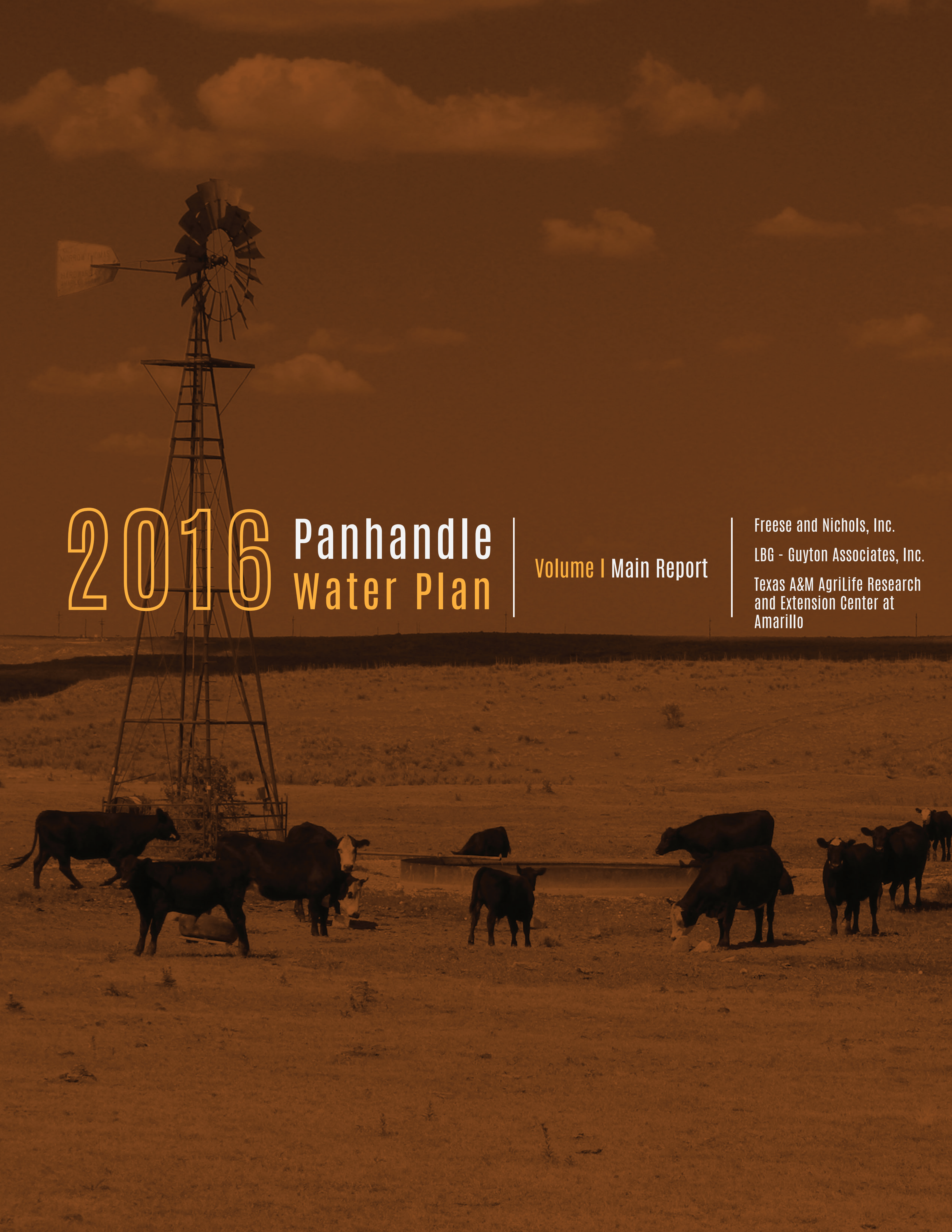

2016 Panhandle Water Plan

Volume I Main Report

Freese and Nichols, Inc.

LBG - Guyton Associates, Inc.

Texas A&M AgriLife Research and Extension Center at Amarillo

PANHANDLE WATER PLANNING GROUP

P.O. Box 9257 Amarillo, Texas 79105
Phone: 806-372-3381 Fax: 806-373-3268

Kevin Patteson 11-17-15
Executive Director
Texas Water Development Board
1700 North Congress Avenue
Austin, TX 78701

This water plan represents the culmination of five years of working together with varied statutorily required interest groups and technical consultants to map out a path forward to meet the projected water needs of our region. This regional water 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 Region A - 2016 Panhandle Regional Water Plan was unanimously adopted by over 2/3 of the voting membership of the Panhandle Water Planning Group (PWPG) on November 17, 2015.

As you read this water plan, the Panhandle Water Planning Group would like you to keep in mind the following points:

- The plan does not predict or forecast future water disasters. Water is generally available to meet all municipal and industrial water needs. Conservation has the potential to meet most of the projected agricultural shortages.
- The Ogallala aquifer, which is the predominant water source for the region, is a finite resource. At some point in the future (beyond this plan's timeframe) this resource will have limited supplies to meet the projected demands.
- The Panhandle Water Planning Group 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 or local groundwater district.
- 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 *Panhandle Water Planning Area Regional Water Plan* presents a comprehensive overview of the water supply issues in the region. It will take a concerted effort to continue to conserve and preserve our valuable water resources for the future. We appreciate your contributions to these efforts as we work together in making the Panhandle area a desirable place to work and live.

Sincerely,

C.E. Williams
Chairman, Panhandle Water Planning Group

2016 PANHANDLE WATER PLAN

Prepared for:

Panhandle Water Planning Group

STATE OF TEXAS
SIMONE FREY KIEL
93615
LICENSED
PROFESSIONAL ENGINEER

11-20-15

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

Simone F. Kiel, P.E.

Steve Amosson, PhD

STATE OF TEXAS
JAMES A. BEACH
GEOLOGY
No. 2965
LICENSED
PROFESSIONAL GEOSCIENTIST

11/20/2015

LBG-GUYTON ASSOCIATES
TEXAS REGISTERED
GEOSCIENCE FIRM
50111

James A. Beach, P.G.

Prepared by:

FREESE AND NICHOLS, INC.

LBG – GUYTON ASSOCIATES, INC.

TEXAS A&M AGRILIFE RESEARCH AND EXTENSION CENTER AT AMARILLO

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List of Acronyms

Acronym	Name	Meaning
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.
PDRA	Palo Duro River Authority	River authority 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 referrd 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.
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

List of Acronyms

Acronym	Name	Meaning
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 1,000 ac-ft/yr or more of wholesale water.

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 enter 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 three regional water plans. This plan is the fourth regional water plan, which is an update of the 2011 Regional Water Plan for the PWPA.

This water plan is developed in accordance with the Planning Guidelines set forth in 31 Texas Administrative Code § 357.7 and all applicable rules. As required by rule, the plan is organized into eleven 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

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

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 is 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. The PWPA has designated six Wholesale Water Providers (1,000 acre-feet per year or more of wholesale water):

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

POPULATION AND WATER DEMAND PROJECTIONS

In 2010, the region accounted for 1.5 percent of the State's total population and about 13 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.

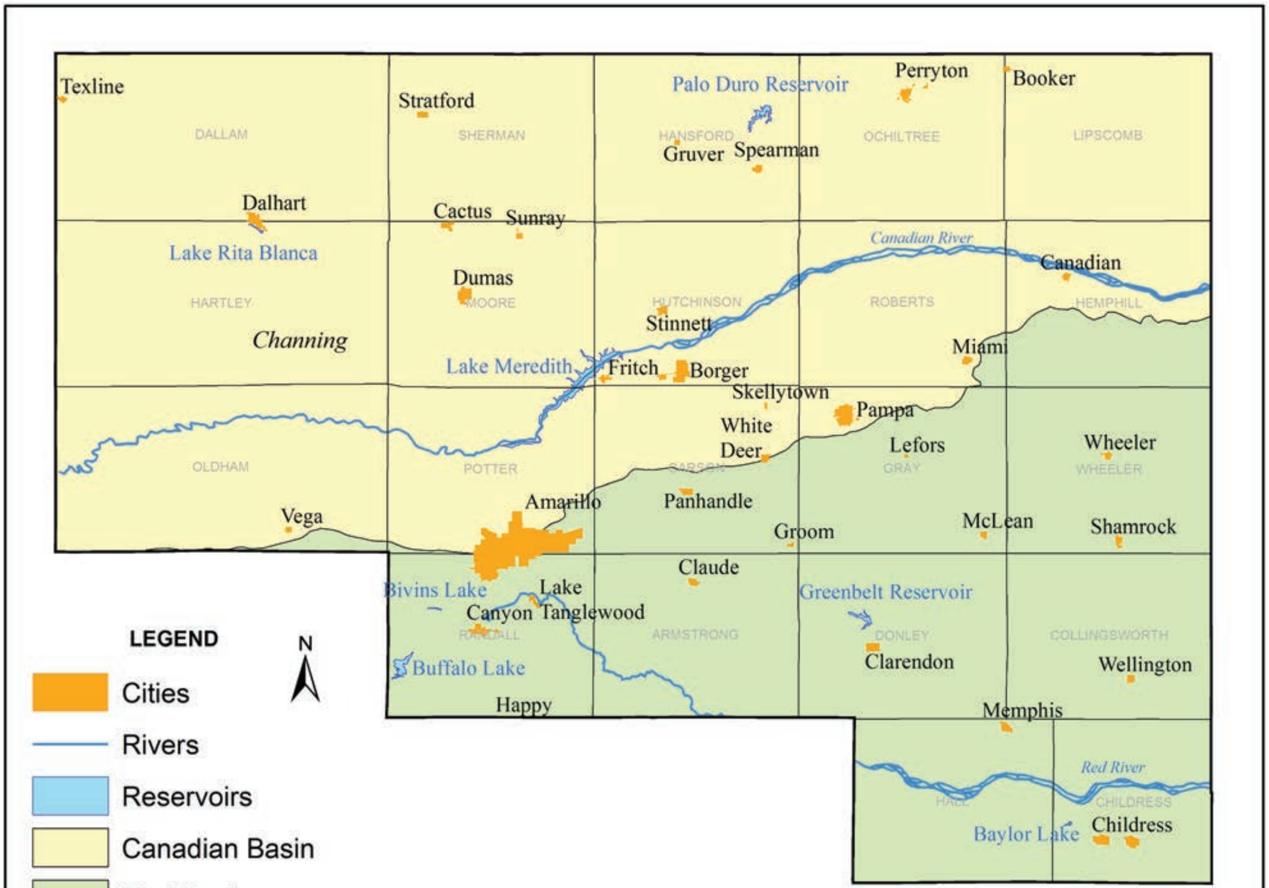


Figure ES-1: Panhandle Water Planning Area

Regional population is expected to grow from 380,733 in 2010 to 639,220 in 2070. Much of this growth is located in larger cities and surrounding rural areas. Projections for water demand indicate that total water usage in the PWPA will decrease from 1,733,659 acre-feet in 2020 to 1,166,209 acre-feet in 2070. Dallam County has the highest projected water use of 376,493 acre-feet in 2020 decreasing to 221,798 acre-feet by 2070. Hartley County demands are very similar in demand levels. For both of these counties irrigation use accounts for 98% of the demand. Only Randall and Potter Counties have projected increases in demand during the

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

	2020	2030	2040	2050	2060	2070
Population	418,626	461,008	503,546	547,060	592,266	639,220
Water User Group	Water Demand (ac-ft/yr)					
Irrigation	1,513,469	1,426,414	1,312,384	1,166,561	1,020,743	874,922
Livestock	40,532	41,425	43,009	44,718	46,567	48,564
Manufacturing	49,695	52,589	55,369	57,763	61,343	65,194
Mining	11,330	9,909	7,223	4,465	2,996	2,968
Municipal	91,637	98,792	106,285	114,644	123,866	133,572
Steam Electric Power	26,996	28,916	30,707	32,963	37,202	40,989
Total	1,733,659	1,658,045	1,554,977	1,421,114	1,292,717	1,166,209

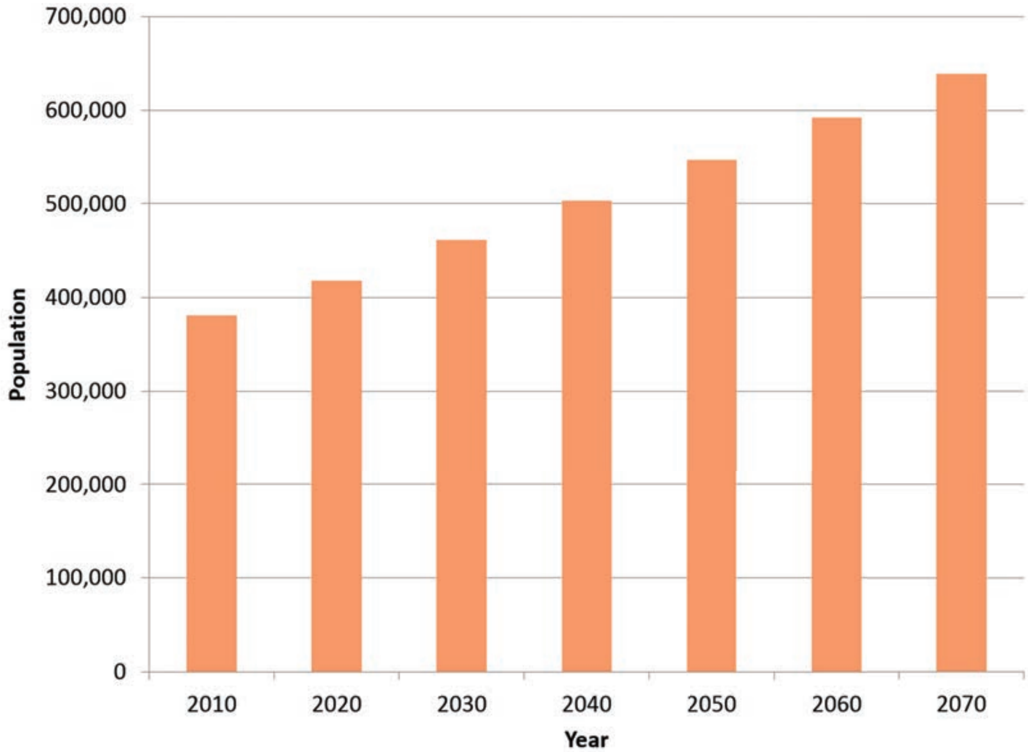


Figure ES-2: PWPA Population

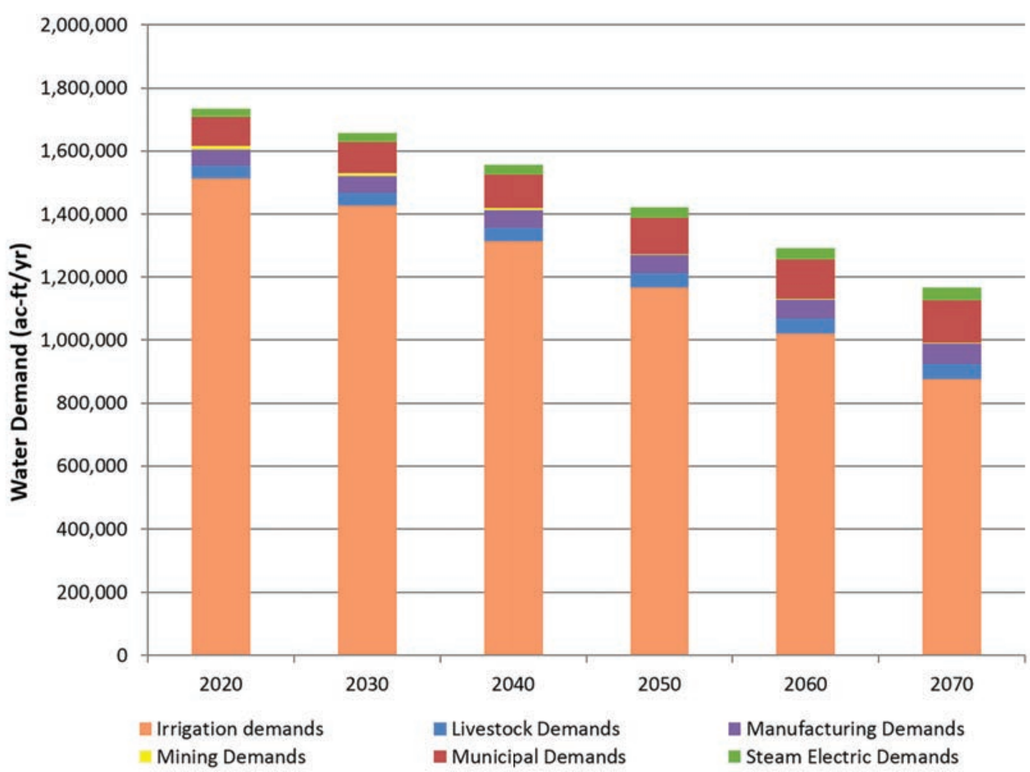


Figure ES-3: Projected Demands in the PWPA planning period. This is due to the projected increases in municipal demand associated with Amarillo and surrounding areas. The remaining 19 counties are projected to have decreases in projected water demand during the planning period, which is mostly attributed to declining irrigation demands.

WATER SUPPLY ANALYSIS

The PWPA is located within portions of the Canadian River Basin and Red River Basin. In 2010, only two 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. 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 historical performance and conditional reliability modeling. For Palo Duro Reservoir, the yield as determined from the Canadian WAM was reported. This resulted in significant reductions of available surface water supplies in the region (see Table ES-2). Lake Meredith is shown to have little to no available supply and the reliable supply of Greenbelt Reservoir was reduced by over 40%. 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 1% 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

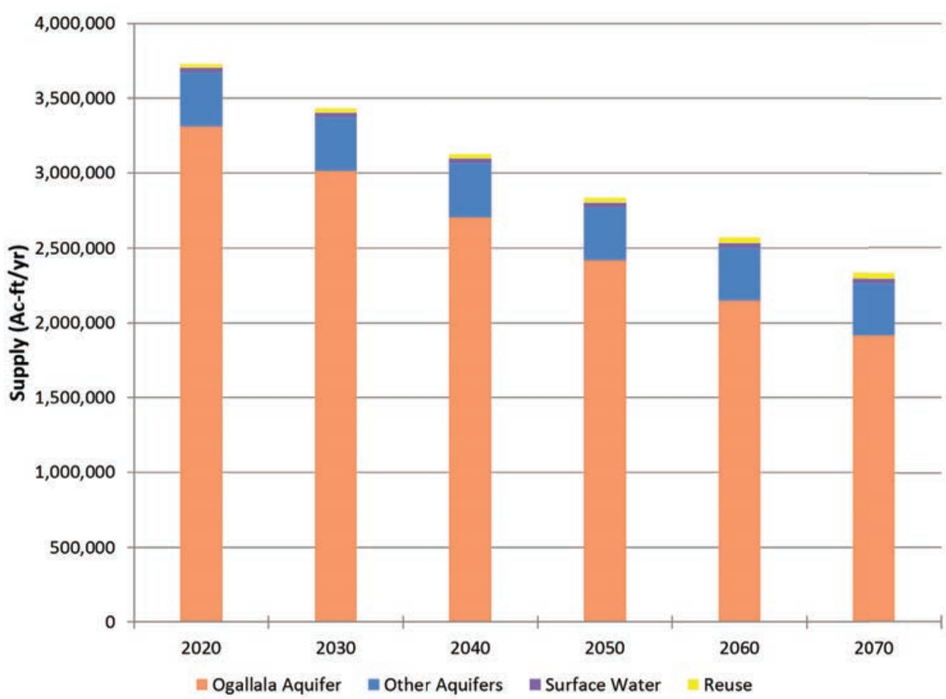


Figure ES-4: Total Available Supplies in the PWPA[1]

[1] The total available supply is the reliable firm 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 PWPA

Source	Supply (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Lake Meredith [1]	0	0	0	0	0	0
Greenbelt Lake [1]	3,850	3,782	3,714	3,646	3,578	3,440
Palo Duro Reservoir [2]	3,917	3,875	3,833	3,792	3,750	3,708
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	10,305	10,195	10,085	9,976	9,866	9,686
Ogallala/ Rita Blanca Aquifer	3,310,163	3,012,056	2,707,647	2,418,801	2,151,403	1,915,780
Seymour Aquifer	28,762	26,429	24,926	23,126	22,125	21,229
Blaine Aquifer	311,088	311,088	311,088	311,088	309,786	308,501
Dockum Aquifer	21,223	21,223	21,223	21,223	21,223	21,223
Other Aquifer	2,753	2,753	2,753	2,753	2,753	2,753
Total Groundwater	3,673,989	3,373,549	3,067,637	2,776,991	2,507,290	2,269,486
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	29,820	31,296	32,959	34,628	38,807	42,438
Total Other Supplies	46,602	48,078	49,741	51,410	55,589	59,220
Total Supply in PWPA	3,730,897	3,431,823	3,127,464	2,838,378	2,572,746	2,338,393

[1] Reliable supply is shown for Lake Meredith and Greenbelt Reservoir. These supply values were used for planning purposes.

[2] No current infrastructure

Table ES-3: Existing and Projected Developed Water Supplies in PWPA

Water User Group	Existing Supply (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Irrigation	1,360,086	1,244,605	1,122,766	989,854	859,324	730,397
Livestock	42,326	43,080	44,621	46,293	48,091	50,033
Manufacturing	46,678	46,378	46,046	44,146	43,497	43,063
Mining	11,330	9,909	7,223	4,465	2,996	2,968
Municipal	85,198	77,524	70,461	64,361	58,945	53,509
Steam Electric Power	26,996	28,916	30,707	32,963	37,202	40,989
Total	1,572,614	1,450,412	1,321,824	1,182,082	1,050,055	920,959

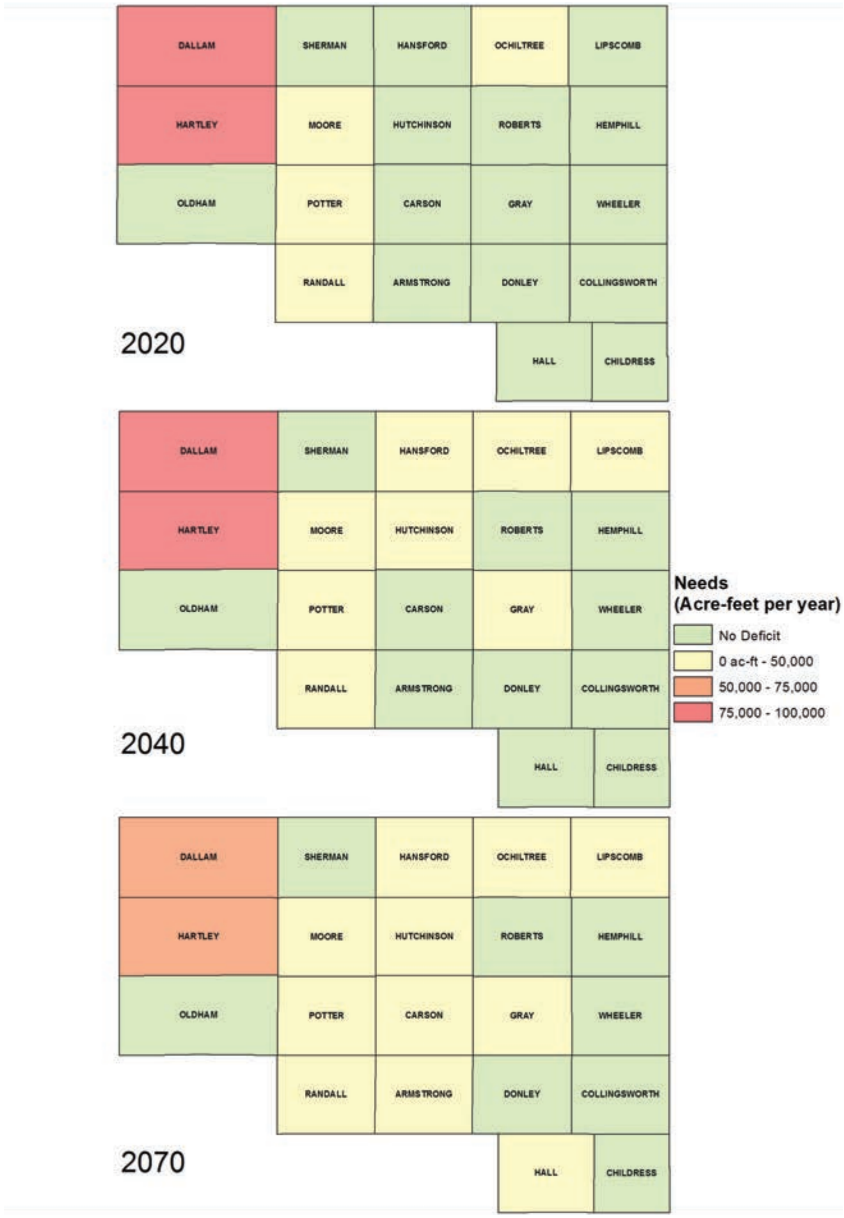


Figure ES-5: Needs in PWPA for Planning Period Year 2020 – Year 2070

determine the annual availability from these sources. In total, the PWPA has nearly 3.7 million acre-feet per year of groundwater in 2020. The Ogallala aquifer constitutes 90% 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.

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 1.57 million acre-feet per year in 2020, which is about 40% 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.

Table ES-4: Undeveloped Water Supplies in PWPA

Source	Supply (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Lake Meredith	0	0	0	0	0	0
Greenbelt Lake	1,538	1,339	1,145	935	736	472
Palo Duro Reservoir	3,917	3,875	3,833	3,792	3,750	3,708
Ogallala Aquifer	1799,145	1,630,434	1,455,326	1,306,476	1,174,168	1,070,157
Seymour Aquifer	9,847	8,176	7,157	7,849	8,716	9,651
Blaine Aquifer	294,573	295,189	296,124	297,752	298,087	298,438
Dockum Aquifer	13,448	13,459	13,469	13,479	13,488	13,497
Other Aquifer	436	436	436	436	501	604
Total Groundwater	2,117,449	1,947,694	1,773,070	1,625,992	1,494,960	1,392,347
Other Supplies	0	0	0	0	0	0
Total	2,122,904	1,952,908	1,778,048	1,630,719	1,499,446	1,396,527

Note: The amount shown for undeveloped supplies accounts for water that is used outside of the PWPA.

Table ES-5: Projected Water Needs in PWPA

Water User Group	Water Need (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Irrigation	156,704	185,043	192,876	180,151	165,133	148,519
Livestock	0	0	0	0	0	0
Manufacturing	4,017	6,986	10,048	14,243	18,369	22.538
Mining	0	0	0	0	0	0
Municipal	10,074	24,142	38,521	52,624	66,847	81,559
Steam Electric Power	0	0	0	0	0	0
Total	170,795	216,171	241,445	247,018	250,349	252,616

Considering the developed supplies, water demands exceed the supplies on a regional basis by 174,000 acre-feet per year in 2020, increasing to 252,000 acre-feet per year by 2070. Most of this need is associated with irrigation use in Dallam and Hartley counties. The increase in water needs is attributed to municipal growth and reductions in supply for municipal water providers. There are 14 counties with 33 water user groups with projected water needs during the planning period.

