

6.5.3 New or Expanded Use of Groundwater

This strategy is recommended for entities with limited alternative sources and available groundwater supplies to meet needs. Groundwater supplies do not exceed the Modeled Available Groundwater (MAG) values that were determined to meet the desired future conditions of the groundwater source. These future conditions are considered protective of the water resource. Large transfers of groundwater may have potential impacts to local surface water and springs. Such impacts were considered during the evaluation of the strategies. Where possible, strategies were selected that minimized impacts to surface water.

6.5.4 Brush Control

Brush control is recommended for the Lake Meredith watershed. This strategy will support the surface water supplies for Lake Meredith by reducing losses associated with evapotranspiration of invasive brush.

6.5.5 Aquifer Storage and Recovery

Aquifer Storage and Recovery represents an important operational solution for managing supplies and minimizing evaporation. CRMWA, Amarillo, and Pampa are planning to use ASR to store surplus supplies during low demand periods for use during periods of high demands. This will provide operational flexibility for CRMWA and its customers by fully using the capacity in the pipeline from Roberts County and water treatment facilities. It also provides Amarillo increased usability of its Randall County well field. The ASR strategy is not expected to threaten water resources of the State, but rather to preserve surface water resources for future use and allow the use of groundwater in a more economical manner.

6.5.6 Advanced Treatment

The City of Wellington has a recommended long-term strategy for nitrate removal. Advanced treatment represents a potential additional source of water that could be used to augment existing freshwater sources.

6.6 Consistency with Protection of Agricultural Resources

Agricultural resources are an important component of the Panhandle economy and way of life. According to the 2017 Census of Agriculture, the PWPA has approximately 12,013,120 acres of land in 6,039 farms, of which around 17% is harvested cropland. Approximately 68 percent of the harvested cropland occurred in seven counties (Carson, Dallam, Hansford, Hartley, Moore, Ochiltree, and Sherman). The 2017 Census saw a reduction in the number of farms and the amount of land in farms relative to the 2012 Census, although the acres in cropland increased slightly. While the reductions are not significant, it may be a future trend and protection of these resources is critical to the PWPA.

The greatest needs identified in the PWPA are associated with irrigated agriculture. The plan assumes a level of demand reduction over time and the PWPG recommended water conservation to meet the remaining needs. The PWPG also recognized the benefits of recommending conservation for all irrigation users to conserve and preserve limited water sources for future use.

Water management strategies for irrigated agriculture include a suite of strategies to conserve irrigation water. These strategies will reduce the projected deficit in the heavily irrigated counties and preserve water supplies for future use in the counties with no identified needs. The Water Plan also recommends the development of new groundwater, but most of these strategies are on lands with existing water rights. The transfer of agricultural water for other purposes would only occur on a willing buyer, willing seller basis.

6.7 Consistency with Protection of Natural Resources

The PWPA contains many natural resources and the water management strategies recommended in this plan are intended to protect those resources while still meeting the projected water needs of the region. The impacts of recommended strategies on specific resources are discussed below.

6.7.1 Threatened and Endangered Species

The abundance and diversity of wildlife in the PWPA is influenced by vegetation and topography, with areas of greater habitat diversity having the potential for more wildlife species.

The presence or potential occurrence of threatened or endangered species is an important consideration in planning and implementing any water resource project or water management strategy. Both the state and federal governments have identified species that need protection. Species listed by the U.S. Fish and Wildlife Service (USFWS) are afforded the most legal protection, but the Texas Parks and Wildlife Department (TPWD) also has regulations governing state-listed species. As detailed in Chapter 1, there are 12 state- or federally protected species which have the potential to occur within the PWPA. This does not include species without official protection such as those proposed for listing or species that are considered rare or otherwise of special concern.

The proposed infrastructure strategies in the Panhandle Water Plan can be designed to avoid and/or minimize impacts to threatened and endangered species. Most of the recommended strategies include the development or expansion of groundwater, which has flexibility in the placement of wells and pipelines. The recommended conservation strategies in the Water Plan will continue to preserve water for wildlife. Brush control activities could potentially impact habitat for wildlife, including threatened and endangered species. However, the proposed methods can be implemented to minimize impacts. Also, the expected increase in stream flow from brush removal will provide water to these species.

6.7.2 Parks and Public Lands

The PWPA contains over 103,000 acres of protected parks and public lands. The PWPA is home to Palo Duro Canyon State Park, approximately 20,000 acres located in Armstrong and Randall Counties. Lake Meredith National Recreation Area, which encompasses the area surrounding Lake Meredith, is part of the National Park Service and offers recreational and ecological benefits to the region. The Alibates Flint Quarries National Monument located adjacent to the Lake Meredith Recreation Area is the only national monument in the State of Texas. Buffalo Lake National Wildlife Refuge is also located in the Region and is a valuable wintering area for migratory waterfowl. In addition to these lands, the Region contains three National Grasslands. These include Black Kettle National Grassland in Hemphill County, McClellan Creek National Grassland in Gray County and Rita Blanca National Grassland in Dallam County. No recommended strategies require water supply projects located within these areas. Implementation of water management strategies should not directly impact these lands.

6.7.3 Energy Reserves

The oil and gas industry represent an important economic base for the region with significant activities in the PWPA. In addition, there has been renewed interest in the Granite Wash shale formation (Anadarko Basin) in the northeastern Panhandle. The projected water demands reflect the increased water needs for production of local energy reserves. The Panhandle Water Plan identifies sufficient water to meet these needs. None of the recommended water management strategies is expected to impact oil or gas production in the region.

6.8 Consistency with Protection of Public Health and Safety

Consistent with the guiding principles for regional water planning, the Panhandle Water Plan protects the public health and safety of current and future residents in the PWPA through the identification of water management strategies. There is one county in the PWPA that has limited supplies to serve future municipal water needs. In Moore County, water savings associated with irrigation conservation provides sufficient groundwater to meet the municipal water needs in the county. With these assumptions, the municipal water users are expected to have sufficient water supplies for public health and safety.

6.9 Consistency with State Water Planning Guidelines

To be considered consistent with long-term protection of the State's water, agricultural, and natural resources, the PWPA water plan must also be in compliance with the following regulations:

- 31 TAC Chapter 357.35
- 31 TAC Chapter 357.40
- 31 TAC Chapter 357.41
- 31 TAC Chapter 358.3

The information, data, evaluation, and recommendations included in the 2021 Panhandle Water Plan collectively demonstrate compliance with these regulations. Appendix E presents a summary of the major components of the plan and references the regulations. The content of the 2021 Plan has been evaluated against the regulatory matrix in Appendix E.

6.10 Summary of Protections of State's Resources

The PWPG balanced meeting water needs with good stewardship of the water, agricultural, and natural resources within the region. During the strategy selection process, long-term protection of the State's resources was considered through the assessment of environmental impacts, impacts to agricultural and rural areas and impacts to natural resources.

In this plan, existing in-basin or region supplies were utilized as feasible before recommendations for new water supply projects. Wastewater reuse is an active water source to meet long-term power generation and future municipal water needs in the PWPA. The incorporation of aquifer storage and recovery further utilizes existing infrastructure and resources to meet projected water needs. The proposed conservation measures for the PWPA will continue to protect and conserve the State's resources for future water use.

Despite the best efforts to conserve and use the State's resources efficiently, the PWPA has unmet needs for irrigations. Most of these unmet needs occur early in the planning cycle and decline as more water is saved through conservation. The total amount of unmet water needs for irrigation is shown in Table 6-2.

Table 6-2: PWPA Unmet Needs

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(81,419)	(235,828)	(123,363)	(65,504)	(48,048)	(42,031)

7 DROUGHT RESPONSE INFORMATION, ACTIVITIES, AND RECOMMENDATIONS

7.1 Drought Conditions and Droughts of Record

Numerous definitions of drought have been developed to describe drought conditions based on various factors and potential consequences. In the simplest of terms, drought can be defined as "a prolonged period of below-normal rainfall." However, the *State Drought Preparedness Plan* [(1)] provides more specific and detailed definitions:

- *Meteorological Drought.* A period of substantially diminished precipitation duration and/or intensity that persists long enough to produce a significant hydrologic imbalance.

- *Agricultural Drought.* Inadequate precipitation and/or soil moisture to sustain crop or forage production systems. The water deficit results in serious damage and economic loss to plant and animal agriculture. Agricultural drought usually begins after meteorological drought but before hydrological drought and can also affect livestock and other agricultural operations.

- *Hydrological Drought.* Refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, and as lake, reservoir, and groundwater levels. There is usually a lack of rain or snow and less measurable water in streams, lakes, and reservoirs, making hydrological measurements not the earliest indicators of drought.

- *Socioeconomic Drought.* Occurs when physical water needs start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product.

These definitions are not mutually exclusive and provide valuable insight into the complexity of droughts and their impacts. They also help to identify factors to be considered in the development of appropriate and effective drought preparation and contingency measures.

Definitions

Drought of Record: The worst drought to occur in a region during the entire period of hydrologic and/or meteorological record keeping.

Drought Contingency Plan: State mandated plan that identifies different stages of drought and specific triggers and response for each stage. In addition, the plan must specify quantifiable targets for water use reductions for each stage, and a means and method for enforcement.

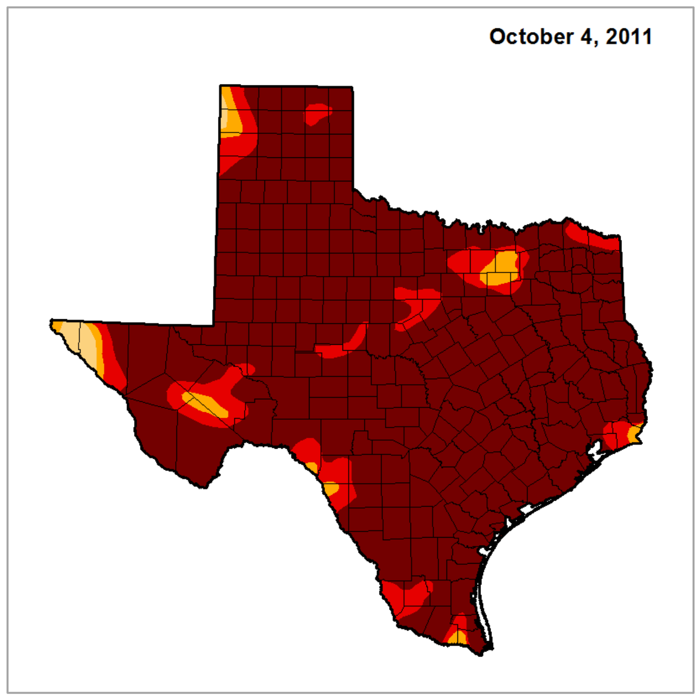
Run of River Supply: Water right permit that allows the permit holder to divert water directly out of a stream or river." 2012 State Water Plan

Droughts have often been described as "insidious by nature." This is mainly due to several factors:

- Droughts cannot be accurately characterized by well-defined beginning or end points.
- Severity of drought-related impacts is dependent on antecedent conditions, as well as ambient conditions such as temperature, wind, and cloud cover.
- Droughts, depending on their severity, may have significant impacts on human activities; and human activities during periods of drought may exacerbate the drought conditions through increased water usage and demand.

Furthermore, the impact of a drought may extend well past the time when normal or above-normal precipitation returns.

Various indices have been developed in an attempt to quantify drought severity for assessment and comparative purposes. One numerical measure of drought severity that is frequently used by many federal and state government agencies is the Palmer Drought Severity Index (PDSI). It is an estimate of soil moisture that is calculated based on precipitation and temperature. Another is the Drought Monitor that incorporates measurements of climatic, hydrologic and soil conditions as well as site-specific observations and reports. The Drought Monitor is distributed weekly and is often the tool used to convey drought conditions to the public and water users. In 2011, most, if not all, of the counties in the PWPA experienced at least some periods of severe or extreme drought. Conditions have improved since 2011 with significant rainfalls in recent years, but some areas in the PWPA are still experiencing hydrological drought conditions. Figure 7-1 shows the historical storage of PWPA reservoirs.



Drought Monitor, October 2011

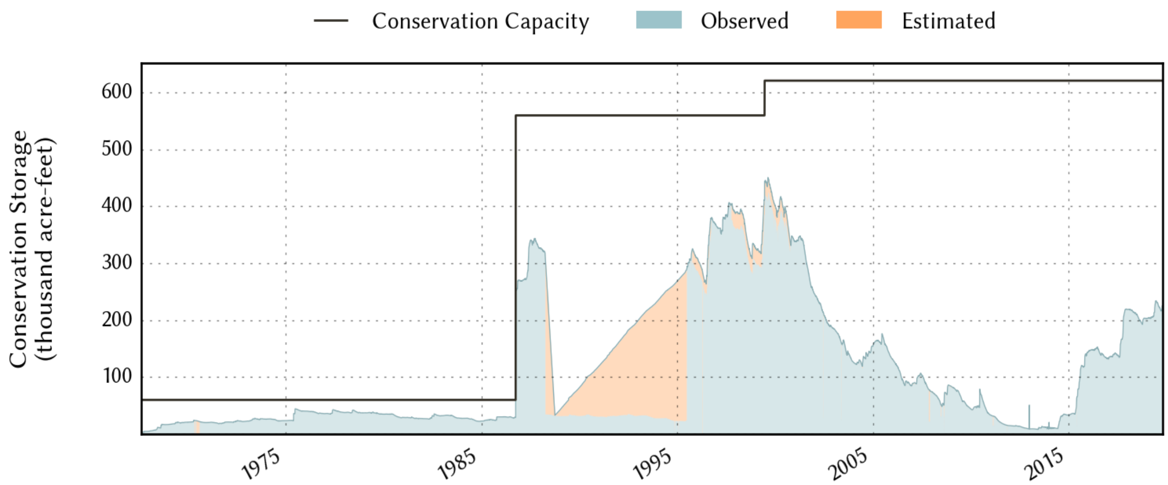


Figure 7-1: Combined Reservoir Storage in the PWPA

Source: Water Data For Texas: https://www.waterdatafortexas.org/reservoirs/region/panhandle

7.1.1 Drought of Record in the Panhandle Water Planning Area

The drought of record is commonly defined as the worst drought to occur in a region during the entire period of hydrologic and/or meteorological record keeping. Historically, for much of Texas the drought of record occurred from 1950 to 1957. During the 1950s drought, many wells, springs, streams, and rivers went dry and some cities had to rely on water trucked in from other areas to meet drinking water demands. By the end of 1956, 244 of the 254 Texas counties were classified as disaster areas due to the drought.

For most of the PWPA, the current drought has eclipsed the drought of the 1950s. This drought has had a substantial impact on surface water supplies within the PWPA. All three major reservoirs in the PWPA are currently in the critical drought period. In 2011, Lake Meredith recorded the lowest historical inflow at approximately 6,300 acre-feet. Both Lake Meredith and Palo Duro Reservoir, which are in the Canadian River Basin, were at less than 10 percent until 2015. As of May 2019, Lake Meredith has improved to approximately 40 percent (Figure 7-2), and Palo Duro Reservoir remains at less than 10 percent (Figure 7-3). Greenbelt Reservoir, located in the Red River Basin, is approximately 20 percent full. (Figure 7-4).

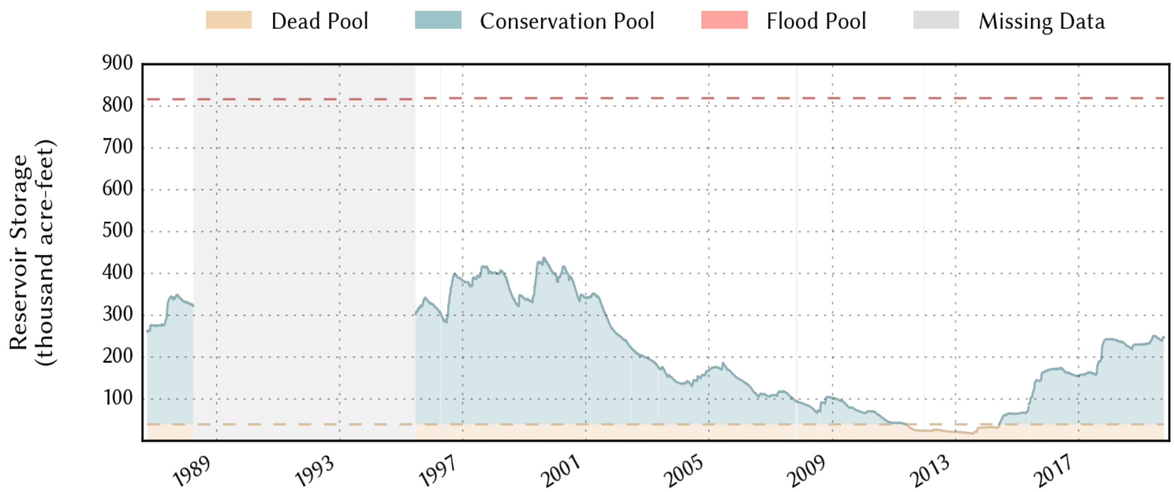


Figure 7-2: Historic Storage in Lake Meredith

Source: Water Data For Texas: https://www.waterdatafortexas.org/reservoirs/individual/meredith

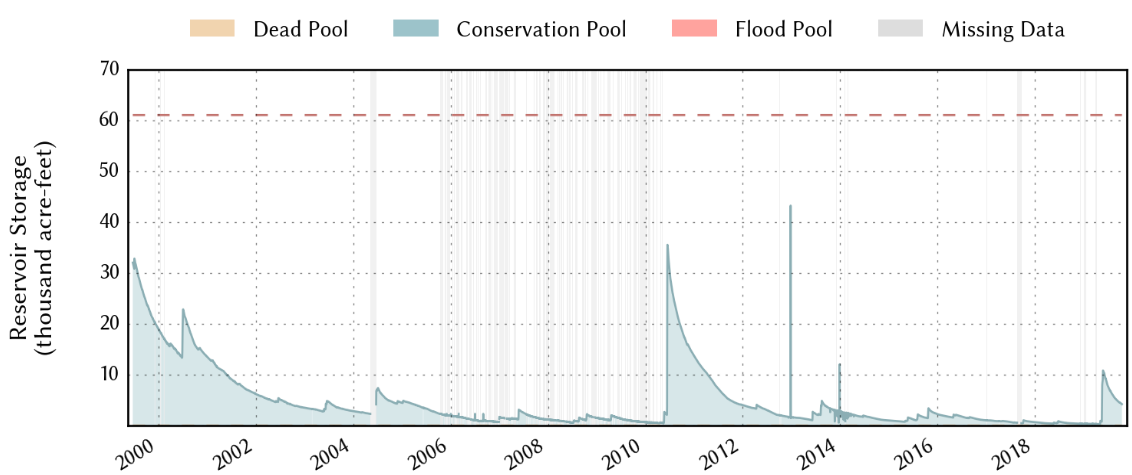


Figure 7-3: Historic Storage in Palo Duro Reservoir

Source: Water Data For Texas: https://www.waterdatafortexas.org/reservoirs/individual/palo-duro

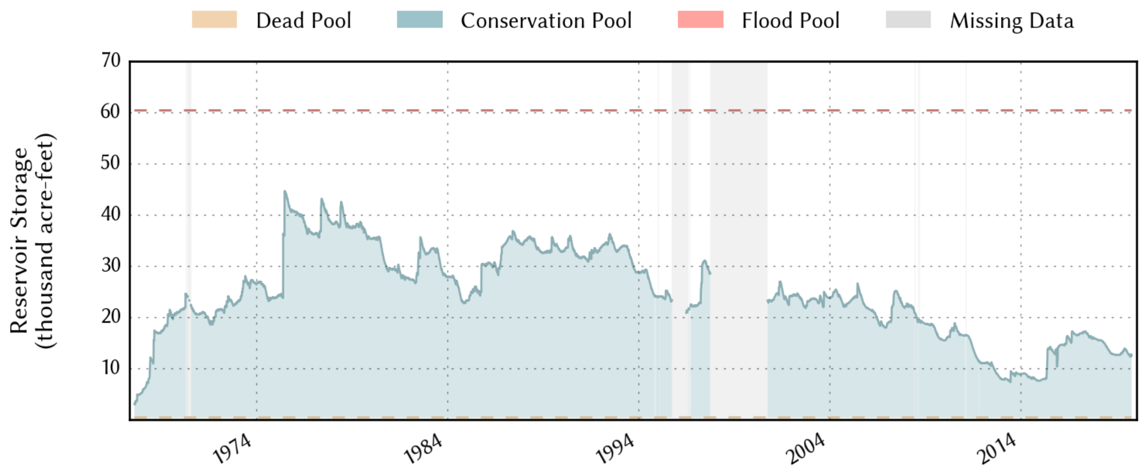


Figure 7-4: Historic Storage in Greenbelt Reservoir

Source: Water Data For Texas: https://www.waterdatafortexas.org/reservoirs/individual/greenbelt

For reservoirs, the drought of record is defined as the period of record that includes the minimum content of the reservoir. The period is recorded from the last time the reservoir spills before reaching its minimum content to the next time the reservoir spills. If a reservoir has reached its minimum content but has not yet filled enough to spill, then it is considered to be still in drought of record conditions. Based on the water availability modeling, the droughts of record for the reservoirs in the PWPA are shown in Table 7-1.

Table 7-1: Droughts of Record for PWPA Reservoirs

Reservoir	Date last full[1]	Date of minimum content	Drought of Record
Meredith	April 2000	March 2012[2]	2000 - Current
Palo Duro	May 1973	June 1996[3]	1973 - Current
Greenbelt	June 1962	June 2011[2]	1962 - Current

[1] None of the PWPA lakes have ever filled. The Date Last Full is based on the firm yield analyses. (Note: Firm yield analyses assume the reservoir is full at the beginning of the simulation.)
[2] Date of the end of the simulation.
[3] Hydrology for WAM simulation for the Palo Duro Reservoir ends in 2004. It was not extended.

For groundwater supplies, meteorological and agricultural conditions were considered for defining the drought of record in the PWPA. The National Atmospheric and Oceanic Administration (NOAA) maintains data on the historical meteorological conditions and drought indices across the country. Figure 7-5 shows the historical precipitation in the High Plains Region of Texas.

Based on this graph, the annual precipitation across the region averages 18.56 inches from 1895 to 2013. The years with the lowest historical precipitation occurred in 1956 and 2011 with 9.57 inches recorded in 1956 and 7.39 inches recorded in 2011. Both years occur during extreme drought.