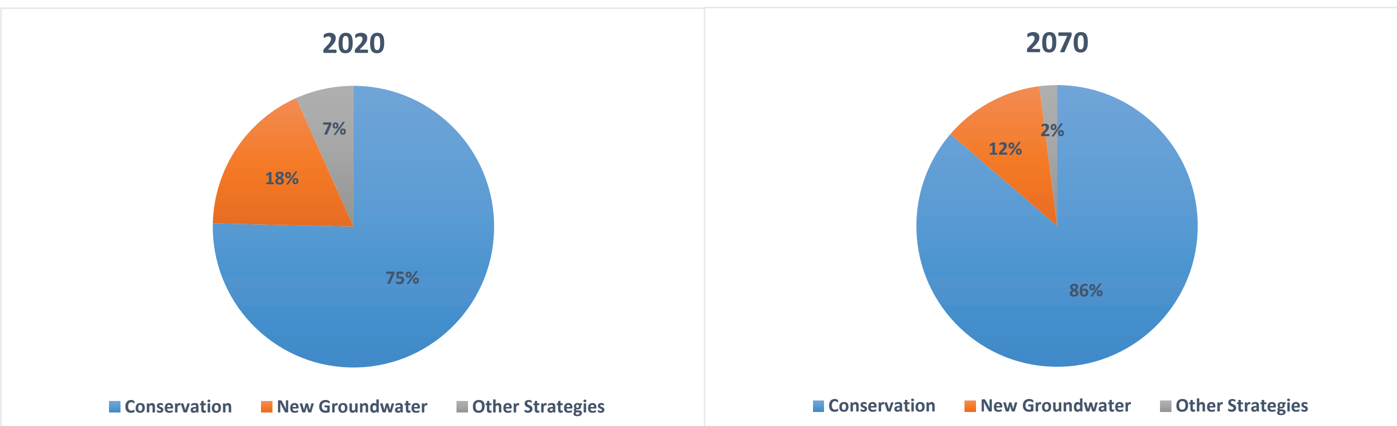
Conservation and demand management are important strategies to meet the projected needs and offset dependence on expanding supply development. The PWPA considers conservation a priority and in maintaining future supplies. Water infrastructure strategies were developed to meet the needs that could not be met through conservation. All potentially feasible strategies for each strategy 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; and
- Other relevant factors such as: key water quality parameters, regulatory requirements, political and local issues, implementation time, recreational impacts and socioeconomic benefits or impacts.

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 50 strategies are recommended to meet the water needs in the PWPA (see Table ES-8). Collectively, conservation is expected to provide 523,563 acre-feet per year of water savings by 2070 as shown in Figure ES-6. New groundwater development is recommended to provide approximately 33,525 acre-feet per year in 2020, increasing to 70,898 acre-feet per year by 2070. These two strategy types account for 98% of the supplies from the recommended water management strategies. Other strategies include conjunctive use with Lake Meredith, brush control and water quality improvements. There are three alternate strategies recommended in the PWPA. These are shown on Table ES-8.

Table ES-6: Percentage by Water Management Strategy Type



Even with these strategies, there are a couple of unmet needs in the PWPA (Table ES-7). Irrigation is shown to have an unmet need early in the planning period prior to full implementation of the conservation strategies. Also, Potter County-Other may have an unmet need late in the planning period due to growth and limited groundwater supplies in Potter County. However, it is expected that as some of the rural unincorporated areas grow, these areas will incorporate and purchase water from Amarillo.

Table ES-7: Unmet Water Needs in PWPA

Water User Group	2020	2030	2040	2050	2060	2070
Potter County-Other	0	0	0	0	0	(535)
Irrigation	(93,289)	(71,708)	(8,174)	0	0	0

KEY FINDINGS AND RECOMMENDATIONS

- Significant reductions in surface water supplies have resulted in additional water needs in the PWPA. This is especially true for Lake Meredith and CRMWA customers. With the development of additional groundwater in Roberts County, CRMWA can better manage their sources conjunctively to continue to utilize Lake Meredith.
- Ogallala groundwater supplies were allocated to irrigation and municipal water users such that the regional water planning goal was met both spatially and in time. This results in immediate needs for some users that have geographical constraints for using groundwater. The actual distribution of water supplies over time may differ from these assumptions.
- Large irrigation needs are concentrated in two counties: Dallam and Hartley. Most of these needs are due to the spatial constraints for supply for irrigated agriculture. The recommended strategies are conservation.
- Four wholesale water providers are projected to have needs over the planning period. The recommended strategies for each provider are to develop additional groundwater.
- 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 follow in Attachment ES-1.

Table ES-8: Recommended WMSs and Costs Summary for the PWPA

Recommended and Alternate Water Management Strategies and Costs Summary

Entity	County Used	Recommended Water Management Strategy	Total Capital Costs	First Decade Estimated Annual Average Unit Cost ($/ac-ft/yr)	Water Supply (ac-ft/yr)						Year 2070 Estimated Annual Average Unit Cost ($/ac-ft/yr)
					2020	2030	2040	2050	2060	2070	
Region A		Irrigation Conservation	$55,637,900	$17	123,414	221,931	388,585	438,997	477,393	504,566	$17
Region A		Weather Modification	$0	$8	13,565	13,565	13,565	13,565	13,565	13,565	$8
Region A		Municipal Conservation	$37,564,700	$470	3,690	4,022	4,333	4,675	5,044	5,431	$447
Claude	Armstrong	New Groundwater (Ogallala)	$2,891,100	$790	0	0	400	400	400	400	$185
Panhandle	Carson	New Groundwater (Ogallala)	$3,217,800	$621	600	600	600	600	600	600	$173
Wellington	Collingsworth	New Groundwater (Seymour)	$2,589,800	$1,485	180	180	180	180	180	180	$279
Wellington	Collingsworth	Expanded Use (RO Treatment)	$3,679,700	$1,029	500	500	500	500	500	500	$413
Dalhart	Dallam	New Groundwater (Ogallala)	$4,197,900	$213	2,700	2,700	2,700	2,700	2,700	2,700	$83
Texline	Dallam	New Groundwater (Ogallala)	$1,056,000	$778	0	0	0	150	150	150	$192
McLean	Gray	New Groundwater (Ogallala)	$789,400	$446	200	200	200	200	200	200	$116
Pampa	Gray	New Groundwater (Ogallala)	$8,618,100	$490	2,000	2,000	2,000	2,000	2,000	2,000	$130
Pampa	Gray	Purchase from CRMWA	[1]	[1]	181	1,125	1,142	2,967	3,119	3,309	[1]
Memphis	Hall	New Groundwater (Ogallala)	$1,183,900	$848	0	0	0	150	150	150	$188
County-Other (Brice-Lesley)	Hall	New Groundwater (Ogallala)	$299,300	$688	50	50	50	50	50	50	$188
County-Other (Estelline)	Hall	New Groundwater (Seymour)	$141,100	$360	50	50	50	50	50	50	$120
County-Other (Lakeview)	Hall	Nitrate Removal (RO Treatment)	$1,600,800	$3,345	75	75	75	75	75	75	$1,558
County-Other (Turkey)	Hall	New Groundwater (Ogallala)	$1,345,300	$1,380	100	100	100	100	100	100	$250
Gruver	Hansford	New Groundwater (Ogallala)	$1,385,600	$450	0	0	350	350	350	350	$118
Spearman	Hansford	New Groundwater (Ogallala)	$3,665,600	$636	0	0	0	650	650	650	$164
Stinnett	Hutchinson	New Groundwater (Ogallala)	$908,000	$477	0	0	0	225	225	225	$139
TCW	Hutchinson	New Groundwater (Ogallala)	$3,890,200	$736	575	575	575	575	575	575	$169
Booker	Lipscomb	New Groundwater (Ogallala)	$1,560,400	$270	0	0	550	550	550	700	$83
Dumas	Moore	New Groundwater (Ogallala)	$12,544,700	$332	2,000	2,000	2,000	4,500	4,500	4,500	$98
Sunray	Moore	New Groundwater (Ogallala)	$3,526,100	$474	0	850	850	850	850	850	$126
Manufacturing	Moore	New Groundwater (Ogallala)	$11,244,800	$332	0	0	0	4,000	4,000	4,000	$97
Perryton	Ochiltree	New Groundwater (Ogallala)	$10,584,100	$425	1,400	1,400	1,400	2,800	2,800	2,800	$109
County-Other	Potter	New Groundwater (Ogallala)	$3,979,400	$488	900	900	900	900	900	900	$118
County-Other	Potter	New Groundwater (Dockum)	$3,345,600	$527	700	700	700	700	700	700	$127
Manufacturing	Potter	Additional Purchase from Amarillo	[1]	[1]	2,000	2,000	2,500	3,000	3,000	3,500	[1]
Canyon	Randall	New Groundwater (Dockum, Ogallala)	$11,614,100	$425	1,400	2,100	2,800	2,800	3,800	4,300	$189
Lake Tanglewood	Randall	New Groundwater (Ogallala)	$2,976,400	$1,035	300	300	300	300	300	300	$205
County-Other	Randall	New Groundwater (Ogallala)	$5,299,300	$248	500	1,000	1,200	2,600	2,600	2,800	$90
Manufacturing	Randall	New Groundwater (Ogallala)	$746,000	$301	0	300	300	300	300	300	$94
Wheeler	Wheeler	New Groundwater (Ogallala)	$2,795,600	$625	500	500	500	500	500	500	$157
Wholesale Water Providers:											
Amarillo	Potter, Randall	Purchase from CRMWA	[1]	[1]	19,596	23,596	25,687	29,218	31,246	33,271	[1]
		Potter Co. Well Field	$53,397,000	$941	6,000	5,600	5,200	4,800	4,400	4,000	$196
		Carson Co. Well Field	$37,528,000	$441	0	0	11,200	11,200	11,200	11,200	$161
		Roberts Co. Well Field	$170,217,000	$1,538	0	0	0	0	0	11,200	$266
Borger	Hutchinson	Purchase from CRMWA	[1]	[1]	3,447	3,484	3,633	4,130	4,414	4,700	[1]
		New Groundwater (Ogallala)	$29,463,900	$577	6,000	6,000	6,000	6,000	6,000	6,000	$166
Cactus	Moore	New Groundwater (Ogallala)	$18,191,900	$422	5,500	5,500	5,500	5,500	5,500	5,500	$145
CRMWA		Replacement Wells	$24,800,750	$177	0	9,000	13,000	19,000	23,000	28,000	$105
		Roberts Co. Well Field	$250,299,000	$676	0	0	48,000	48,000	48,000	48,000	$240
		Conjunctive Use with Lake Meredith[2]	$67,649,300	$20	10,000	16,400	16,400	16,400	16,400	16,400	$106

Table ES-8: Recommended WMSs and Costs Summary for the PWPA (continued)

Greenbelt MIWA		Donley Co. Well Field	$12,617,000	$629	2,000	2,000	2,000	2,000	2,000	2,000	$101
Entity	**County Used**	**Alternative Water Management Strategy**	**Total Capital Costs**	**First Decade Estimated Annual Average Unit Cost ($/ac-ft/yr)**	**Water Supply (ac-ft/yr)**						**Year 2070 Estimated Annual Average Unit Cost ($/ac-ft/yr)**
Amarillo	Potter, Randall	Develop Direct Potable Reuse Supply	$63,566,200	$1,368	0	6,100	6,100	6,100	6,100	6,100	$496
Manufacturing	Potter	Purchase Direct Reuse Supply (Amarillo)	$57,732,350	$1,312	0	0	5,700	5,700	5,700	5,700	$205
Palo Duro River Authority[3]		Develop PDRA Transmission System	$139,574,500	$3,810	0	3,875	3,875	3,875	3,875	3,875	$796

[1] Capital and annual costs are shown on the developer of the project. No additional capital costs are assumed. Purchase water costs are negotiated between the respective parties.

[2] Water savings and costs include conjunctive use with Lake Meredith, brush control and ASR.

[3] This alternate strategy is also an alternate strategy for each of PDRA's member cities (Cactus, Dumas, Spearman, Sunray, Stinnett and Gruver). The total strategy cost and supply is shown only for PDRA.

Attachment ES-1

County Summary Pages

ARMSTRONG COUNTY

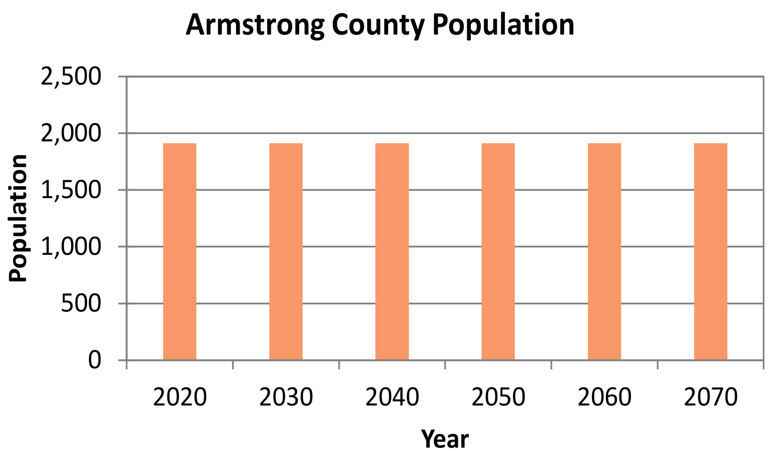
Who are my representatives?

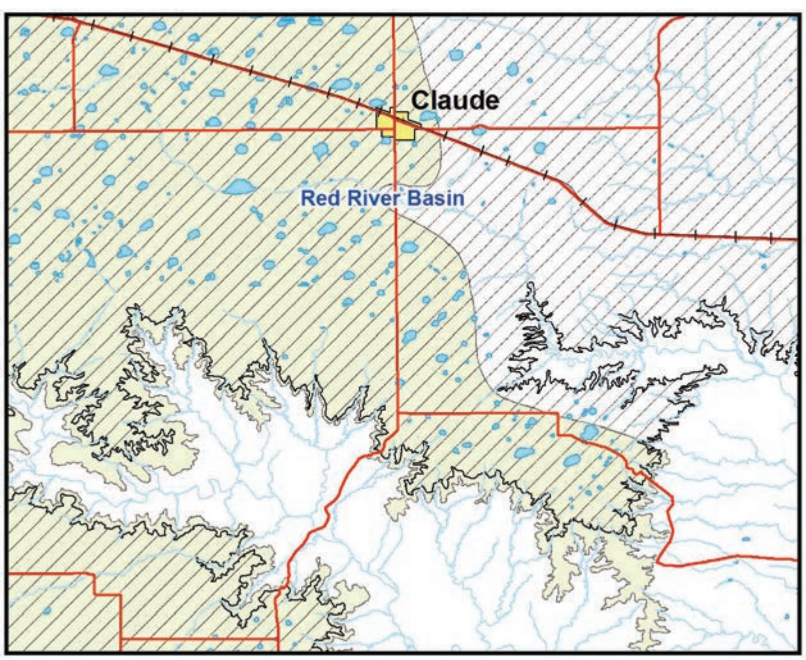
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

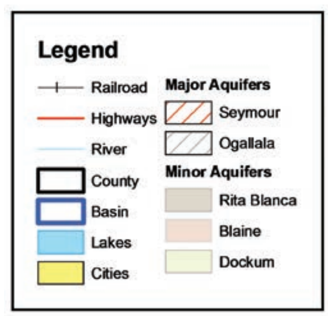
County Seat: City of Claude

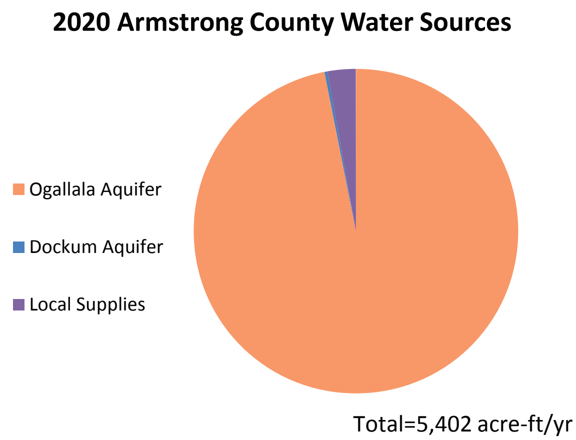
Economy: Agribusiness, tourism

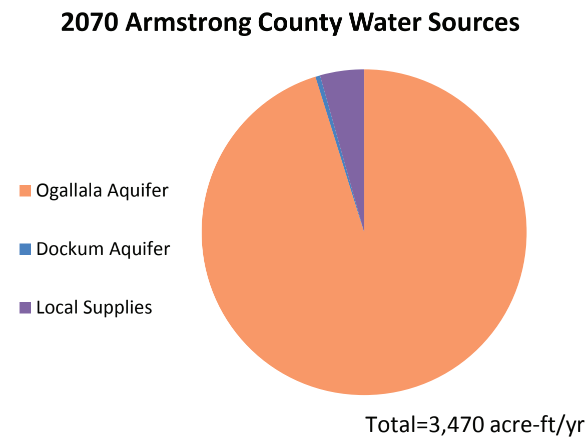
What is the source of my water? Ogallala, Dockum Aquifers

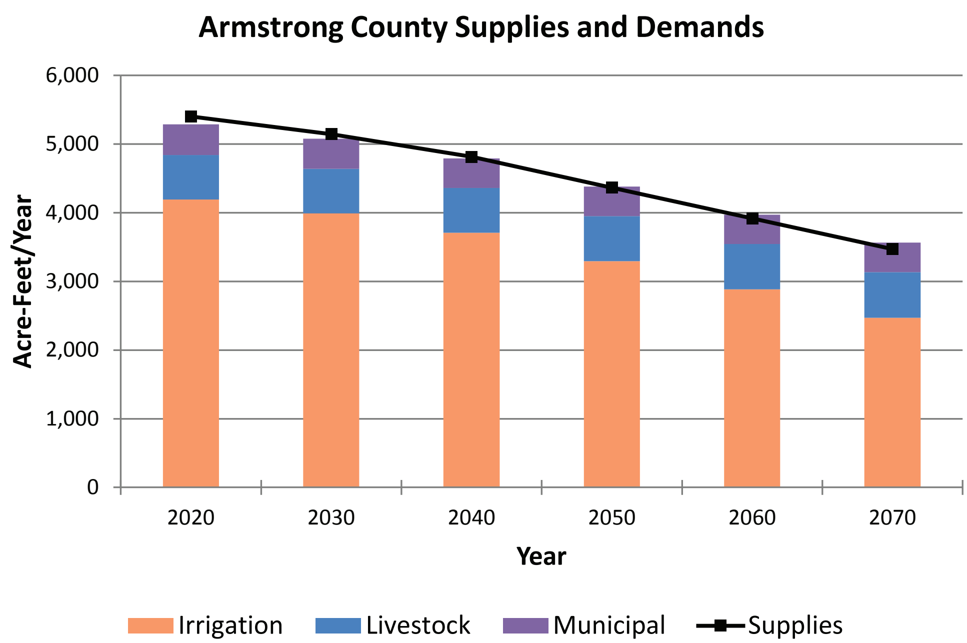












Water User Group	Strategy
Claude	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

CARSON COUNTY

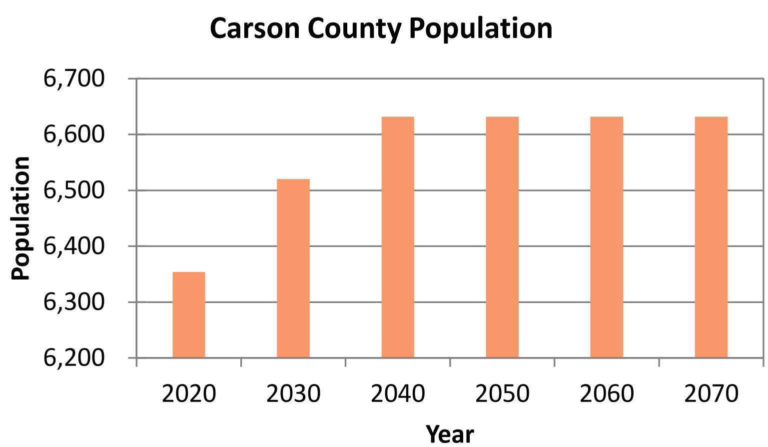
Who are my representatives?

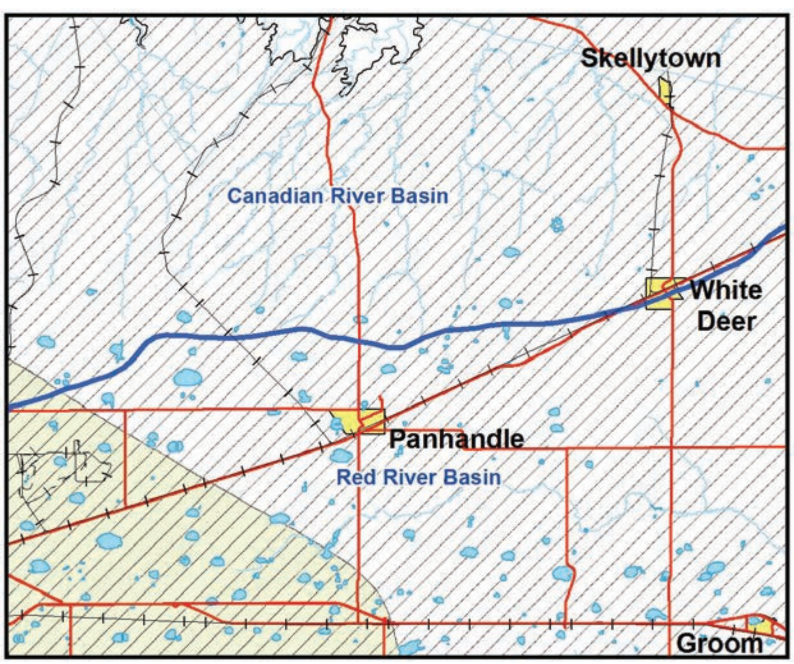
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Danny Krienke	- GMA #1

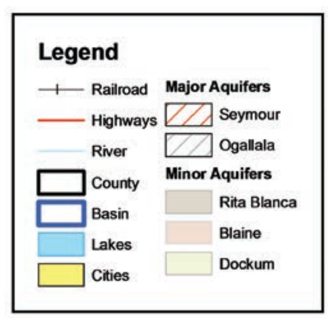
County Seat: City of Panhandle

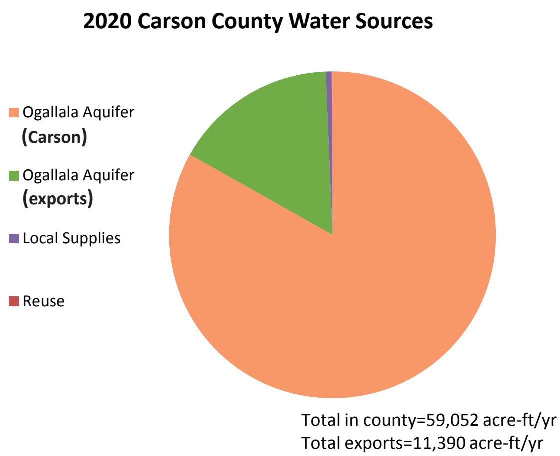
Economy: Agribusiness, Petroleum

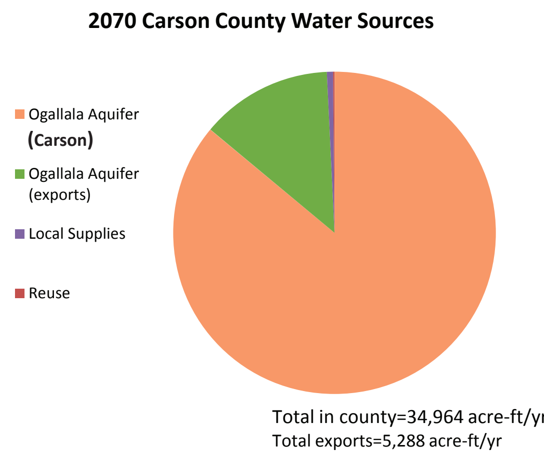
What is the source of my water? Ogallala Aquifer

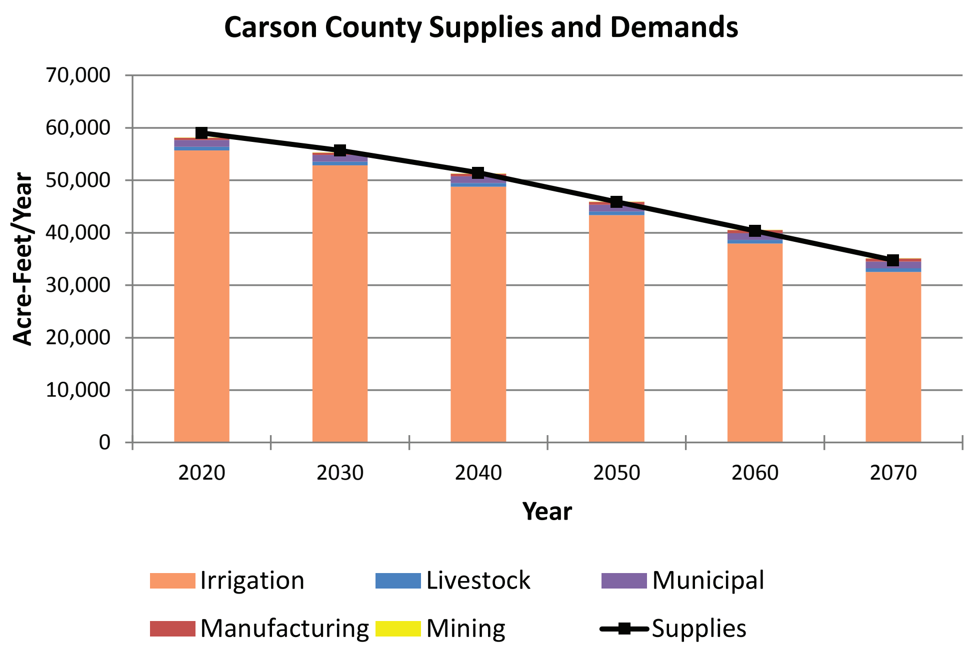












Water User Group	Strategy
Groom	Conservation
Panhandle	Conservation, New Wells
White Deer	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

CHILDRESS COUNTY

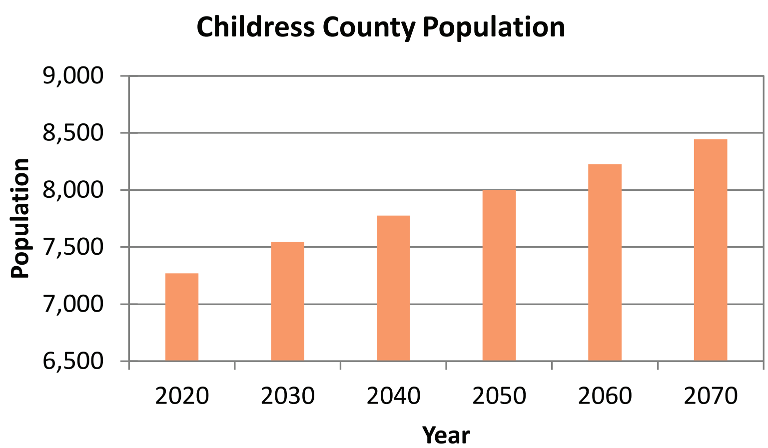
Who are my representatives?

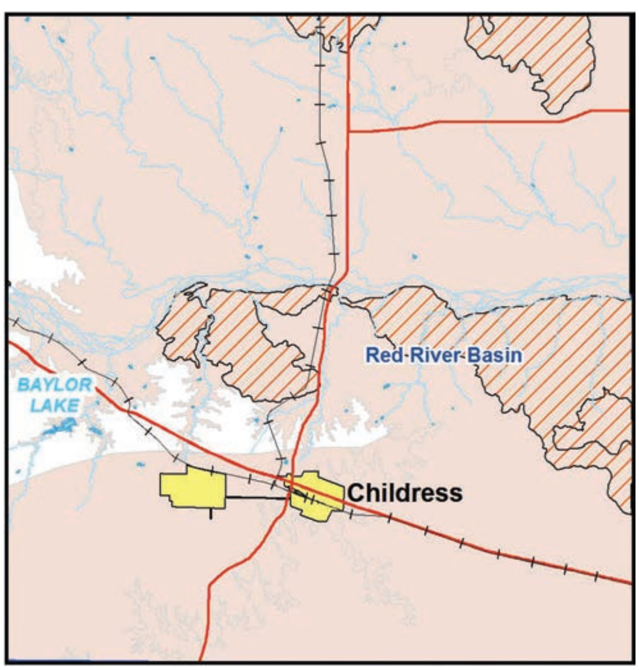
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
John Sweeten - Higher Education
Rick Gibson - Xcel Energy
Bobbie Kidd - Greenbelt MIWA
Amy Crowell - GMA #6

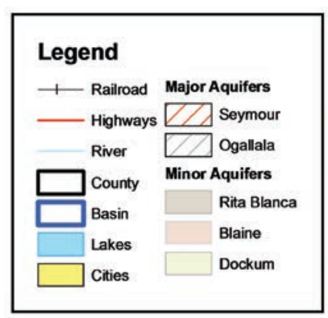
County Seat: City of Childress

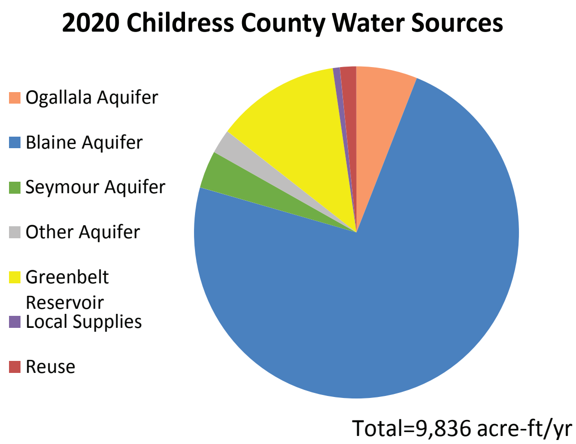
Economy: Agribusiness, Tourism

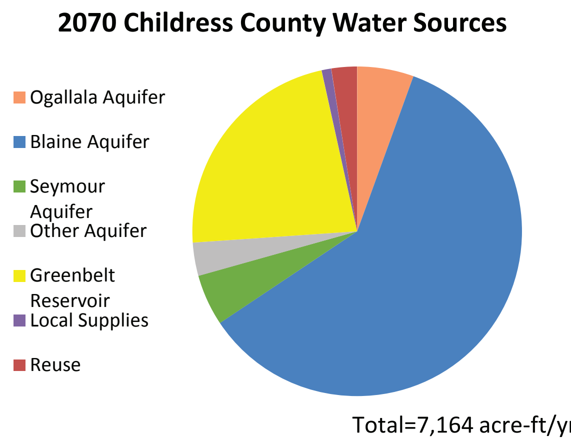
What is the source of my water? Ogallala, Seymour, Blaine Aquifers, Greenbelt Reservoir

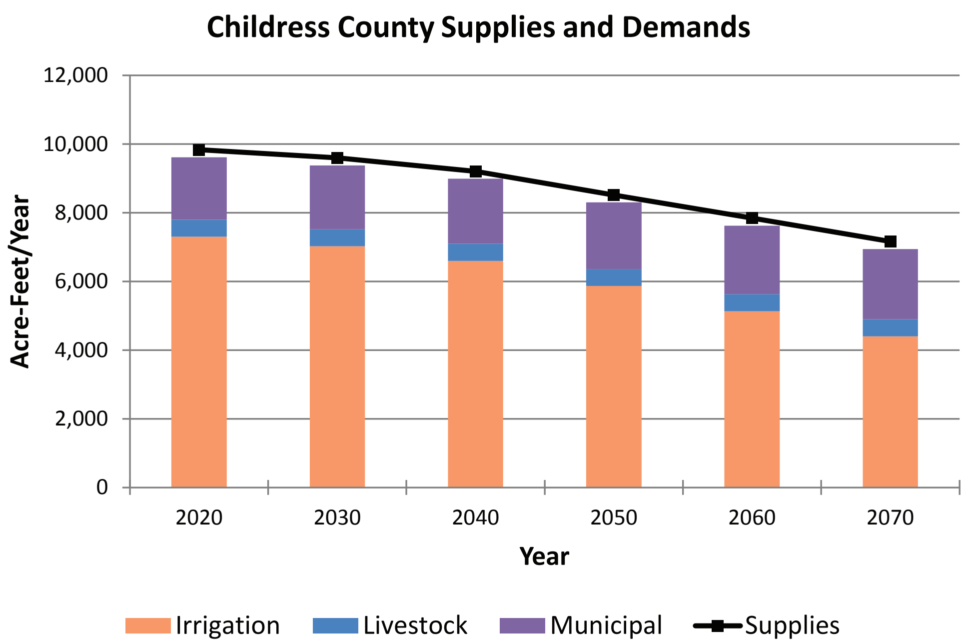












Water User Group	Strategy
Childress	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

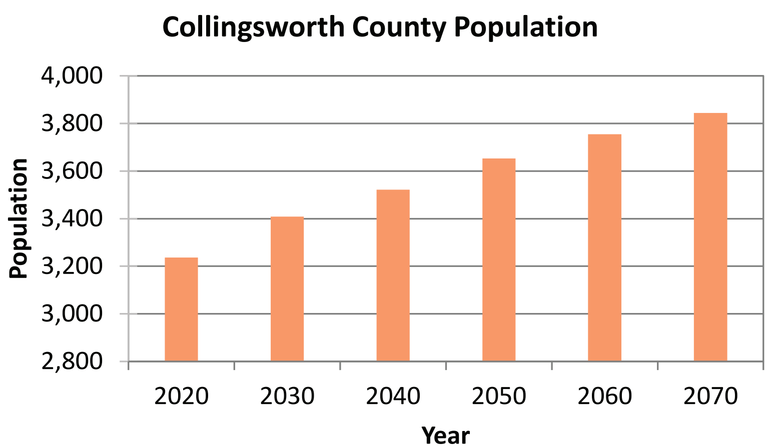
Who are my representatives?

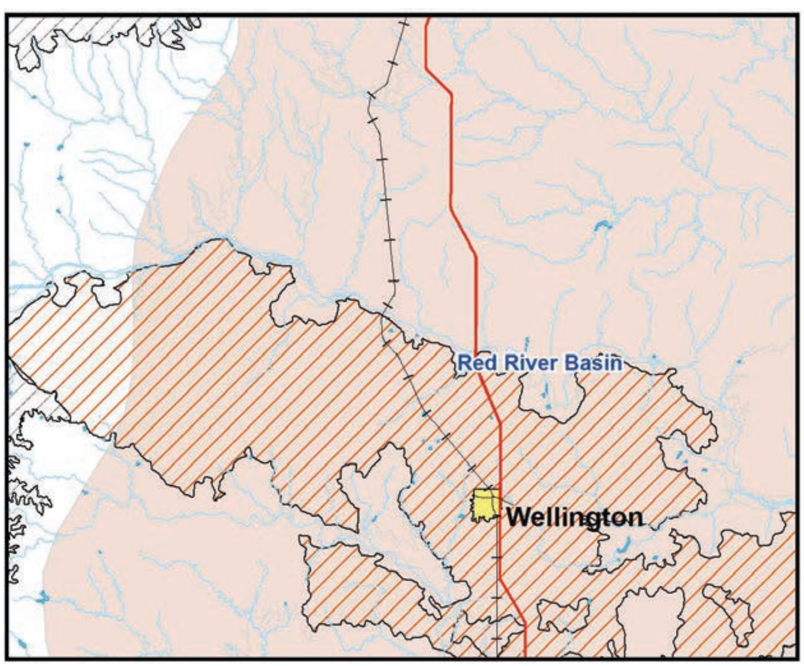
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Joe Baumgardner	- Farmer
Bobbie Kidd	- Greenbelt MIWA
Amy Crowell	- GMA #6

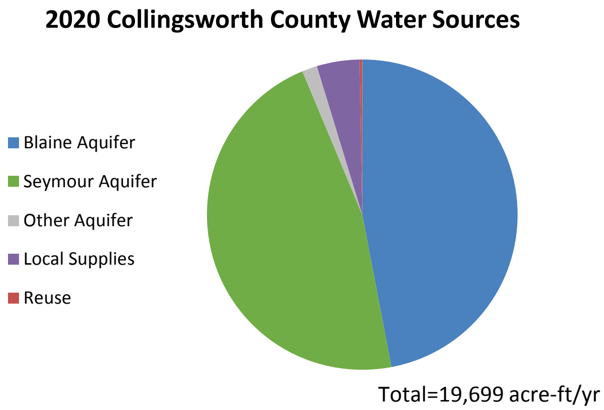
County Seat: City of Wellington

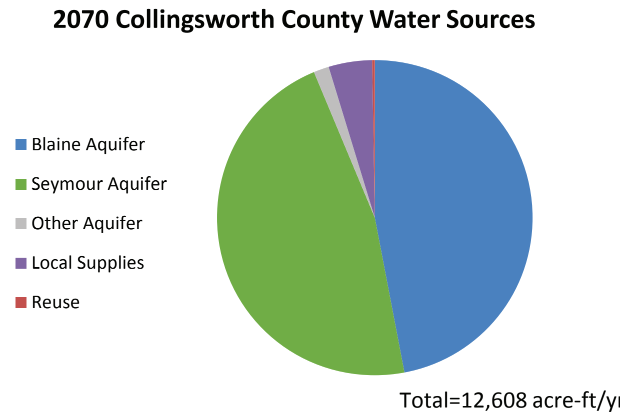
Economy: Agribusiness

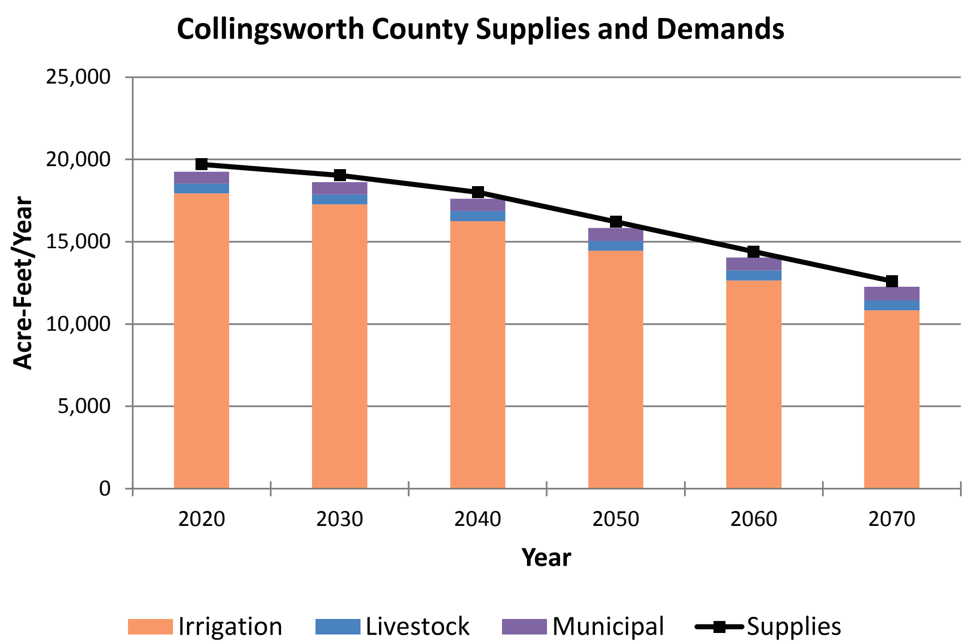
What is the source of my water? Seymour, Blaine Aquifers











Water User Group	Strategy
Wellington	Conservation, Water Quality Improvements
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

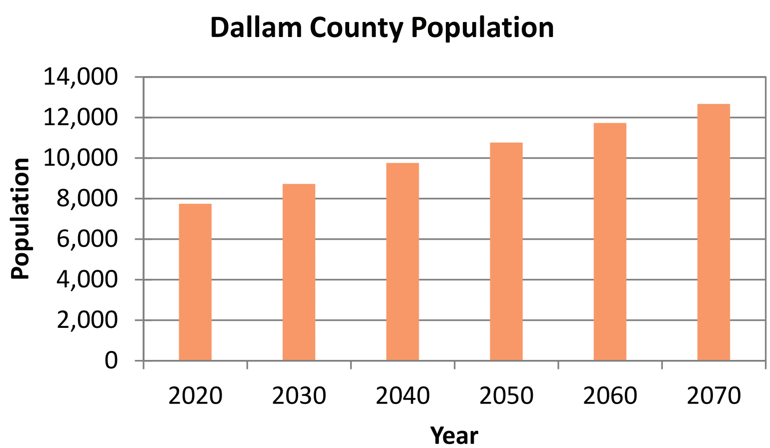
Who are my representatives?

Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Rusty Gilmore	- Water Well Driller
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

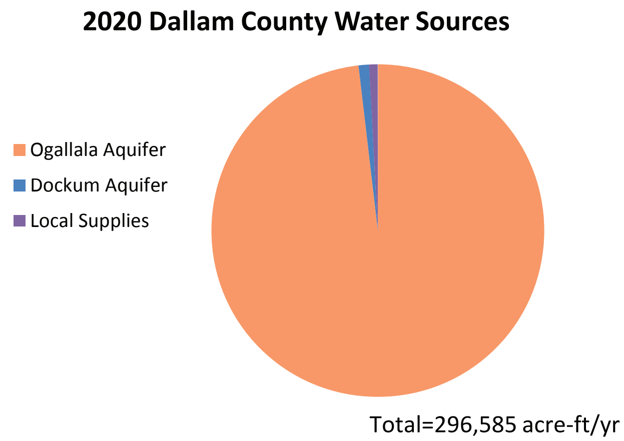
County Seat: City of Dalhart

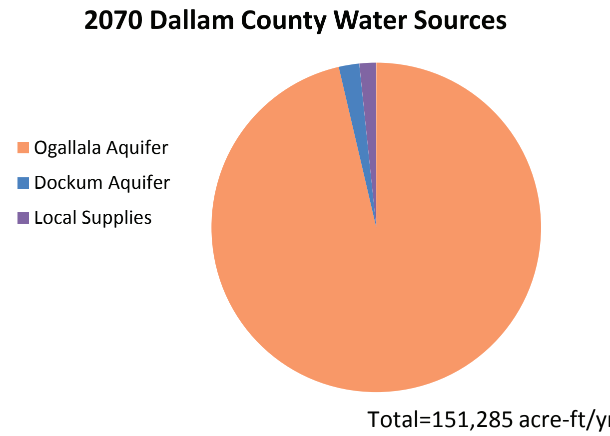
Economy: Agribusiness, Manufacturing, Tourism

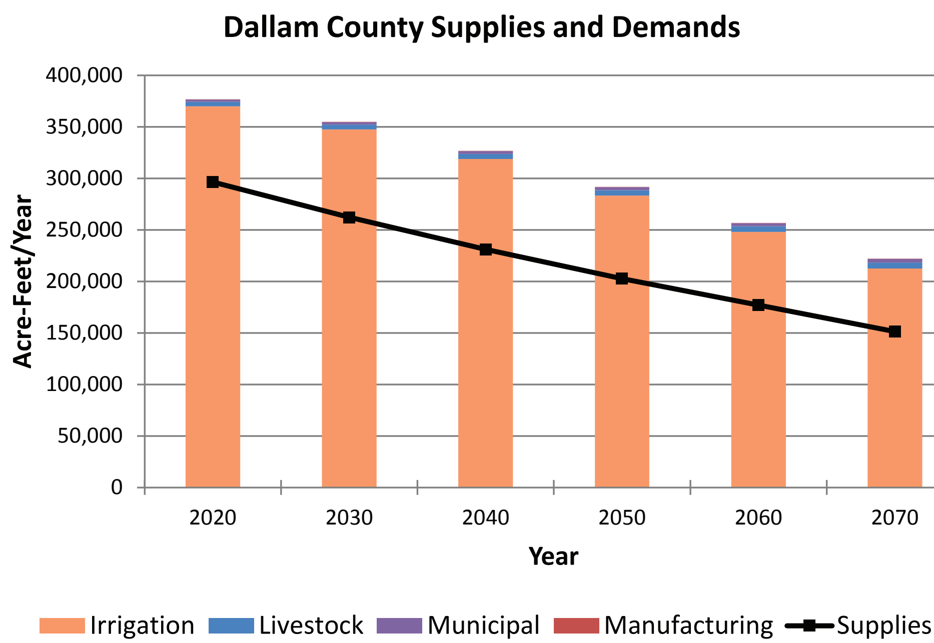
What is the source of my water? Ogallala, Dockum Aquifers



LESA IRRIGATION SYSTEM IN USE IN DALLAM

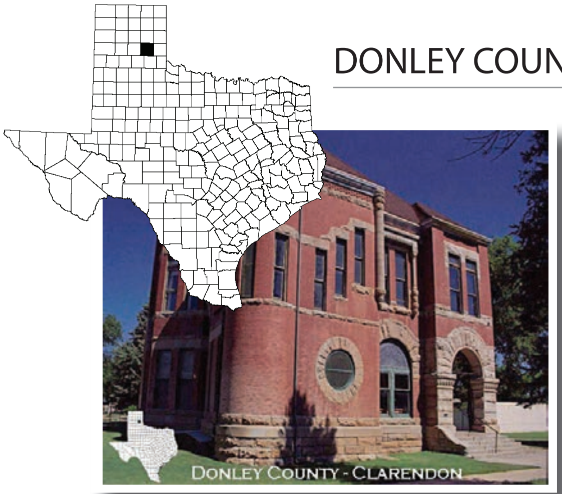






Water User Group	Strategy
Dalhart	Conservation, New Wells
Texline	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Change in Crop Type, Irrigation Equipment, Irrigation Scheduling, Advances in Plant Breeding
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Demands In This Category
Steam Electric Power	No Demands In This Category

DONLEY COUNTY



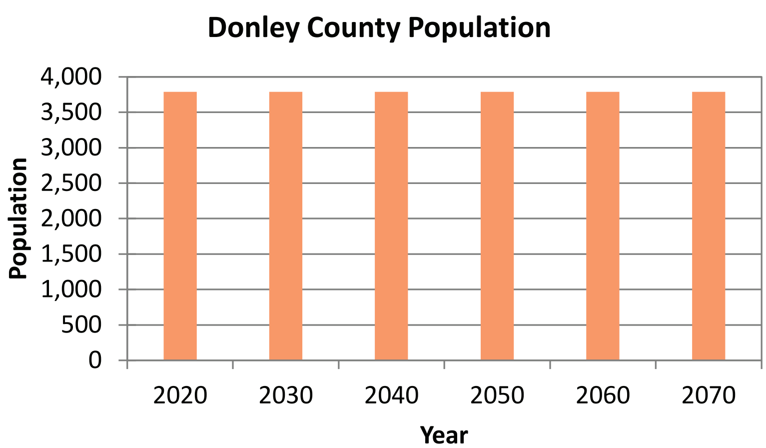
Who are my representatives?

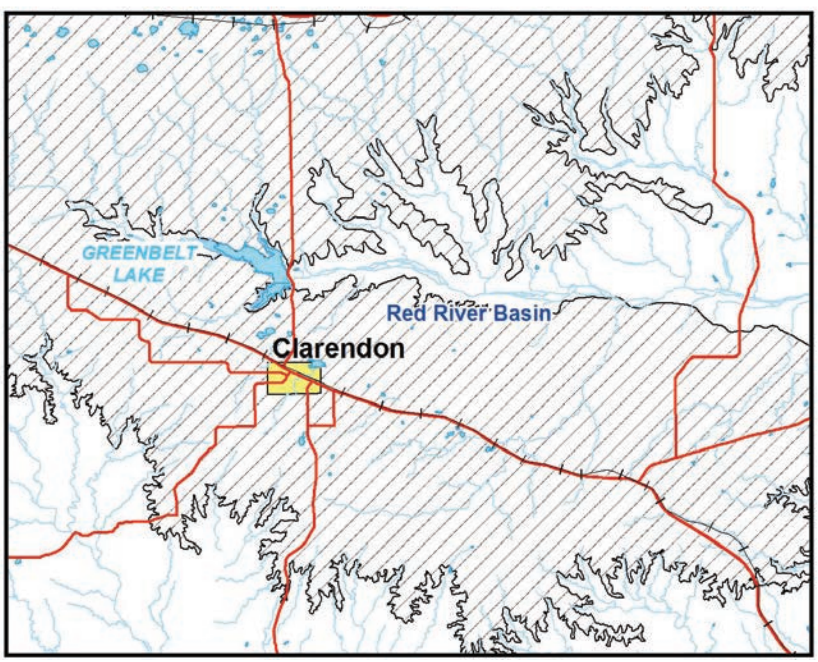
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Bobbie Kidd	- Greenbelt MIWA
Danny Krienke	- GMA #1

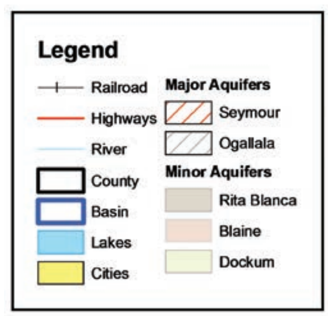
County Seat: City of Clarendon

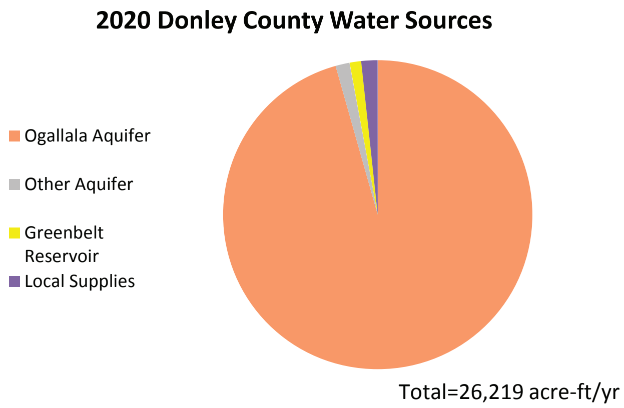
Economy: Agribusiness, Tourism

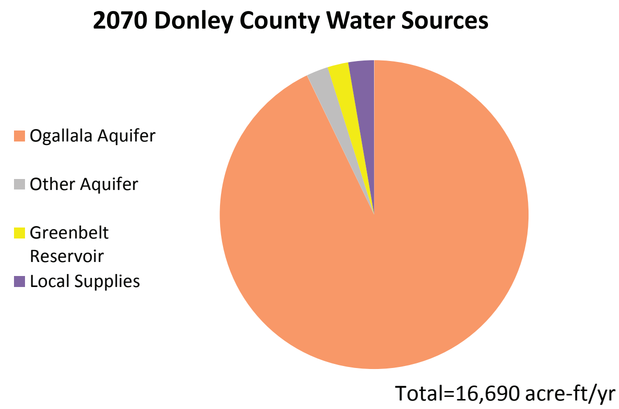
What is the source of my water? Ogallala Aquifer, Greenbelt Reservoir

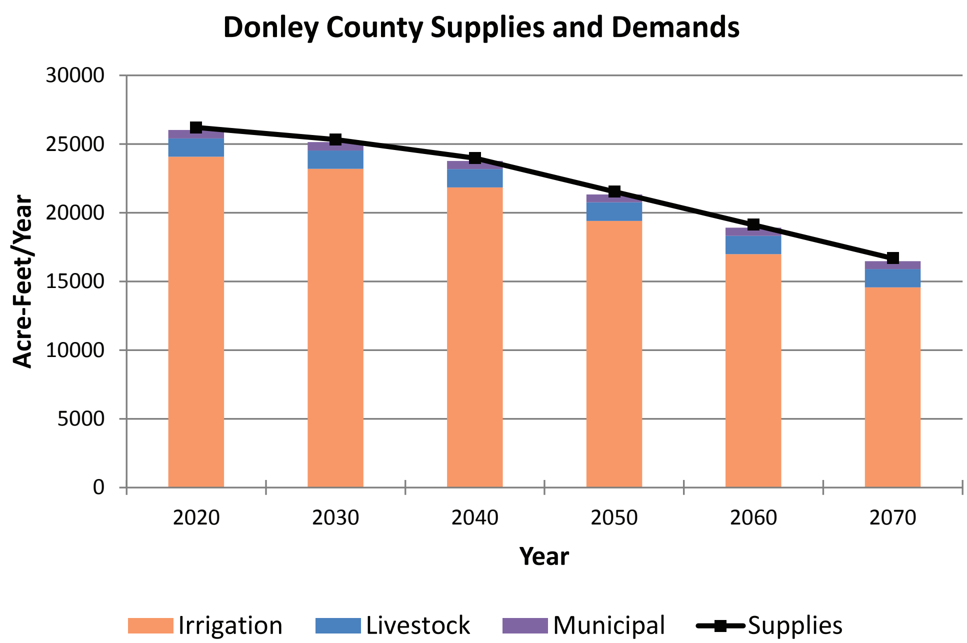




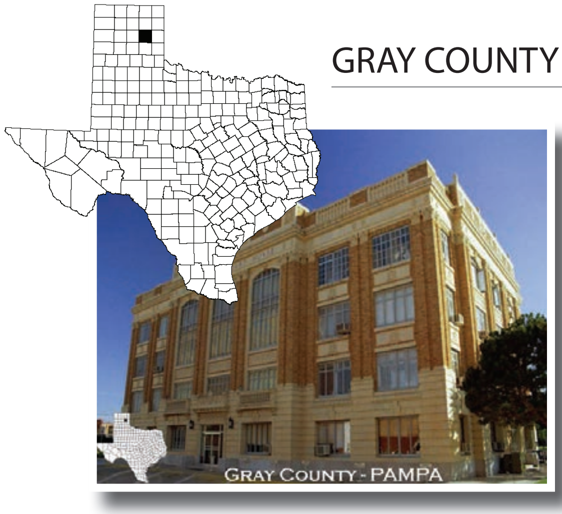








Water User Group	Strategy
Clarendon	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category



Who are my representatives?