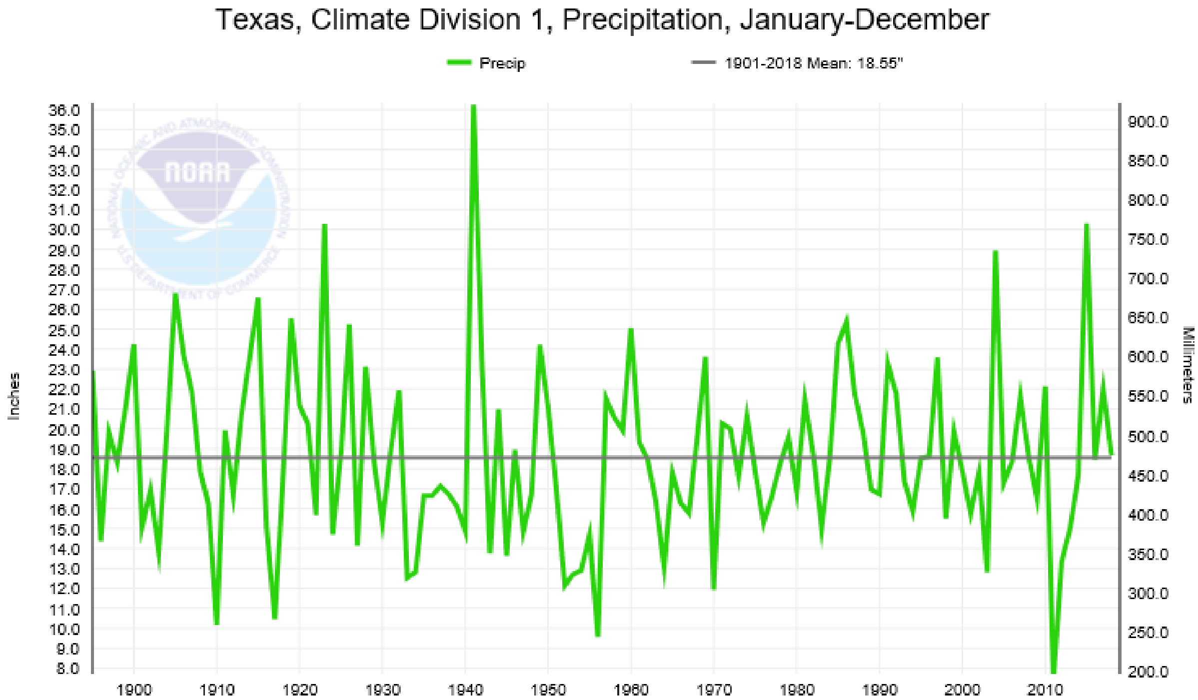


Figure 7-5: Historical Annual Precipitation for the High Plains of Texas

Source: NOAA website (http://www.ncdc.noaa.gov/cag/time-series/us)

Drought of record conditions for run-of-river supplies are typically evaluated based on minimum annual stream flows. Figure 7-6 shows the historical stream flows for selected gages in the PWPA for both the Canadian and Red River Basins. Based on these gages, 2011 was the year with the lowest annual stream flow in the Canadian River Basin. It also was an extreme drought year in the Red River Basin, but there were other years with lower annual flows on the Salt Fork (2013) and North Fork (1996) of the Red River. Considering the overall basin drought, 2011 is the drought of record for the run-of-river supplies in the PWPA.

Drought of Record in PWPA

Reservoir Drought of Record: For reservoirs, the drought of record is defined as the period from the last time the reservoir spills before reaching its minimum content to the next time the reservoir spills. All major reservoirs in PWPA are currently in the Drought of Record.

Run of River Drought of Record: Based on minimum annual stream flows. For both the Canadian River Basin and the Red River Basin, the Drought of Record is considered to be the year 2011.

Groundwater Drought of Record: Generally defined by meteorological and agricultural conditions. In Region A, the years with the lowest recorded precipitation were 1956 and 2011.

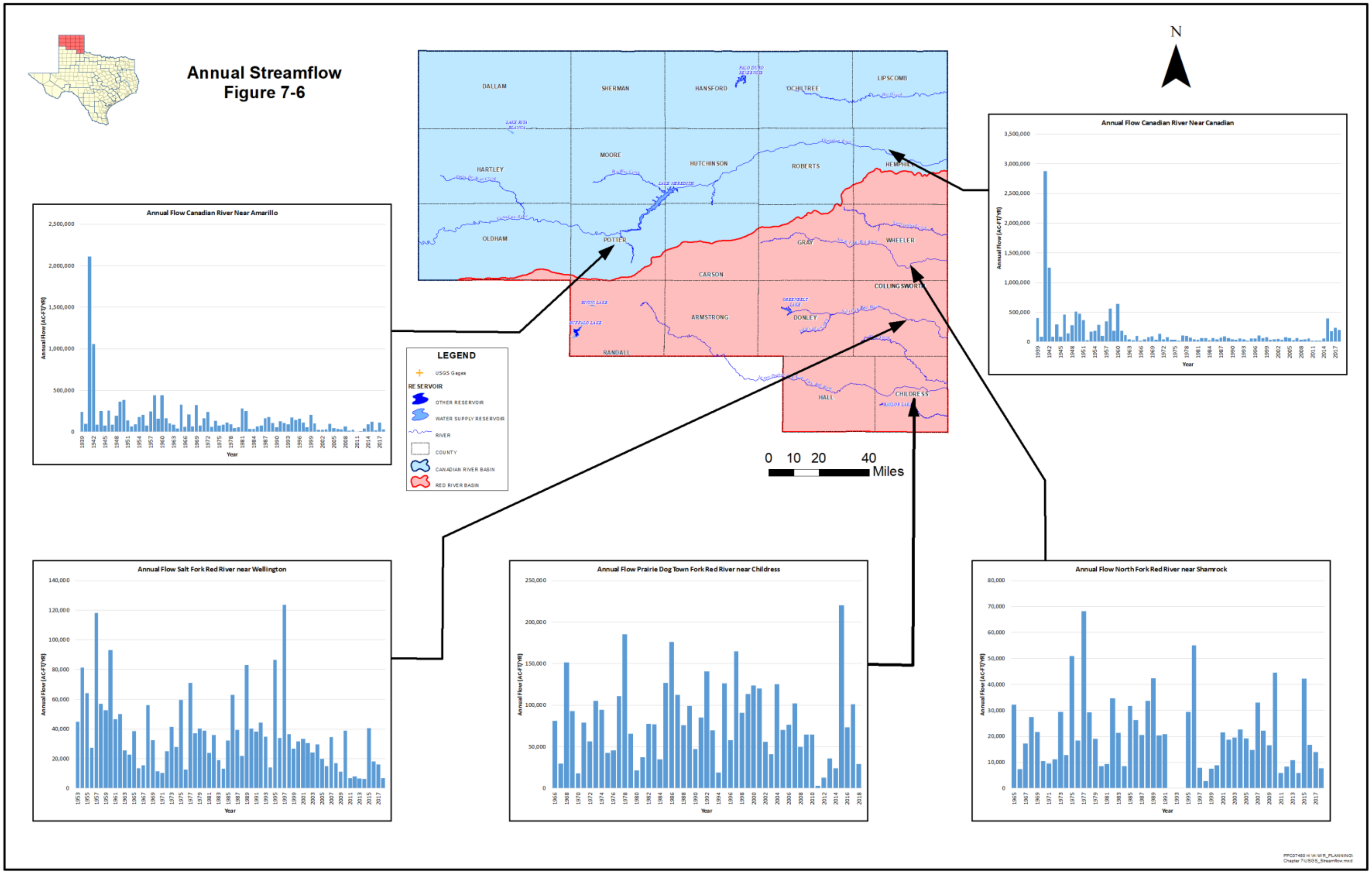


Figure 7-6: Historical Streamflows in the Canadian and Red River Basins

Looking at the PDSI over the same time period, Figure 7-7 clearly shows the drought impacts during the 1950s and again since 2011. The PDSI provides a measurement of long-term drought based on the intensity of drought during the current month plus the cumulative patterns of previous months. It considers antecedent soil moisture and precipitation. For the PWPA, these considerations are important in assessing the potential impacts to groundwater sources during drought from increases in water demands and agricultural water needs.

Considering both the annual precipitation and PDSI in the region, the drought of record for groundwater sources is the current drought that started in 2011.

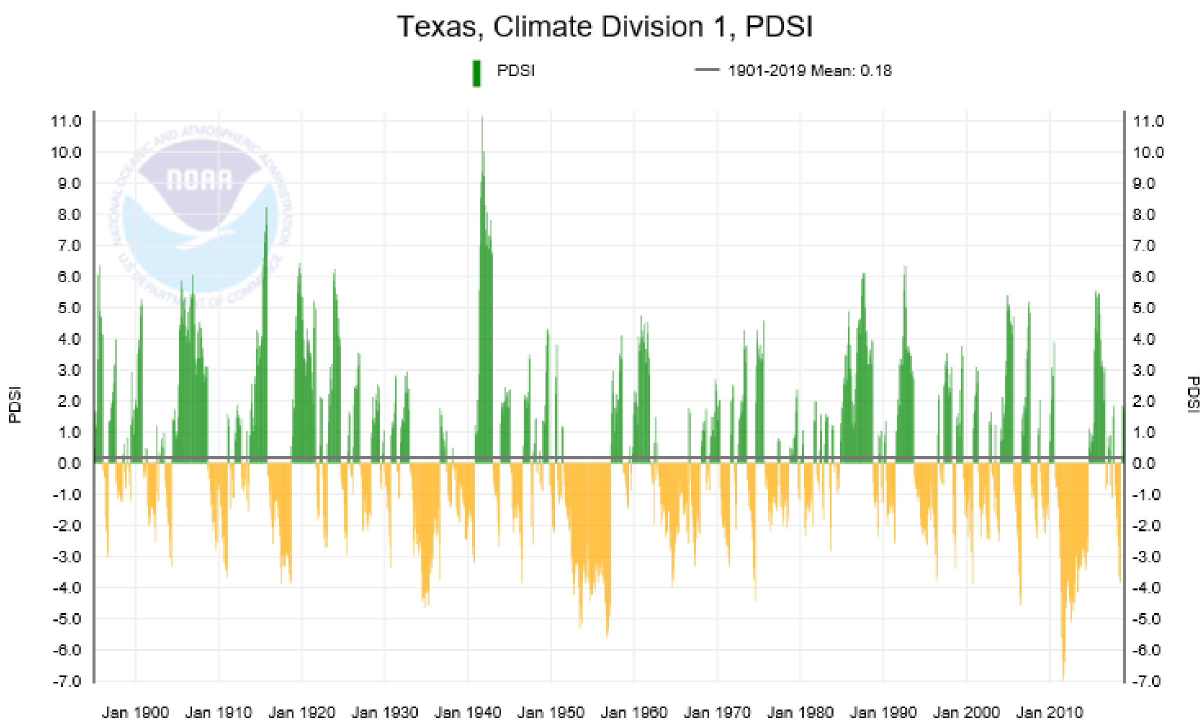


Figure 7-7: Palmer Drought Severity Indices for the High Plains of Texas

Source: NOAA website (http://www.ncdc.noaa.gov/cag/time-series/us)

7.1.2 Impact of Drought on Water Supplies

Drought is a major threat to surface water supplies in the PWPA and groundwater supplies that rely heavily on recharge (such as the Seymour aquifer). The Ogallala aquifer, which provides most of the water supplies in the PWPA, is less impacted by reduced recharge associated with meteorological droughts. However, the Ogallala aquifer is greatly impacted by agricultural droughts (which typically follow meteorological droughts) because the demands on the water source can increase significantly. Over time, the lack of recharge combined with increased demands can impact the amount of storage in the aquifer for future use.

For surface water supplies, hydrological drought is significant because it impacts the yield of water source. Typically, multi-year droughts have the greatest impacts on a reservoir yield. As previously discussed, the Lake Meredith watershed is currently experiencing its lowest inflows since the reservoir was constructed. This impacts water supplies to users in both the PWPA and Llano Estacado Region. To better understand some of the factors contributing to the decline in inflows, a special study on the Lake Meredith watershed was conducted as part of the 2011 regional water plan (Salazar and Schnier, 2010). A concurrent study on drought in the entire Canadian River watershed above Lake Meredith was conducted by the Bureau of Reclamation in conjunction with others (Brauer et al, 2011).

Both studies concluded that it appears there is no one factor or event that appears to be the major contributor to the decline of inflows to Lake Meredith. Annual precipitation, potential evaporation, and changes in irrigation practices do not appear to be contributing factors. The Salazar and Schnier study hypothesized that the combination of factors, including reduced rainfall intensities, increasing shrubland and declining groundwater levels, have resulted in decreased runoff below Ute Reservoir. The Brauer study did not attribute the impacts of increased shrubland to the declining runoff. This conclusion was supported by the continued low stream flows in the watershed following extensive brush control and removal. The Brauer study noted that the entire Canadian River watershed was experiencing drought conditions and reduced reservoir storage. Both studies acknowledged that the activities in the watershed above the Logan gage (Ute Reservoir) may be a significant factor with respect to the total amount of inflow to Lake Meredith. Figure 7-8 shows the historical gage flow at Logan (just below Ute Reservoir) and the historic water levels in Lake Meredith. Most of the flows at the Logan gage are releases from Ute Reservoir.

These studies show that drought can have a significant impact on a water source’s reliable supply, but if drought is combined with other factors the results can be catastrophic.

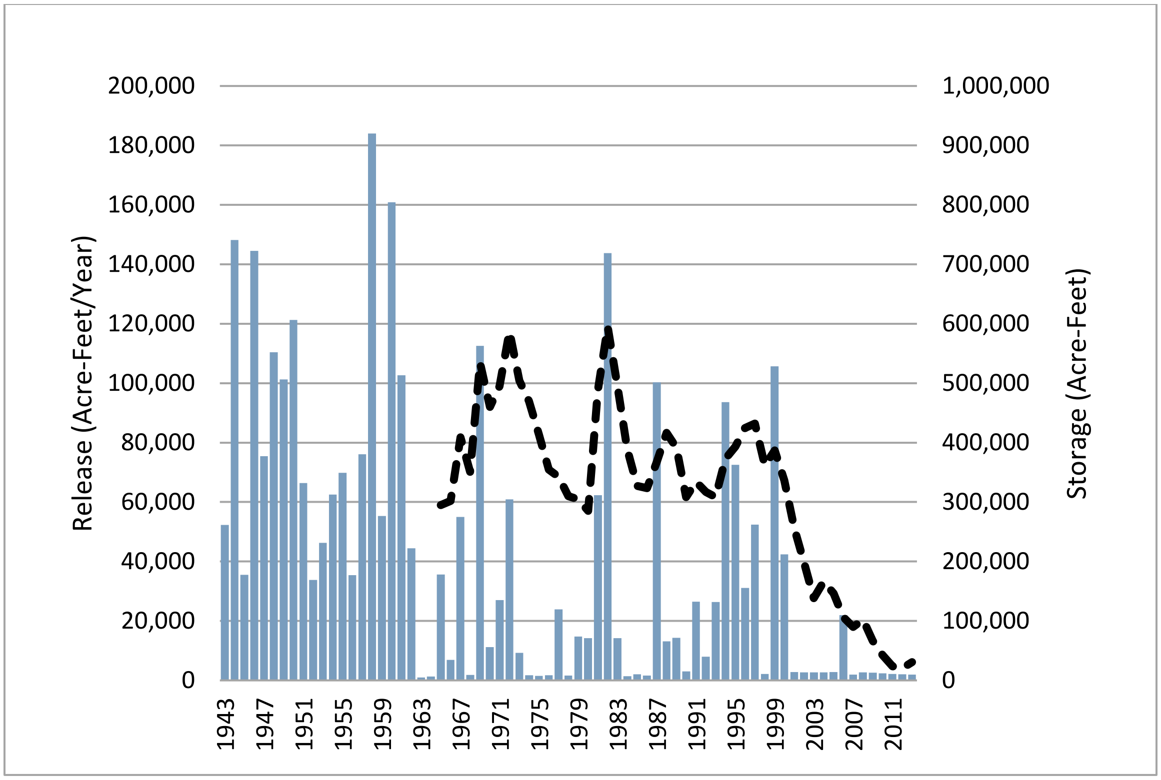


Figure 7-8: Comparison of Lake Meredith Lake Levels to Flows at Logan Gage

7.2 Current Drought Preparations and Response

In 1997, the Texas Legislature directed the TCEQ to adopt rules establishing common drought plan requirements for water suppliers in response to drought conditions throughout the state. Since 1997, the TCEQ has required all wholesale public water suppliers, retail public water suppliers serving 3,300 connections or more, and irrigation districts to submit drought contingency plans (DCP). TCEQ now also requires all retail public water suppliers serving less than 3,300 connections to prepare and adopt DCPs by no later than May 1, 2009. All DCPs shall be updated every five years and be available for inspection upon request. The most recent updates were to be submitted to the TCEQ by May 1, 2019.

All wholesale water providers and most municipalities in the PWPA have taken steps to prepare for and respond to drought through efforts including the preparation of individual DCPs and readiness to implement the DCPs as necessary. These drought plans include specific water savings goals and measures associated with multiple drought stages. In addition to these plans, many water providers have a Management Supply Factor (or safety factor) greater than 1.0 for demands that are essential to public health and safety.

DCPs typically identify different stages of drought and specific triggers and response for each stage. In addition, the plan must specify quantifiable targets for water use reductions for each stage, and a means and method for enforcement.

7.2.1 Drought Preparedness

In general, water suppliers in PWPA identify the onset of drought (drought triggers) based on either their current level of supply or their current level of demand. Often the triggers for surface water reservoirs are based on the current capacity of the reservoir as a percentage of the total reservoir capacity. In the PWPA, the reservoir operators use a combination of reservoir storage (elevation triggers) and/or demand levels. Triggers for groundwater supplies are commonly determined based on water well elevations or demand. Suppliers set these triggers as needed based on the individual parameters of their system. Customers of a wholesale water provider are subject to the triggers and measures of the providers' DCPs.

Eight DCPs were submitted to the PWPG during this round of planning. Twelve other plans were submitted during the previous planning cycle and are considered in this plan. The majority of the submitted plans use trigger conditions based on the demands placed on the water distribution system. Of the plans reviewed, three users based trigger actions on well levels, eight based actions on storage reservoir levels, and nine based actions on demands/consumption. Table 7-2 summarizes the basis of the drought triggers by provider. Attachment 7-1 summarizes the triggers and actions by water provider for initiation and response to drought. Attachment 7-2 summarizes the DCPs submitted to the PWPG.

Table 7-2: Type of Trigger Condition for Entities with Drought Contingency Plans

Entity	Type of Trigger Condition		Implemented since 2015
	Demand	Supply	
Amarillo	X	X	No
Borger	X	X	No
Canyon		X	No
Childress	X		No
Claude	X		No
CRMWA		X	No
Dalhart	X		No
Dumas	X		No
Greenbelt	X	X	No
Gruver	X		No
Higgins	X	X	No
McLean	X	X	No
Palo Duro RA		X	No
Pampa		X	No
Perryton	X		No
Red River Authority		X	No
Shamrock	X		No
Turkey		X	No
Wellington	X		No
White Deer	X		No

While the DCPs triggers and responses are unique to each entity, they are clear and specific to the entity. Differences between entities should not confuse the public or otherwise impede drought response efforts due to the geographic separation of the entities in the PWPA. Drought responses for Major Water Providers, such as CRMWA, are clearly conveyed to all customers. No entity in the PWPA has implemented their DCP in the last five years.

Challenges to the drought preparedness in the PWPA include the resources available to smaller cities to adequately prepare for drought and respond in a timely manner. Also, for many cities the drought of 2011 truly tested the entity's drought plan and triggers. Some water providers found that the triggers were not set at the appropriate level to initiate different stages of the drought plan. The 2011 drought came quickly and was very intense. This increased demands on local resources and for many groundwater users increased competition for the water. Some systems had difficulty meeting demands and little time to make adjustments. Also, increased demands placed additional competition for water between agriculture and municipalities leading to lower water levels.

Water providers of surface water sources have proactively developed supplemental groundwater sources, providing additional protections during drought. Many groundwater users expand groundwater production in response to drought. Groundwater in the PWPA provides a more drought-resilient water source, but it needs to be managed to assure future supplies.

7.3 Existing and Potential Emergency Interconnects

According to Texas Statute §357.42(d),(e) [2] regional water planning groups are to collect information on existing major water infrastructure facilities that may be used in the event of an emergency need of water. Pertinent information includes identifying the potential user(s) of the interconnect, the potential supplier(s), the estimated potential volume of supply that could be provided, and a general description of the facility. Texas Water Code §16.053(c) requires information regarding facility locations to remain confidential.

This section provides general information regarding existing and potential emergency interconnects among water user groups within the PWPA.

7.3.1 Existing Emergency Interconnects

Major water infrastructure facilities within the PWPA were identified through a survey process in order to better evaluate existing and potentially feasible emergency interconnects. Several main water suppliers identified were Philips, which obtains water from the Ogallala, Tri-City Water Company, and the Greenbelt MIWA. Table 7-3 presents the survey results for the existing emergency interconnects among water users and neighboring systems.

Table 7-3: Existing Emergency Interconnects to Major Water Facilities in the PWPA

Entity *Providing* Supply	Entity *Receiving* Supply
Phillips County	TCW Supply
Greenbelt Water Authority	City of Memphis
Tri-City Water Company	City of Stinnett
Phillips County	City of Stinnett
Phillips Borger Plant	City of Borger

7.3.2 Potential Emergency Interconnects

Responses to survey questions helped identify other potential emergency interconnects for various WUGs in the PWPA. Table 7-4 presents a list of cities for those receiving and those supplying the potential emergency interconnects.

It was determined that additional emergency interconnects to the CRMWA system are feasible. However, it is assumed that the interconnects are probably limited to those facilities either currently within the CRMWA structure or near existing distribution lines. One of the most limiting factors for developing practical interconnects in the PWPA is the large distance that separates many cities and small towns.

In addition, an assessment was conducted to identify cities within a fifteen-mile radius to existing CRMWA distribution lines. Fifteen miles was assumed to be the farthest distance any system would find feasible for an alternative water supply during an emergency water need. Cities that meet the fifteen-mile radius requirement include: Stinnett, Fritch, TCW Supply Inc., Sanford, and Lake Tanglewood (Table 7-4).

The Greenbelt MIWA was not surveyed but should be included in the discussion of being a potential emergency interconnect. Within the PWPA, Greenbelt MIWA serves customers in the counties of Donley, Collingsworth, Hall and Childress. Only one small community was identified that potentially could interconnect to the Greenbelt MIWA system during an emergency water need. Several other rural communities in the PWPA are already served by this provider. As shown in Table 7-4, the community meeting the maximum 15-mile radius requirement is Lakeview.

Emergency interconnects were found to be not practical for many of the entities that were evaluated for potential emergency water supplies due to the long distance of transmission and size of facilities. The type of infrastructure required between entities to provide or receive water during an emergency need was deemed impractical due to long transmission distances. Furthermore, it was deemed impractical during an emergency situation, to complete the required construction time in a reasonable timeframe.

Table 7-4: Potential Emergency Interconnects to Major Water Facilities in the PWPA

Entity *Providing* Supply	Entity *Receiving* Supply
CRMWA	Stinnett
	Fritch
	TCW Supply Inc.
	Sanford
	Lake Tanglewood
Greenbelt MIWA	Lakeview
WRB Refining	Borger
Amarillo	Borger
Borger	Sanford
	Stinnett
	RBC

7.4 Emergency Responses to Local Drought Conditions or Loss of Municipal Supply

Texas Statute §357.42(g) [(3)] requires regional water planning groups to evaluate potential temporary emergency water supplies for all County-Other WUGs and municipalities with 2010 populations less than 7,500 that rely on a sole source of water. The purpose of this evaluation is to identify potential alternative water sources that may be considered for temporary emergency use in the event that the existing water supply sources become temporarily unavailable due to extreme hydrologic conditions such as emergency water right curtailment, unanticipated loss of reservoir conservation storage, or other localized drought impacts.

This section provides potential solutions that should act as a guide for municipal water users that are most vulnerable in the event of a loss of supply. This review was limited and did not require technical analyses or evaluations following in accordance with 31 TAC §357.34.

7.4.1 Emergency Responses to Local Drought Conditions

A survey was conducted to identify and evaluate the municipal water users that are most vulnerable in the event of an emergency water need. The analysis included all 'county-other' WUGs and rural cities with a population less than 7,500 and on a sole source of water that were within 5 miles of another water system.