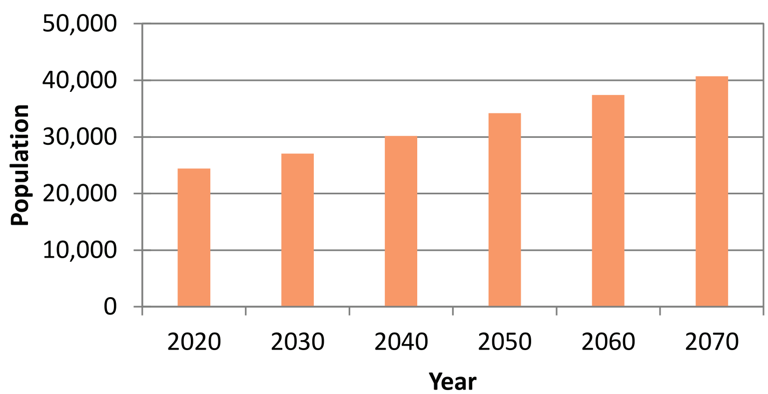
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Kent Satterwhite	- Canadian River MWA
Danny Krienke	- GMA #1

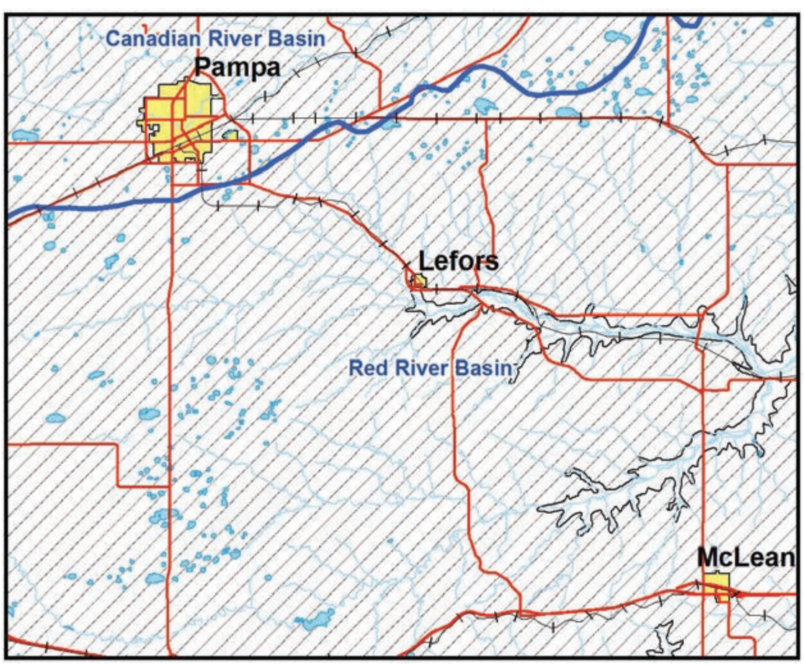
County Seat: City of Pampa

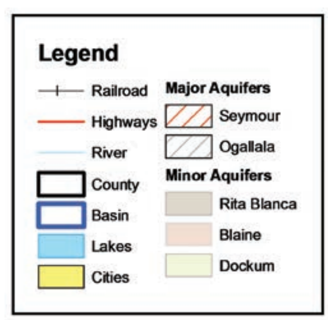
Economy: Agribusiness, Manufacturing, Tourism

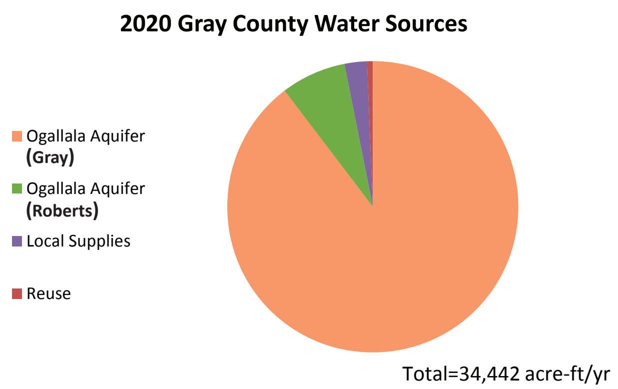
What is the source of my water? Ogallala Aquifer

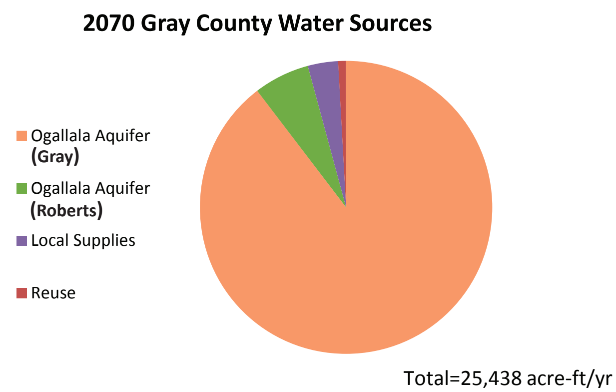
Gray County Population

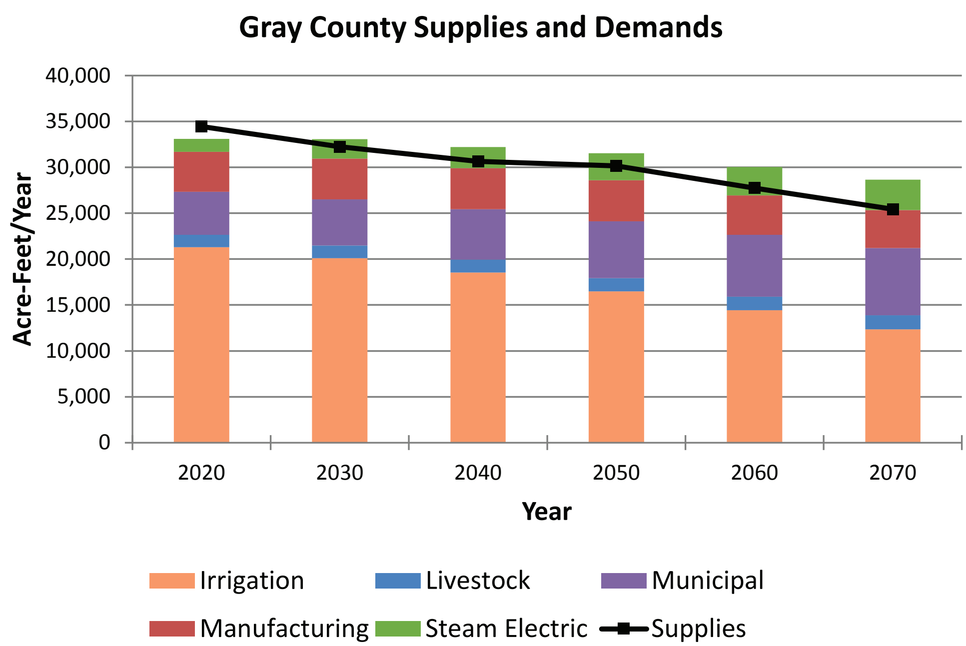












WATER USER GROUP	STRATEGY
McLean	Conservation, New Wells
Pampa	Conservation, New Wells, Purchase Supply From CRMWA
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Water Need Identified

HALL COUNTY

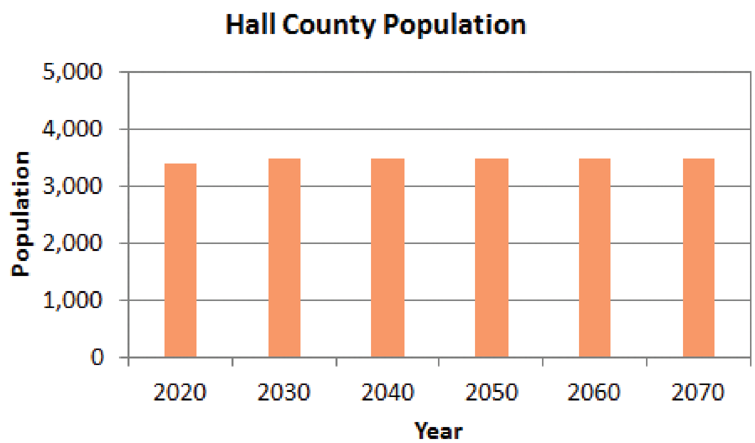
Who are my representatives?

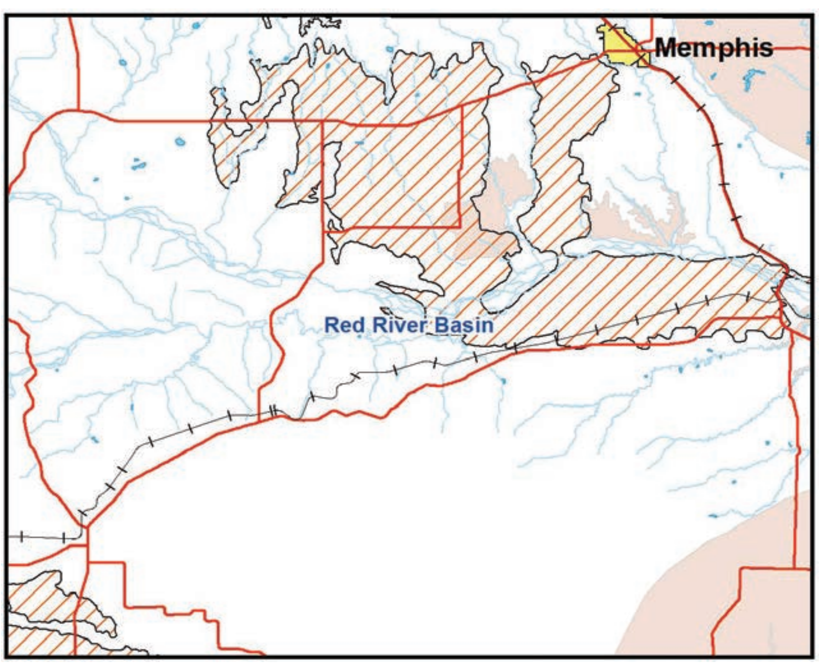
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Bobbie Kidd	- Greenbelt MIWA
Amy Crowell	- GMA #6

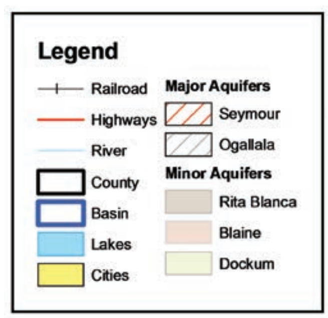
County Seat: City of Memphis

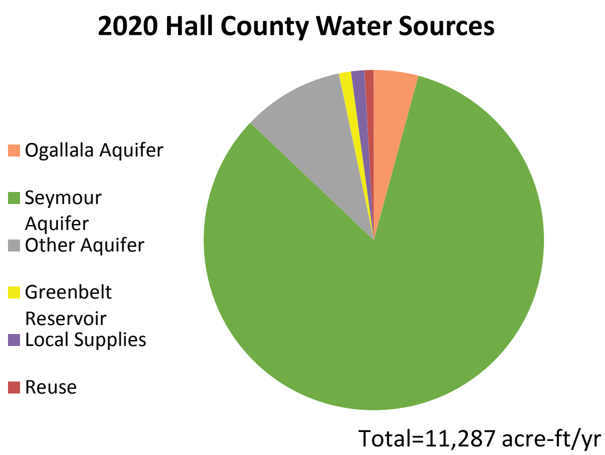
Economy: Agribusiness

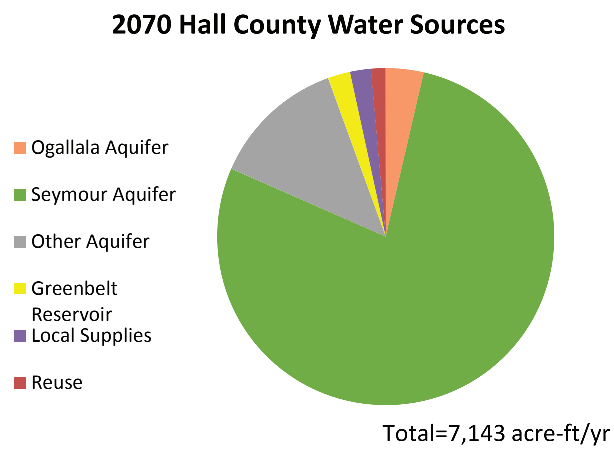
What is the source of my water? Ogallala, Seymour Aquifers, Greenbelt Reservoir

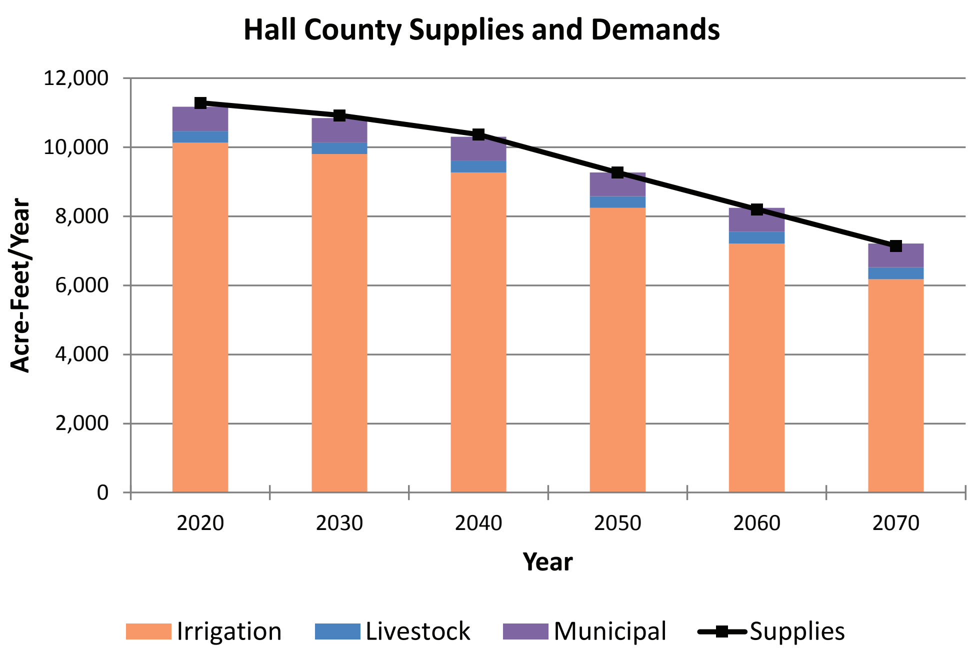












Water User Group	Strategy
Memphis	Conservation, New Wells
County-Other	Water Quality Improvements, New Wells
Irrigation	Conservation
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

HANSFORD COUNTY

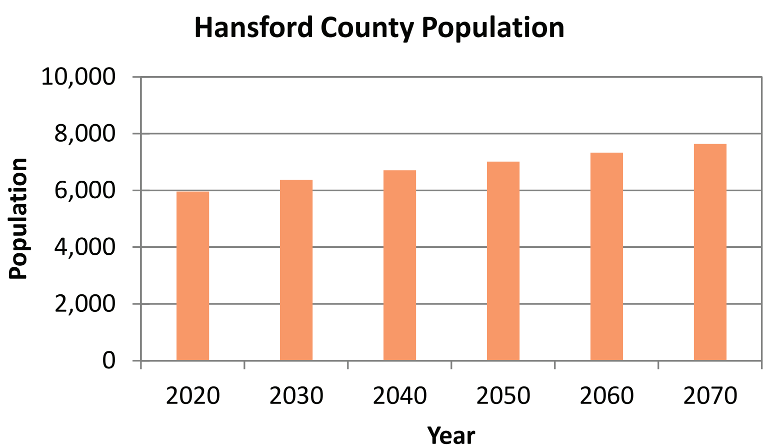
Who are my representatives?

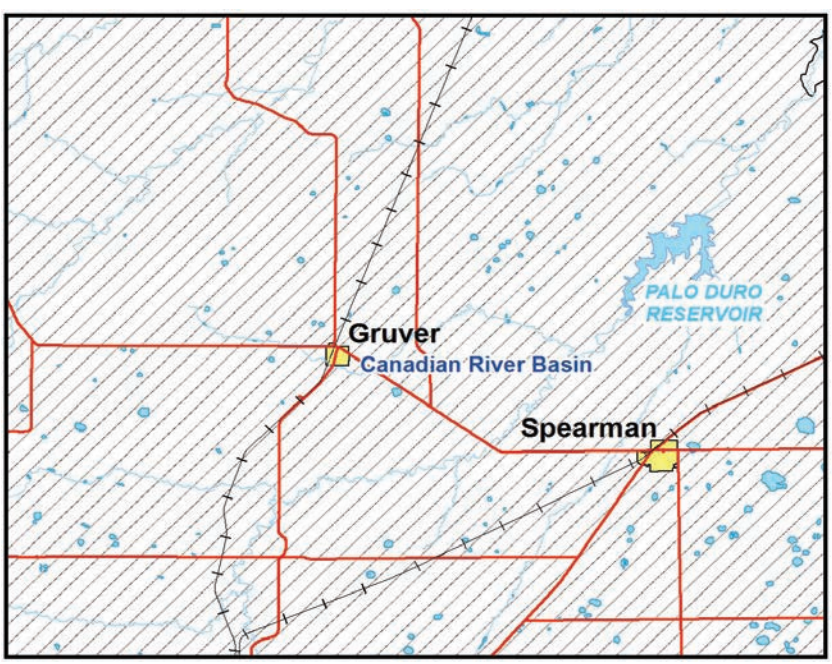
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Jim Derington	- Palo Duro River Authority
Danny Krienke	-GMA #1

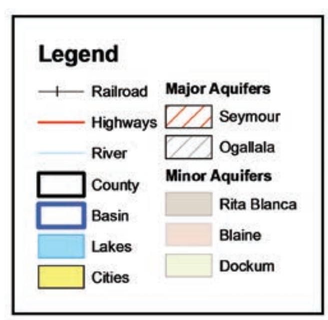
County Seat: City of Spearman

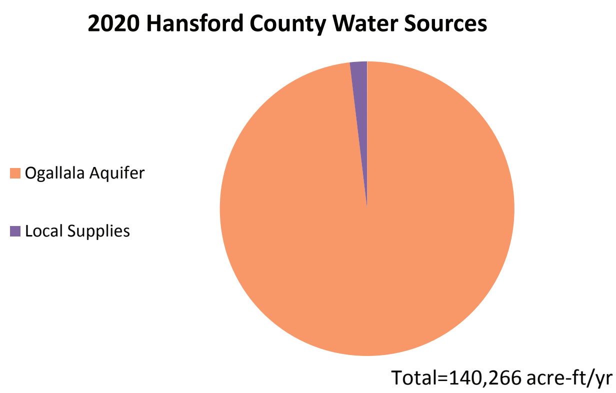
Economy: Agribusiness, Petroleum

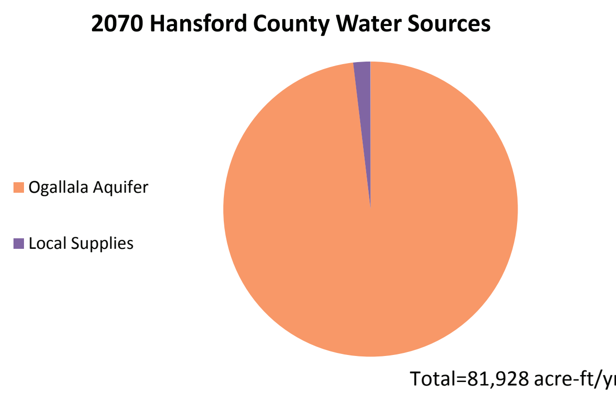
What is the source of my water? Ogallala Aquifer

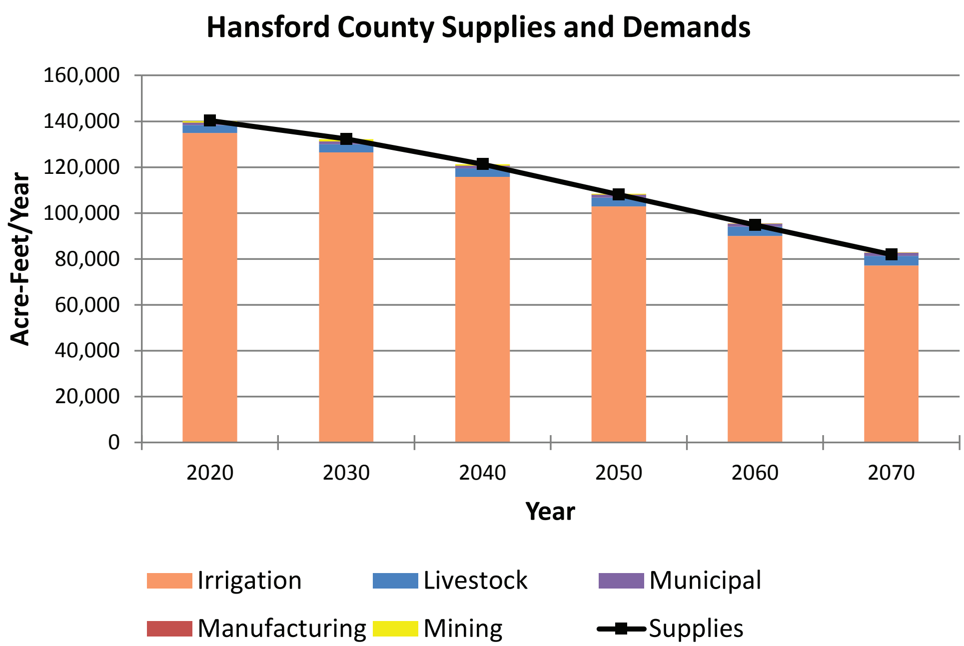












WATER USER GROUP	STRATEGY
Gruver	Conservation, New Groundwater Wells
Spearman	Conservation, New Groundwater Wells
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

HARTLEY COUNTY

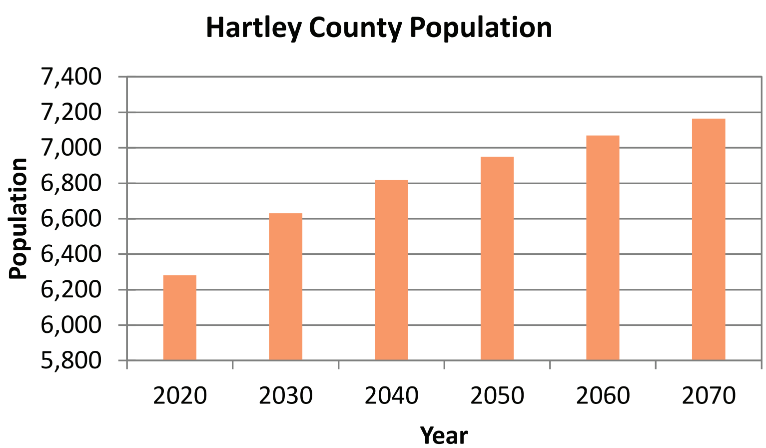
Who are my representatives?

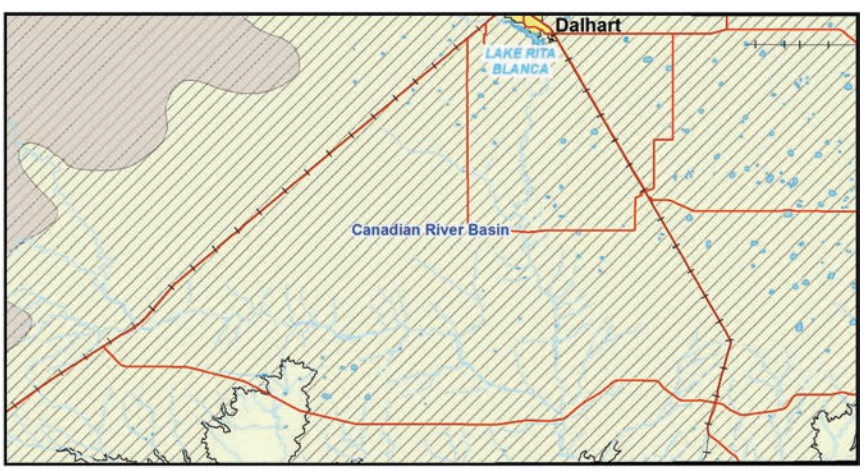
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

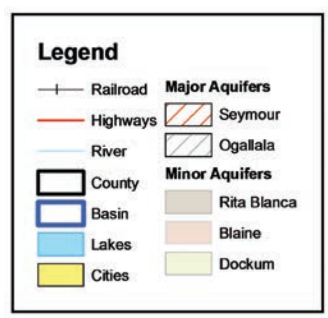
County Seat: City of Channing

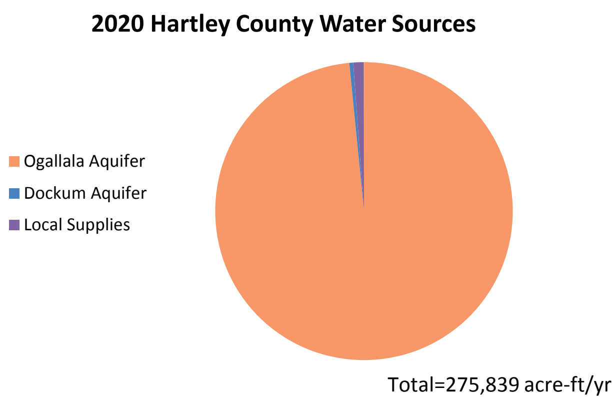
Economy: Agribusiness, Manufacturing, Petroleum

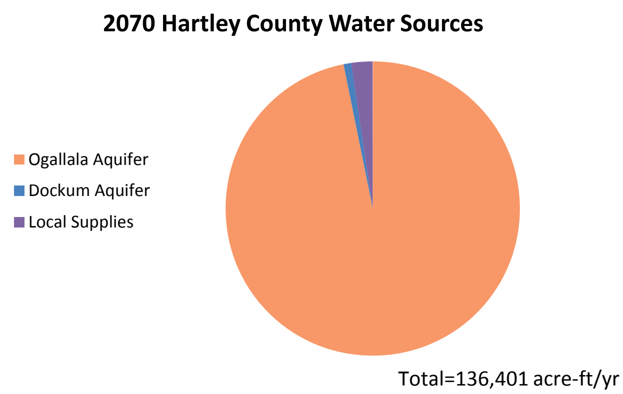
What is the source of my water? Ogallala, Dockum Aquifers

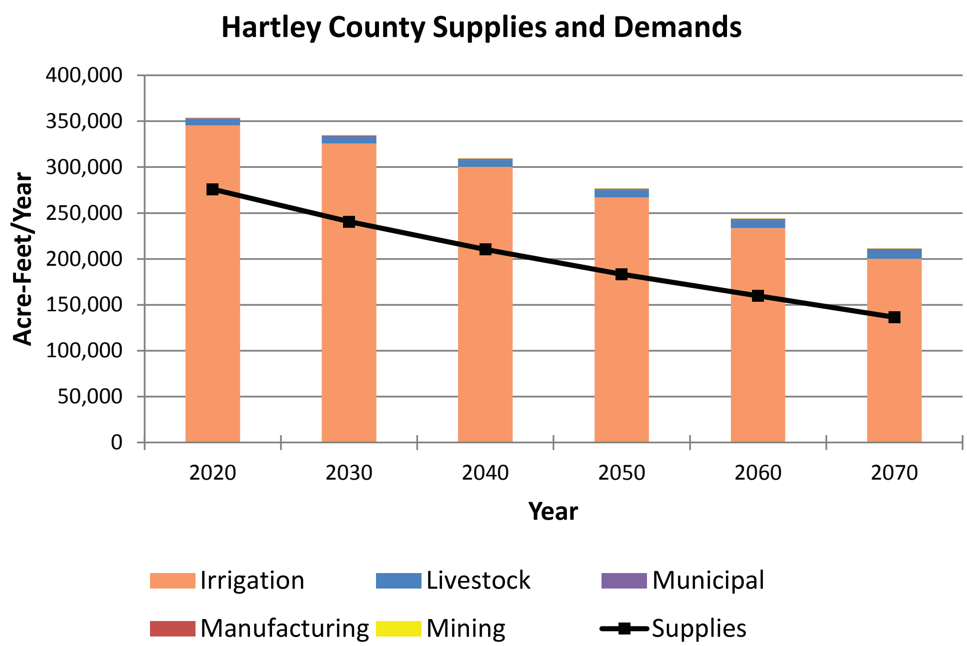




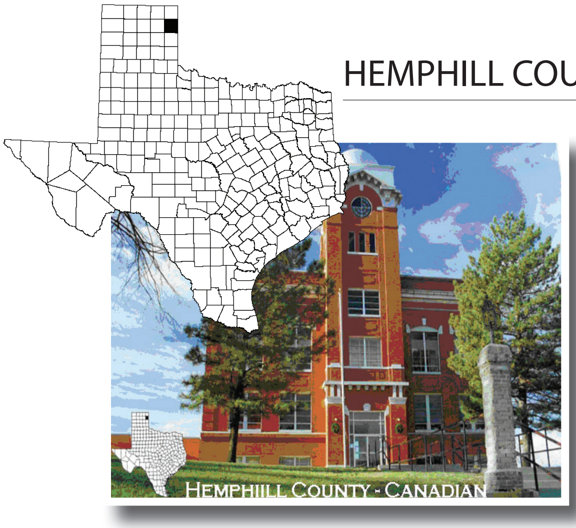








Water User Group	Strategy
Dalhart	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Change in Crop Type, Irrigation Equipment, Irrigation Scheduling, Advances in Plant Breeding
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Demands In This Category
Steam Electric Power	No Demands In This Category



Who are my representatives?