Figure 7-9 presents a PWPA map delineating municipalities that meet the analysis requirements. Three main reservoirs (Greenbelt, Lake Meredith and Palo Duro) were included on the map, along with the major water infrastructure facilities (CRMWA and Greenbelt) discussed in Section 7.3. The map illustrates a general proximity to potential alternative water sources that may be considered for temporary emergency use.

Table 7-5 presents temporary responses that may or may not require permanent infrastructure. It was assumed in the analysis that the entities listed would have approximately 180 days or less of remaining water supply.

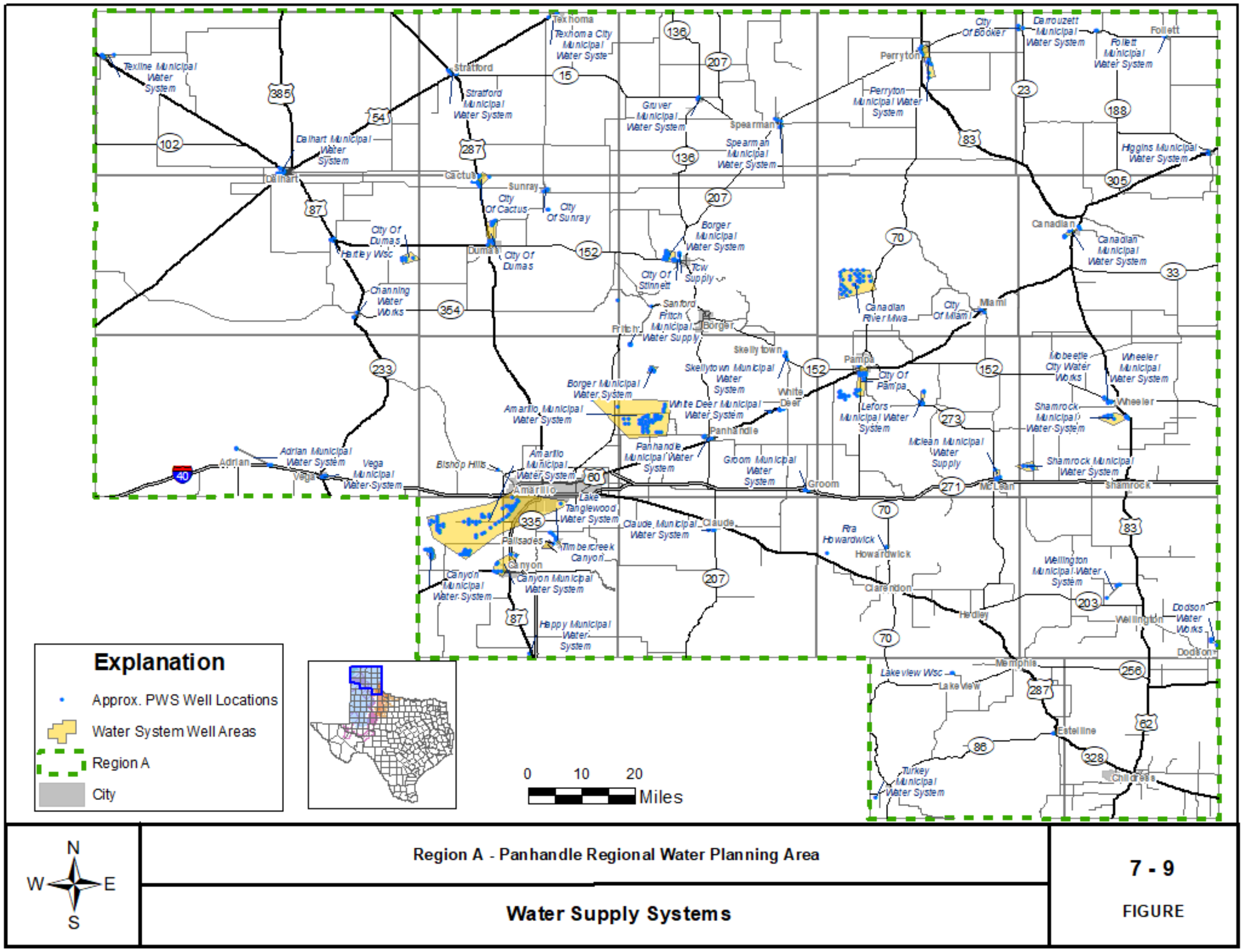


Figure 7-9: Entities Considered for Emergency Supplies

Table 7-5: Emergency Responses to Local Drought Conditions in the PWPA.

Entity				Potential Emergency Water Supply Source(s)							Implementation Requirements		
Water User Group Name	County	2020 Population	2020 Demand (ac ft/yr)	Drill additional groundwater wells	Brackish groundwater limit treatment	Brackish groundwater desalination	Emergency interconnect	Other named local supply	Trucked in water	Voluntary transfer from irrigation	Type of infrastructure required	Entity providing supply	Emergency agreements already in place
Booker	Lipscomb	1,740	496	■					■	■			
	Ochiltree	22	6	■					■	■			
Cactus	Moore	3,179	985	■	■	■			■	■			
Canadian	Hemphill	2,775	823	■					■				
Claude	Armstrong	1,202	360	■	■	■			■	■			
Fritch	Hutchinson	2,968	592	■					■	■		CRMWA	
	Moore	14	3	■					■				
Groom	Carson	568	177	■					■	■			
Gruver	Hansford	1,353	350	■					■	■			
Happy	Randall	678	10	■	■	■			■				
Lake Tanglewood	Randall	1,096	438	■	■	■			■	■		CRMWA	
McLean	Gray	800	210	■		■			■	■			
Miami	Roberts	600	225	■					■	■			
Panhandle	Carson	2,470	576	■					■	■			
Shamrock	Wheeler	1,910	350	■		■			■	■			
Spearman	Hansford	3,364	670	■					■	■			
Stinnett	Hutchinson	1,917	454	■			■			■		Phillips; Tri-City Water Company	Stinnett

Entity				Potential Emergency Water Supply Source(s)							Implementation Requirements		
Water User Group Name	County	2020 Population	2020 Demand (ac ft/yr)	Drill additional groundwater wells	Brackish groundwater limit treatment	Brackish groundwater desalination	Emergency interconnect	Other named local supply	Trucked in water	Voluntary transfer from irrigation	Type of infrastructure required	Entity providing supply	Emergency agreements already in place
Stratford	Sherman	2,134	496	▪					▪	▪			
Sunray	Moore	1,945	450	▪					▪	▪			
TCW Supply Inc.	Hutchinson	1,955	690	▪			▪		▪	▪		Phillips	▪
Texline	Dallam	512	219	▪	▪	▪			▪	▪			
Vega	Oldham	1,036	272	▪	▪	▪			▪				
Wellington	Collingsworth	2,189	524	▪					▪				
Wheeler	Wheeler	1,547	493	▪					▪	▪			
White Deer	Carson	1,068	113	▪					▪	▪	Pump Station & Treatment	Groom	
County-Other[1]		2010 Population											
Skellyton	Carson	619		▪					▪	▪			
Adrian	Oldham	166		▪	▪	▪			▪				
Bishop Hills	Potter	193		▪	▪	▪			▪				
Channing	Hartley	363		▪	▪	▪			▪	▪			
Darrouzett	Lipscomb	350		▪					▪	▪			
Dodson	Collingsworth	109		▪		▪			▪				

Entity				Potential Emergency Water Supply Source(s)							Implementation Requirements		
Water User Group Name	County	2010 Population	2020 Demand (ac ft/yr)	Drill additional groundwater wells	Brackish groundwater limited treatment	Brackish groundwater desalination	Emergency interconnect	Other named local supply	Trucked in water	Voluntary transfer from irrigation	Type of infrastructure required	Entity providing supply	Emergency agreements already in place
Follett	Lipscomb	459		▪					▪	▪			
Hartley	Hartley	540		▪	▪	▪			▪	▪			
Higgins	Lipscomb	397		▪					▪	▪			
Howardwick	Donley	402		▪		▪			▪	▪			
Lakeview	Hall	199		▪					▪			Greenbelt	
Mobeetie	Wheeler	101		▪			▪		▪	▪	Piping from well to treatment plant	Wheeler	
Palisades	Randall	325		▪	▪	▪			▪				
Sanford	Hutchinson	164		▪					▪	▪		CRMWA; Borger	
Texhoma	Sherman	346		▪					▪	▪			
Timbercreek Canyon	Randall	418		▪	▪	▪			▪				
Turkey	Hall	421		▪		▪			▪				
Lefors	Gray	540		▪		▪			▪	▪			
Grandview	Gray			▪					▪		Pump Station & Treatment	Groom	

[1] The analysis included all 'county-other' WUGs and rural cities with a population less than 7,500 and on a sole source of water that were within 5 miles of a potential water system. Figure 7-9 illustrates a general proximity (within 5 miles) to potential alternative water sources that may be considered for temporary emergency use.

7.4.2 Voluntary Transfer of Irrigation Rights

An additional evaluation was conducted which considered voluntary transfer of irrigation rights as an emergency response to local drought conditions. Voluntary transfer of irrigation rights is the payment for temporary transfer of local irrigation supplies for other uses. Voluntary transfer or "irrigation suspension" programs have been implemented successfully by the Edwards Aquifer Authority. The plan is that WUGs would be willing and able to pay for temporary suspension and transfer of irrigation water from local wells to avoid trying to develop more distant sources that may prove impractical. By tapping local sources, WUGs could minimize construction cost and time required to develop infrastructure required for the emergency solution. Table 7-5 presents the entities in the PWPA where voluntary transfer of irrigation rights might be feasible, given their proximity to currently used irrigated areas. Of the 42 entities listed, 31 communities were found to be located in applicable areas, making voluntary transfer of irrigation rights a potential drought management response.

7.4.3 Releases from Upstream Reservoirs and Curtailment of Rights

Releases from upstream reservoirs and the curtailment of upstream/downstream water rights were considered but were not identified as appropriate responses for the rural communities in the PWPA.

7.4.4 Brackish Groundwater

Brackish groundwater was evaluated as a temporary source during an emergency water need. Some brackish groundwater is found in certain places in the Ogallala, but other brackish groundwater supplies can be obtained from the Dockum, Rita Blanca, and other formations which underlie the shallow aquifers found in the PWPA.

Required infrastructure would include additional groundwater wells, potential treatment facilities and conveyance facilities. Brackish groundwater at lower TDS concentrations may require only limited treatment. Eighteen of the 43 entities listed in Table 7-5 will be able to potentially use brackish groundwater as a feasible solution to an emergency local drought condition.

7.4.5 Drill Additional Local Groundwater Wells and Trucking in Water

In the event that the existing water supply sources become temporarily unavailable, drilling additional groundwater wells and trucking in water are optimal solutions. Table 7-5 presents these options as viable for all 43 entities listed.

7.5 Region-Specific Drought Response Recommendations and Model Drought Contingency Plans

As required by the TWDB, the PWPG shall develop drought recommendations regarding the management of existing groundwater and surface water sources. These recommendations must include factors specific to each source as to when to initiate drought response and actions to be taken as part of the drought response. These actions should be specified for the manager of a water source and entities relying on the water source. The PWPG has defined the manager of water sources as the entity that controls the water production and distribution of the water supply from the source. For purposes of this assessment, a manager must also meet the TCEQ requirements for development of DCP. Entities that rely on the water sources include customers of the water source manager and direct users of the water sources, such as irrigators. A list of each surface water and groundwater source in the PWPA and the associated managers and users of the source is included in Attachment 7-1.

7.5.1 Drought Trigger Conditions for Surface Water Supply

Drought trigger conditions for surface water supply are customarily related to reservoir levels. The PWPG acknowledges that the DCPs for the suppliers who have surface water supplies are the best management tool for these water supplies. The PWPG recommends that the drought triggers and associated actions developed by the regional operator of the reservoirs are the PWPA regional triggers for these sources. A summary of these triggers and actions by reservoir as effective October 1, 2019 follows. The region also recognizes any modification to these drought triggers that are adopted by the regional operator.

Lake Meredith (Canadian River Municipal Water Authority)

CRMWA adopted a DCP on July 14, 1999 and the same was revised on January 12, 2011 and reviewed on April 10, 2019. Since CRMWA has multiple sources of water (Lake Meredith and Roberts County groundwater), the drought triggers are based on the Authority's total water supply. Lake Meredith has been in drought conditions for over a decade, with water levels generally declining since 2000. Recent rains have increased the water levels, but the lake is still in drought of record conditions. The triggers and actions for CRMWA are shown in the following table (Table 7-6). These triggers can be implemented at the time of any review of the supply by the CRMWA Board of Directors.

Table 7-6: Lake Meredith Drought Triggers and Actions

Drought Stage	Trigger (No. of Member Cities with Needs):	Action[1]
Mild	1 to 2	Public awareness; Promote conservation; Technical assistance to users; Cities to initiate appropriate stage of DCP
Moderate	3 to 5	Above
Severe	> 5	Above

[1] At any stage, CRMWA may restrict deliveries based on pro rata shares in accordance with State law, if needed.

Greenbelt Reservoir (Greenbelt Municipal and Industrial Water Authority)
The Board of Directors for Greenbelt Municipal and Industrial Water Authority passed a resolution adopting a DCP on August 19, 1999. Triggering criteria are based on water storage levels in the Greenbelt Reservoir and are described as follows:

Table 7-7: Greenbelt Reservoir Drought Triggers and Actions

Drought Stage	Trigger	Action (1)
Mild	Water level = 2,637 feet mean sea level (msl)	Voluntary measures to achieve 10% use reduction
Moderate	Water level = 2,634 feet msl; Demand > 7.5 million gallons per day (MGD)	20% use reduction; reduce customer storage to 75% capacity; initiate customer's Stage 2 of DCP
Severe	Water level = 2,631 feet msl; Demand > 7.5 MGD	30% use reduction; reduce customer storage to 50% capacity; initiate customer's Stage 3 of DCP
Emergency	Water level = 2,628 feet msl; Demand > 7.5 MGD Equipment failure; Water quality impairment	Actions as appropriate

[1] All stages include communications with customers and media.

Palo Duro Reservoir (Palo Duro Water District)
Palo Duro River Authority (now Palo Duro Water District) adopted a conservation plan for Palo Duro Reservoir in May of 1987. Triggering criteria are based on water storage levels in Palo Duro Reservoir and are described as follows:

Table 7-8: Palo Duro Reservoir Drought Triggers and Actions

Drought Stage	Trigger	Action
Mild	Water level = 2,876 feet msl	Communication, voluntary outdoor water schedule
Moderate	2,864 feet msl < Water level < 2,876 feet msl	10% reduction in deliveries, request mandatory limits in outdoor water use
Severe	Water level < 2,864 feet msl	Curtail deliveries as needed, request no outdoor water use, consider alternative supplies
Emergency	Equipment failure	Above

7.5.2 Drought Trigger Conditions for Run-of-River and Groundwater Supply

Both run-of-river and groundwater supplies are more regional than reservoirs and typically there are many users of these sources. As noted in Section 7.2.1, some water providers will have developed DCPs that are specific to their water supplies. Other water users, such as agricultural or industrial users, may not have DCPs. To convey drought conditions to all users of these resources in the PWPA, the PWPG proposes to use the Drought Monitor. This information is easily accessible and updated regularly. It does not require a specific entity to monitor well water levels or stream gages. It is also geographically specific so that drought triggers can be identified on a sub-county level that is consistent with the location of use. The PWPG adopted the same nomenclature for the Drought Monitor for corresponding PWPA drought triggers. Table 7-9 shows the categories adopted by the U.S. Drought Monitor and the associated PDSI.

Table 7-9: Drought Severity Classification

Category	Description	Possible Impacts	Palmer Drought Severity Index
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water needs developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9
D2	Severe Drought	Crop or pasture losses likely; water needs common; water restrictions imposed	-3.0 to -3.9
D3	Extreme Drought	Major crop/pasture losses; widespread water needs or restrictions	4.0 to 4.9
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; needs of water in reservoirs, streams, and wells creating water emergencies	5.0 or less

Source: U.S. Drought Monitor: http://droughtmonitor.unl.edu/AboutUs/ClassificationScheme.aspx

For groundwater and run-of-river supplies, the PWPG recognizes that the initiation of drought response is the decision of the manager of the source and/or user of the source. The PWPG recommends the following actions based on each of the drought classifications listed above:

- Abnormally Dry – Entities should begin to review their DCP, status of current supplies and current demands to determine if implementation of a DCP stage is necessary.
- Moderate Drought – Entities should review their DCP, status of current supplies and current demands to determine if implementation of a DCP stage is necessary.
- Severe Drought – Entities should review their DCP, status of current supplies and current demands to determine if implementation of a DCP stage or changing to a more stringent stage is necessary. At this point if the review indicates current supplies may not be sufficient to meet reduced demands, the entity should begin considering alternative supplies.

- Extreme Drought – Entities should review their DCP, status of current supplies and current demands to determine if implementation of a DCP stage or changing to a more stringent stage is necessary. At this point if the review indicates current supplies may not be sufficient to meet reduced demands, the entity should consider alternative supplies.

- Exceptional Drought – Entities should review their DCP, status of current supplies and current demands to determine if implementation of a DCP stage or changing to a more stringent stage is necessary. At this point if the review indicates current supplies are not sufficient to meet reduced demands, the entity should implement alternative supplies.

7.5.3 Model Drought Contingency Plans

Model DCPs were developed for the PWPG and are available online through the PWPG website (http://www.panhandlewater.org/). Each plan identifies four drought stages: mild, moderate, severe and emergency. Some plans also include a critical drought stage. The recommended responses range from notification of drought conditions and voluntary reductions in the "mild" stage to mandatory restrictions during an "emergency" stage. Each entity will select the trigger conditions for the different stages and the appropriate response. Entities should use the TAC 228 rules mandated by the TCEQ as the guideline in development of these plans.

7.6 Drought Management Strategies

Drought management is a temporary strategy to conserve available water supplies during times of drought or emergencies. This strategy is not recommended to meet long-term growth in demands, but rather acts as means to minimize the adverse impacts of water supply needs during drought. The TCEQ requires drought contingency plans for wholesale and retail public water suppliers and irrigation districts. A drought contingency plan may also be required for entities seeking State funding for water projects. The PWPG does not recommend specific drought management strategies. The PWPG recommends the implementation of DCPs by suppliers when appropriate to reduce demand during drought and prolong current supplies. The PWPG also recommends the implementation of conservation measures for all users to conserve its water resources for the future.

7.7 Other Drought-Related Considerations

7.7.1 Texas Drought Preparedness Council and Drought Preparedness Plan

In accordance with TWDB rules, all relevant recommendations from the Drought Preparedness Council were considered in the writing of this Chapter. The Texas Drought Preparedness Council is composed of representatives from multiple State agencies and plays an important role in monitoring drought conditions, advising the governor and other groups on significant drought conditions, and facilitating coordination among local, State, and federal agencies in drought-response planning. The Council meets regularly to discuss drought indicators and conditions across the state and releases Situation Reports summarizing their finding.

Additionally, the Council has developed the State Drought Preparedness Plan, which sets forth a framework for approaching drought in an integrated manner in order to minimize impacts to people and resources. The PWPG supports the ongoing efforts of the Texas Drought Preparedness Council and recommends that water providers and other interested parties regularly review the Situation Reports as part of their drought monitoring procedures. The Council provided two recommendations to all RWPGs which are addressed in this chapter:

1. Follow the outline template for Chapter 7 provided to the regions by Texas Water Development Board staff in April of 2019, making an effort to fully address the assessment of current drought preparations and planned responses, as well as planned responses to local drought conditions or loss of municipal supply.
2. Develop region-specific model drought contingency plans for all water use categories in the region that account for more than 10 percent of water demands in any decade over the 50-year planning horizon.

To meet these recommendations, the PWPG has developed this chapter to correspond with the sections of the outline template. The PWPG has also developed a model DCP for water use categories that exceed 10 percent of the demands. For the PWPA, these use categories include irrigation only. A model DCP for irrigation is included in the 2021 Plan (see Section 7.5.3).

The PWPG does not recommend any drought management strategies as a long-term supply solution. Instead, it reserves these types of strategies for unanticipated emergency situations only.

7.7.2 Other Drought Recommendations

One of the challenges with drought in the PWPA is that the response to drought and associated impacts can vary depending upon the timing of the drought. Droughts that occur during the agricultural growing season can have a greater impact than if it occurs at other times. Since irrigated agriculture accounts for such a large percent of the water use in the region, the impacts of agricultural droughts on water supplies can be significant because it not only affects agricultural producers but also impacts other users that rely on those supplies.

To be better prepared for future droughts, the PWPG has the following recommendations:

- Municipal water users that rely on groundwater should consider protecting its water supplies from competition through the acquisition of additional water rights and/or expansion of current well fields. Municipalities should take advantage of such opportunities if they become available.
- To minimize potential catastrophic failure of an entity's water system, the entity should provide sufficient resources to maintain its infrastructure in good condition. The PWPG recognizes that water main breaks and system failures do occur, but with proper maintenance these may be able to be reduced.
- Water users should continue to use water efficiently to conserve limited resources.

List of References

(1) Texas Water Development Board: *Chapter 357, Regional Water Planning Guidelines*, Austin, August 12, 2012.

(2) Texas Water Development Board: *Chapter 357, Regional Water Planning Guidelines*, *Rule 357.42 Drought Response Information, Activities, and Recommendations,* Austin, August 12, 2012.

(3) Drought Preparedness Council: *State Drought Preparedness Plan*, January 2001.