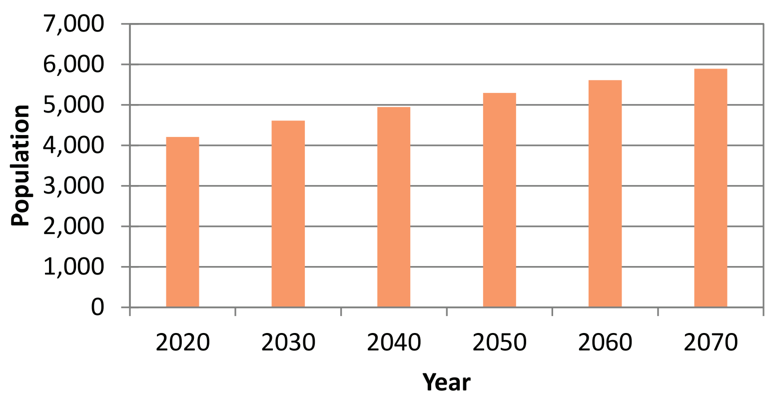
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Janet Guthrie	- Public
Rick Gibson	- Xcel Energy
Danny Krienke	- GMA #1

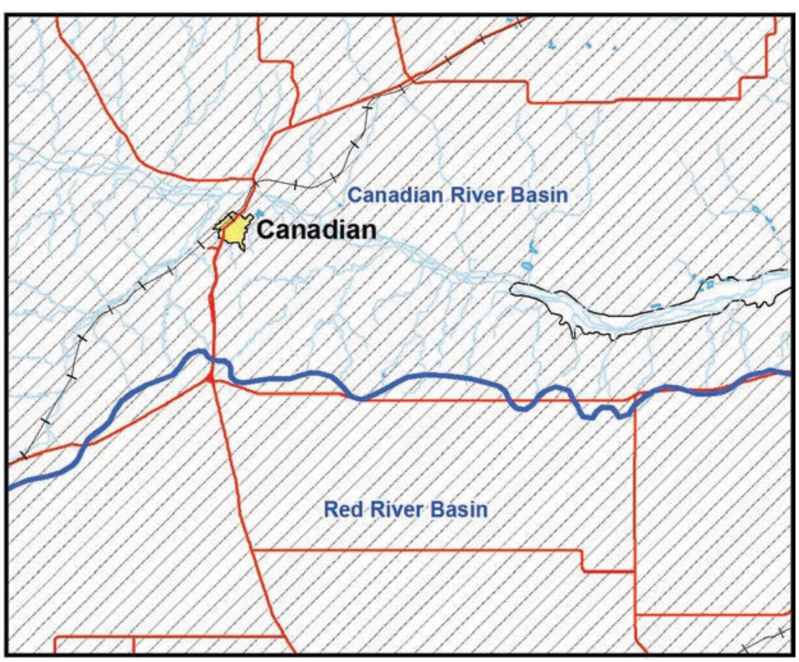
County Seat: City of Canadian

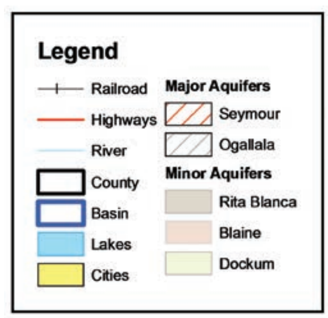
Economy: Agribusiness, Petroleum

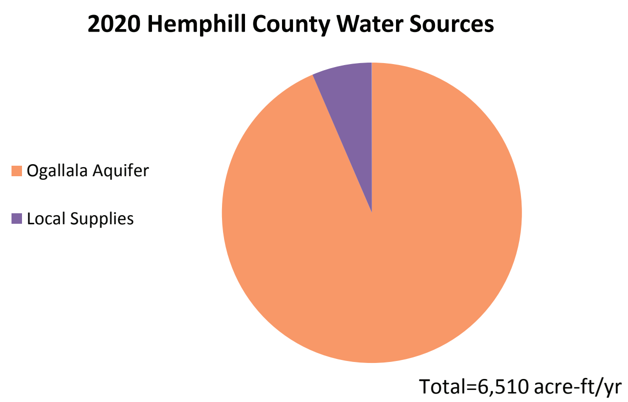
What is the source of my water? Ogallala Aquifer

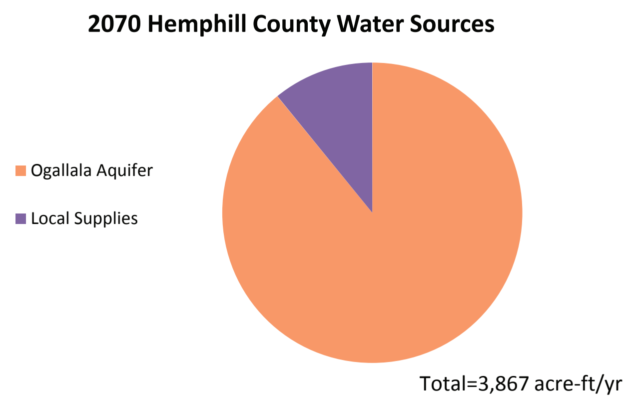
Hemphill County Population

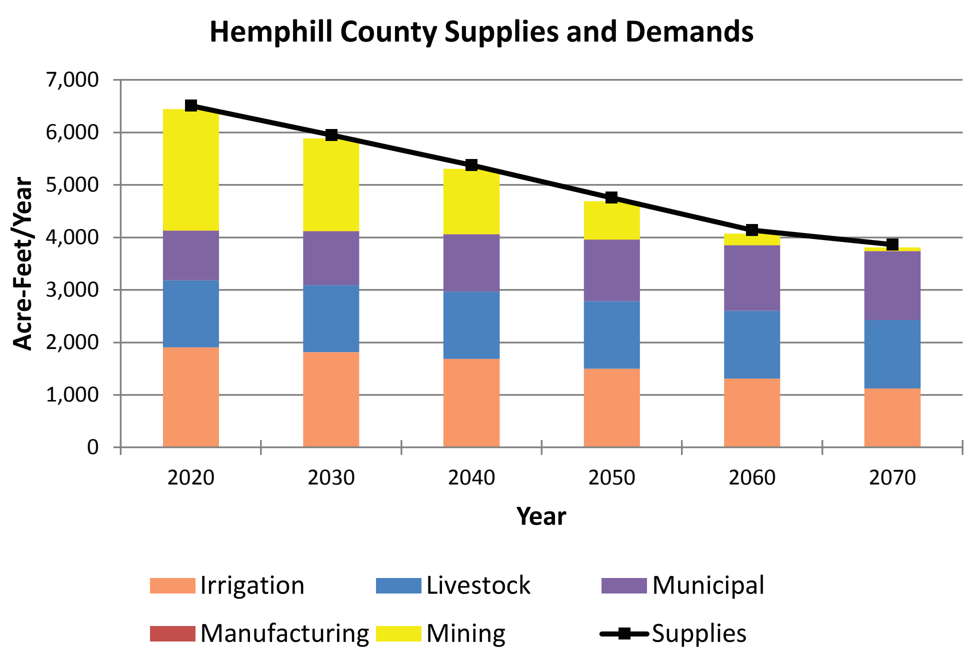












Water User Group	Strategy
Canadian	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Water Need Identified
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

HUTCHINSON COUNTY

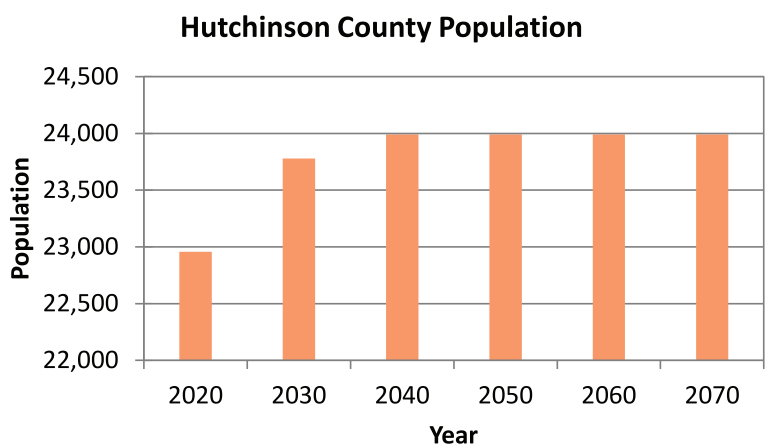
Who are my representatives?

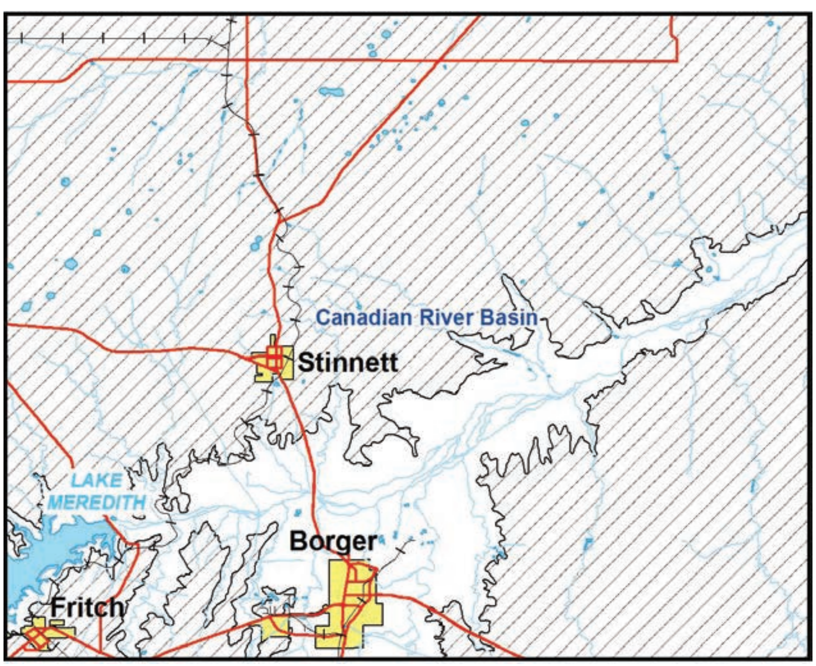
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
John Sweeten - Higher Education
Rick Gibson - Xcel Energy
Jay Weber - Conoco Phillips
Dean Cooke - TCW Supply
Kent Satterwhite - Canadian River MWA
Steve Walthour - North Plains GCD
Jim Derington - Palo Duro River Authority
Danny Krienke - GMA #1

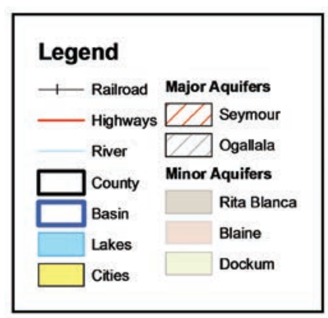
County Seat: City of Stinnett

Economy: Agribusiness, Manufacturing, Petroleum, Tourism

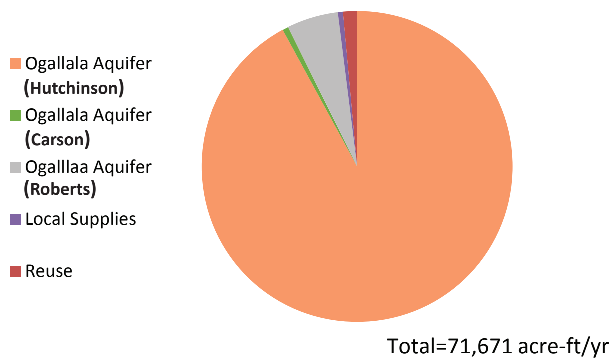
What is the source of my water? Ogallala Aquifer, Reuse



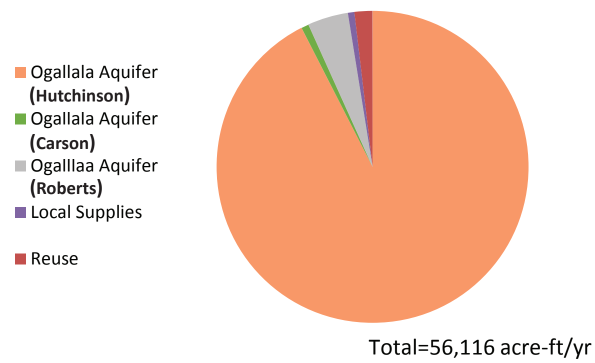




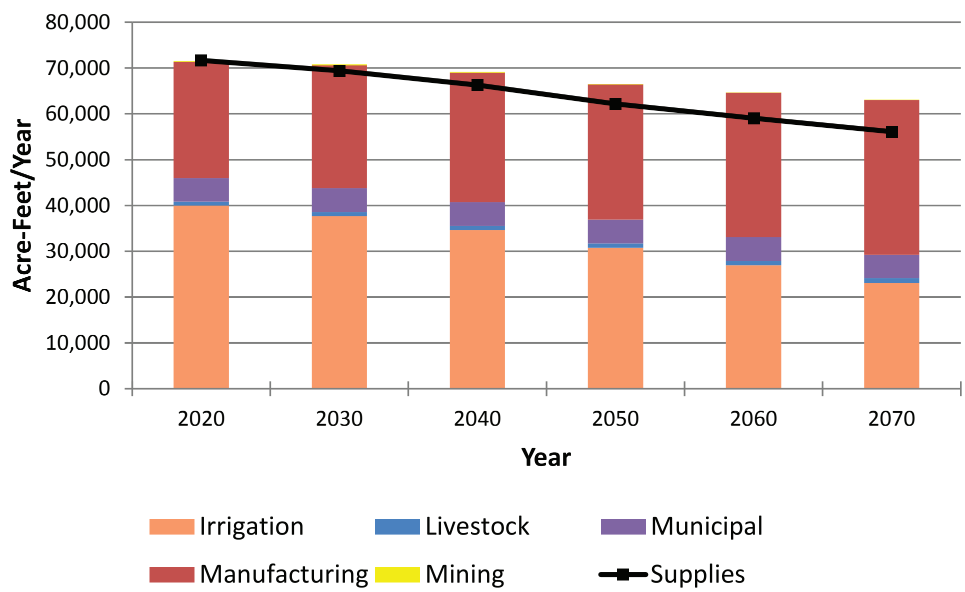
2020 Hutchinson County Water Sources



2070 Hutchinson County Water Sources



Hutchinson County Supplies and Demands



Water User Group	Strategy
Borger	Conservation, New Wells, Purchase Supply From CRMWA
Fritch	Conservation
Stinnett	Conservation, New Wells
TCW Water Supply Inc.	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	Purchase Supply From Borger
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

LIPSCOMB COUNTY

Who are my representatives?

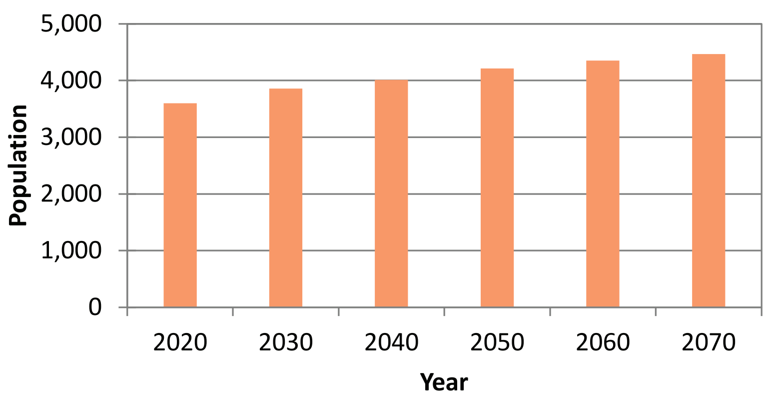
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Janet Tregellas	- Farmer/Rancher
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

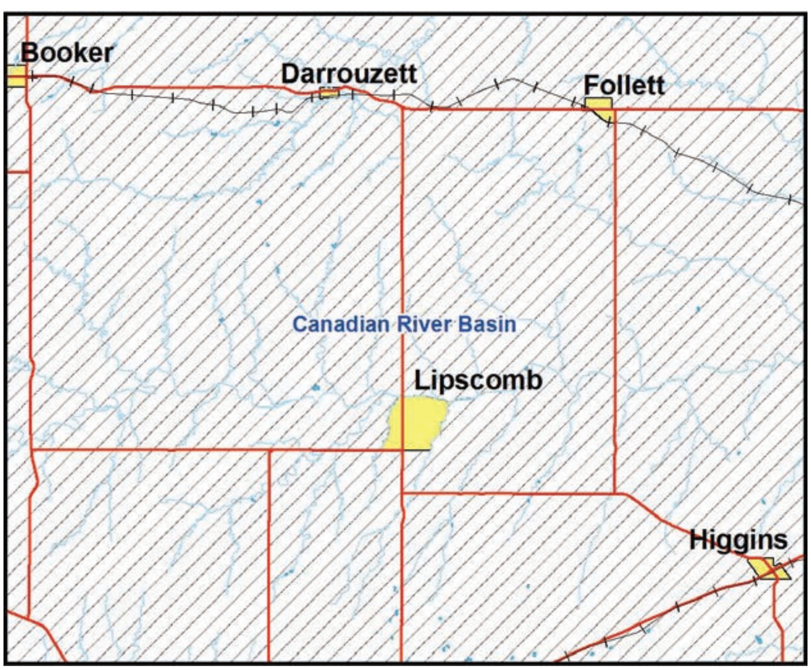
County Seat: City of Lipscomb

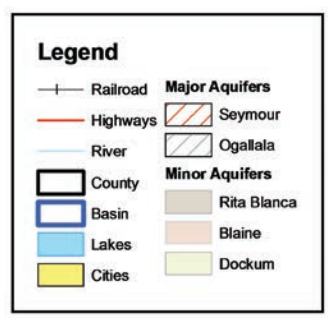
Economy: Agribusiness, Petroleum

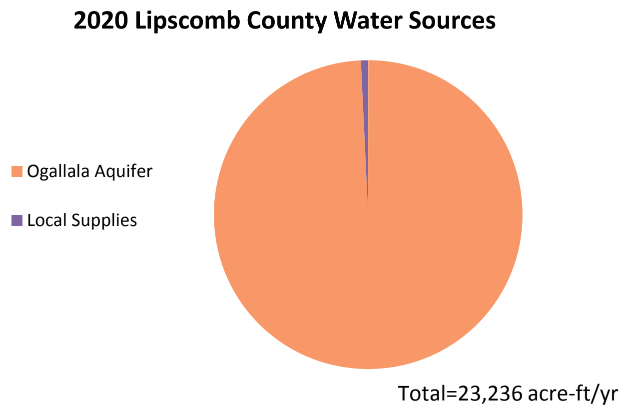
What is the source of my water? Ogallala Aquifer

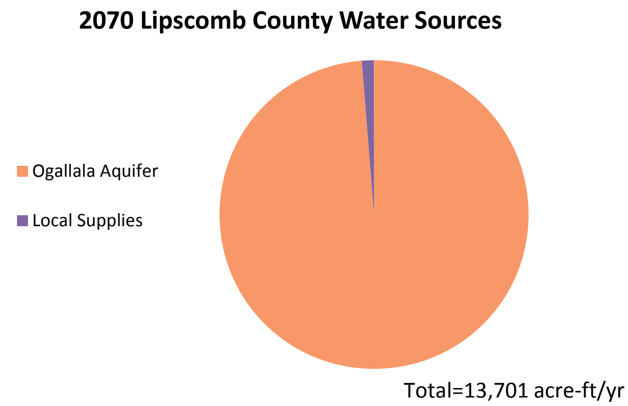
Lipscomb County Population

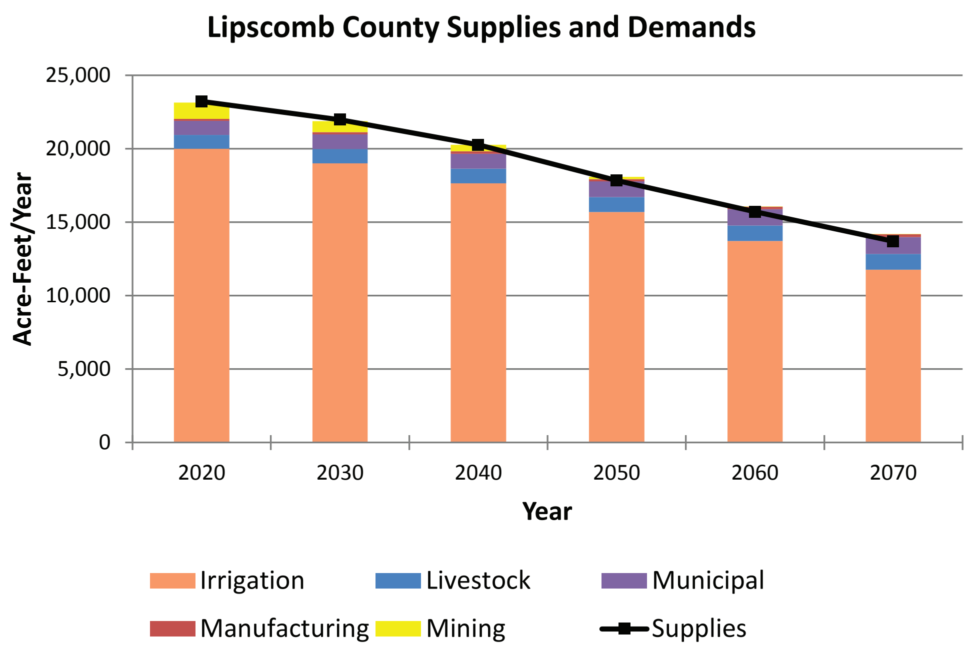












Water User Group	Strategy
Booker	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	Purchase Supply From Booker
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

MOORE COUNTY

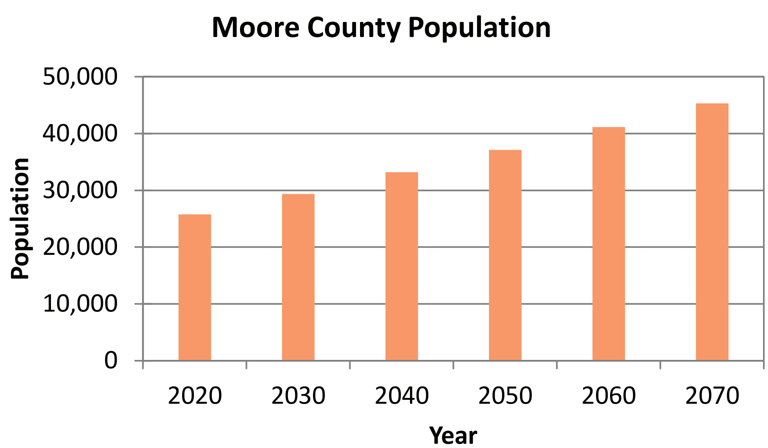
Who are my representatives?