ATTACHMENT 7-1

SOURCES, SOURCE MANAGER, AND DROUGHT CONTINGENCY PLAN TRIGGERS

Sources, Source Manager, Drought Contingency Plan Triggers

Source	Manager[1]	PWPA User
Lake Meredith	CRMWA	Amarillo
		Borger
		Pampa
		Manufacturing (Potter County)
		Canyon
		County-Other (Randall County)
		Manufacturing (Randall County)
		Manufacturing (Hutchison County)
Greenbelt Lake	GMIWA	Childress County-Other
		Childress
		Donley County-Other
		Clarendon
		Hall County-Other
		Red River Authority (Childress County)
		Red River Authority (Collingsworth County)
		Red River Authority (Donley County)
		Red River Authority (Hall County)
		Memphis
Palo Duro Reservoir	PDRA	
Canadian River Run-of-River - Gray County		Irrigation (Gray County)
Canadian River Run-of-River - Hutchinson County		Irrigation (Hutchinson County)
Canadian River Run-of-River - Lipscomb County		Irrigation (Lipscomb County)
Canadian River Run-of-River - Moore County		Irrigation (Moore County)
Canadian River Run-of-River - Roberts County		Irrigation (Roberts County)
Canadian River Run-of-River - Hansford County		Irrigation (Hansford County)
Canadian River Run-of-River - Hutchinson County		Manufacturing (Hutchinson County)
Canadian River Run-of-River - Sherman County		Irrigation (Sherman County)
Red River Run-of-River - Carson County		Irrigation (Carson County)
Red River Run-of-River - Childress County		Irrigation (Childress County)
Red River Run-of-River - Collingsworth County		Irrigation (Collingsworth County)
Red River Run-of-River - Donley County		Irrigation (Donley County)
Red River Run-of-River - Gray County		Irrigation (Gray County)
Red River Run-of-River - Hall County		Irrigation (Hall County)
Red River Run-of-River - Randall County		Irrigation (Randall County)
Red River Run-of-River - Wheeler County		Irrigation (Wheeler County)
Blaine Aquifer - Hall County		Livestock (Hall County)
Blaine Aquifer - Collingsworth County		County-Other (Collingsworth County)
		Irrigation (Collingsworth County)
		Livestock (Collingsworth County)
Blaine Aquifer - Wheeler County		County-Other (Wheeler County)
		Irrigation (Wheeler County)
		Livestock (Wheeler County)
Blaine Aquifer - Childress County		Irrigation (Childress County)
		Livestock (Childress County)
Dockum Aquifer - Armstrong County		County-Other (Armstrong County)
		Irrigation (Armstrong County)
Dockum Aquifer - Dallam County		Irrigation (Dallam County)
Dockum Aquifer - Hartley County		Livestock (Hartley County)
		Irrigation (Hartley County)
Dockum Aquifer - Moore County		Irrigation (Moore County)
Dockum Aquifer - Sherman County		Irrigation (Sherman County)
Dockum Aquifer - Oldham County		County-Other (Oldham County)
		Irrigation (Oldham County)
		Livestock (Oldham County)
		Mining (Oldham County)
Dockum Aquifer - Potter County		County-Other (Potter County)
		Irrigation (Potter County)
		Manufacturing (Potter County)
		Livestock (Potter County)
Dockum Aquifer - Randall County	Happy	County-Other (Randall County)
		Canyon
		Lake Tanglewood
		Irrigation (Randall County)
		Livestock (Randall County)

Sources, Source Manager, Drought Contingency Plan Triggers

Source	Manager[1]	PWPA User
Ogallala Aquifer - Armstrong County	Claude	County-Other (Armstrong County)
		Irrigation (Armstrong County)
		Livestock (Armstrong County)
Ogallala Aquifer - Carson County	Amarillo	County-Other (Carson County)
	Groom	Irrigation (Carson County)
	Panhandle	Livestock (Carson County)
	Skellytown	Manufacturing (Carson County)
		Fritch
		Manufacturing (Hutchinson County)
	White Deer	Mining (Carson County)
Ogallala Aquifer - Dallam County	Dalhart	County-Other (Dallam County)
	Texline	Irrigation (Dallam County)
		Manufacturing (Dallam County)
		Livestock (Dallam County)
Ogallala Aquifer - Donley County		County-Other (Donley County)
		Red River Authority (Childress County)
		Red River Authority (Collingsworth County)
		Red River Authority (Donley County)
		Red River Authority (Hall County)
		Childress
		Clarendon
		Memphis
		Irrigation (Donley County)
		Livestock (Donley County)
Ogallala Aquifer - Gray County	Lefors	County-Other (Gray County)
	McLean	Irrigation (Gray County)
	Pampa	Mining (Gray County)
		Livestock (Gray County)
		Manufacturing (Gray County)
Ogallala Aquifer - Hansford County	Gruver	County-Other (Hansford County)
	Spearman	Irrigation (Hansford County)
		Livestock (Hansford County)
		Manufacturing (Hansford County)
		Mining (Hansford County)
Ogallala Aquifer - Hartley County		County-Other (Hartley County)
		Irrigation (Hartley County)
		Hartley WSC
		Mining (Hartley County)
		Dumas
		County-Other (Moore County)
		Livestock (Hartley County)
Ogallala Aquifer - Hemphill County	Canadian	County-Other (Hemphill County)
		Irrigation (Hemphill County)
		Livestock (Hemphill County)
		Manufacturing (Hemphill County)
		Mining (Hemphill County)
Ogallala Aquifer - Hutchinson County	Borger	County-Other (Hutchinson County)
		Irrigation (Hutchinson County)
	Stinnett	Livestock (Hutchinson County)
	TCW Supply Inc	Manufacturing (Hutchinson County)
		Mining (Hutchinson County)
Ogallala Aquifer - Lipscomb County	Booker	County-Other (Lipscomb County)
		Darrouzett
		Follett
		Higgins
		Irrigation (Lipscomb County)
		Livestock (Lipscomb County)
		Manufacturing (Lipscomb County)
		Mining (Lipscomb County)
Ogallala Aquifer - Moore County	Cactus	County-Other (Moore County)
	Dumas	Irrigation (Moore County)
	Fritch	Livestock (Moore County)
	Sunray	Manufacturing (Moore County)
		Mining (Moore County)

Sources, Source Manager, Drought Contingency Plan Triggers

Source	Manager[1]	PWPA User
Ogallala Aquifer - Ochiltree County	Booker	County-Other (Ochiltree County)
	Perryton	Irrigation (Ochiltree County)
		Livestock (Ochiltree County)
		Manufacturing (Ochiltree County)
		Mining (Ochiltree County)
Ogallala Aquifer - Oldham County	Vega	County-Other (Oldham County)
		Irrigation (Oldham County)
		Livestock (Oldham County)
Ogallala Aquifer - Potter County	Amarillo	County-Other (Potter County)
		Irrigation (Potter County)
		Livestock (Potter County)
		Mining (Potter County)
Ogallala Aquifer - Randall County	Amarillo	County-Other (Randall County)
	Canyon	Irrigation (Randall County)
	Lake Tanglewood	Livestock (Randall County)
		Manufacturing (Randall County)
Ogallala Aquifer - Roberts County	CRMWA	Amarillo
	Miami	Borger
		Pampa
		Canyon
		Manufacturing (Hutchinson County)
		Manufacturing (Potter County)
		Manufacturing (Randall County)
		County-Other (Roberts County)
		Irrigation (Roberts County)
		Livestock (Roberts County)
		Mining (Roberts County)
Ogallala Aquifer - Sherman County	Stratford	County-Other (Sherman County)
		Texhoma
		Manufacturing (Sherman County)
		Irrigation (Sherman County)
		Livestock (Sherman County)
		Mining (Sherman County)
Ogallala Aquifer - Wheeler County	Shamrock	County-Other (Wheeler County)
	Wheeler	Irrigation (Wheeler County)
		Livestock (Wheeler County)
		Mining (Wheeler County)
Other Aquifer - Armstrong County		Livestock (Armstrong County)
Other Aquifer - Childress County		Irrigation (Childress County)
		County-Other (Childress County)
Other Aquifer - Collingsworth County		Irrigation (Collingsworth County)
		Livestock (Collingsworth County)
Other Aquifer - Donley County		Livestock (Donley County)
Other Aquifer - Hall County		Livestock (Hall County)
		Irrigation (Hall County)
Other Aquifer - Wheeler County		County-Other (Wheeler County)
		Irrigation (Wheeler County)
		Livestock (Wheeler County)
Seymour Aquifer - Childress County		County-Other (Childress County)
		Irrigation (Childress County)
		Livestock (Childress County)
Seymour Aquifer - Collingsworth County	Wellington	County-Other (Collingsworth County)
		Irrigation (Collingsworth County)
		Livestock (Collingsworth County)
Seymour Aquifer - Hall County		County- Other (Hall County)
		Irrigation (Hall County)
		Turkey
		Red River Authority (Hall County)
		Livestock (Hall County)

1. Muncipalities that are shown as Manager of a source are also a User of the source.
   CRMWA and Greenbelt MIWA are the only entities that are only Managers of a source.

Summary of Drought Triggers and Action Recommendations

Source Name	Type (sw/gw)	Factor considered	TRIGGERS						ACTIONS					
			Source Manager			Users			Source Manager			Users		
			Mild	Severe	Critical/ Emergency	Mild	Severe	Critical/ Emergency	Mild	Severe	Critical/ Emergency	Mild	Severe	Critical/ Emergency
Lake Meredith	sw	Cities with shortages	1 to 2	> 5	> 5	Approaching shortage	shortage	shortage	Public awareness; Promote conservation; Technical assistance to affected customers			Implement appropriate stage of DCP		
Greenbelt Lake	sw	Water level	2637 msl	2631 msl	2628 msl	Same as Manager			Request users to reduce use by 10%	30% use reduction; customer storage reduced to 50%	Actions as appropriate	Voluntary reduction by 10%; review DCP	30% use reduction; Implement Stage 3 of DCP	Actions as appropriate
		Demand		> 7.5 MGD	> 7.5 MGD									
Palo Duro Reservoir	sw	Water level	2876 msl	< 2864 msl	equipment failure	NA	NA	NA	Voluntary outdoor water reductions	Limit deliveries; no outdoor water use	Limit deliveries; no outdoor water use	NA	NA	NA
Red River	sw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Canadian River	sw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Ogallala Aquifer	gw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Seymour Aquifer	gw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Blaine Aquifer	gw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Dockum Aquifer	gw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	
Other Aquifer	gw	Drought Monitor	D1 (Moderate)	D2 (Severe)	D4 (Critical)	D1 (Moderate)	D2 (Severe)	D4 (Critical)	Review DCP; Initiate actions if appropriate	Review DCP; Initiate actions; consider additional supplies		Review DCP and implement ,if appropriate; consider voluntary demand reductions	Review DCP; Initiate actions; consider additional supplies	

NA - Not Applicable. Currently there are no users of Palo Duro Reservoir

ATTACHMENT 7-2

SUMMARY OF DROUGHT CONTINGENCY PLANS IN PWPA

Summary of Current Drought Triggers and Responses in PWPA

		Onset of Drought						Severe Drought	
Water Provider	Water Sources	Stage 1 Trigger	Response	Stage 2 Trigger	Response	Stage 3 Trigger	Response	Stage 4 Trigger	Response
Amarillo	Ogallala, CRMWA	Demand>70% production capacity for 5 consecutive days	Request voluntary Watering Schedules and encourage other Conservation measures	Demand>80% production capacity for 5 consecutive days	Require mandatory Watering Schedule and other Conservation Methods as ordered by the Director	Demand>85% production capacity for 5 consecutive days	Require mandatory Watering Schedule between 8PM and 6AM and may prohibit nonessential water use	Demand>90% production capacity for 5 consecutive days	All nonessential watering prohibited. All commercial, institutional, industrial, and wholesale users shall be notified to initiate appropriate stage. Washing of mobile equipment is permitted only to a commercial vehicle washing facility. Director shall begin preparations for implementation of pro rata curtailment.
Borger	Ogallala, CRMWA	Total supply<6,240 AF/Y and supplies from CRMWA < 3,600 AF/Y	Achieve a voluntary 10% reduction in total water use. Best management practices for supply management. Voluntary water use restrictions for retail customers. Voluntary water use restrictions for wholesale and industrial customers.	Total supply<6,420 AF/Y and supplies from CRMWA <3,080 AF/Y	Achieve a 20% reduction in total water use. Best management practices for supply management. Water use restrictions for retail customers. Water use restrictions for wholesale and industrial customers.	Total supply<6,356 AF/Y and supplies from CRMWA <2,524 AF/Y	Achieve a 30% reduction in total water use. Best management practices for supply management. Water use restrictions for retail customers. Water use restrictions for wholesale and industrial customers.	Total supply<6,471AF/Y and supplies from CRMWA <1,967AF/Y	Achieve a 35% reduction in total water use. Best management practices for supply management. Water use restrictions for retail customers. Water use restrictions for wholesale and industrial customers.
Canyon	Ogallala, Dockum, Amarillo	Supply=<72.5% full	Achieve voluntary 5% reduction in use of total contracted water from storage. Implementation of supply management and demand measurement measures.	Supply=< 64% full	Achieve 10% voluntary reduction in uses of total contracted water from storage. Implementation of supply management and demand measurement measures.	Supply =< 56% full	Achieve 15% voluntary reduction in use of total contracted water from storage. Implementation of supply management and demand measurement measures.	Mechanical or system failures. Natural or man-made contamination.	Assess severity of emergency. Inform the utility director of each wholesale water customer. Undertake necessary actions for cleanup.
Childress	Ogallala	Supply and demand (Non Specified)	Voluntary 10% reduction in use	Supply and demand (Non Specified)	20% reduction in demand	Supply and demand (Non Specified)	30% reduction in water use	Supply and demand (Non Specified)	Initiate emergency response procedures.
Claude	Ogallala	Dry weather conditions before and during then normal landscape growing season	Voluntary 15% reduction in use	Demand>0.55 MGD for 3 consecutive days	Voluntary 25% reduction in use	Demand>0.575 MGD for 3 consecutive days	Voluntary 35% reduction in use	Water supply emergency such as major water line breaks, pump system failures	Voluntary 15% reduction in use
CRMWA	Ogallala, Meredith	One or two members cities cannot meet actual or expected demand	CRMWA will issue a press release in the cities affected, describing the initiation of Stage 1 of the Drought Contingency Plan and the general condition of water supply. Work with affected city(s) to promote water conservation. Provide technical help for affected city(s).	Three to five members cities cannot meet actual or expected demand.	Continue Stage 1 Responses. Work with additional affected cities to promote water conservation to the public. Work with additional affected cities to provide technical and request cities to initiate appropriate stage of DCP.	More than five members cities cannot meet actual or expected demand	Continue Stage 1 & Stage 2 Responses. Work with additional affected cities to promote water conservation to the public. Work with additional affected cities to provide technical and request cities to initiate appropriate stage of DCP.	N/A	

Summary of Current Drought Triggers and Responses in PWPA

		Onset of Drought						Severe Drought	
Water Provider	**Water Sources**	**Stage 1 Trigger**	**Response**	**Stage 2 Trigger**	**Response**	**Stage 3 Trigger**	**Response**	**Stage 4 Trigger**	**Response**
Dalhart	Ogallala	Dry weather conditions before and during then normal landscape growing season	Achieve 10% voluntary reduction in water use.	Demand>5.7 MGD for 3 consecutive days or equals 6 MGD on a single day	Achieve 20% reduction in daily demand.	Demand>6 MGD for 3 consecutive days or equals 6.3 MGD on a single day	Achieve 30% reduction in daily water demand.	Water supply emergency such as major water line breaks, pump system failures	Initiate emergency response procedures.
Dumas	Ogallala	Demand>85% production capacity of 3 consecutive days	Achieve a voluntary 10% reduction in daily water demand. Voluntary limit irrigation of landscaped areas by street address. Request practice of water conservation and nonessential water use.	Demand>90% production capacity for 3 consecutive days	Achieve a 15% reduction in daily water demand. Irrigation to be limited to two days a week. Use of water to wash a moto vehicle is prohibited except on watering days at designated hours. Water will be served at restaurants only when requested.	Demand=100% production capacity for 3 consecutive days	Achieve a 20% reduction in daily water demand. All Stage 2 requirements except irrigation of landscapes is prohibited by hose-end sprinklers. The watering of golf courses is prohibited and use of water for construction purposes from designated fire hydrants under special permit is to be discontinued.	Demand>=100% production capacity for 3 consecutive days	Achieve a 25% reduction in daily water demand. Irrigation of landscapes is limited to designated watering days and prohibited by used of hose-end sprinklers or permanently installed automatic sprinkler systems. Use of water to wash any motor vehicle, motorbike, boat, trailer or other vehicle not occurring on the premises of a commercial car or truck wash and not in immediate interest of public health/welfare is prohibited.
Greenbelt		Reservoir Elevation Level=2,367.00	Achieve a voluntary 10% reduction in total water use.	Reservoir Elevation Level=2,634.00 or Demand>=7.5MGD	Achieve a 20% reduction in total water use. Water authority would lower the level in all storage tanks to no more than 75% of capacity. Implement demand management measures.	Reservoir Elevation Level=2,631.00 or Demand>=7.5MGD	Achieve a 30% reduction in total water use. Water authority would lower the level in all storage tanks to no more than 50% of capacity. Implement demand management measures.	Reservoir Elevation Level=2,628.00 or Demand>=7.5MGD. Event of major water line water or pump or system failures occur. Natural or man-made contamination of water supply	Assess severity of the emergency and identify actions needed and time required to solve the problem. Inform all necessary parties and notify parties for assistance.
Gruver	Ogallala	Consumption reached 65% total production capacity for 5 consecutive days	Public notification of Stage 1 condition and encouragement of voluntary water conservation measures	Consumption reached 75% total production capacity for 5 consecutive days	City may require even/odd watering days or other restrictions on non-essential water uses	Consumption reached 80% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days	Consumption reached 90% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days
Higgins	Ogallala	Supply<= 90% of wells capacity or Demand>0.3 MGD for 3 consecutive days	Request voluntary water restrictions	Supply>90% of original well capacity for 3 consecutive days	Comply with requirements and restrictions on certain non-essential water use	Supply>95% of original well capacity for 3 days	Comply with requirements for Stage 3 non-essential water usages	Water supply outage	Comply with requirements for Stage 4
McLean	Ogallala	Consumption reached 65% total production capacity for 5 consecutive days	Public notification of Stage 1 condition and encouragement of voluntary water conservation measures	Consumption reached 75% total production capacity for 5 consecutive days	City may require even/odd watering days or other restrictions on non-essential water uses	Consumption reached 80% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days	Consumption reached 90% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days
Pampa	Ogallala, CRMWA	CRMWA provides that all or part of the city supply has initiated Stage 1. CRMWA informs member cities that the Reservoir Operation Model projections shows a projected three year future supply in Lake Meredith. City wells, supply lines, pumps or storage where continuously falling water storage levels do not refill above 70%.	Reduce water use by 5%. May implement the following: notify major water users of the situation and request voluntary water use reductions, review Stage 1 cause, and intensify leak detection and repair efforts.	CRMWA provides that all or part of the city supply has initiated Stage 2. CRMWA informs member cities that the Reservoir Operation Model projections shows a projected two year future supply in Lake Meredith. City wells, supply lines, pumps or storage where continuously falling water storage levels do not refill above 50%.	Reduce water by 10%. May implement the following: irrigation utilizing sprinkler systems, notify major users of the situation and should reduce water usage, car wash shall use minimum practical water settings,etc.	CRMWA provides that all or part of the city supply has initiated Stage 3 .CRMWA informs member cities that the Reservoir Operation Model projections shows a projected 1.5 year future supply in Lake Meredith. City wells, supply lines, pumps or storage where continuously falling water storage levels do not refill above 40%.	Reduce water by 15%. Prohibited allowing irrigation water to run off into gutter, ditch, or drain, failure to repair a controllable leak, and washing sidewalks driveways, parking areas, tennis courts, or other paved areas, except to alleviate immediate fire or health hazards.	CRWS provides that all or part of the city supply has initiated Stage 4. CRMWA inform Pampa that a water line fails or pump or system failures occur which cause unprecedented loss of capability to provide water services or natural or man-made contamination of the water supply source occurs.	Reduce water by 30%. Outdoor irrigation of vegetation shall be allowed only between hours of 8PM to 2AM on designated days. Washing of automobiles, trucks, trailers, boats, airplane, etc. is prohibited unless on premises of commercial car washes and commercial service stations.
Panhandle	Ogallala	Demand =90% system capacity	Request voluntary Watering Schedules and encourage other Conservation measures	N/A	N/A	Demand reaches safe limit of 2.5 MGD system capacity for 15 consecutive days	Request voluntary Watering Schedules and encourage other Conservation measures	Demand reaches safe limit of 2.5 MGD system capacity for 10 consecutive days	Request voluntary Watering Schedules and encourage other Conservation measures
Perryton		Dry weather conditions before and during then normal landscape growing season	Achieve a voluntary 10% reduction in total water use. Request voluntary water conservation and prescribed restrictions on certain water uses.	Daily demand>= 4.9 MGD for 3 consecutive days	Achieve a 20% reduction in total water use. Comply with requirements and restrictions on certain non-essential water uses	Daily demand>= 5.25 MGD for 3 consecutive days	Achieve a 30% reduction in total water use. Comply with requirements and restrictions on certain non-essential water use for Stage 3	Water supply emergencies	Initiate emergency response procedures. Mandatory water use restrictions such as prohibited landscape irrigation and filling of swimming pools.
Red River Authority	Ogallala	System Water production capacity drops 20% and remains consistent for a period of at least 60 consecutive days.	Raise public awareness. Achieve up to 20% reduction in demand.	System water production capacity drops by 30% and remains consistent for a period of at least 30 consecutive days.	Increase public awareness. Achieve a 30% reduction in demand.	System water production capacity drops by 40% and remains consistent for a period of at least 20 consecutive days.	Inform public of critical situation. Reduce demand by 40%.	System water production capacity drops by 50% and remains consistent for a period of at least 10 consecutive days.	Inform public of critical and possible hazardous situation. Reduce demand to a level necessary to maintain public health and safety.

Summary of Current Drought Triggers and Responses in PWPA

		Onset of Drought						Severe Drought	
Water Provider	**Water Sources**	**Stage 1 Trigger**	**Response**	**Stage 2 Trigger**	**Response**	**Stage 3 Trigger**	**Response**	**Stage 4 Trigger**	**Response**
Shamrock	Ogallala	Consumption reached 65% total production capacity for 5 consecutive days	Public notification of Stage 1 condition and encouragement of voluntary water conservation measures	Consumption reached 75% total production capacity for 5 consecutive days	City may require even/odd watering days or other restrictions on non-essential water uses	Consumption reached 80% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days	Consumption reached 90% total production capacity for 5 consecutive days	Restrictions for non-essential water uses and may require odd/even water days
Turkey	Ogallala	Supply>= 75% capacity	Voluntary 25% reduction in use	Supply>= 50% capacity	50% reduction in water use	Supply>= 25% capacity	75% reduction in water use	Water supply emergency	Identify action needed, inform wholesale water supply customers, and if appropriate notify city/country emergency response officials
Wellington	Ogallala	Demand >=90% system capacity for 5 consecutive days	Voluntary 10% reduction in use	Demand >=95% system capacity for 3 consecutive days	15% reduction in demand	Demand >=100% system capacity for 3 consecutive days	20% reduction in water use	Water supply emergency	20% reduction in water use
White Deer	Ogallala	Dry weather conditions before and during then normal landscape growing season	Request voluntary water conservations	Demand>0.55 MGD for 3 consecutive days	Comply with requirements and restrictions on certain non-essential water use	Demand>0.575 MGD for 3 consecutive days	Comply with requirements and restrictions on certain non-essential water use	Water supply emergency such as major water line breaks, pump system failures	Comply with requirements for Stage 4

8 REGULATORY, ADMINISTRATIVE AND LEGISLATIVE RECOMMENDATIONS

Regional Water Planning Guidelines specified in the Texas Administrative Code call for the regional water planning groups to make recommendations regarding ecologically unique river and stream segments; unique sites for reservoir construction; and regulatory, administrative, or legislative actions that will facilitate the orderly development, management, and conservation of water resources. Recommendations of the PWPG are presented in this section.

PWPG Recommendations:

- No unique stream segments or unique reservoir sites are recommended.
- Over 15 regulatory, legislative, and state water planning recommendations:
  - Reuse
  - Groundwater
  - Conservation
  - Brush Control
  - Data Collection and Updates
  - Funding

8.1 Unique Stream Segments

Under regional planning guidelines, each planning region may recommend specific river or stream segments to be considered by the Legislature for designation as ecologically unique. The Legislative designation of a river or stream segment would only mean that the State could not finance the construction of a reservoir that would impact the segment. The intent is to provide a means of protecting the segments from activities that may threaten their environmental integrity.

TPWD provided guidance for such designations and the following criteria shall be used when recommending a unique river or stream segment:

Biological Function: Segments which display significant overall habitat value including both quantity and quality considering the degree of biodiversity, age, and uniqueness observed and including terrestrial, wetland, aquatic, or estuarine habitats;

- *Hydrologic Function*: Segments which are fringed by habitats that perform valuable hydrologic functions relating to water quality, flood attenuation, flow stabilization, or groundwater recharge and discharge;
- *Riparian Conservation Areas*: Segments which are fringed by significant areas in public ownership including state and federal refuges, wildlife management areas, preserves, parks, mitigation areas, or other areas held by governmental organizations for conservation purposes under a governmentally approved conservation plan;
- *High Water Quality/Exceptional Aquatic Life/High Aesthetic Value*: Segments and spring resources that are significant due to unique or critical habitats and exceptional aquatic life uses dependent on or associated with high water quality; or
- *Threatened or Endangered Species/Unique Communities*: Sites along segments where water development projects would have significant detrimental effects on state or federally listed threatened and endangered species, and sites along segments that are significant due to the presence of unique, exemplary, or unusually extensive natural communities.