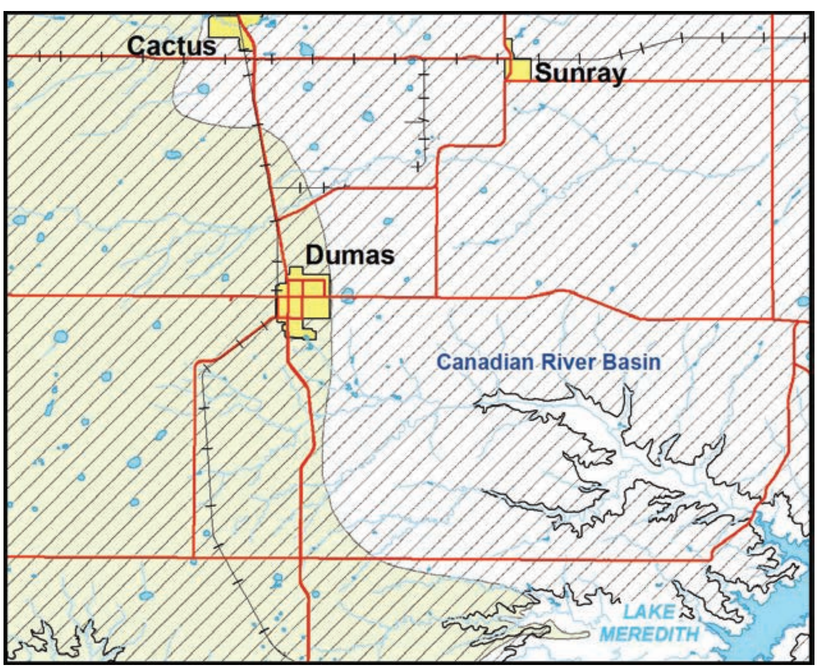
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Jim Derington	- Palo Duro River Authority
Danny Krienke	- GMA #1

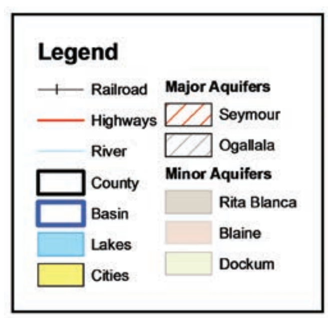
County Seat: City of Dumas

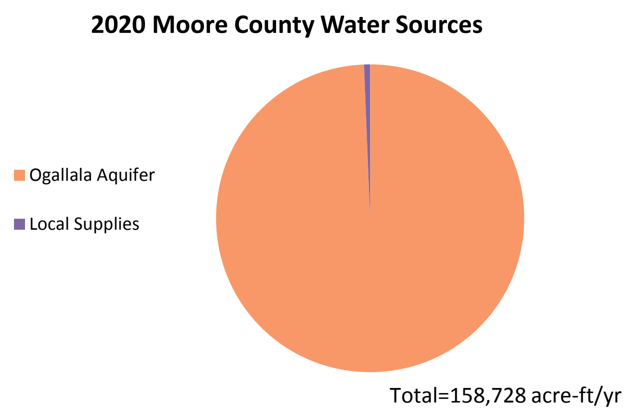
Economy: Agribusiness, Petroleum

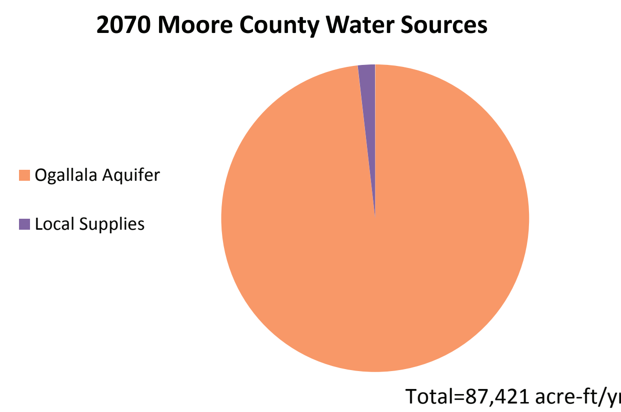
What is the source of my water? Ogallala Aquifer

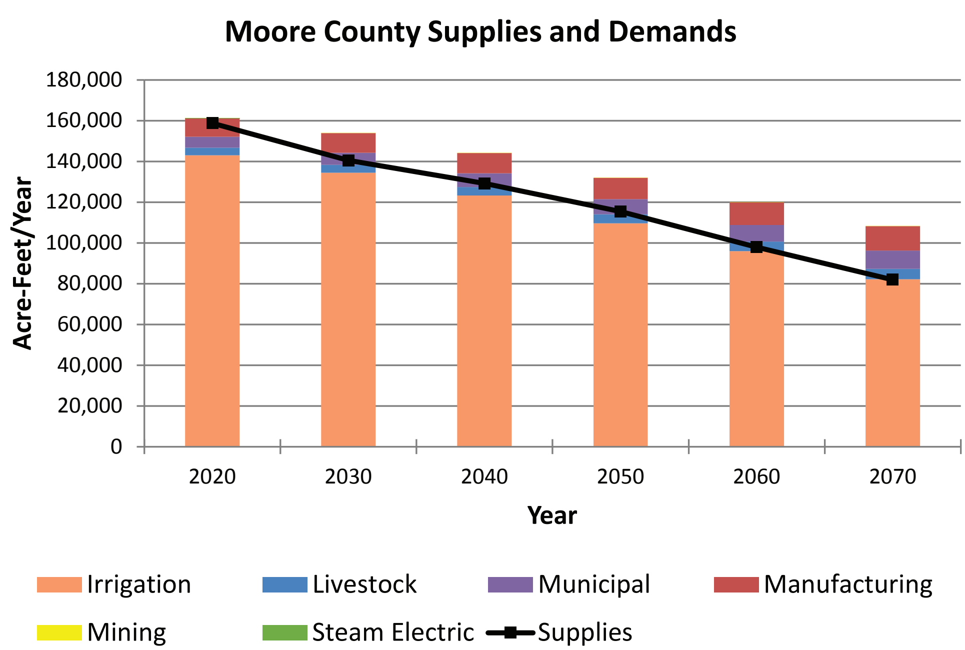












WATER USER GROUP	STRATEGY
Cactus	Conservation, New Groundwater Wells
Dumas	Conservation, New Groundwater Wells
Fritch	Conservation
Sunray	Conservation, New Groundwater Wells
County-Other	Conservation
Irrigation	Change in Crop Type, Irrigation Equipment, Irrigation Scheduling, Advances in Plant Breeding
Manufacturing	Purchase Supply From Cactus
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Water Need Identified

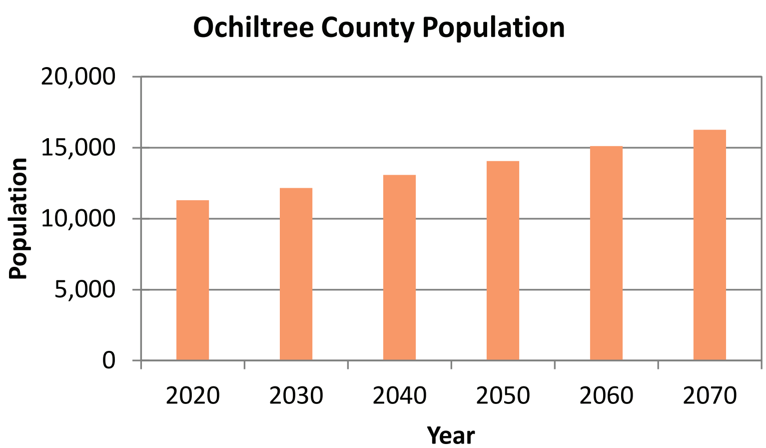
Who are my representatives?

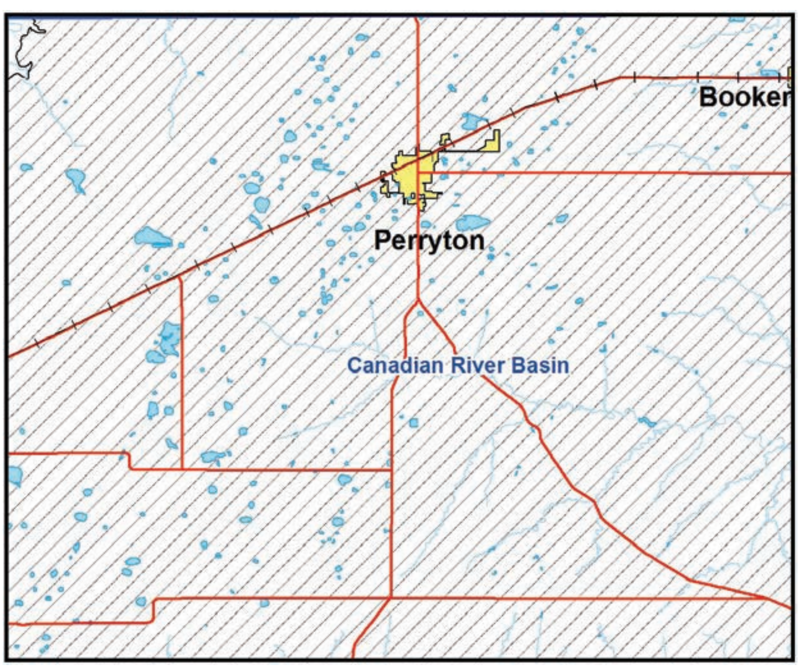
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
David Landis	- City of Perryton
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

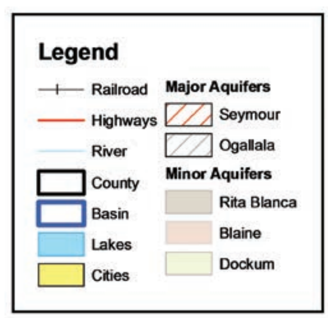
County Seat: City of Perryton

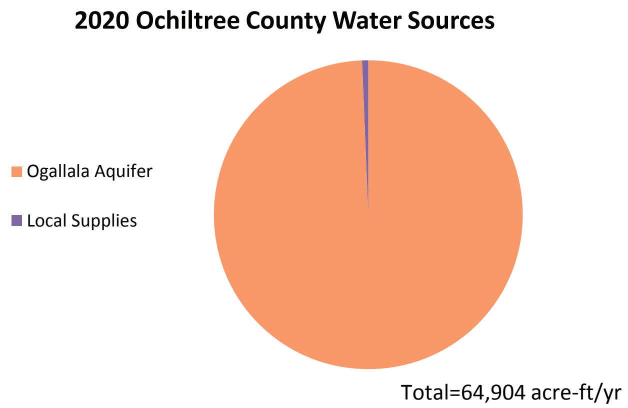
Economy: Agribusiness, Petroleum

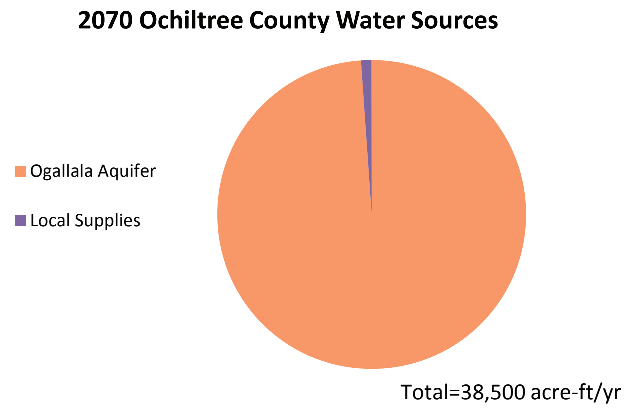
What is the source of my water? Ogallala Aquifer

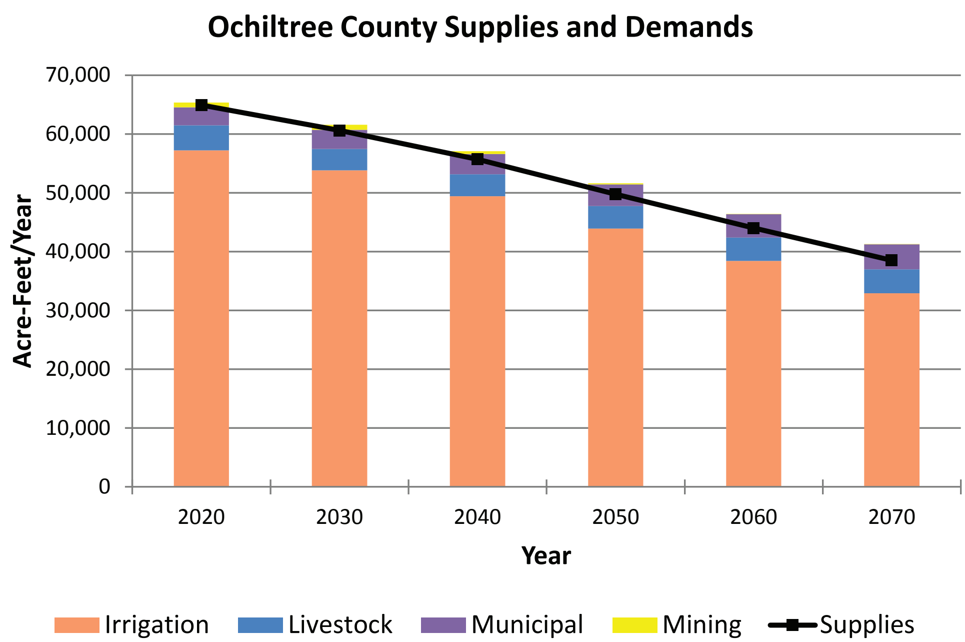




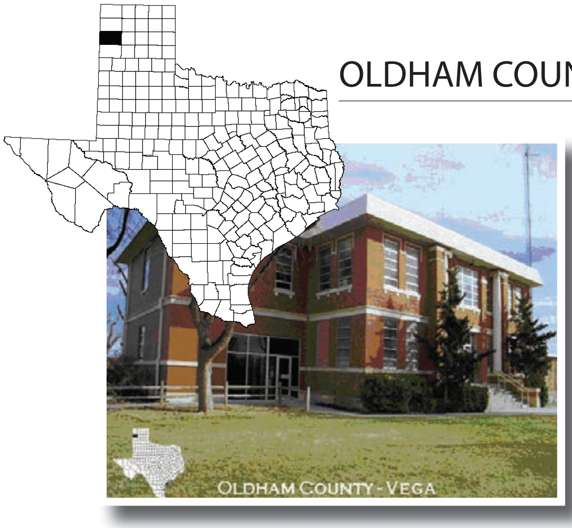








Water User Group	Strategy
Perryton	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category



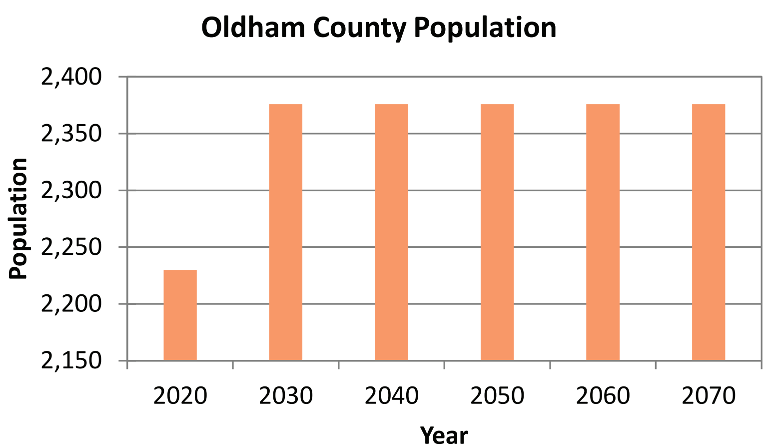
Who are my representatives?

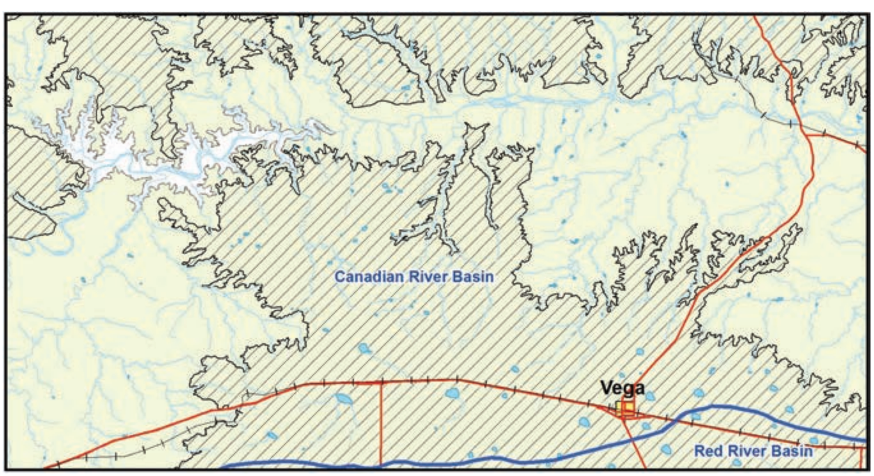
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Danny Krienke	- GMA #1

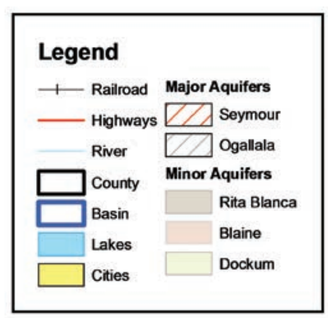
County Seat: City of Vega

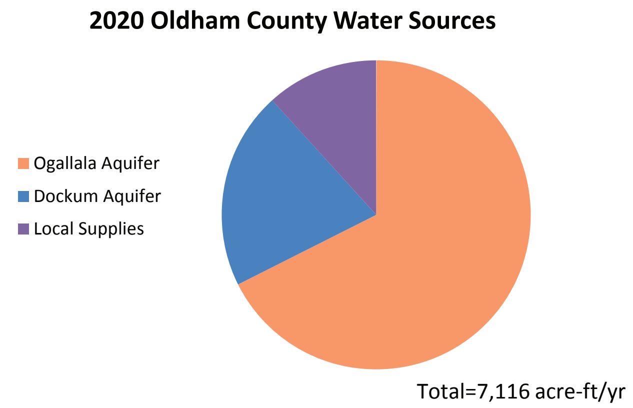
Economy: Agribusiness

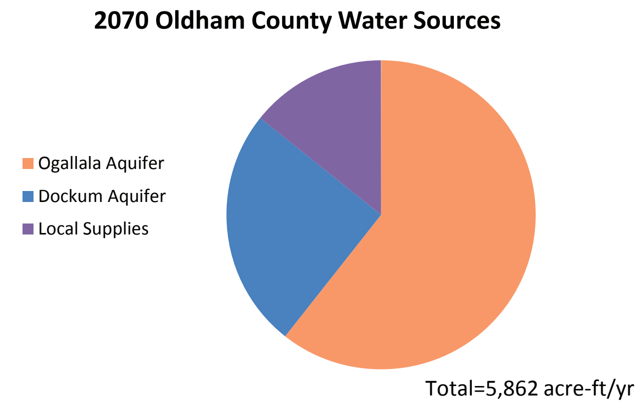
What is the source of my water? Ogallala, Dockum Aquifers

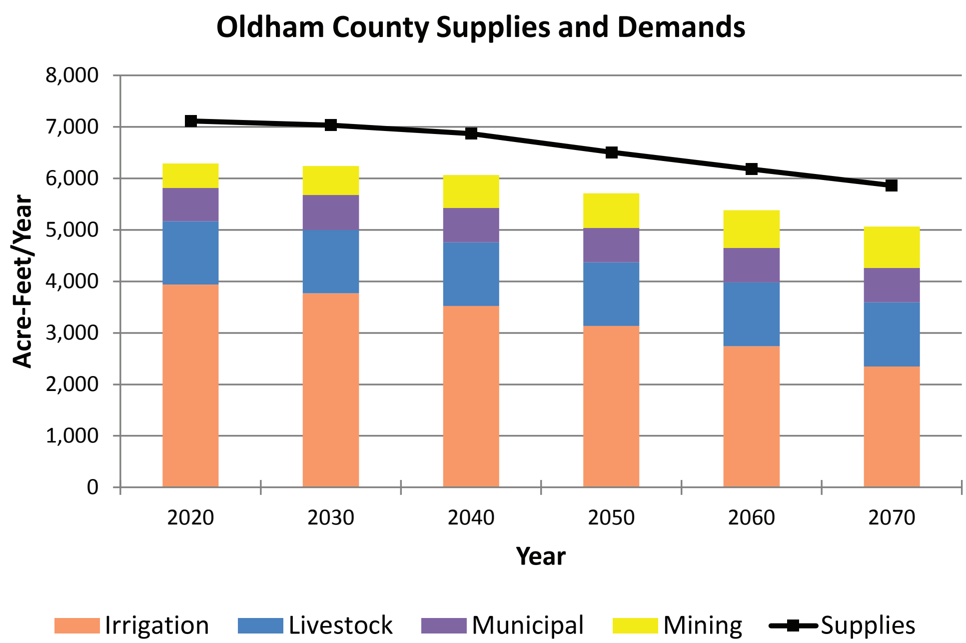






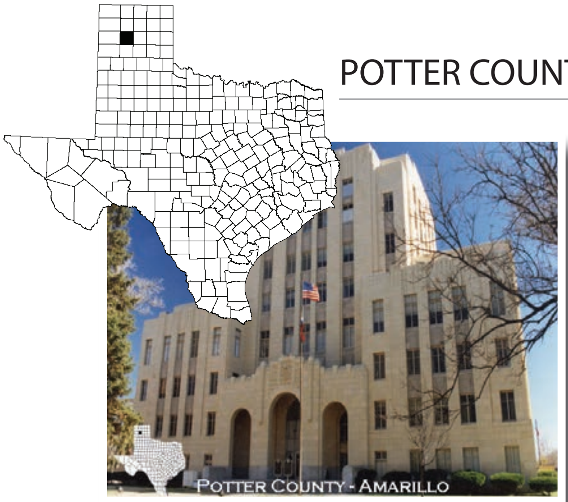






Water User Group	Strategy
Vega	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

POTTER COUNTY



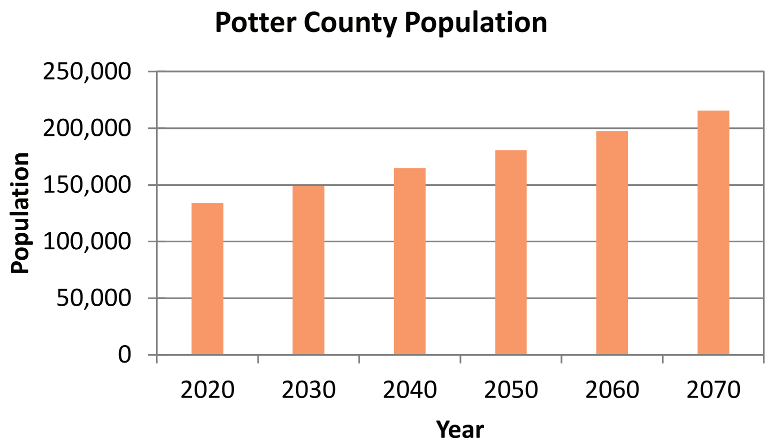
Who are my representatives?

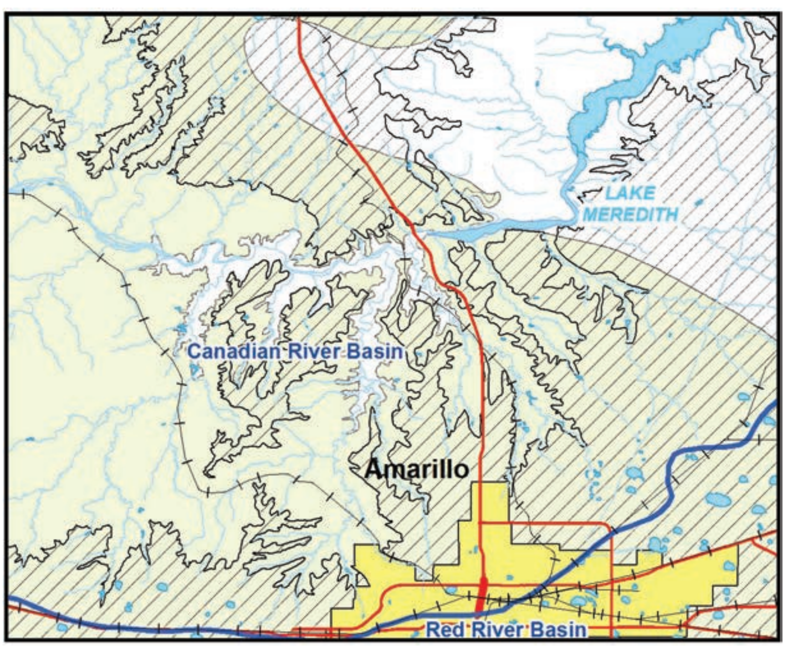
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Emmett Autrey	- City of Amarillo
Tonya Kleuskens	- Farmer
Bill Hallerberg	- Retired (Potter County)
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Kent Satterwhite	- Canadian River MWA
Danny Krienke	- GMA #1

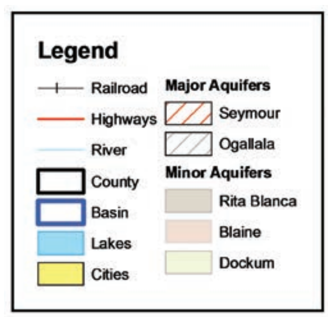
County Seat: City of Amarillo

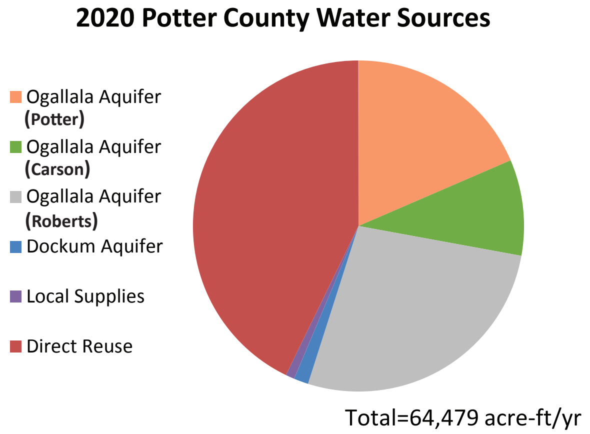
Economy: Agribusiness, Manufacturing, Petroleum, Tourism

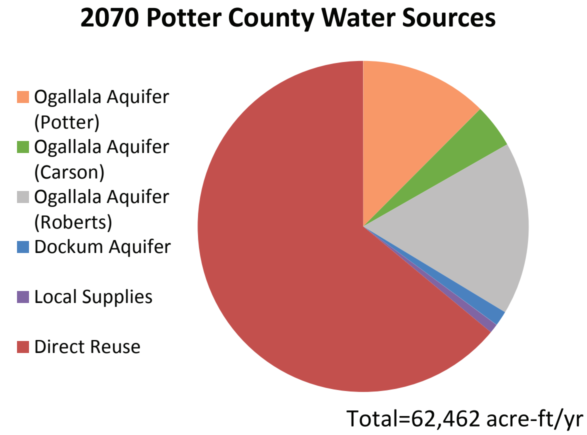
What is the source of my water? Ogallala, Dockum Aquifers, Reuse

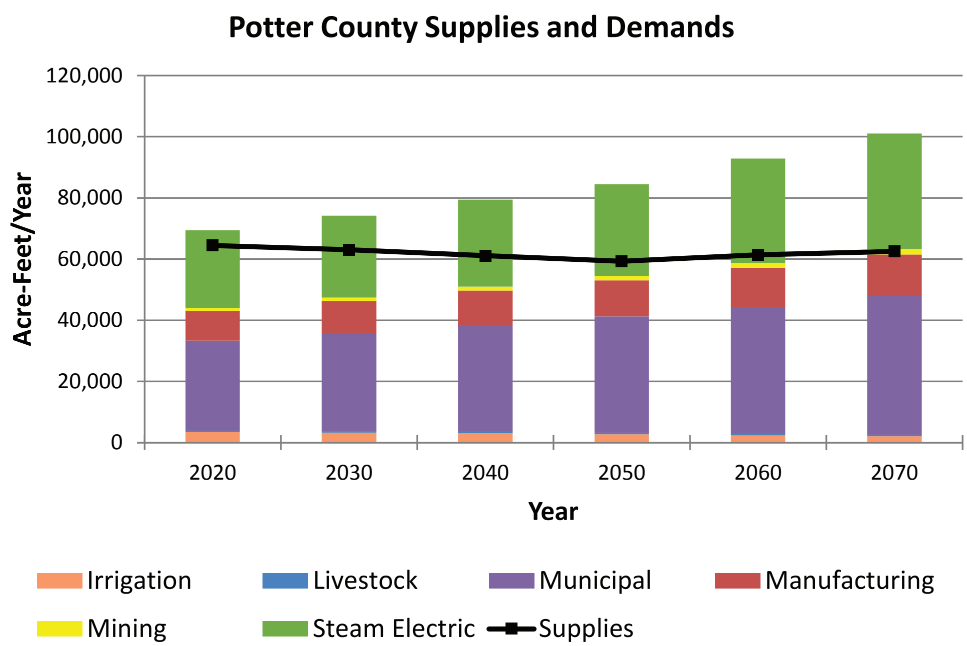




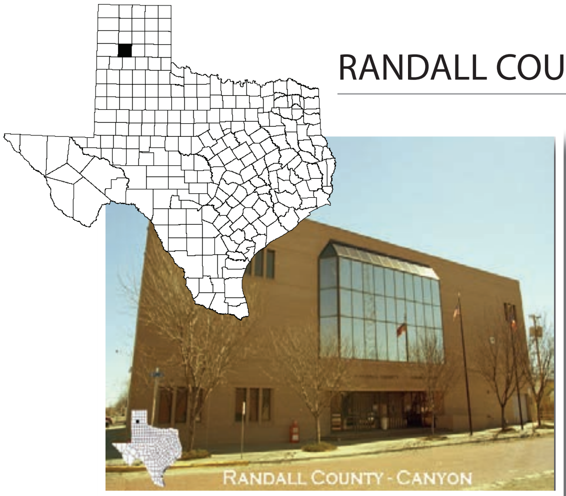








Water User Group	Water Management Strategy
Amarillo	Conservation, Potter Co. Well Field, Roberts Co. Well Field, Carson Co. Well Field, Purchase Supply From CRMWA
County-Other	Conservation, New Wells
Irrigation	Conservation, Weather Modification
Manufacturing	Purchase Potable and Reuse Supply From Amarillo
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Water Need Identified



RANDALL COUNTY

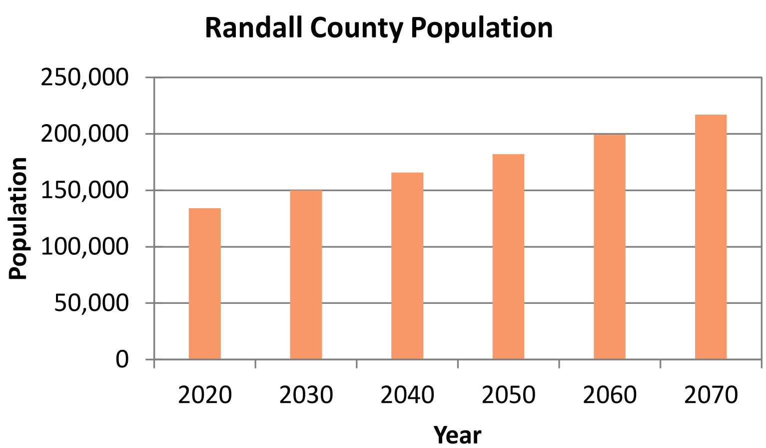
Who are my representatives?