During the first round of planning (2001 Regional Water Plans), TPWD compiled a listing of potential ecologically significant stream segments located in the PWPA (see Figure 8-1). These stream segments were selected by TPWD because of the above-listed criteria.

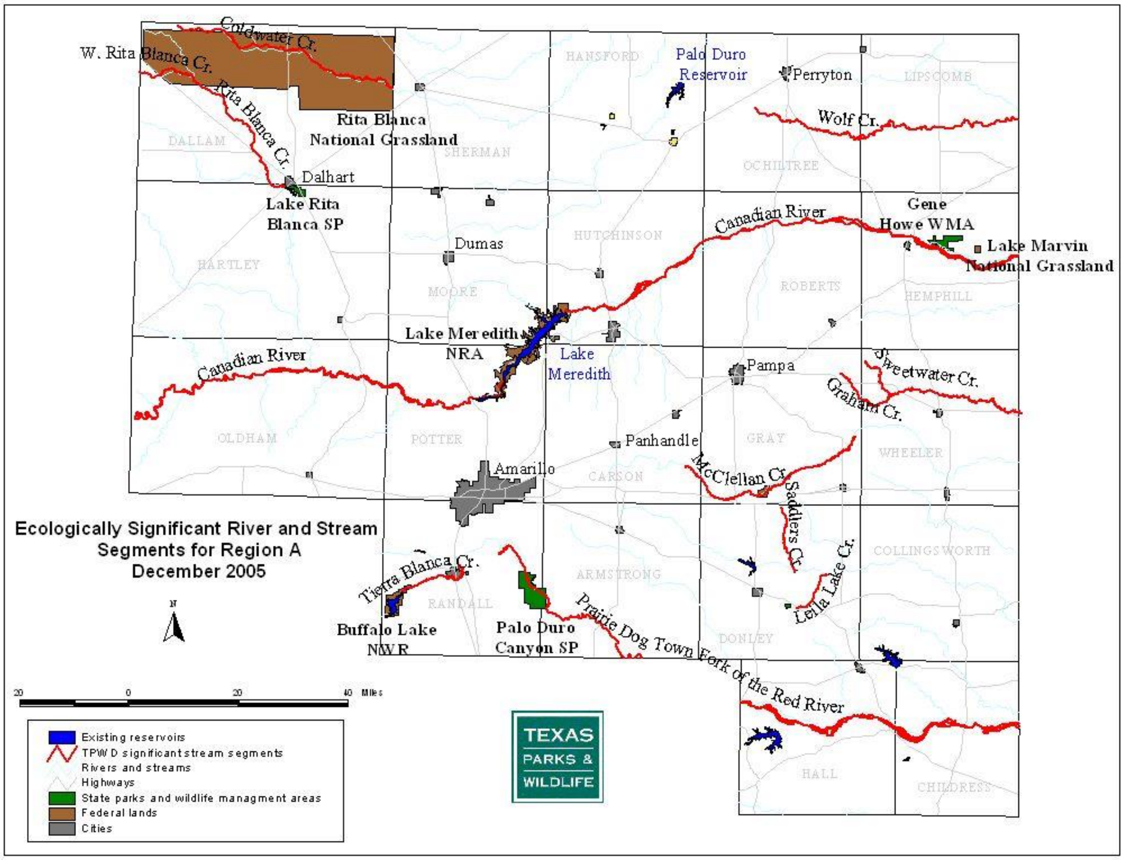


Figure 8-1: TPWD Identified Streams Segments for Consideration of Designation as Ecologically Significant in the PWPA

As part of the initial planning process, each of the TPWD-identified segments were evaluated by the PWPG for potential recommendation as unique stream segments. After careful consideration of the unknown consequences of recommendation, the PWPG made no recommendations for river and stream segments for designation as ecologically unique. The following stream segments were presented to the planning group by TPWD for consideration:

- Canadian River (TCEQ Segment 0101)
  From the Oklahoma State line in Hemphill County upstream to Sanford Dam in Hutchinson County
- Canadian River (TCEQ Segment 0103)
  From a point immediately upstream of the confluence of Camp Creek in Potter County to the New Mexico State line in Oldham County
- Coldwater Creek
  From the Dallam/Sherman County line upstream to the Texas/Oklahoma State line

- Graham Creek
  From the confluence with Sweetwater Creek east of Mobeetie in Wheeler County upstream to SH 152 in northeast Gray County
- Lelia Lake Creek
  From the confluence with the Salt Fork of the Red River in Donley County upstream to US 287 in Donley County
- McClellan Creek
  From the confluence with the North Fork of the Red River in east Gray County upstream to its headwaters in the southwestern part of Gray County
- Prairie Dog Town Fork Red River (TCEQ Segment 0229)
  From the Armstrong/Briscoe County line upstream to Lake Tanglewood in Randall County
- Prairie Dog Town Fork Red River (TCEQ Segment 0207)
  From the Childress/Hardeman County line upstream to the Hall/Briscoe County line
- Rita Blanca Creek
  From the headwaters of Lake Rita Blanca in Hartley County upstream to US 87 in Dallam County
- Saddlers Creek
  From the confluence with the Salt Fork of the Red River eight miles northeast of Clarendon in Donley County upstream to its headwaters located about two miles southeast of Evans in north Donley County
- Sweetwater Creek
  From the Oklahoma State line in Wheeler County upstream to its headwaters in northwest Wheeler County
- Tierra Blanca Creek
  From the confluence with Prairie Dog Town Fork of the Red River upstream to Buffalo Lake in Randall County
- West Fork of Rita Blanca Creek
  From the confluence with Rita Blanca Creek in Dallam County upstream to the New Mexico State line
- Wolf Creek (TCEQ Segment 0104)
  From the Oklahoma State line in Lipscomb County to a point 1.2 miles upstream of FM 3045 in Ochiltree County

During subsequent planning cycles, the PWPG considered each of these stream segments for designation as ecologically unique and did not designate any segments. As part of this update to the regional water plan, the PWPG again considered each of these stream segments. Portions of several segments are currently protected by other means, such as a designated wildlife management area; others have protections through existing regulations like the Threatened and Endangered Species Act. These local, state, and federal protections provide a mechanism to preserve the ecological value of these streams. By law, the designation of ecologically unique stream segment only prevents the state from funding a new reservoir project that impacts the segment, but the designation could be used to prevent other valid activities. Since there are no new reservoir sites currently being considered in the PWPA, the designation would add no additional protections. In light of these considerations, the PWPG chose not to designate any ecologically unique stream segments in the PWPA.

8.2 Sites of Unique Value for the Construction of Reservoirs

Planning groups may recommend sites of unique value for construction of reservoirs by including descriptions of the sites, reasons for the unique designation, and expected beneficiaries of the water supply to be developed at the site. The following criteria shall be used to determine if a site is unique for reservoir construction:

- Site-specific reservoir development is recommended as a specific water management strategy or in an alternative long-term scenario in an adopted plan; or
- The location, hydrologic, geologic, topographic, water availability, water quality, environmental, cultural, and current development characteristics, or other pertinent factors make the site uniquely suited for:
    - Reservoir development to provide water supply for the current planning period; or
    - Where it might reasonably be needed to meet needs beyond the 50-year planning period.

Local river and stream segments were evaluated by the PWPG for potential recommendation as unique reservoir sites. No sites were recommended by the planning group as sites of unique value for the construction of reservoirs.

8.3 Legislative Recommendations

As the PWPG has gone through the preparation of the regional water supply plan, several items have been identified which the PWPG recommends be considered before the next planning cycle. Title 31 of the Texas Administrative Code (TAC) §357.43 states that the regional water plans will include regulatory, administrative, legislative or "Any other recommendations that the regional water planning group believes are needed and desirable to achieve the stated goals of the state and regional water planning, including to facilitate the orderly development, management, and conservation of water resources and prepare for and respond to drought conditions." The rules also encourage the PWPG to consider recommendations that would facilitate more voluntary transfers in the PWPA.

Over previous planning cycles, the PWPG has developed a detailed list of regulatory and legislative recommendations. Some of these recommendations have been implemented. Others are currently being considered. In light of the continual changes in water management and development, the PWPG identified recommendations for the 2021 Panhandle Water Plan. The following sections discuss the PWPG recommendations.

8.3.1 Regulatory Issues

Continue to evaluate the rules governing reuse to encourage the use of wastewater effluent. The current regulatory environment provides a number of barriers to encourage the reuse of wastewater effluent. TCEQ should re-evaluate the current rules and change the rules to provide and quantify incentives for municipalities, industries and agriculture to reuse wastewater effluent

8.3.2 Legislative Issues

Manage groundwater resources through local groundwater conservation districts. There remain certain areas of the PWPA that are not within the boundaries of a groundwater district. Many of these areas do not have substantial quantities of groundwater or located in areas with no aquifers. However, areas with groundwater should be included in a local district contained within the regional planning area to create an equitable situation with regard to groundwater management, provided that it is feasible and locally supported.

Create a water conservation reserve program for irrigated acreage management. A water conservation reserve program should be created to make it economically feasible for farmers to convert irrigated acreage to dryland.

Encourage the federal government to continue to support Conservation Reserve Program (CRP) participation. This program continues to help protect local groundwater resources. As properties currently in CRP are coming out, property owners may convert and reestablish the properties to irrigated agriculture and utilize higher volumes of groundwater.

Evaluate policy barriers to use playa lakes for conservation purposes. The State should evaluate the current legislative barriers to using playa lakes. The barriers should be removed or reduced to allow using the playas for aquifer recharge or other beneficial water supply purposes.

Maintain the functionality and viability of the Water Conservation Advisory Council. The group currently operates on a volunteer basis with no state or federal funding.

Provide funding for administration of the regional water planning process. Current funding only allows reimbursement of direct expenses for administrative activities. The public process requires considerable coordination and staff assistance to comply. The costs to administer the PWPA regional planning process are $70,000 per year, which is funded solely through local funds. As a result of the lack of funding, several planning areas are struggling to identify and maintain a political subdivision administrator.

Provide funding for educational events including demonstrations of irrigation conservation strategies to encourage adoption. Irrigation conservation relies on the adoption of measures by individual producers. Education is the first step to making long-term conservation efforts become a reality.

Provide funding for more information on agricultural water use to better inform the TWDB baseline estimates and irrigation conservation strategies. Considering that agricultural use accounts for more than 90 percent of total usage in the PWPA, a thorough understanding of agricultural water use is critical to the future of the region. Many of the agricultural conservation strategies are dependent on knowing the water use and acreage by crop.

Provide funding for the Water Supply Enhancement Program (WSEP). The WSEP provides funding to landowners and surface water suppliers to control invasive brush that threatens to reduce stream flows, shallow springs, and groundwater seeps. Currently this program is not funded by the Legislature. The PWPG recommends funding this program to promote land stewardship and conservation of water supplies.

8.4 Recommendations for Future State Water Plans

TWDB should establish and continue to promote clear guidelines for eligibility for funding and needs assessment for very small cities and unincorporated areas. Statements to the effect that "entities which fall under the planning limits retain eligibility for state funding assistance for water-related projects without having specific individual needs identified in the Regional Water Plan" would greatly enhance the ability of these small systems to provide their users with a safe and adequate supply of water.

TWDB should continue to improve the monitoring and quantification of small communities, county-other, manufacturing, and livestock operator water use to provide better information for planning purposes.

TCEQ should be made an ex-officio member of the RWPGs and be required to attend RWPG meetings to provide input on known water quality/quantity problems.

Clarification of relationship between drought contingency planning and regional water supply planning. It is not clear what role drought contingency planning has in the regional planning process.

Salinity and brush control projects for the Canadian River and/or Red River Basin. Although there have been salinity and brush control projects recently implemented in the Canadian and Red River Basins, future State Water Plans should continue to plan for future salinity and brush control projects and their funding to continue to improve water quality and quantity in the basins.

Brush control. TWDB guidance is needed on how to account for brush control projects in the context of a source of "new surface water" for municipal, industrial, agricultural, and other uses. The Canadian River watershed has more than 50% cover of mixed brush species that are amenable to control for rangeland improvement and water enhancement purposes.

Enhance groundwater recharge. Groundwater accounts for a major source of water in the PWPA. Recharge rates are near zero for most of the area over the Ogallala aquifer with slopes around playas having the highest rates. Other regional aquifers, such as the Seymour Aquifer, may be more amenable to enhanced recharge. Means of enhanced recharge also include any man-made structure(s) that slow down or hold surface water to increase the probability of groundwater recharge. With current drought conditions, alternative sources of rechargeable water need to be identified and studies conducted to determine the feasibility of enhancing recharge with these water sources.

Updated analysis of surface water supply inflows and availability. The regional surface water supply has steadily decreased over the past ten to fifteen years to the extent that regional lakes experienced new historical low storage levels. The existing tools to assess the reliable supply from regional surface water do not include the recent droughts. The Legislature did recommend that four river basin Water Availability Models be updated, including the Red River Basin. It is recommended that TCEQ also extend the current Water Availability Model for the Canadian Basin to capture the current drought in the PWPA.

Updated analysis of groundwater supplies and availability. The PWPG supports continuing funding of the TWDB's groundwater availability models for the major and minor aquifers of Texas. The PWPG appreciates TWDB's leadership in this initiative and recognizes the importance of the data that comes from these models. Therefore, the PWPG stresses how imperative it is to continue funding this effort at an amount similar to or greater than the past.

9 WATER INFRASTRUCTURE FUNDING RECOMMENDATIONS

9.1 Introduction

The TWDB and Legislative Action governing the regional water planning process require that an Infrastructure Financing Report (IFR) be incorporated into the 2021 Regional Water Plan. To meet this requirement, each regional water planning group is required to examine the funding needed to implement the water management strategies and projects identified and recommended in the region's 2021 Regional Water Plan.

The IFR survey and report were sent to entities with a capital cost project during the summer of 2020 and the results are incorporated in this chapter. Aggregated WUGs, such as County-Other, Manufacturing and Irrigation, were not sent a survey. Of the 23 entities surveyed, three returned the IFR survey. This represents a response rate of approximately 13 percent.

9.2 State Water Planning Funding

The TWDB offers financial assistance for the planning, design and construction of projects identified in the regional water plans or State Water Plan. Programs available include the State Participation Program (SP), the Rural and Economically Distressed Areas Program (EDAP), and the State Water Implementation Fund for Texas (SWIFT). In order to be eligible to apply for funding from the SP and EDAP, the applicant must be a political subdivision of the state, or in some cases a water supply corporation, and the proposed project must be a recommended water management strategy in the most recent approved regional plan or State Water Plan. To be eligible for SWIFT the proposed project must be a recommended strategy in the adopted State Water Plan. The results of the current surveys carried out by each of the planning regions will be used to identify the amount of additional funds that will be needed for water supply projects through the end of the 2070 planning horizon.

9.3 State Participation Program (SP)

The State Participation Program (SP) is geared towards large projects which are regional in scope and meant to capitalize on economies of scale in design and construction, but where the local project sponsors are unable to assume the debt for an optimally sized facility. The TWDB assumes a temporary ownership interest in the project, and the local sponsor repays the cost of the funding through purchase payments on a deferred schedule. The goal of the program is to build a project that will be the right size for future needs, even if that results in the short term in building excess capacity, rather than constructing one or more smaller projects now. On new water supply projects, the TWDB can fund up to 80 percent of the costs, provided that the applicant can fund the other 20 percent through an alternate source and that at least 20 percent of the total capacity of the project serves current needs.

9.4 Rural and Economically Distressed Areas (EDAP)

Both grants and 0 percent to low interest loans for planning, design and construction costs are offered through these programs, which are available to eligible small, low-income communities. Rural and economically distressed areas that meet population, income and other criteria are eligible to apply for these funds. EDAP funding eligibility also requires adoption of the Texas Model Subdivision Rules by the applicant planning entities.

9.5 State Water Implementation Fund for Texas (SWIFT)

SWIFT is a funding vehicle passed by the Legislature and approved by Texas voters through a constitutional amendment in 2014 which aims to fund the State Water Plan through low-interest loans, extended repayment terms, deferral of loan repayments, and incremental repurchase terms for projects with state ownership aspects (similar to the SP fund discussed above). The legislation outlines that no less than 10 percent of SWIFT funding should go towards projects for rural communities and agricultural water conservation, and not less than 20 percent of the funding should support water conservation and reuse projects. Funds can be used for planning, acquisition, design, and construction costs. Only projects included in the most recently adopted state water plan are eligible for funds.

9.6 Infrastructure Financing Survey

The surveys were distributed via electronic mail. Each survey was prefaced with an explanation of its purpose in identifying the need for financial assistance programs offered by the State of Texas and administered by the TWDB. The surveys listed each recommended strategy and its total capital cost. Following this basic data, the water user group or major water provider was asked: 1) to enter the portion of the total costs associated with the planning and acquisition phase of the project and the year needed; 2) to enter the portion of the total costs associated with the construction phase of the project and the year needed; 3). to enter the total anticipated State funding assistance; and 4) to enter the percent share of the total project capacity that will not be needed within the first 10 years of the project life.

Political subdivisions of the state whose water supply strategies were noted in the regional plan as having zero capital costs were not surveyed. Where a water user group with needs and strategies to meet those needs have multiple water management strategies, some of which have capital costs and others that have no capital costs, those water user groups were only surveyed for the strategies with a capital cost. Surveys were delivered the middle of May 2020 and received until July 2020. Several entities that were surveyed did not respond. The results of this survey represent the best effort of the group to complete the survey.

Table 9-1 summarizes the capital costs for all recommended strategies in Panhandle Water Planning Area.

Table 9-1: Summary of Total Capital Costs by Entity

Entity	Total Capital Cost for Recommended Strategies
Amarillo	$436,900,000
Booker	$1,796,000
Cactus	$16,598,000
Canyon	$21,290,000
CRMWA[1]	$527,300,000
Dalhart	$7,279,000
Dumas	$19,739,600
Greenbelt MIWA[1]	$17,879,000
Gruver	$891,000
Higgins	$594,500
Irrigation	$47,302,000
Manufacturing	$4,300,000
McLean	$414,000
Memphis	$1,128,000
Pampa	$6,274,000
Panhandle	$1,814,000
Perryton	$9,097,000
Spearman	$2,604,000
Stinnett	$848,000
Sunray	$4,465,000
TCW Supply Inc.	$3,945,000
Texline	$495,000
Turkey	$2,146,800
Wellington	$9,825,000
Wheeler	$2,776,000

[1]The capital costs shown for CRMWA and Greenbelt MIWA also provide beneficial water development for users outside of the PWPA (Regions B and O).

9.7 Summary of Responses to Surveys

Three of the 23 entities surveyed responded. The total funding required by the responding entities was approximately $965 million dollars, which accounts for about 84 percent of the total costs for recommended strategies in the PWPA. Of the responding entities, about 12 percent of the funds will be needed for planning and acquisition. The remaining 88 percent of the funds will be needed for construction. Responses to the survey were recorded in a spreadsheet and submitted to the Texas Water Development as well as included in Appendix G.

10 PLAN ADOPTION AND PUBLIC PARTICIPATION

This chapter describes the various public participation, information, outreach, and education activities conducted by the Panhandle Water Planning Group (PWPG). All activities and events discussed in this section were performed in direct support of the regional water planning effort and serve to support the PWPG's dedication and commitment to ensuring that the public is provided with timely, accurate information regarding the planning process and that opportunities to provide input to the planning process are available as often as possible.

The chapter also details the plan adoption process followed by the PWPG. The process explains the required hearing, receipt of comment, comment response, and final adoption of the PWPA's Regional Water Plan.

10.1 Panhandle Water Planning Group

The PWPG was created in accordance with and operates under the auspices of SB1 and updated under subsequent legislation. The enabling legislation and TWDB planning rules and guidelines established the basis for the creation and composition of the regional planning groups. The original statute listed eleven required interest groups that must be represented at all times on the planning groups. To these original eleven interest groups, the PWPG has elected to add an additional group to adequately ensure that the interests of the region are fully protected. In 2011, groundwater management areas were added as a required interest category. The following lists the thirteen interest groups represented by the 23 voting members of the PWPG:

- General Public
- Counties
- Municipalities
- Industrial
- Agricultural
- Environmental
- Small Business
- Electric Generating Utilities
- River Authorities
- Water Districts
- Water Utilities
- Groundwater Management Areas
- Higher Education (added interest)

Table 10-1 lists the voting members of the PWPG (as of November 2019), their respective interest groups, and their principal county of interest. Table 10-1 also lists the six former members of the PWPG who also participated in the planning process for the 2021 PWPA Plan. The PWPG appreciates the contributions of these individuals and would like for their efforts to be recognized along with the current members.

Table 10-1: Panhandle Water Planning Group - Voting Members

Interest	Name	Entity	County (Location of Interest)
Public	Don Allred	Oldham County	Oldham
Counties	Judge Vernon Cook	Retired (Roberts County)	Roberts
Municipalities	Floyd Hartman	City of Amarillo	Potter and Randall
	David Landis	City of Perryton	Ochiltree
Industries	Roy Messer Bill Hallerberg (former)	J.D. Heiskell & Co.	Potter
	Beverly Stephens	Phillips 66	Hutchinson
Agricultural	Ben Weinheimer	Texas Cattle Feeders Association	Serves entire region
	Joe Baumgardner	Farmer	Collingsworth
	Janet Tregellas	Farm/Ranch	Lipscomb
Environmental	Nolan Clark	Retired (USDA-ARS)	Serves entire region
	Rick Gibson	Environmental Consultant	Serves entire region
	Dillion Pool Donna Raef Kizziar (former)	Enviro-Ag	Randall
Small Businesses	Rusty Gilmore	Water Well Driller	Dallam
Electrical Generating Utilities	Glen Green	Xcel Energy	Potter (serve entire region)
River Authorities	Kent Satterwhite	Canadian River MWA	Multiple counties
Water Districts	Steve Walthour	North Plains GCD	Moore and 7 other counties in the region
	Bobbie Kidd	Greenbelt M and I Water Authority	Donley and 3 other counties in the region
	C.E. Williams	Panhandle Groundwater Conservation Dist. No. 3	Carson and 7 other counties in the region
	Janet Guthrie	Hemphill UGCD	Hemphill
Water Utilities	Dean Cooke	TCW Supply	Hutchinson
Groundwater Management Areas	Danny Krienke	GMA#1	Ochiltree and 17 other counties
	Lynn Smith	GMA#6	Collingsworth, Childress and Hall
Higher Education	Brent Auvermann	Texas A&M AgriLife Research and Extension Center at Amarillo	Serves entire region

Former – Retired during the planning cycle.

In addition to the 23 voting members, the PWPG has six key state resource agency stakeholder positions in accordance with the appropriate regulations governing the process. Table 10-2 lists the six key stakeholder positions on the PWPG and their respective interests: Also listed are the liaisons from the PWPG to adjoining regions.