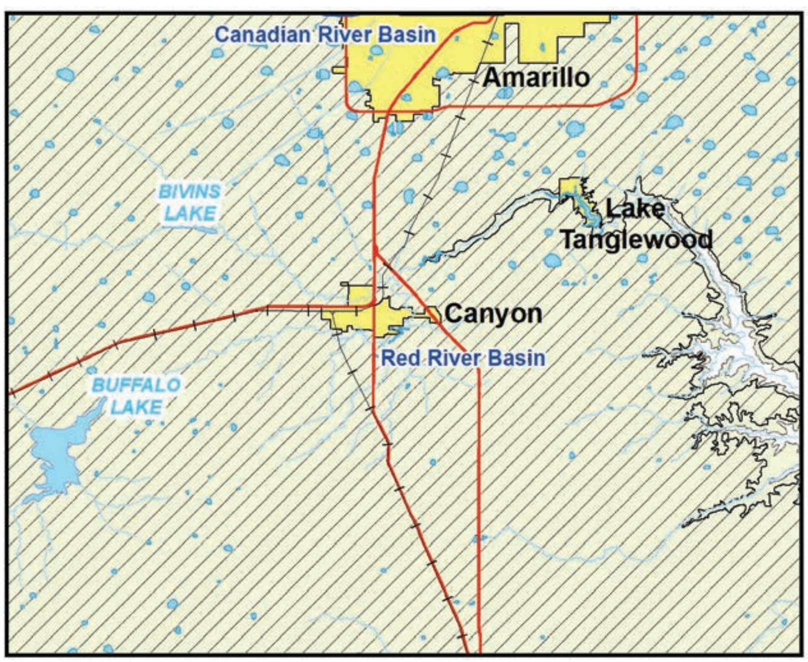
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
John Sweeten - Higher Education
Emmett Autrey - City of Amarillo
Rick Gibson - Xcel Energy, Environment
Kent Satterwhite - Canadian River MWA
Danny Krienke - GMA #1

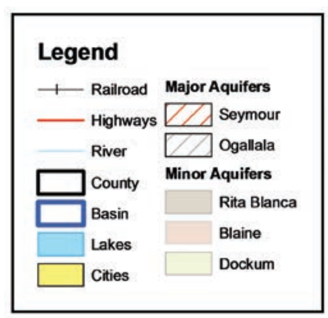
County Seat: City of Canyon

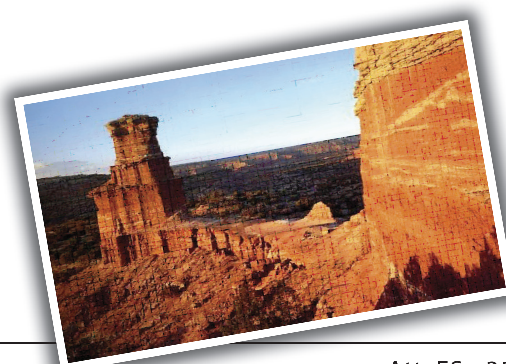
Economy: Agribusiness, Manufacturing, Tourism

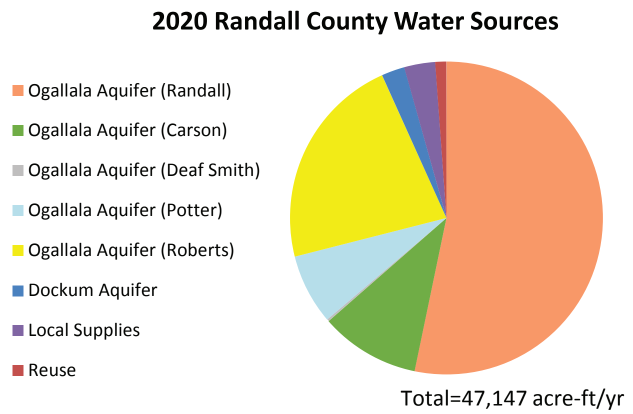
What is the source of my water? Ogallala, Dockum Aquifers, Reuse

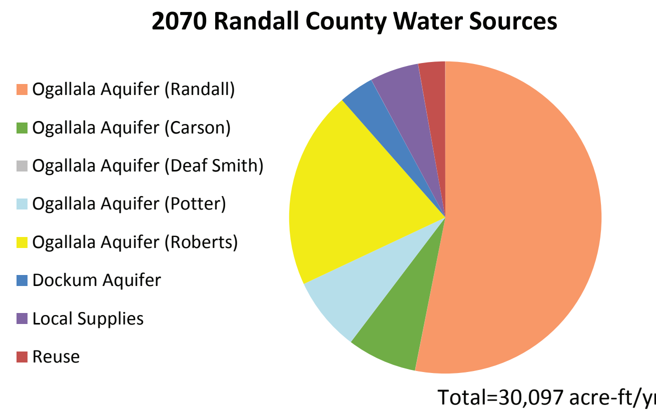


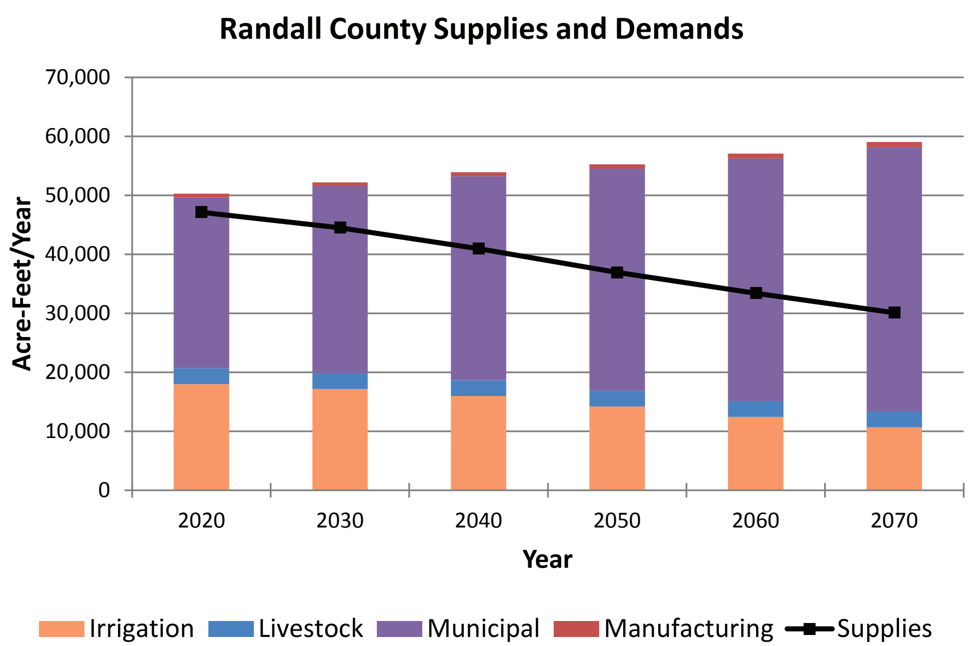




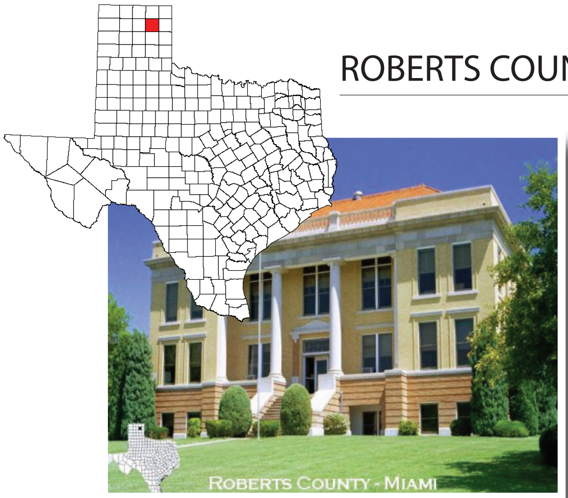








Water User Group	Strategy
Amarillo	Conservation, Potter Co. Well Field, Roberts Co. Well Field, Carson Co. Well Field, Purchase Supply From CRMWA
Canyon	Conservation, New Wells
Happy	Conservation
Lake Tanglewood	Conservation, New Wells
County-Other	Conservation, New Wells
Irrigation	Conservation
Manufacturing	New Wells
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category



ROBERTS COUNTY

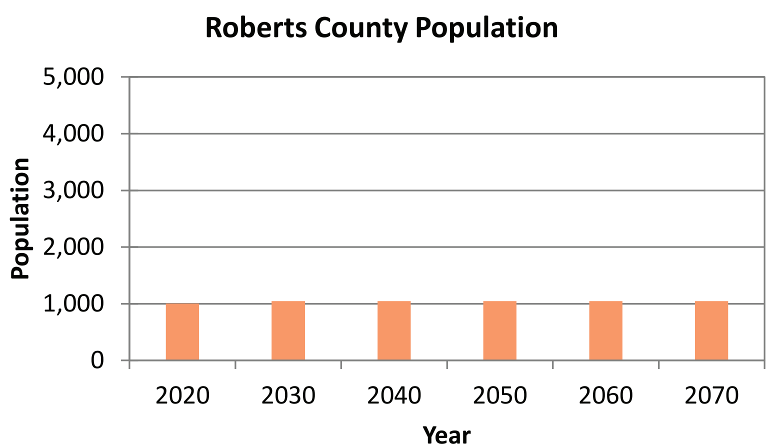
Who are my representatives?

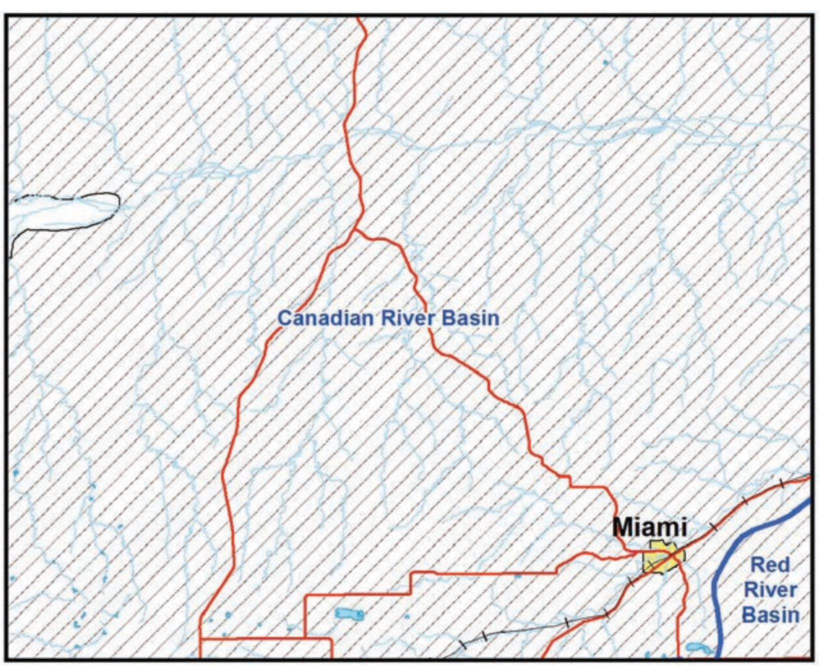
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Judge Vernon Cook	- Retired (Roberts County)
Rick Gibson	- Xcel Energy
C.E. Williams	- Panhandle GCD
Kent Satterwhite	- Canadian River MWA
Danny Krienke	- GMA #1

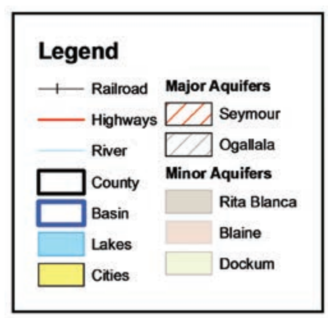
County Seat: City of Miami

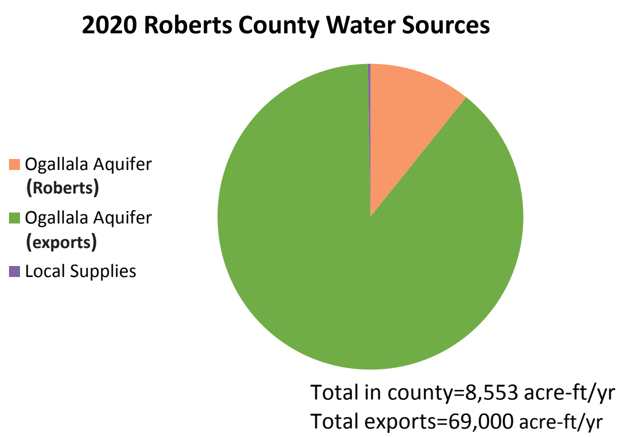
Economy: Agribusiness, Petroleum

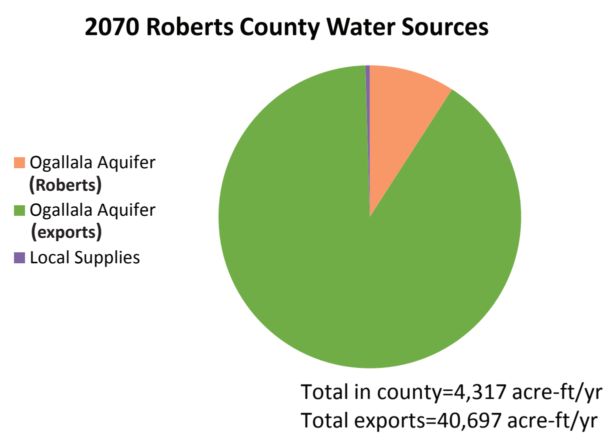
What is the source of my water? Ogallala Aquifer

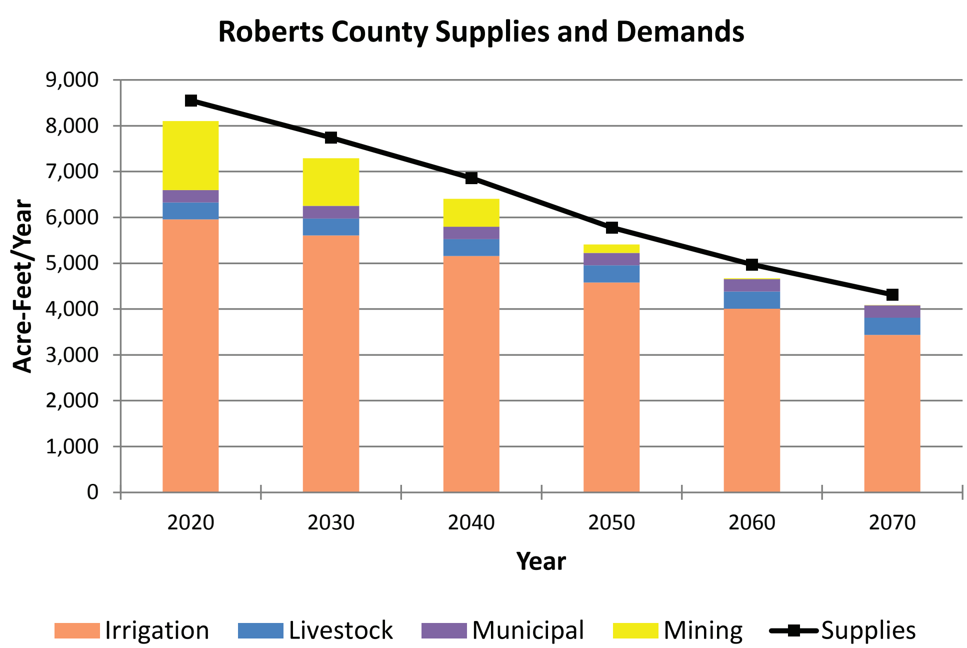












Water User Group	Strategy
Miami	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

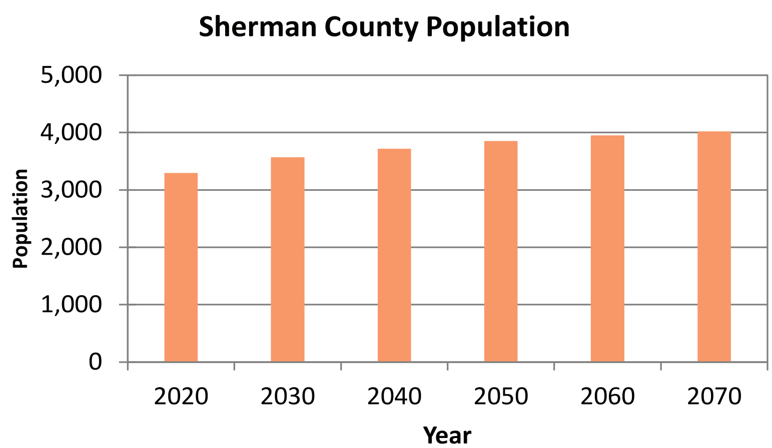
Who are my representatives?

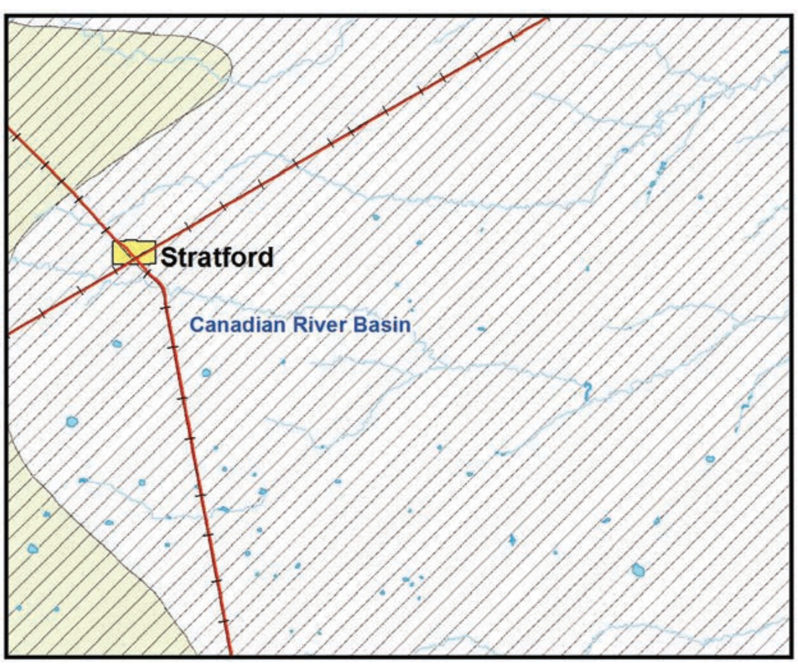
Dr. Nolan Clark	- Retired (USDA-ARS)
Ben Weinheimer	- Texas Cattle Feeders Association
John Sweeten	- Higher Education
Rick Gibson	- Xcel Energy
Steve Walthour	- North Plains GCD
Danny Krienke	- GMA #1

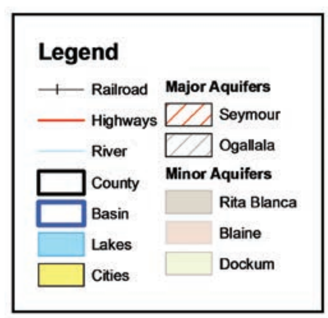
County Seat: City of Stratford

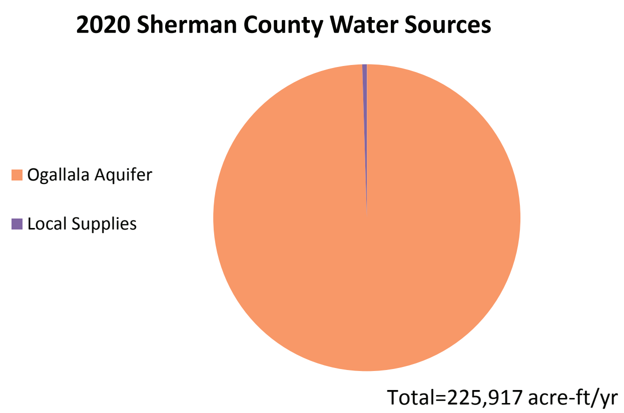
Economy: Agribusiness, Petroleum

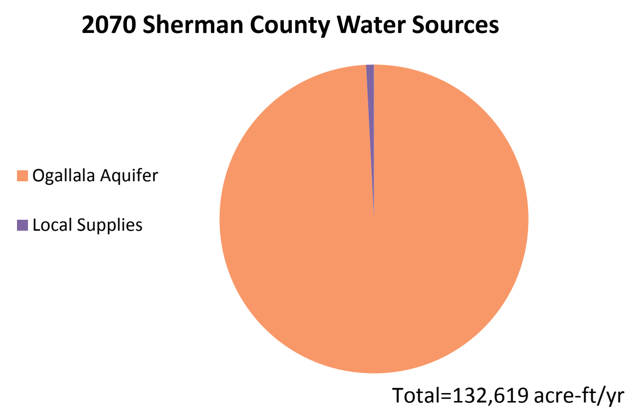
What is the source of my water? Ogallala Aquifer

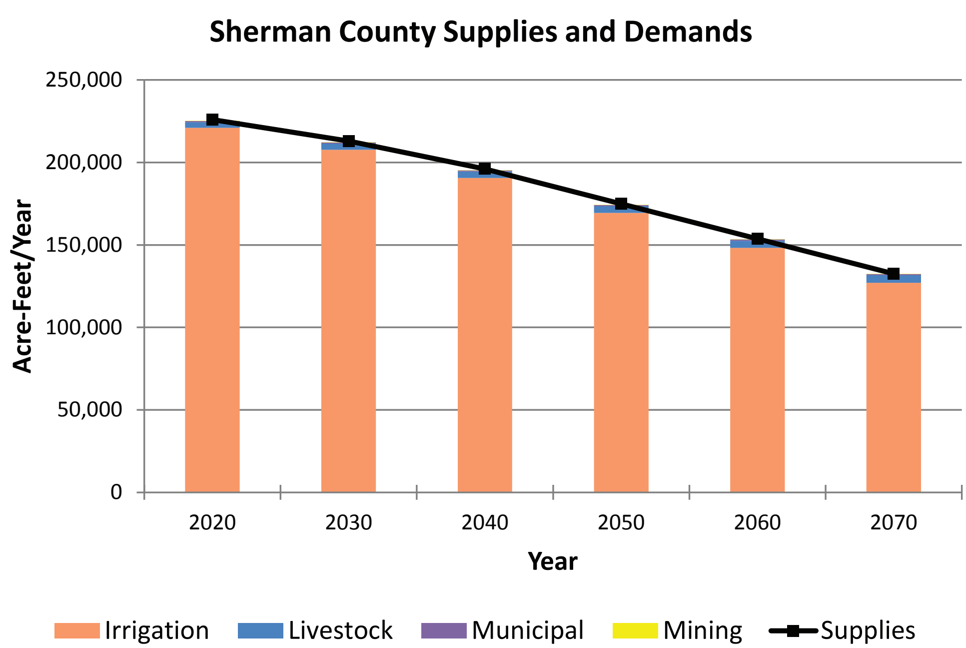












WATER USER GROUP	STRATEGY
Stratford	Conservation
County-Other	No Water Need Identified
Irrigation	Conservation
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

WHEELER COUNTY

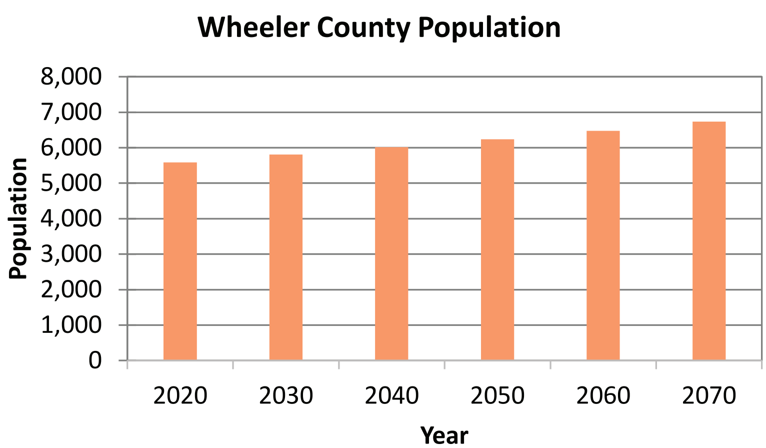
Who are my representatives?