Table 10-2: Panhandle Water Planning Group - Other Key Stakeholders

PWPG Member	Position	Interest Group	Membership
William Alfaro Sarah Backhouse (former)	Texas Water Development Board (TWDB)	TWDB (Rules)	Non-Voting
Carol Faulkenberry Matt Williams (former)	Texas Department of Agriculture (TDA)	TDA (Rules)	Non-Voting
Bobbie Kidd	Region B Liaison	Water Districts	Voting
Kent Satterwhite	Region O Liaison	Water Districts	Voting
Troy Headings	USDA/NRCS	Agricultural	Non-Voting
Caleb Huber	Texas Parks & Wildlife Department	TPWD (Rules)	Non-Voting
Troy Headings Mickey Black (former)	USDA/NRCS	Agriculture	Non-Voting
Rusty Ray	Texas State and Soil Water Conservation Board	TSSWCB (Rules)	Non-Voting

10.2 Panhandle Water Planning Group Public Information and Education Commitment

The PWPG is firmly committed to ensuring the activities of the planning group are open and accessible to all interested parties. In addition, the PWPG has worked diligently to ensure that the public throughout the region is afforded every opportunity to participate in planning group activities and to receive timely information regarding the planning process. Participation in the regional water planning effort by local entities and the public was engaged throughout the process. Public participation opportunities were afforded to the region through the following broad categories. The PWPG met all requirements of the Public Information Act.

Media – Media throughout the region were provided notification of all Planning Group activities. Media outlets participated in various planning activities throughout the process, with PWPG representatives appearing at media events as well as routine press in regional newspapers. In addition, regional radio stations provided recaps of PWPG activities on occasion. PRPC Staff has conducted interviews with local television and newspaper outlets in conjunction with many regular meetings and public hearings for the PWPG.

Electronic Communication – Web Access to Planning Information The PWPG has developed and placed on-line a dedicated project website www.panhandlewater.org. The site is updated on a regular basis and provides the general public with quick, reliable access to planning data at any time. Each meeting is posted on this site and/or provided to the County Clerk of each county in the PWPG ahead of the scheduled meetings and all presented meeting materials are made available on the site within 5 working days of each meeting's conclusion. Additionally, each full and committee meeting of the PWPG has been posted electronically with the Texas Secretary of State for easy public access to the notifications. Finally, the PWPG leverages the wider audience that views the TWDB's home page (www.twdb.texas.gov) to disseminate upcoming meeting notices, minutes of previous meetings, contact information, and prior Regional Water Plans.

Public Information Meetings The PWPG held all meetings in accordance with the Open Meetings Act and encouraged public attendance at the meetings. In March 2020 the Governor suspended certain provisions of the Open Meetings Act due to the on-going pandemic. The PWPG conducted all public meetings after March 2020 in accordance with the modified requirements.

Symposiums and Forums PWPG membership has provided technical expertise to several symposiums and forums during the planning process. Included among these are Water Conservation Symposium, the High Plains Irrigation Annual Conferences and the Agricultural Water Planning Summit and other public forums.

Required Public Meeting One public meeting was conducted to solicit input and comments on the scope of work for development of the updated regional water plan. This meeting was held in Amarillo at the PRPC office on May 17, 2016.

Required Public Hearing The public hearing on the Initially Prepared Water Plan (IPP) was held on April 23, 2020 via a virtual platform due to the Governor's suspension of certain provisions of the Open Meetings Act. Members of the public and PWPG were invited to attend the hearing and were provided directions to join the meeting.

Panhandle Water Planning Group Meetings The PWPG conducted numerous public meetings over the past five years as necessary to develop the 2021 Panhandle Water Plan. In addition, subcommittee meetings were held on specific technical and planning topics. All meetings of the PWPG are conducted as in accordance with the Texas Open Meetings Act and public attendance has been good. Though not required, the PWPG Chair includes a public comment item on each agenda to provide even more opportunities for public input into the process.

10.3 Surveys

Throughout the planning process, the PWPG conducted multiple surveys and reached out individually to specific water users with needs, major water providers and groundwater conservation districts. One survey was sent to all municipal water users, major water providers and county judges to solicit input on population and water demands, current water sources and drought planning. Other surveys collected information on existing water rights, the status of the proposed 2016 Plan water strategies, potential emergency interconnections, Water Conservation Plans and Drought Contingency Plans, proposed 2021 Plan water strategies, and potential financing options for strategies that are included in the 2021 Plan. Responses from

Members of the PWPG have been quite active and very committed to the planning process. Through the course of the functions detailed below, Planning Group members have contributed approximately 848 non-reimbursed hours of time. In addition, PWPG members have traveled over 21,500 miles. This level of participation by these Planning Group members speaks very highly of not only the commitment of the people of the region to the water planning process but also to the intense effort and dedication to the process. Based on miles traveled and hours contributed to the effort, over $64,000 in personal contributions have been granted to this cycle's planning process. As mentioned previously, the PWPG has not reimbursed any members for the time they have committed to the process and none of the miles traveled have been reimbursed through use of local funds. This fact becomes quite important when the membership of the PWPG is analyzed. The majority of these members work in the public sector or are retired experts, so the donation of time and travel by these individuals with restricted budgets is of great value to the region.

10.5 Panhandle Water Planning Group Meetings

Through the Initially Prepared Plan planning process, the PWPG has conducted 25 formal Planning Group meetings. Attendance at the meetings by the 23 voting members of the PWPG has been excellent, with appropriate quorums in attendance far

the various surveys were used to develop the information in the 2021 Plan:

10.4 Panhandle Water Planning Group Functions

exceeded at all meetings. PWPG meetings have been conducted in the central location of the planning area in Amarillo at the office of the political subdivision, the PRPC. Frequency of PWPG meetings has averaged almost one per quarter. The frequency of PWPG meetings has declined in the third, fourth and fifth planning cycles for two reasons compared to the first two planning cycles. First, PWPG members and consultants have a greater understanding at this point of how to meet planning objectives more efficiently now that they have four cycles of experience. Second, the GMA process has shared some of the responsibility in groundwater modeling and setting desired future conditions. GMA 1 has held over 13 meetings in the same period and is monitored very closely by PWPG membership with regular reports presented at PWPG meetings.

10.6 Panhandle Water Planning Group Committee Activities

To further enhance the regional planning process, the PWPG has established a committee structure to assist in evaluating planning progress and to provide recommendations to the PWPG. The committees, as authorized, serve only in an advisory capacity. In addition, committee membership includes, where appropriate, PWPG members as well as nonmembers.

Historically, the PWPG has utilized up to five committees for a myriad of purposes. However, in this cycle the PWPG utilized only three committees with the Executive

Committee serving multiple purposes previously handled in multiple Committee settings.

Within the first two years of the fifth cycle of the planning process the Modeling Committee met once to review the availability figures issued by the TWDB and provide recommendation to the full PWPG voting membership. The Modeling Committee met only one time during the fifth cycle of regional water planning.

The Agriculture Committee met six times in the fifth planning cycle to review multiple aspects of the planning process since agriculture demand constitutes such a large portion of water usage in the region. The first meetings of the Agriculture Committee focused on reviewing, revising, and recommending agriculture demand numbers for the TWDB to more accurately account for agriculture demand in the region. Subsequent Agriculture Committee meetings focused on the agricultural supplies, projected needs and development of agriculture strategies for the 2021 Panhandle Regional Water Plan.

The Executive Committee of the PWPG has served multiple functions throughout the fifth planning cycle. The Executive Committee has continued to function in the role of conducting administrative reviews for member nominations, identification of Major Water Providers, and contractual requirements. Additionally, the Executive Committee functioned as the consultant review body as the Panhandle Regional Planning Commission went through the procurement process for professional services in the development of the fifth plan. The Executive Committee also acted in this cycle at the request of the voting membership of the PWPG in an oversight role for the Scope of Work development, financial review, and Public Participation activities. The Executive Committee met eight times over the planning period.

10.7 Interregional Coordination

As part of the planning process, the PWPG determined that coordination with adjacent Region B and Region O water planning groups was necessary. The PWPG appointed a board member to be the liaison between each respective region and charged them with the assignment of attendance of their region's meetings. Coordination was made with the notice and exchange of meeting agendas and when necessary, attendance and participation in their meetings was provided by additional PWPG Board members and staff. At every regular meeting of the PWPG, the liaison reported to the Board the activity of their respective planning group's activity. Communication among the Board Chairmen and Board members was also utilized and allowed for a secondary line of exchange of information to take place.

10.8 Local Participation in the Regional Water Planning Process

Participation by local entities in the regional water planning process was quite commendable. Local funds were necessary to provide for the maintenance and operation of the PWPG, fiscal accountability, meeting costs, posting costs, etc. The PWPG estimated that $79,000 annually in local funds would be needed to cover these costs. Working through the public participation committee, the original formula from the first round of planning was updated in the fifth cycle and implemented to attempt to keep up with inflation and spread these costs equally throughout the region. Possible participants were divided into the following categories: municipalities, counties, water utilities, groundwater districts, surface water districts, and solicited contributions. Entities and organizations in each of these categories were contacted by mail requesting their pro-rata share of the local planning cost. Solicitations were made once, and these various entities and organizations provided approximately $350,000 for regional water planning over the 5-year planning cycle. Ninety percent of funds solicited were received over the planning cycle. The PWPG believes this is a strong indicator of the local commitment to water resource planning throughout the region.

The PWPG would like to thank and recognize all those entities and organizations who contributed funds to the regional water planning effort.

In addition to the local funds received, the PWPG adopted a policy whereby all local water use groups are considered to have participated in the Regional Water Plan by virtue of their inclusion in and review of the Plan.

10.9 Plan Adoption Process

In accordance with Texas Administrative Code Chapter 357 and the relevant rules governing the water planning process, the PWPG conducted a formal process for the adoption of the Regional Water Plan. Activities under this section are primarily along two main lines. The first series of activities are directly related to the adoption of the Initially Prepared Plan and the second series of activities are related to final adoption of the completed Regional Water Plan.

10.9.1 Initially Prepared Plan Adoption

The PWPG conducted a formal Planning Group meeting on February 18, 2020 prior to the Public Hearing. Sixteen of the 23 voting members were present or represented (including ex-officio members) were in attendance. The Initially Prepared Regional Plan was given unanimous approval for submission to the TWDB.

10.9.2 Public Hearing

The PWPG conducted the required public hearing on April 23, 2020. The hearing was held virtually. All required notifications for the hearing were posted prior to the 30-days before the hearing. Electronic or printed copies of the Initially Prepared Regional Plan were placed in the County Clerk's office of each of the 21 counties in the region and were also placed in the primary public library in each of the 21 counties. In addition, full posting requirements regarding County Clerks, Mayors, Judges, and all interested parties were conducted. Finally, the newspaper of general circulation in each county ran the Hearing Notice over 30 days prior to the Hearing. Oral comments from the public were solicited at the hearing and written comments were accepted for 60 days following the hearing. No formal public comments were received.

10.9.3 State and Federal Agency Review

The adopted Initially Prepared Plan was provided to the TWDB by the March 3, 2020 deadline. Comments were accepted from the TWDB Executive Director and other state and federal agencies in accordance with the review periods set forth by the regional planning guidelines. The PWPG received comments from the TWDB, Texas Parks and Wildlife, and the Texas State Soil and Water Conservation Board. No other state or federal agency comments were received.

10.9.4 Response to Comments

Comments received on the Initially Prepared Plan were carefully considered and responses were developed. Modifications to the final plan were made in response to the comments and are documented in Appendix H.

10.9.5 Final Regional Water Plan Adoption

The final 2021 Panhandle Water Plan was adopted by the PWPG on September 25, 2020. This plan and supporting materials were submitted to the TWDB in accordance with the contractual requirements.

10.10 Conclusion

The PWPG has maintained a high level of commitment to public participation throughout the planning process. The PWPG believes that public information and participation activities are at least as important to the success of regional planning initiatives as is the data accumulated and analyzed. A key recommendation of the PWPG is to continue to fund and encourage public information activities throughout all subsequent planning processes.

11 IMPLEMENTATION AND COMPARISON TO PREVIOUS REGIONAL WATER PLAN

11.1 Introduction

The Regional and State Water Planning process administered by the TWDB operates on a five-year cycle. Inherently, this cycle enables continual refinements and changes to major components of the planning process, such as water demands, supplies, and recommended strategies. This chapter assesses the changes between cycles of Regional Water Plans. This chapter includes a discussion on the major differences between the 2021 Panhandle Water Plan and the previous Plan (2016 Panhandle Water Plan) and a description of strategies that have been implemented since the publication of the 2016 Plan.

11.2 Differences Between Previous and Current Regional Water Plans

The following sections specifically address changes between the 2016 and 2021 Plan in:

- Population projections,
- Water demand projections,
- Drought of record and hydrologic modeling and assumptions,
- Groundwater and surface water availability,
- Existing water supplies for water users,
- Identified water needs for WUGs and MWPs, and
- Recommended and alternate water management strategies.

11.2.1 Population Projections

Population projections for the 2021 Plan are based on the 2010 Census and expected growth associated with major metropolitan areas and future oil and gas activities. The 2016 Plan population projections were also based on the 2010 Census and as a result, population projections in the 2021 Plan and the 2016 Plan are about the same on a regional basis throughout the planning period (Figure 11-1). One of the major changes for this round of planning is the use of water utility boundaries rather than city limits. This resulted in changes of individual WUG populations as customers outside the city limits were included in the WUG population. Also, the criteria for defining a municipal WUG was changed from a population basis to a water demand basis. This resulted in the addition of seven new municipal WUGs in the 2021 Panhandle Water Plan (Red River Authority of Texas, Turkey Municipal Water System, Hartley Water Supply Corporation, Darrouzett, Follett, Higgins Municipal Water System, and Texhoma). No municipal WUGs were removed.

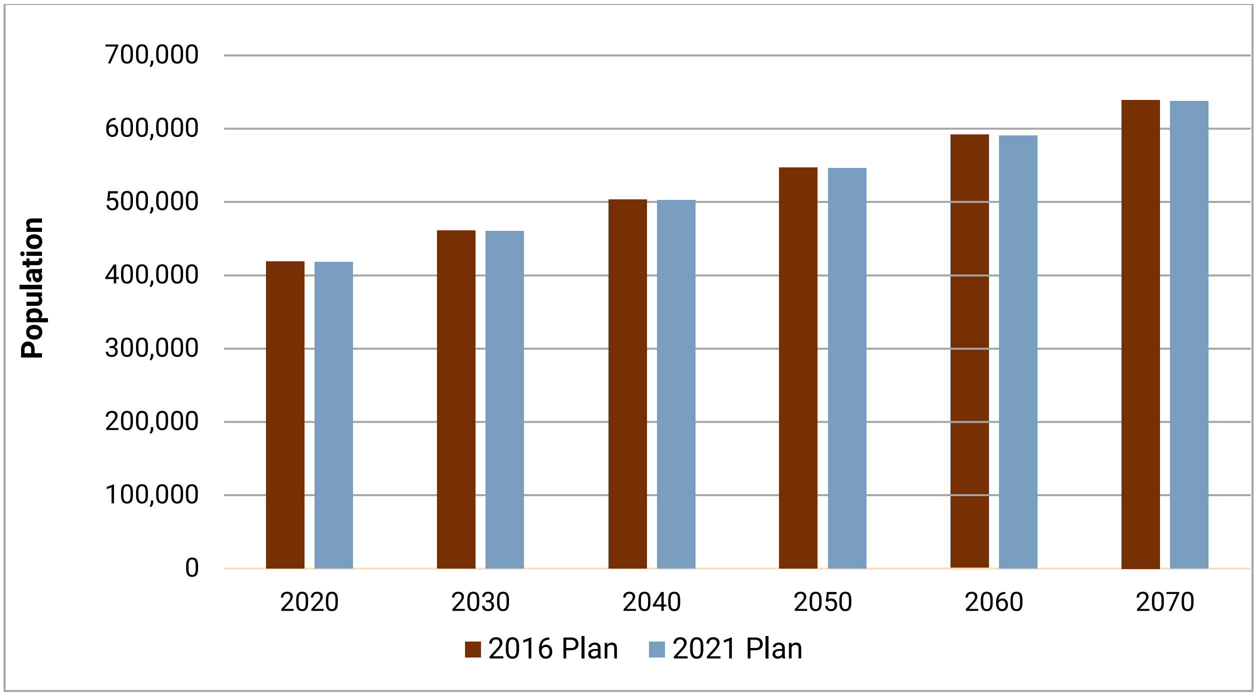


Figure 11.1: Comparison of PWPA Population

In addition to the changed definition of municipal WUG, the 2021 Plan now includes a new category for planning: Major Water Provider. For the PWPA, all of the previously designated wholesale water providers, with the exception of the Palo Duro River Authority (now Palo Duro Water District) are designated as a Major Water Provider.

11.2.2 Water Demand Projections

Development of municipal water demands for the 2021 Plan was similar to the methodology in the 2016 Plan. However, there are significant differences in the methodologies used for the non-municipal demands. As a result of these changes, water demands in the PWPA for the 2021 Plan increased in comparison to the 2016 Plan (Figure 11-2) by approximately 22 to 37 percent. Irrigation water demands are primarily driving these increases (Table 11-2). In the 2016 Plan, irrigation demands were estimated based on water needs by crop and then a demand decline curve was applied to each county's irrigation demand. For the 2021 Plan, irrigation demands are based on a ten-year historical average and then are held constant unless the demands exceed the groundwater availability (MAG). Irrigation demands decline in only five counties: Collingsworth, Dallam, Hartley, Moore, and Sherman. This approach along with a higher base year use results in higher irrigation demands over time. Also, for the 2021 Plan, manufacturing demands were increased between 2020 and 2030 based on the growth in the county. After 2030, these demands were held constant. While this may be a reasonable approach for the more rural counties in the PWPA, it likely underestimates future manufacturing water needs in the high growth areas. The 2016 Plan did not cap manufacturing demands early in the planning period. There are also lower demands for steam electric power in the 2021 Plan. This is due to the closing of a steam electric facility in Gray County and a change in the methodology for estimating future steam electric demand. Future water needs for steam electric power are no longer considered in the regional plans unless there is a facility already planned. This eliminates placement of demands in counties that may not be the future location. However, it also underestimates the need for water for future power generation across the state.

As shown on Figure 11-3, projected demands for irrigation are significantly higher in the 2021 Plan. Table 11-2 identifies changes in irrigation demand by county.

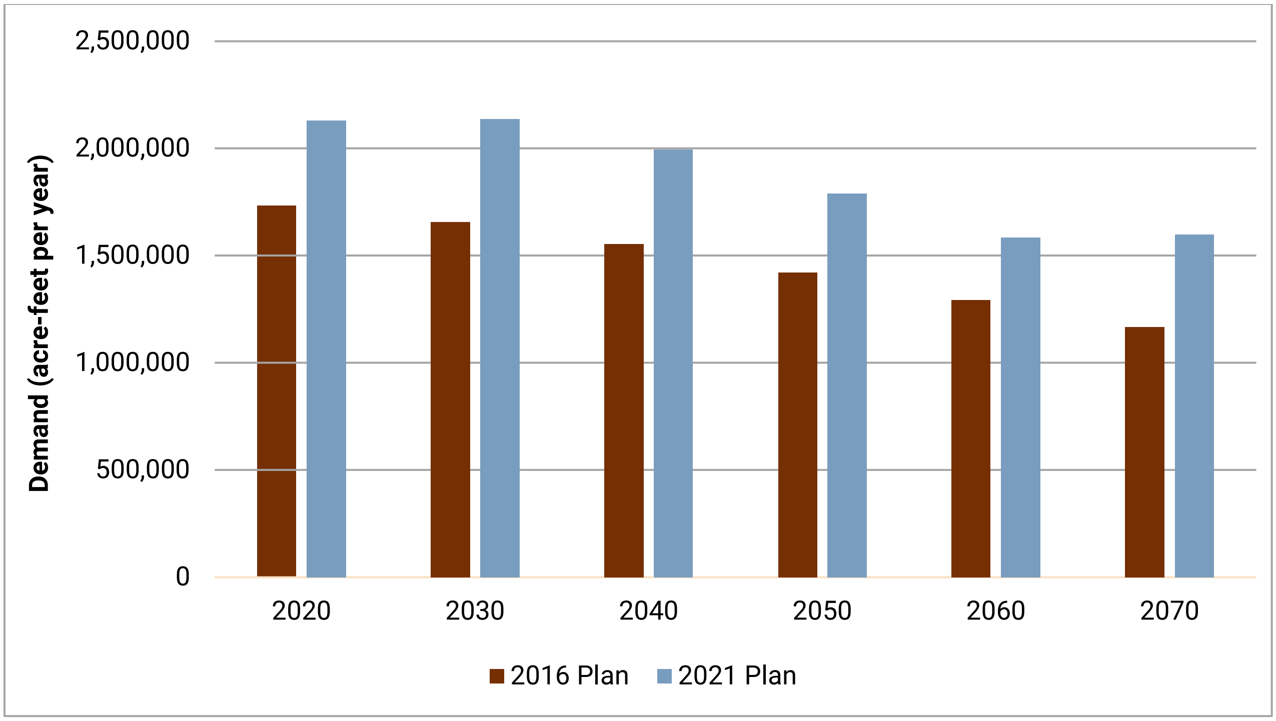


Figure 11.2: Comparison of PWPA Water Demand

Table 11-1: Changes in Projected Demands from the 2016 Plan to the 2021 Plan by Use Type

Use Type	Changes in Projected Water Demands (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Irrigation	405,601	487,727	451,575	382,477	314,930	460,751
Livestock	(773)	2,012	2,722	3,478	4,280	5,136
Manufacturing	(325)	245	(2,535)	(4,929)	(8,509)	(12,360)
Mining	0	0	0	0	0	0
Municipal	809	816	812	810	814	814
Steam Electric Power	(8,442)	(10,362)	(12,153)	(14,409)	(18,648)	(22,435)
Total	**396,870**	**480,438**	**440,421**	**367,427**	**292,867**	**431,906**

Note: Negative numbers indicate lower demand in the 2021 Plan and positive numbers show higher demand in the 2021 Plan.

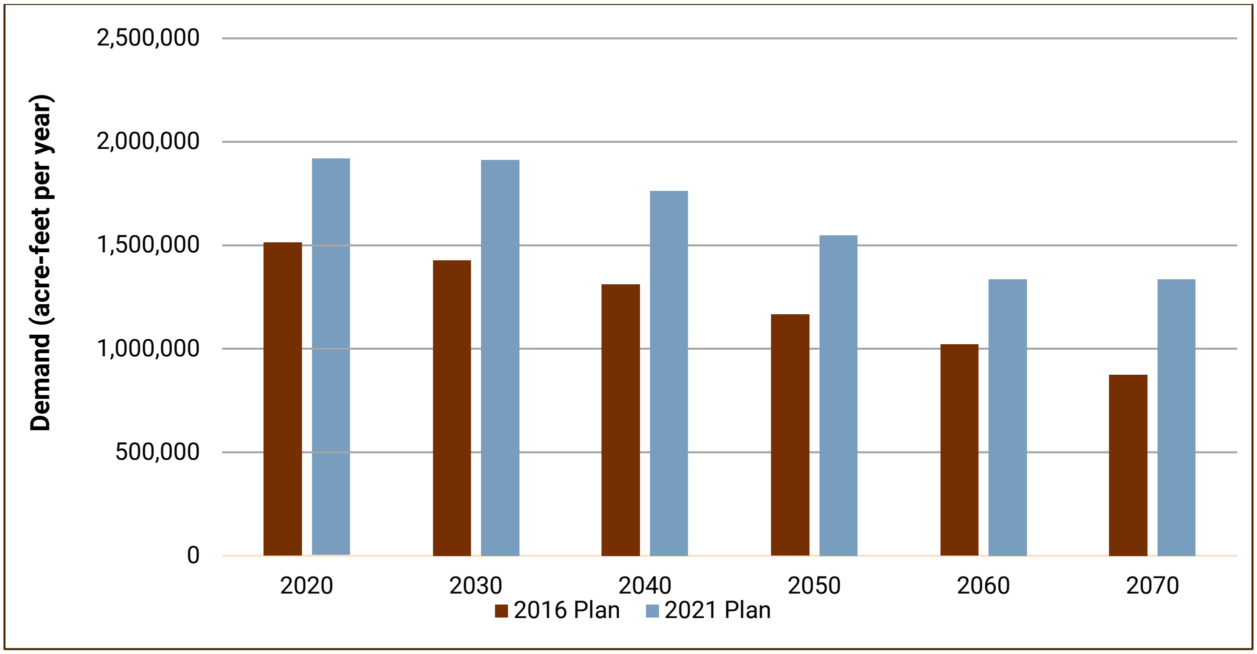


Figure 11.3: Comparison of PWPA Irrigation Water Demand

Table 11-2: Changes in Projected Irrigation Demands from the 2016 Plan to the 2021 Plan

County	Change in Projected Irrigation Demand (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Armstrong	2,050	2,254	2,536	2,948	3,360	3,772
Carson	31,587	34,451	38,513	43,933	49,352	54,772
Childress	6,834	7,116	7,541	8,274	9,008	9,741
Collingsworth	29,528	25,266	23,458	23,766	20,808	22,614
Dallam	(26,034)	(3,694)	(31,867)	(55,130)	(73,735)	(38,313)
Donley	6,830	7,707	9,063	11,491	13,918	16,346
Gray	10,998	12,185	13,750	15,810	17,870	19,930
Hall	21,658	21,986	22,518	23,549	24,579	25,610
Hansford	36,998	45,419	56,141	69,003	81,865	94,727
Hartley	61,625	81,108	44,907	16,941	(6,878)	26,488
Hemphill	3,772	3,865	3,994	4,181	4,368	4,555
Hutchinson	19,902	22,239	25,275	29,124	32,972	36,820
Lipscomb	20,861	21,856	23,220	25,181	27,142	29,103
Moore	57,522	66,155	48,602	26,495	7,027	20,726
Ochiltree	27,217	30,635	35,046	40,537	46,027	51,518
Oldham	784	953	1,197	1,588	1,980	2,371
Potter	(251)	(116)	85	428	772	1,115
Randall	(280)	564	1,744	3,519	5,294	7,070
Roberts	2,585	2,934	3,388	3,961	4,534	5,106
Sherman	83,394	96,603	113,673	77,261	34,224	55,411
Wheeler	8,021	8,241	8,791	9,617	10,443	11,269
Total	**405,601**	**487,727**	**451,575**	**382,477**	**314,930**	**460,751**

Negative numbers indicate lower demand in the 2021 Plan and positive numbers show higher demand in the 2021 Plan.

The counties with the greatest increases in irrigation demand are Carson, Hansford, Hartley, Moore, Ochiltree, and Sherman Counties. These counties accounted for greater than 70 percent of the increase in irrigation demand in the 2021 Plan. Only Dallam, Hartley, Potter and Randall Counties have lower irrigation demands in the 2021 Plan than the 2016 Plan. For Hartley, Potter, and Randall Counties, these differences are small and only seen in one or two decades. For Dallam County, the differences reach over 70,000 acre-feet in 2060. This is because the baseline demands for Dallam County are less than estimated in the 2021 Plan and the decline rate for the 2021 Plan is greater than in the 2016 Plan. This is more a function of the decline rate of the MAG in Dallam County than actual reductions in irrigation water use.

Figure 11-4 shows that the projected municipal water demands are very similar between the two regional water plans. This is because the total populations are nearly the same. The slight differences in municipal demands are due to the changes in definitions of WUGs and how the per capita water use was applied to each WUG's population. There is only a difference of 2 gallons per capita per day on a regional basis between the plans, with the 2021 Plan having a slightly higher per capita water use of 197 gallons per day. For the 2016 Plan, the regional average was 195 gallons per person per day. The rate of decline over time in per capita water use was about the same (Figure 11-4).

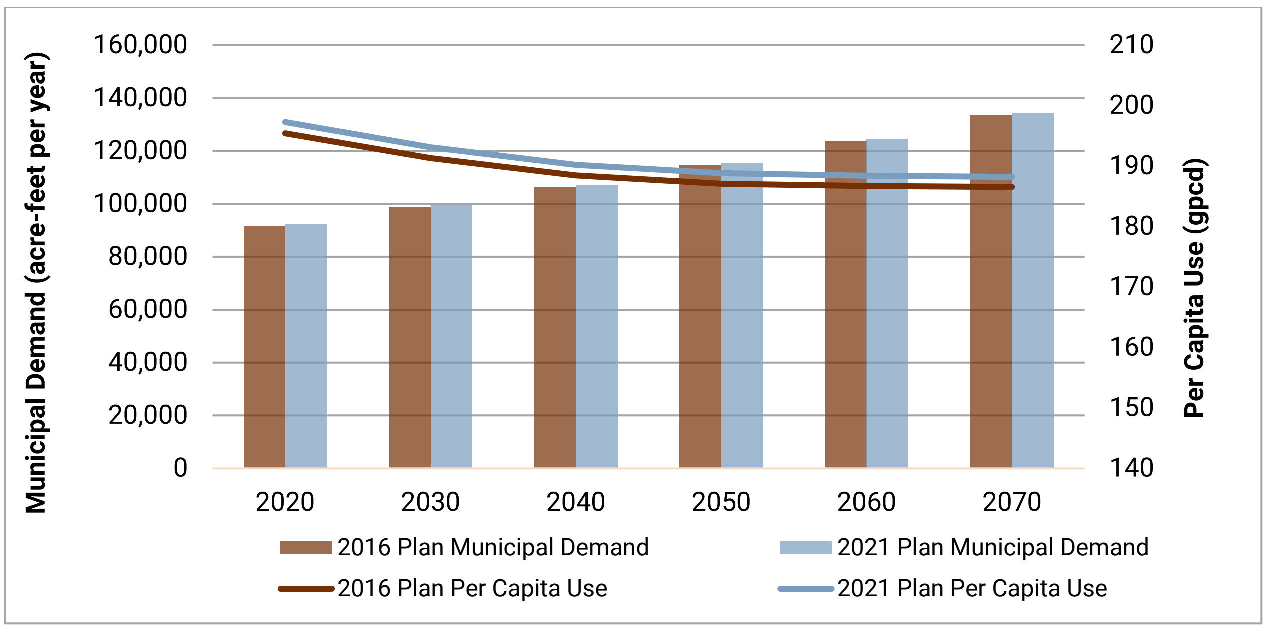


Figure 11.4: Comparison of Projected Per Capita Use and Municipal Demand

11.2.4 Drought of Record and Hydrologic Modeling Assumptions

In general, the drought of record is defined as the worst drought to occur in a region during the entire period of meteorological record keeping. For most of Texas, the drought of record occurred from 1950-1957. Surface water sources in the PWPA were in drought of record conditions for the 2011 and 2016 Plan and continue to be in drought of record conditions for the 2021 Plan. Since the 2016 Plan, the region has experienced some recovery in the area lakes. This recovery was sufficient to estimate new reservoir yields for the 2021 Plan; however, the water level recoveries did not end the droughts of record.

In the 2016 Plan, the estimated reliable supply from Lake Meredith was zero (0). This was based on the CRMWA's inability to use water from the lake. Since the lake has captured some inflows, a firm and safe yield analysis was conducted using extended hydrology through December 2017. The safe supply for Lake Meredith is now estimated at 24,670 acre-feet per year. A similar approach was taken for Greenbelt Reservoir. In the 2016 Plan, Greenbelt Reservoir was at very low levels with no signs of the drought ending. To estimate the reliable supply a conditional reliability model approach was used. This approach provided an estimate of how the reservoir would respond to continuing drought conditions. With new inflows recorded in Greenbelt Reservoir, the historical hydrology was extended through 2016 and a traditional yield analysis was conducted. This resulted in a safe yield of 3,112 acre-feet per year in 2020.

For groundwater, hydrogeologic modeling assumptions change each planning cycle as GMAs adopt new Desired Future Conditions (DFCs) and new or updated groundwater models become available. The biggest differences in the hydrogeologic modeling in the PWPA for the 2021 Plan are the new Ogallala GAM and changes in the modeling assumptions for the Blaine aquifer. The new Ogallala GAM incorporates both the old Northern Ogallala GAM and the Southern Ogallala GAM. It also incorporates the Dockum aquifer as a layer in the model. The new model has updated aquifer parameters and aquifer thicknesses, which results in changes in storage for both the Ogallala and Dockum aquifers. The DFCs for these aquifers for the 2016 Plan and 2021 Plan are basically the same, and the changes in MAG values for the Ogallala and Dockum result from the changes in aquifer parameters in the new model.

For the Dockum aquifer the DFC was set as the average decline in water levels to be no more than 30 feet over the next 50 years for areas within the Panhandle GCD. This is consistent with the DFC used for the 2016 Plan. For the Dockum that falls in the North Plains GCD (Dallam, Hartley, Moore and Sherman Counties), the DFC was set at 40 percent of storage remaining at the end of the simulation (2062). Greater drawdown (approximately 40 feet) was allowed in Randall County, and in the portions of Armstrong and Potter counites within the High Plains UWCD. While the changes in the Dockum DFC for the North Plains and High Plains GCDs likely results in some changes in groundwater availability, the biggest differences are attributed to a new groundwater availability model.

For the 2021 Plan, the DFCs for the Seymour aquifer were modified to reflect drawdown rather than storage. This change results in higher groundwater availabilities.

However, the total supply from the Seymour in the PWPA is less than 60,000 acre-feet per year.

The DFCs for the Blaine aquifer were also set at specific drawdown targets for the 2021 Plan (9 feet in Childress County in the Gateway GCD and 2 feet elsewhere). For the 2016 Plan, the DFCs were set at 50 percent of the volume in storage remaining in 50 years in Wheeler County, and 80 percent of current volume of storage remaining in 50 years in Childress, Collingsworth and Hall Counties. The impact of the new DFCs has led to significantly lower groundwater availabilities for the Blaine aquifer in the PWPA, with a total reduction of nearly 280,000 acre-feet per decade in the 2021 Plan.

11.2.5 Groundwater Availability

Overall groundwater availability increased for the 2021 Plan by a couple of hundred thousand acre-feet (Figure 11-5). However, the differences by aquifer and county are substantial for some areas (Figure 11-6). These larger differences are primarily from increases in the Dockum supplies in Oldham County and significant reductions in supplies from the Blaine aquifer in Collingsworth and Wheeler Counties. Increases in the Ogallala aquifer availability are shown in 16 of the 19 counties in the PWPA, resulting in a net increase of over 200,000 acre-feet per year for the region. Lower Ogallala availability estimates in most of the other counties are small. Both Dallam and Hartley Counties show larger reductions in groundwater availability after 2020, ranging from over 20,000 acre-feet per year to over 100,000 acre-feet per year.

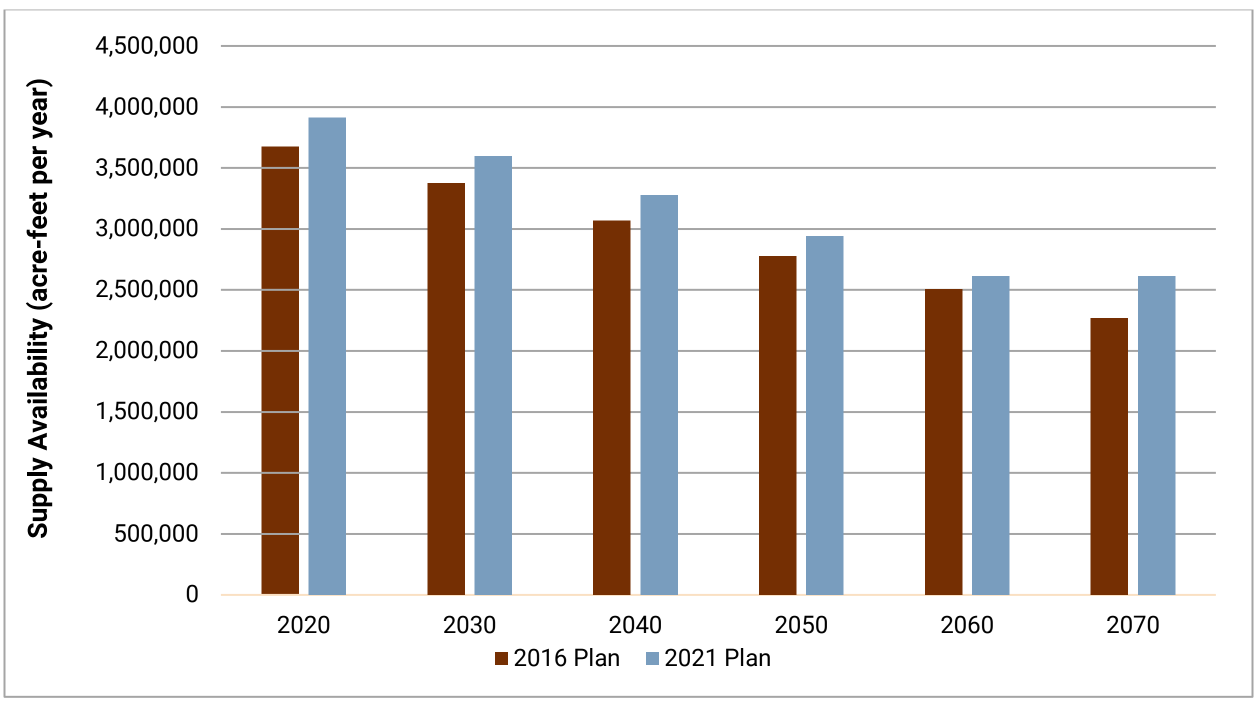


Figure 11.5: Comparison of Groundwater Availability from the 2016 and 2021 Plans

Table 11-3: Change in Groundwater Availability from the 2016 Plan to 2021 Plan

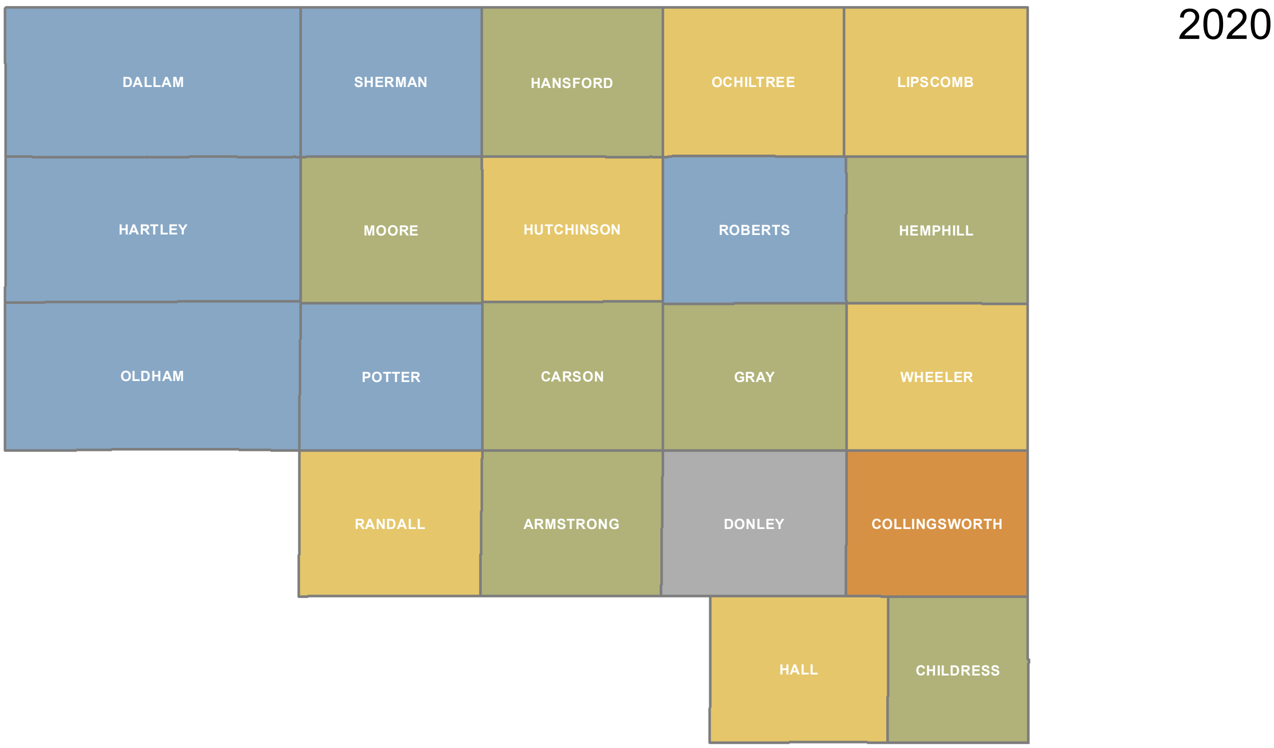
Source	Changes in Groundwater Availability (ac ft/yr)					
	2020	2030	2040	2050	2060	2070
Ogallala & Rita Blanca	243,160	228,085	223,340	187,759	142,170	377,793
Seymour	30,990	25,060	26,714	30,208	29,448	29,432
Blaine	(277,847)	(277,934)	(277,847)	(277,934)	(276,545)	(275,347)
Dockum	239,856	244,324	235,084	223,565	210,905	210,905
Other	0	0	0	0	0	0
Total	**236,159**	**219,535**	**207,291**	**163,598**	**105,978**	**342,783**

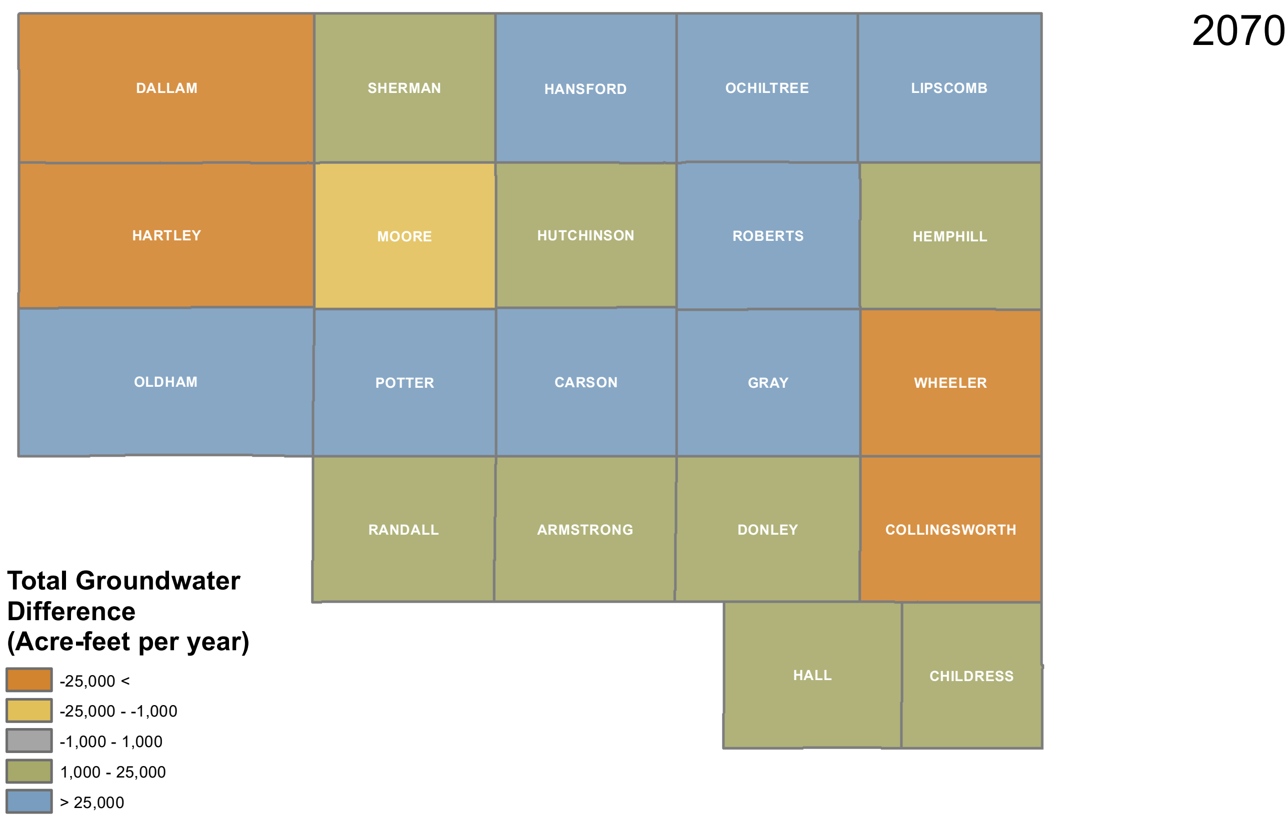
Table 11-4: Changes in Blaine Aquifer Supply by County from the 2016 Plan to 2021 Plan

County	Changes in Blaine Aquifer Availability (ac ft/yr)				
	2020	2030	2040	2050	2060
Childress	8,369	8,304	8,369	8,304	8,369
Collingsworth	(183,316)	(183,322)	(183,316)	(183,322)	(183,316)
Hall	(5,653)	(5,669)	(5,653)	(5,669)	(5,653)
Wheeler	(97,247)	(97,247)	(97,247)	(97,247)	(95,945)

Table 11-5: Changes in Dockum Aquifer Supply by County from the 2016 Plan to 2021 Plan

County	Changes in Dockum Aquifer Availability (ac ft/yr)				
	2020	2030	2040	2050	2060
Armstrong	6,645	8,442	9,006	9,122	8,953
Carson	(215)	(175)	(143)	(114)	(85)
Dallam	10,158	10,154	10,152	10,150	10,150
Hartley	51,682	51,468	51,361	51,297	51,270
Moore	(176)	(288)	(375)	(469)	(606)
Oldham	126,029	125,857	117,546	108,224	98,441
Potter	37,144	37,433	35,257	32,825	30,328
Randall	9,053	11,897	12,744	12,994	12,950
Sherman	(464)	(464)	(464)	(464)	(496)





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N W E S

PANHANDLE WATER PLANNING AREA

TOTAL GROUNDWATER DIFFERENCE IN AVAILABILITY

Location Map

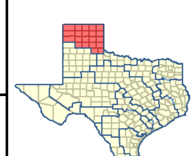

FIGURE 11-6

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11.2.6 Surface Water Availability

Surface water availability increased by approximately 88 percent from the 2016 Plan to the 2021 Plan as shown in Figure 11-7. In 2015, the three major reservoirs (Lake Meredith, Greenbelt Reservoir and Palo Duro Reservoir) began capturing inflow after a long significant drought. Reservoir storage increased, but the reservoirs are still in drought of record conditions. Due to this increase in storage volumes, a traditional yield analysis was performed for these lakes, which resulted in greater water supplies for Lake Meredith than estimated in the 2016 Plan. The available supply from Greenbelt Reservoir is projected to be 34 percent less in 2070 than estimated for the 2016 Plan (Table 11-6).

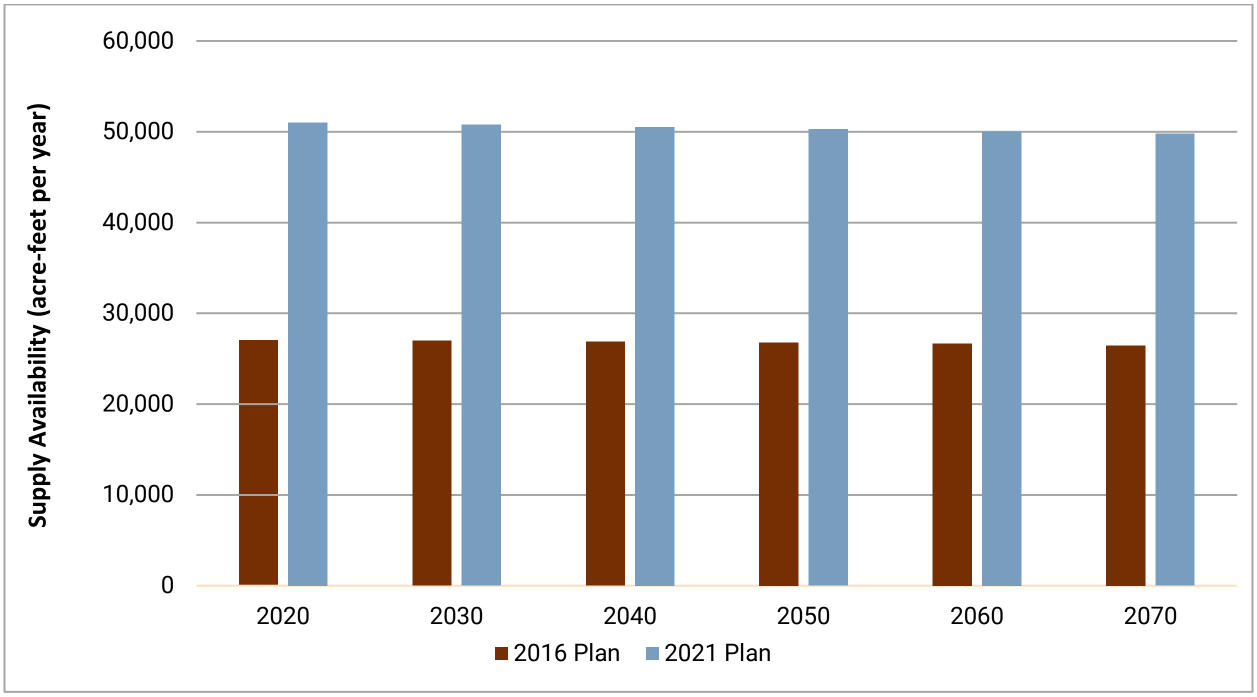

Figure 11.7: Comparison of Surface Water Availability in the 2016 and 2021 Plans

Table 11-6: Projected Change in Surface Water Supply from the 2016 to 2021 Plan in 2070

Supply	2016 Plan (ac ft/yr)	2021 Plan (ac ft/yr)	Percent Change
Lake Meredith	0	24,501	NA
Greenbelt Reservoir	3,440	2,256	-34%
Palo Duro Reservoir	3,708	3,708	0%
Local Supplies	16,783	16,783	0%
Run-of-River	2,538	2,538	0%

11.2.7 Existing Water Supplies of Water Users

Existing supplies to users are based on the source availability and infrastructure developed to provide the water. Due to changes in source availability, supplies to some users increased while others may have decreased. Generally, the increases in groundwater availabilities for the Ogallala and Dockum aquifers resulted in greater availabilities to users. Also, increased surface water from Lake Meredith provides additional supplies to CRMWA and its customers. The users with the larger increases in supplies include irrigation and municipal users in counties with increased groundwater and customers of CRMWA. Some municipal users have implemented new groundwater projects, such as Borger, that increase supplies to the user. Supplies to County-Other and Manufacturing users changed slightly in response to changing demands rather than availability.

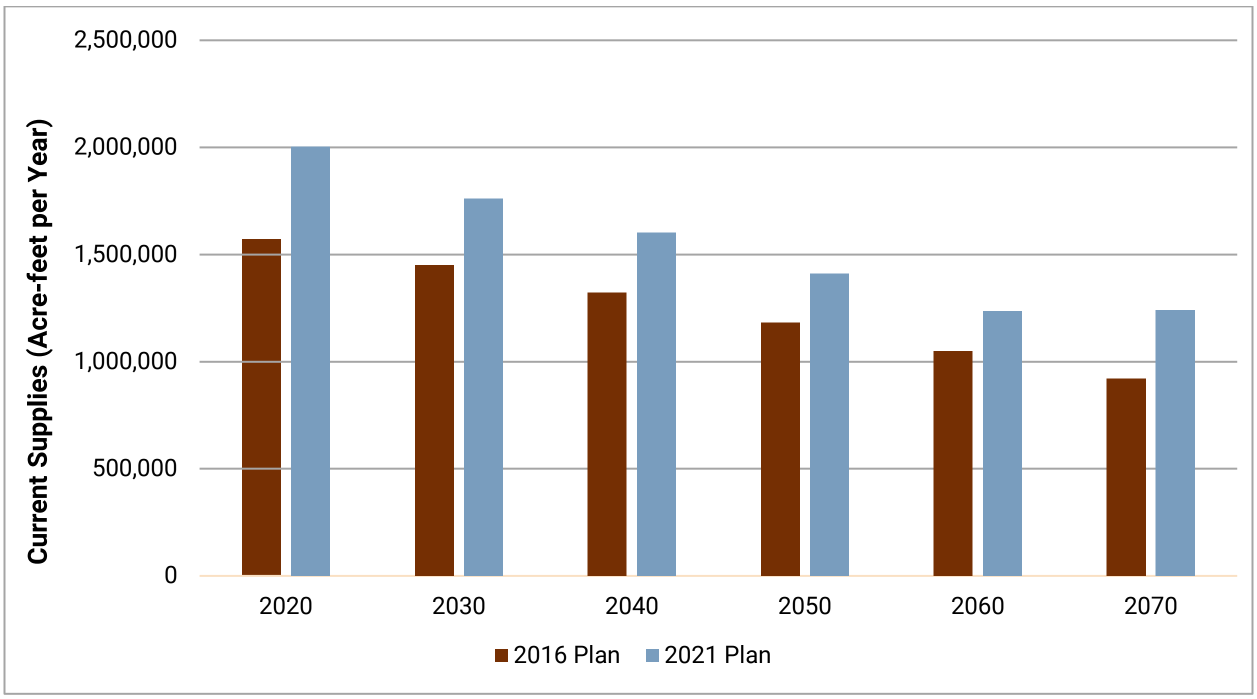

Figure 11.8: Comparison of Current Water Supplies for WUGs

11.2.8 Identified Water Needs

Water Use Type

As mentioned in Section 11.2.2, water demands in the PWPA for the 2021 Plan increased in comparison to the 2016 Plan (Figure 11-2) by approximately 22 to 37 percent. Irrigation water demands are primarily driving these increases. However, a pattern of overall decline continues to be projected throughout the 50-year analysis. Relative consumption of water by use type has remained fairly constant between the two plans with irrigation being the largest consumer followed by municipal, manufacturing, livestock, steam electric power and mining use. There were some absolute differences in demands by use type, with higher demands for irrigation and municipal use and lower demands for livestock, manufacturing, steam electric power, and mining.

Needs

The total needs for the 2021 Plan are less than the 2016 Plan in the 2020 decade, and considerably greater in all decades thereafter (Figure 11-9). While the total available supply in the PWPA is higher in the 2021 Plan compared to the 2016 Plan, total demand, primarily driven by increased irrigation demand, is substantially higher in the 2021 Plan compared to the 2016 Plan. As a result, the distribution of water needs by use type are different with municipal and manufacturing water use having lower needs in the 2021 Plan and irrigation having greater water needs (Figure 11-10). Livestock, Mining, and Steam Electric Power do not have a need in either plan.

There are nine water users shown to have a need in the 2021 Plan but did not have a need in the 2016 Plan. All the municipal users shown with a new need are customers of Greenbelt MIWA that is shown to have a need in the 2021 Plan. These needs will be met through Greenbelt MIWA. There are four new counties shown with irrigation needs. For Collingsworth, Hall, and Sherman Counties, these needs are associated with reduced groundwater availabilities and higher irrigation demands. For Gray County, this small need is the result of lower groundwater availability in the Canadian River Basin for irrigation in the GAM model. This need may not be realistic but was retained for the 2021 Plan.

There are four water user groups that do not have a need for the 2021 Plan that were shown to have a need in the 2016 Plan. These users have increased water supplies as more groundwater became available with the new MAGs. The changes in entities with needs between the two plans are shown in Table 11-7.

Table 11-7: Entities with New Needs or No Need for the 2021 Plan

New Need	No Need
City of Childress	City of Claude
Red River Authority (Childress County)	Lake Tanglewood
City of Clarendon	County-Other (Potter County)
Irrigation (Collingsworth County)	County-Other (Randall County)
Irrigation (Hall County)	
Irrigation (Gray County)	
Irrigation (Sherman County)	

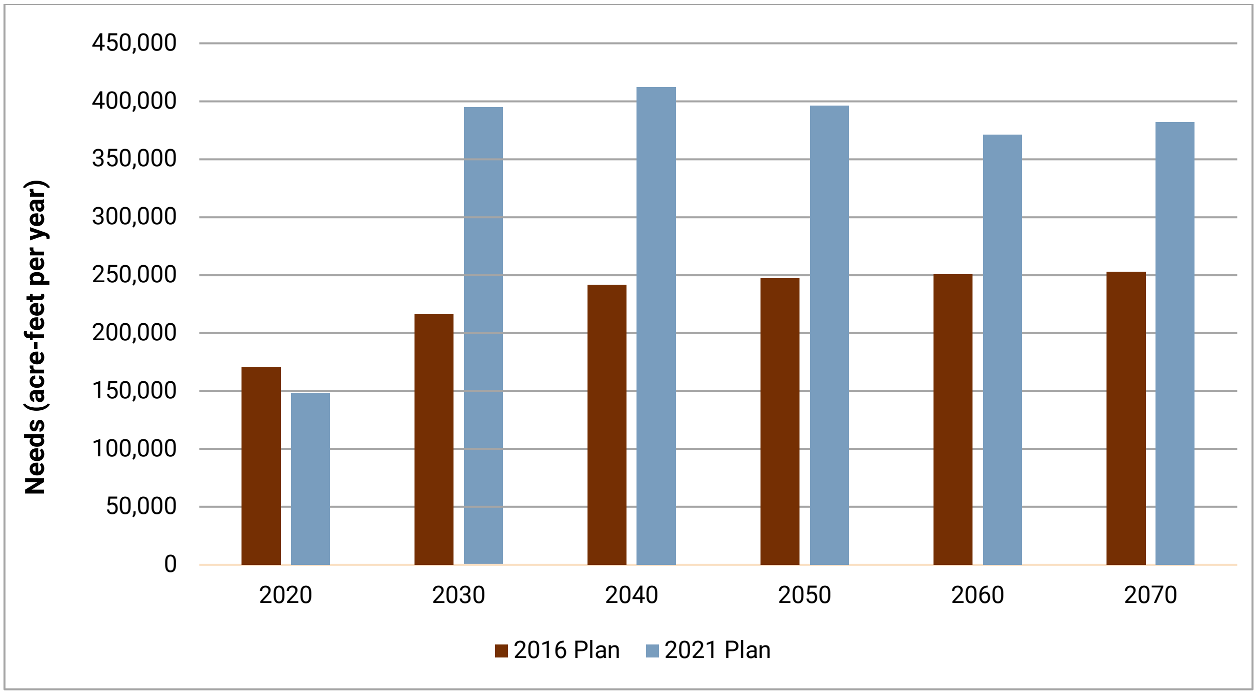

Figure 11.9: Projected Water Need for the 2016 and 2021 Plans

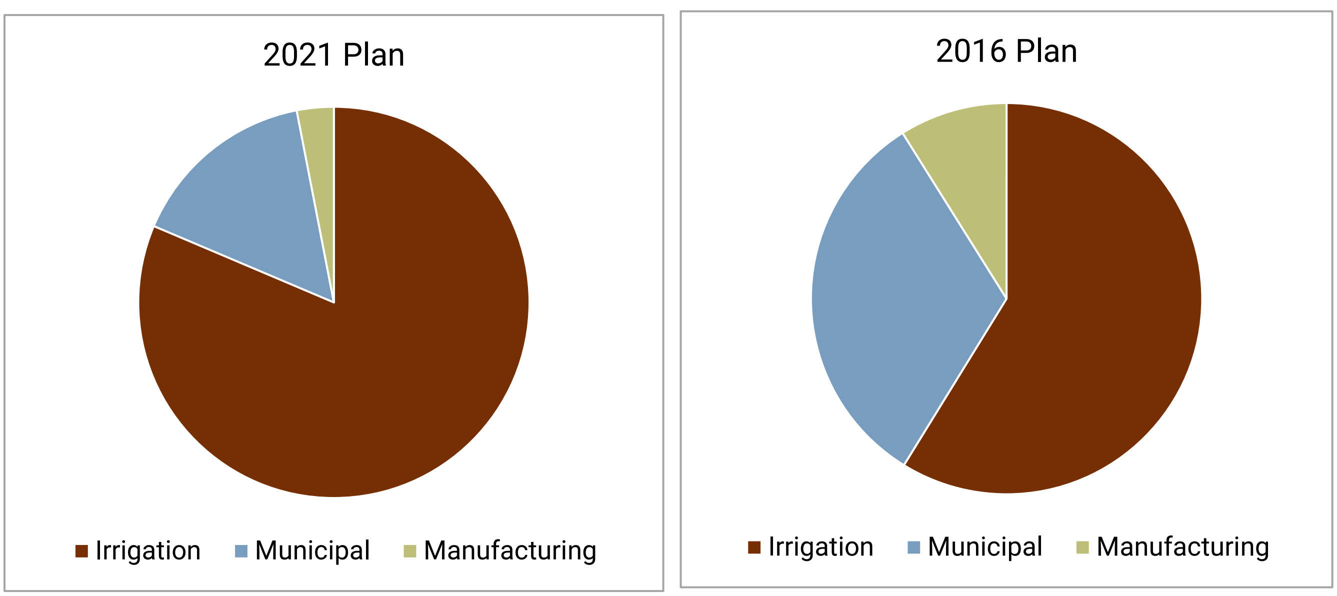

Figure 11.10: Projected Water Need in 2070 by Type

For the 2021 Plan, all five Major Water Providers are shown to have a need at some time during the planning period. In the 2016 Plan, Greenbelt MIWA did not have a need. The other providers' needs are less in the 2021 Plan. This is mostly attributed to the greater supplies to CRMWA associated with Lake Meredith. Both Amarillo and Borger are customers of CRMWA and receive more water from CRMWA in the 2021 Plan. The changes in projected water needs for the Major Water Providers are shown on Figure 11-11.

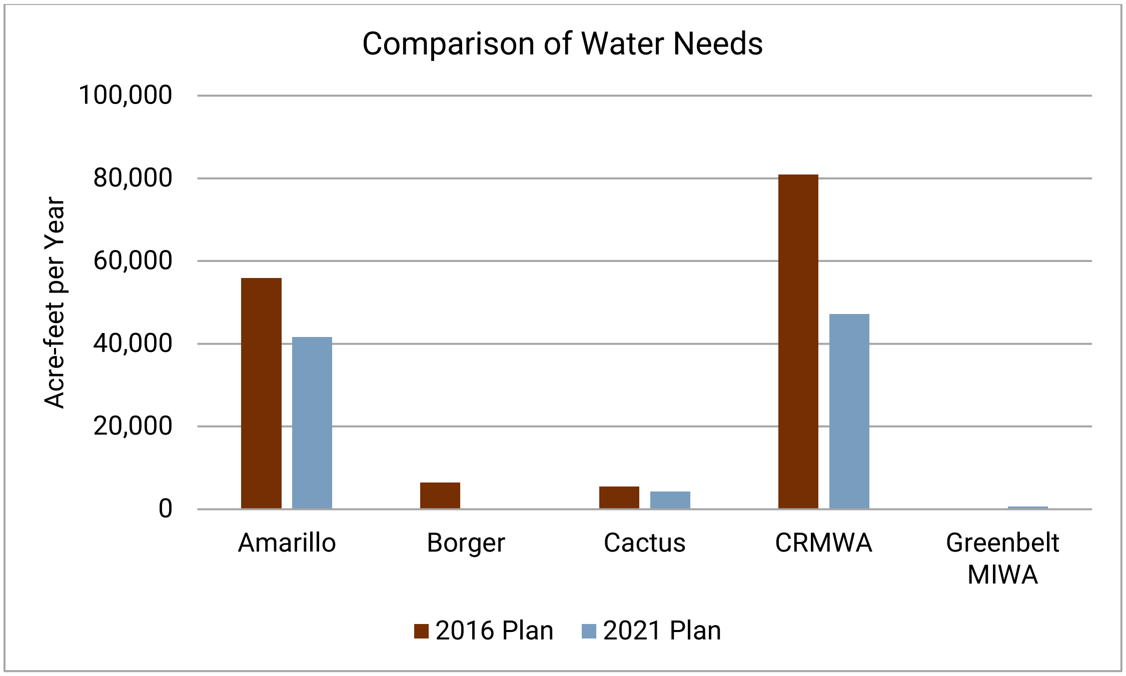

Figure 11.11: Comparison of 2070 Need by Major Water Provider

New Water Management Strategies

Due to changes in water needs, new strategies were developed for the 2021 Water Plan. Table 11-8 lists the 2021 new recommended strategies for water user groups. There are no new alternate strategies for the 2021 Plan.

Table 11-8: New Recommended Water Management Strategies in the 2021 Plan

Water User Group	New Recommended Water Management Strategy
Amarillo	AMI Water Conservation
Moore County Manufacturing	Develop New Well Field (Dockum Aquifer)
Pampa	Aquifer storage and recovery
Potter County Manufacturing	Develop New Well Field (Ogallala Aquifer)

11.2.9 Altered Water Management Strategies

Several strategies in the current plan were listed in the previous plan but have been altered in some way. This section focuses on strategies that were significantly changed from the last plan either due to major conceptual changes, better available data, or considerable changes in assumptions used to calculate the water available from the strategy. This section is meant to highlight the differences, not give a full description of the strategy. More information on these strategies can be found in Chapter 5.

Irrigation Conservation

For the 2016 Plan, a suite of conservation irrigation conservation strategies was identified, and the combined savings determined. Conservation was recommended for all counties, but counties without needs did not include the change in crop type as a recommended BMP in the overall conservation strategy. For the 2021 Plan, this BMP is included for all counties, whether there is a need or not. In addition, there is an adjustment for water savings for savings for counties with declining water demands in the 2021 Plan. No adjustments for declining demands was made in the 2016 Plan. Additional information on agricultural water conservation can be found in subchapter 5B.2.

Major Water Provider Strategies

There were numerous changes to the concepts and details of the strategies for the major water providers. Most of these changes reflect additional information and planning studies conducted since the 2016 Plan. Table 11-9 lists previous and new recommended water management strategies for the PWPA major water providers.

While several of the strategies in the 2021 Plan are the same as in the 2016 Plan, there are some modifications to some strategies. Specifically, the CRMWA conjunctive use strategy in 2016 was modified to two distinct strategies (brush control and ASR). This was done in part because Lake Meredith is shown to have a reliable supply for the 2021 Plan and additional water from Lake Meredith is not included in the 2021 Plan. Also, for the 2021 Plan, CRMWA and Amarillo will jointly develop the CRMWA II pipeline to move groundwater from Roberts County.

For Amarillo's strategies, the concept for the ASR changed from storing water in the Potter or Carson County well field to utilizing the City's existing Randall County well field. The source of water also changed from solely CRMWA supplies to both CRMWA supplies and direct potable reuse. The Amarillo Potter County Well Field (Phase II) strategy is very similar for the 2021 Plan, but there will be greater development in Carson County than previously assumed. This strategy was renamed as the Potter/Carson County Well Field (Phase II) and the Carson County Well Field strategy in the 2016 Plan was removed. There are no changes to the basic recommended strategies for Cactus and Greenbelt MIWA. Borger has developed additional groundwater and no longer has a new groundwater strategy.

Table 11-9: Major Water Provider Strategies and Projects in the 2016 and 2021 Plan

Wholesale Water Providers	2016 Plan	2021 Plan
CRMWA	CRMWA II pipeline	CRMWA II pipeline with Amarillo
	Replace well capacity	Replace well capacity
	Conjunctive Use with Lake Meredith (including brush control and ASR of surface, ground or blended water)	Brush Control
		ASR (with operational efficiencies of CRMWA I and II pipelines)
Amarillo	Potter County Well Field (Phase II)	Potter/Carson County Well Field (Phase II)
	ASR (part of CRMWA's Conjunctive Use strategy)	ASR (Randall County)
	Direct Potable Reuse (Alternate)	Direct Potable Reuse (Recommended)
	Roberts County Well Field	Roberts County Well Field
	Carson County Well Field	
Borger	New Groundwater (Ogallala) [1]	
Cactus	New Groundwater (Ogallala)	New Groundwater (Ogallala)
Greenbelt MIWA	Donley County Well Field	Donley County Well Field

1. Implemented strategy and project since the 2016 Plan

11.2.10 No Longer Recommended or Considered Water Management Strategies

In addition to new and altered strategies, some strategies included in the 2016 Plan are no longer being considered for the entity for various reasons. Most of these strategies are no longer needed because the entity does not have a need in the 2021 Plan. Weather modification is still considered, but no longer recommended. These strategies are outlined in Table 11-10 and Table 11-11.

Table 11-10: Strategies and Projects No Longer Considered in the 2021 Plan

Entity	Strategies No Longer Considered in the 2021 Plan
2016 Recommended Strategies	
Claude	Develop Ogallala Aquifer Supplies
Lake Tanglewood	Develop Ogallala Aquifer Supplies
Potter County Other	Develop Dockum Aquifer Supplies
Potter County Other	Develop Ogallala Aquifer Supplies
Randall County Other	Develop Ogallala Aquifer Supplies
2016 Alternate Strategies	
Potter County Manufacturing	Direct Reuse

1. These strategies and/or projects are not evaluated or discussed in the 2021 Plan.

Table 11-11: Strategies No Longer Recommended in the 2021 Plan

Entity	Strategies No Longer Recommended in the 2021 Plan
Recommended Strategies	
Multiple Counties	Weather Modification (Precipitation Enhancement)

1. These are strategies and/or projects evaluated in the 2021 Plan but are no longer recommended.

11.3 Implementation of Previously Recommended Strategies

There is only one strategy identified that was recommended in the 2016 Plan and has been partially or completely implemented since that plan was published. This strategy is included in the 2021 Plan as currently available supply.

11.3.1 Borger

Ogallala Aquifer

The City of Borger purchased water rights for the Ogallala aquifer in Hutchinson County. This strategy includes drilling 13 groundwater wells to a depth of 500 feet with a capacity of 600 gpm. The infrastructure includes 10 miles of 20-inch pipeline to transport the water to the City of Borger. This strategy is currently online and operating.

11.4 Conclusion

While there were several significant changes to supplies and demands in the PWPA for the 2021 Plan, the overall recommended strategies remain fairly consistent. Conservation remains a major strategy to meet irrigation and municipal water needs and preserve existing supplies. Groundwater is still the preferred source for new supply development. There is increased interest in aquifer storage and recovery and direct potable reuse, as evidenced by the Amarillo's modified strategies. The region continues to show significant demands on groundwater resources and limited quantities available in future decades. The heavy demand on these resources results in some unmet water needs for irrigation, which was also shown in the 2016 Plan.

The PWPA providers continue to identify opportunities for regionalization as evidenced by the CRMWA and Amarillo strategies to move water from Roberts County to Amarillo and CRMWA customers. CRMWA continues to work with its customers to develop sufficient water supplies including the development of a potential ASR strategy for customers in the Llano Estacado Region (Region O).