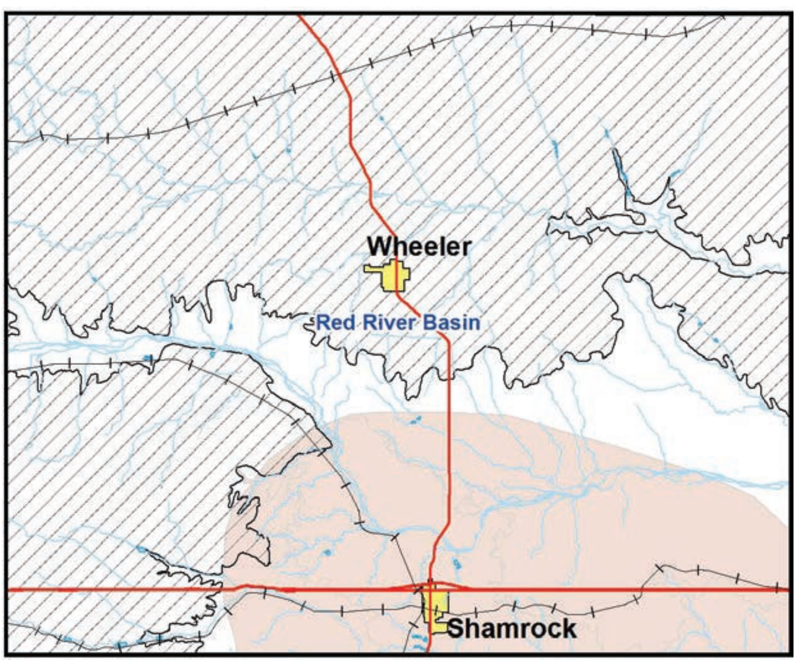
Dr. Nolan Clark - Retired (USDA-ARS)
Ben Weinheimer - Texas Cattle Feeders Association
John Sweeten - Higher Education
Rick Gibson - Xcel Energy
C.E. Williams - Panhandle GCD
Danny Krienke - GMA #1

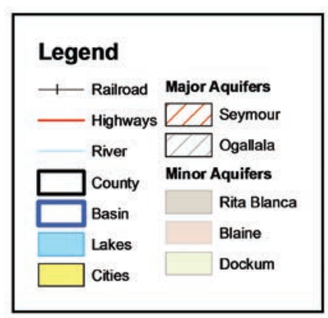
County Seat: City of Wheeler

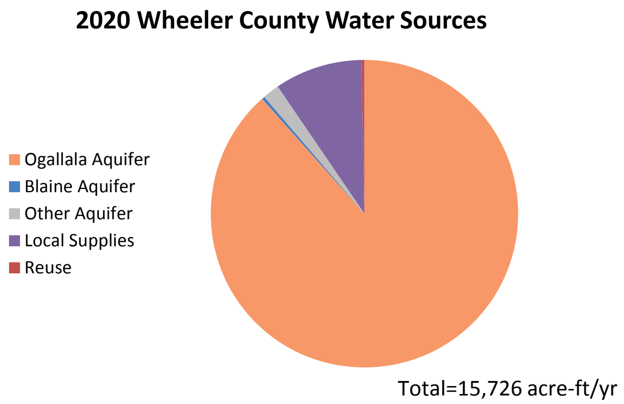
Economy: Agribusiness, Petroleum, Tourism

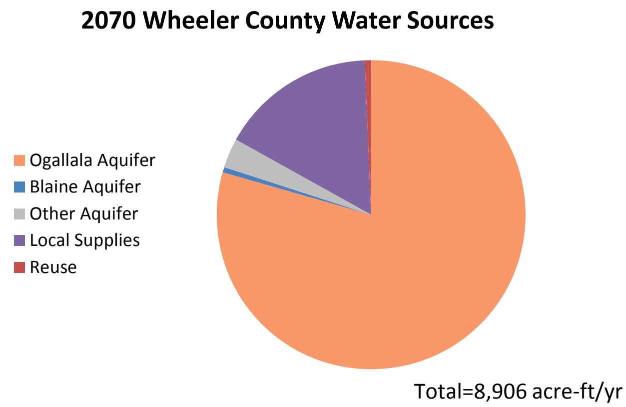
What is the source of my water? Ogallala, Blaine Aquifers

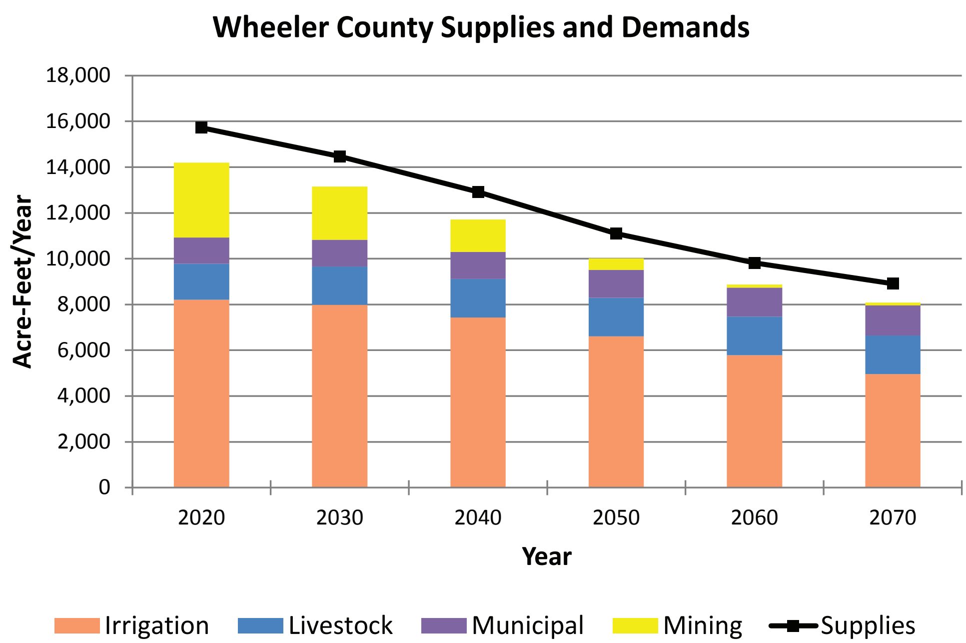












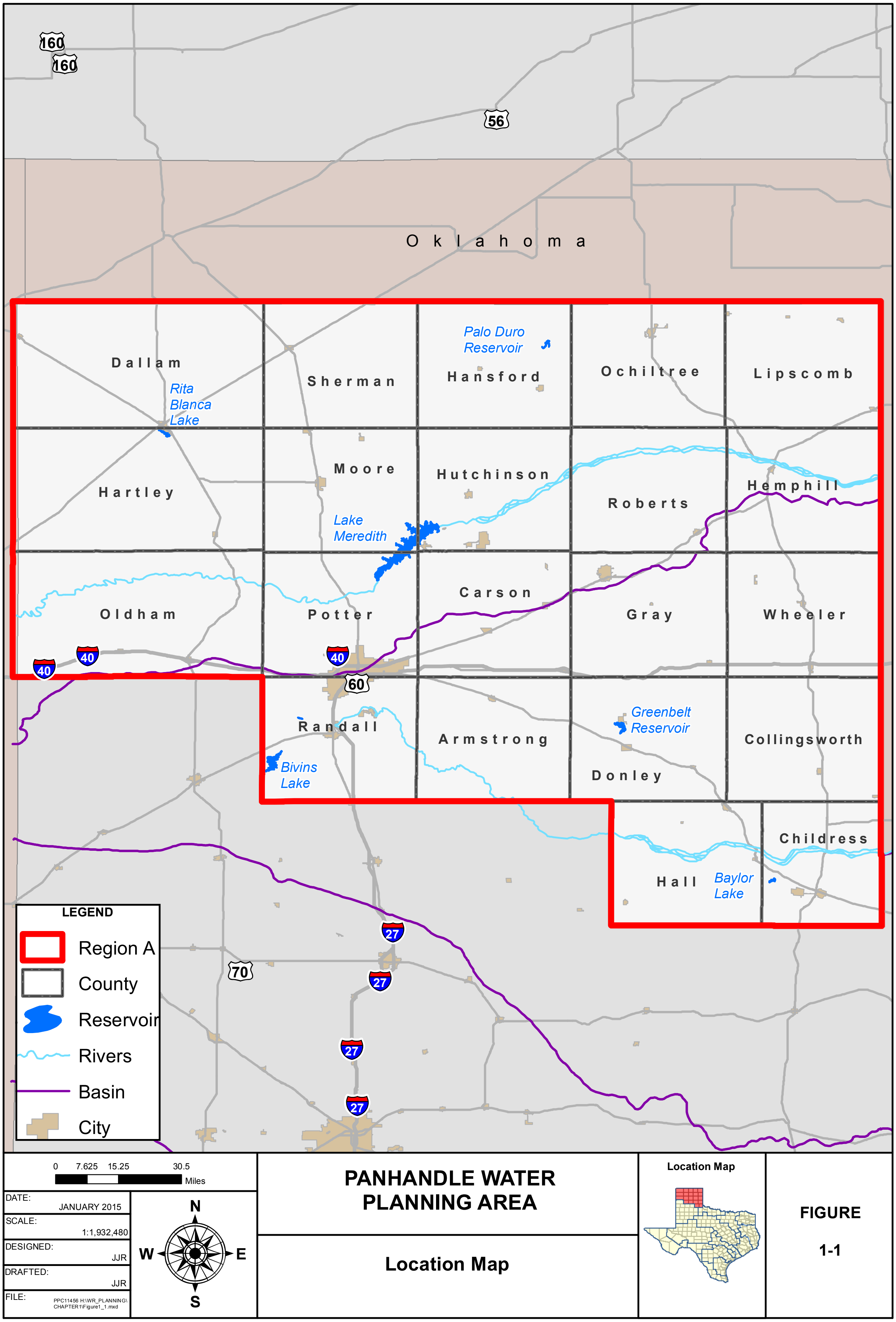
Water User Group	Strategy
Shamrock	Conservation
Wheeler	Conservation, New Wells
County-Other	No Water Need Identified
Irrigation	Conservation, Weather Modification
Manufacturing	No Demands In This Category
Livestock	No Water Need Identified
Mining	No Water Need Identified
Steam Electric Power	No Demands In This Category

Chapter 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 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 and is shown on Figure 1-1. It is comprised of 21 counties with similar characteristics and water sources.

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 (Texas A&M Agrilife), and LBG-Guyton, Inc. The Panhandle Regional Planning Commission (PRPC) serves as the political subdivision and contractor.



160
56
Oklahoma
Dallam
Sherman
Hansford
Ochiltree
Lipscomb
Palo Duro Reservoir
Rita Blanca Lake
Hartley
Moore
Hutchinson
Roberts
Hemphill
Lake Meredith
Oldham
Potter
Carson
Gray
Wheeler
40
60
Randall
Armstrong
Donley
Collingsworth
Greenbelt Reservoir
Bivins Lake
Childress
Hall
Baylor Lake
27
70
LEGEND
Region A
County
Reservoir
Rivers
Basin
City
0 7.625 15.25 30.5 Miles
DATE: JANUARY 2015
SCALE: 1:1,932,480
DESIGNED: JJR
DRAFTED: JJR
FILE: PPC11456 H:\WR_PLANNING\CHAPTER1\Figure1_1.mxd
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PANHANDLE WATER PLANNING AREA
Location Map
Location Map
FIGURE 1-1

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

Interest	Name[1]	Entity	County (Location of Interest)
Public	Janet Guthrie	City of Canadian/Hemphill County	Hemphill
Counties	Judge Vernon Cook	Retired (Roberts County)	Roberts
Municipalities	Emmett Autrey	City of Amarillo	Potter and Randall
	David Landis	City of Perryton	Ochiltree
Industries	Bill Hallerberg	Retired (Potter County)	Potter
	Jay Weber	ConocoPhillips	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[2]	Environmental Consultant	Serves entire region
	Tonya Kleuskens	Farmer	Potter
Small Businesses	Rusty Gilmore	Water Well Driller	Dallam
Electrical Generating Utilities	Rick Gibson[2]	Xcel Energy	Potter (serve entire region)
River Authorities	Jim Derington	Palo Duro RA	Hansford
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
	Kent Satterwhite	Canadian River Municipal Water Authority	Hutchinson and 3 member cities in the region
Water Utilities	Dean Cooke	TCW Supply	Hutchinson
Groundwater Management Areas	Danny Krienke	GMA#1	Ochiltree and 17 other counties
	Amy Crowell	GMA#6	Collingsworth, Childress and Hall
Higher Education	John Sweeten	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.
2. Rick Gibson resigned from the PWPG in March 2015 as the representative for electoral generating utilities. He was appointed in April 2015 as the environmental representative.

The TWDB planning guidelines require each regional water plan to include eleven chapters, which are addressed in the following sections of this report. The chapters are:

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

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 fourth 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 2011 Panhandle Regional Water Plan. Every chapter has been reviewed, updated and in some places, reorganized. Some of the new and/or changed information in this plan include:

- Extension of the planning period through 2070;
- Updated population projections based on the 2010 Census Population;
- 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
- New chapter that consolidates all drought recommendations and identifies potential emergency interconnections during drought;
- New chapter that identifies previously recommended strategies that have been implemented and highlights the major differences in this plan from previous plans; and
- Updated Legislative and other recommendations

1.2 Senate Bill 1 and Senate Bill 2

Senate Bill 1 (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 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 fourth round of planning culminates with the 2016 Regional Water Plan, which is to be submitted to TWDB by December 1, 2015. The TWDB must then approve and incorporate these plans into an all-inclusive state plan that is due in January 2017. 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 90 percent of water used for agricultural purposes in 2010. In 2010, the region accounted for 1.5 percent of the State's total population and about 13 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 requirements. 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, implementation of new crop types, and the use of more efficient irrigation technology.

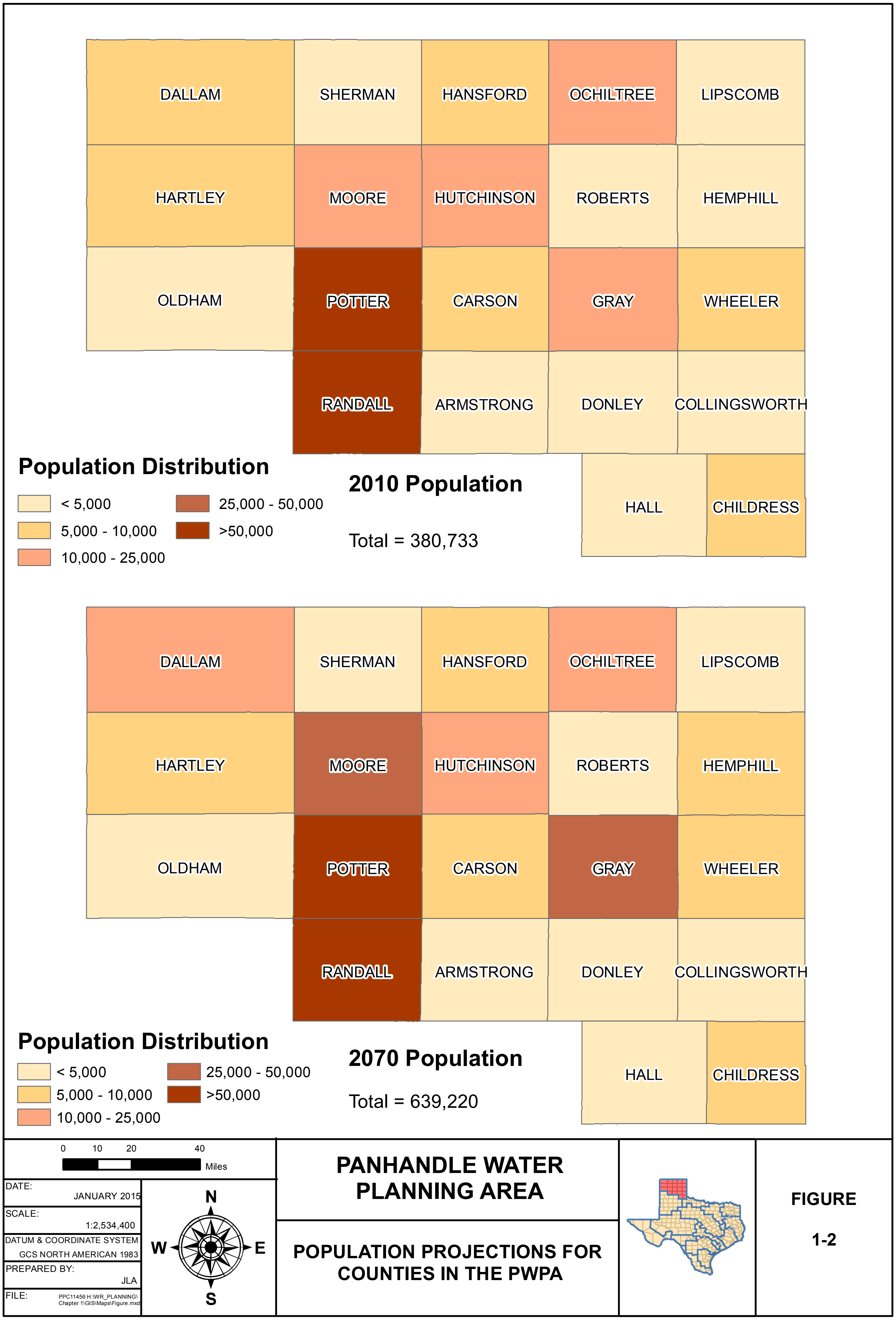
The PWPG is composed of 22 members (Table 1-1), who collectively represent the interest of the public, industry, agriculture, environment, river authorities, counties, municipalities, water districts, water utilities, small business, electrical generation, higher education, and groundwater management 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

According to the 2010 Census, the Texas state population was approximately 25.1 million people. The PWPA accounted for 1.5 percent of the total state population in 2010. The 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. Figure 1-2 shows the distribution of the population across the PWPA for 2010 and the projected populations in 2070. These estimates, developed in 2013 by the PWPG, are divided by city and smaller populated areas and totaled by county. Table 1-2 shows the cities with populations greater than 500 by county.

1.3.2 Economic Activities

Table 1-3 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 per capita income for counties in the PWPA is shown for the year 2012, with an average for the PWPA around $24,600. Payroll data, which is available for 2012, show the total payroll in the PWPA to exceed $5 billion, with approximately 45 percent of the payroll reported in Potter County.


DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
Population Distribution
< 5,000
5,000 - 10,000
10,000 - 25,000
25,000 - 50,000
>50,000
2010 Population
Total = 380,733
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
Population Distribution
< 5,000
5,000 - 10,000
10,000 - 25,000
25,000 - 50,000
>50,000
2070 Population
Total = 639,220
0 10 20 40
Miles
DATE: JANUARY 2015
SCALE: 1:2,534,400
DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983
PREPARED BY: JLA
FILE: PPC11456 H:\WR_PLANNING\Chapter 1\GIS\Maps\Figure.mxd
N
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PANHANDLE WATER PLANNING AREA
POPULATION PROJECTIONS FOR COUNTIES IN THE PWPA
FIGURE
1-2

Table 1-2: Major Cities in the PWPA

County	Population > 10,000	500<Population<10,000
Armstrong		Claude
Carson		Groom, Panhandle, White Deer
Childress		Childress
Collingsworth		Wellington
Dallam		Dalhart, Texline
Donley		Clarendon
Gray	Pampa	McLean
Hall		Memphis
Hansford		Gruver, Spearman
Hartley		Dalhart
Hemphill		Canadian
Hutchinson	Borger	Fritch, Stinnett
Lipscomb		Booker
Moore	Dumas	Cactus, Fritch, Sunray
Ochiltree		Booker, Perryton
Oldham		Vega
Potter	Amarillo	
Randall	Amarillo, Canyon	Happy, Lake Tanglewood
Roberts		Miami
Sherman		Stratford
Wheeler		Shamrock, Wheeler

Source: 2010 Census

Table 1-3: Economic Activities of Counties in the PWPA

	Total Payroll[1] ($)	Per capita income[2] ($)	Major Economic Activities			
County	**2012**	**2013**	**Agribusiness**	**Manufacturing**	**Petroleum**	**Tourism**
Armstrong	6,307,000	26,823	X			X
Carson	25,577,000	26,827	X		X	
Childress	37,605,000	20,248	X			X
Collingsworth	14,002,000	26,823	X			
Dallam	56,154,000	19,752	X	X		X
Donley	9,248,000	21,904	X	X		X
Gray	294,185,000	21,738	X	X	X	
Hall	13,959,000	19,004	X			
Hansford	46,245,000	23,969	X		X	
Hartley	36,272,000	24,566	X	X	X	
Hemphill	77,290,000	29,544	X		X	X
Hutchinson	344,257,000	23,383	X	X	X	X
Lipscomb	34,274,000	29,017	X		X	
Moore	309,191,000	19,770	X		X	
Ochiltree	217,391,000	23,382	X		X	
Oldham	16,061,000	22,519	X			
Potter	2,309,528,000	19,861	X	X	X	X
Randall	1,200,112,000	29,124	X	X		X
Roberts	4,262,000	36,172	X		X	
Sherman	17,876,000	21,936	X			X
Wheeler	111,034,000	30,097	X		X	X
Total	**5,180,830,000**					
Average	**246,706,190**	**24,593**				

[1] 2012 Economic Census
[2] Census 2010 Fact Finder

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.

1.4 Wholesale Water Providers

The term Wholesale Water Provider (WWP) was created within SB2 in order to include major providers of water for municipal and manufacturing use in the regional planning process. WWPs are defined as follows:

> *"Any person or entity, including river authorities and irrigation districts, that has contracts to sell more than 1,000 acre-feet of water wholesale in any one year during the five years immediately preceding the adoption of the last regional water plan. The regional water planning groups shall include as wholesale water providers other persons and entities that enter or that the regional water planning group expects or recommends to enter contracts to sell more than 1,000 acre-feet of water wholesale during the period covered by the plan."*

The PWPA has designated six WWPs.

- Canadian River Municipal Water Authority
- City of Amarillo
- City of Borger
- City of Cactus
- Greenbelt Municipal and Industrial Water Authority
- Palo Duro River 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 the Authority 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 more than 460,000 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 444,833 acres in Roberts and adjacent counties. The Authority 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 190,000 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 services over 5,709 active water accounts. 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), County other, and manufacturing needs.

1.4.4 City of Cactus

The City of Cactus is in Moore County and currently services over 745 active water accounts. The source of supply for Cactus is groundwater from the Ogallala aquifer. Cactus supplies wholesale water to County other and manufacturing needs.

1.4.6 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 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.

1.4.7 Palo Duro River Authority (PDRA)

The Palo Duro River Authority owns and operates Palo Duro Reservoir. The Palo Duro Reservoir is located on Palo Duro River in Hansford County. The lake was completed in 1991. The Authority was authorized to serve Hansford and Moore Counties and the City of Stinnett. PDRA currently does not provide water to any member city.

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 1-4). 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 1-4: 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

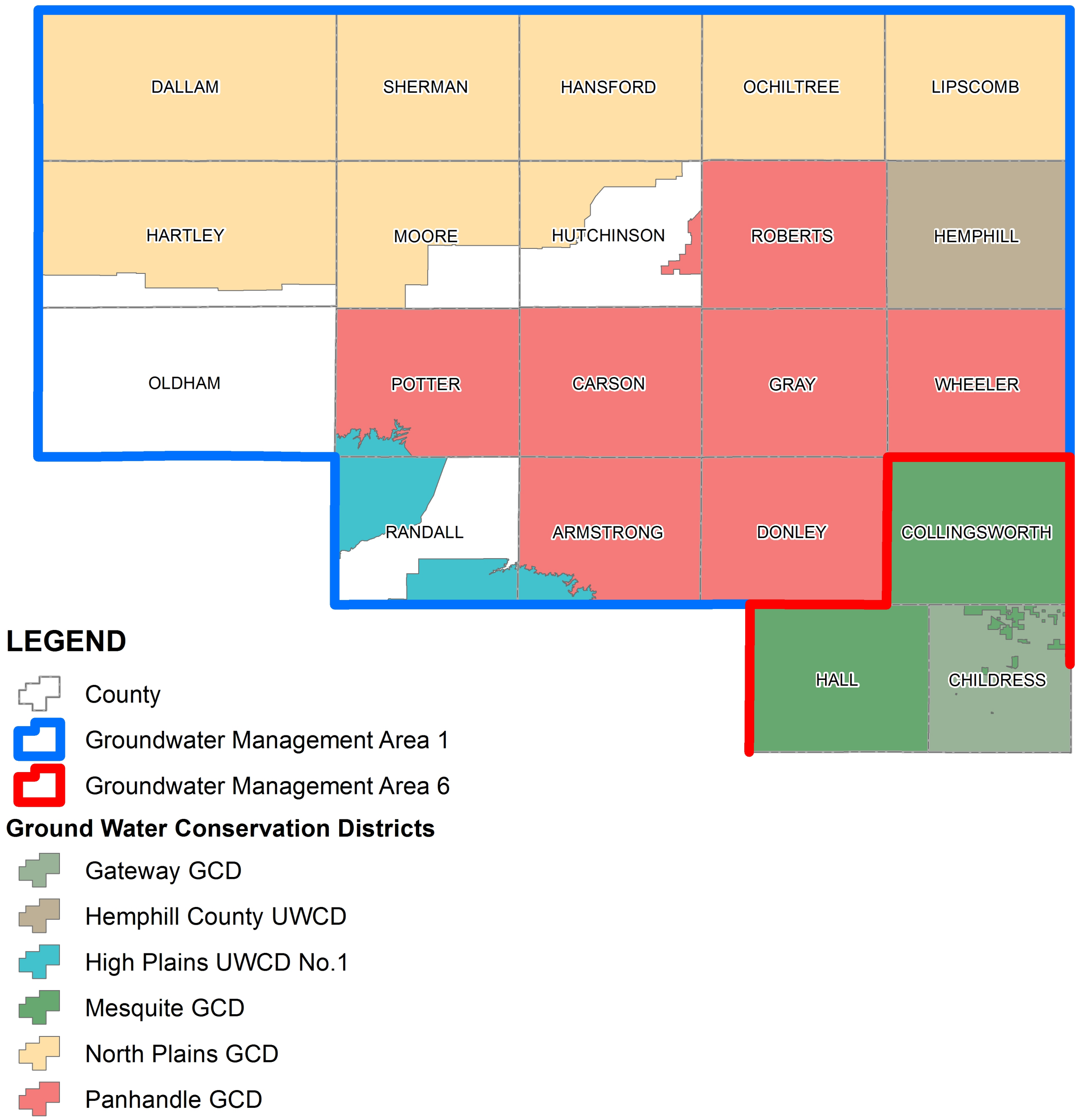
As part of Senate Bill 1, the Legislature established that groundwater conservation districts (GCDs) were the preferred entities for groundwater management in Texas. SB1 contained provisions that required the GCDs to prepare management plans. One of the key provisions of SB1 requires TCEQ to determine areas that warrant special consideration and for those areas to encourage the formation of a new groundwater conservation district or the incorporation of these areas into existing districts. Each groundwater conservation district is required to submit a water management plan to the TWDB for certification.

Senate Bill 2 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 and/or development by the RWPGs. 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 TWDB was also required to calculate the Modeled Available Groundwater 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 used for water supply, including the development of 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 1-5. 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 desired future conditions 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.



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N W E S

PANHANDLE WATER PLANNING AREA

Groundwater Conservation Districts & Groundwater Managment Areas

Location Map

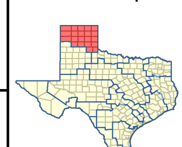


FIGURE 1-3

Table 1-5: Ground Water Conservation Districts in PWPA

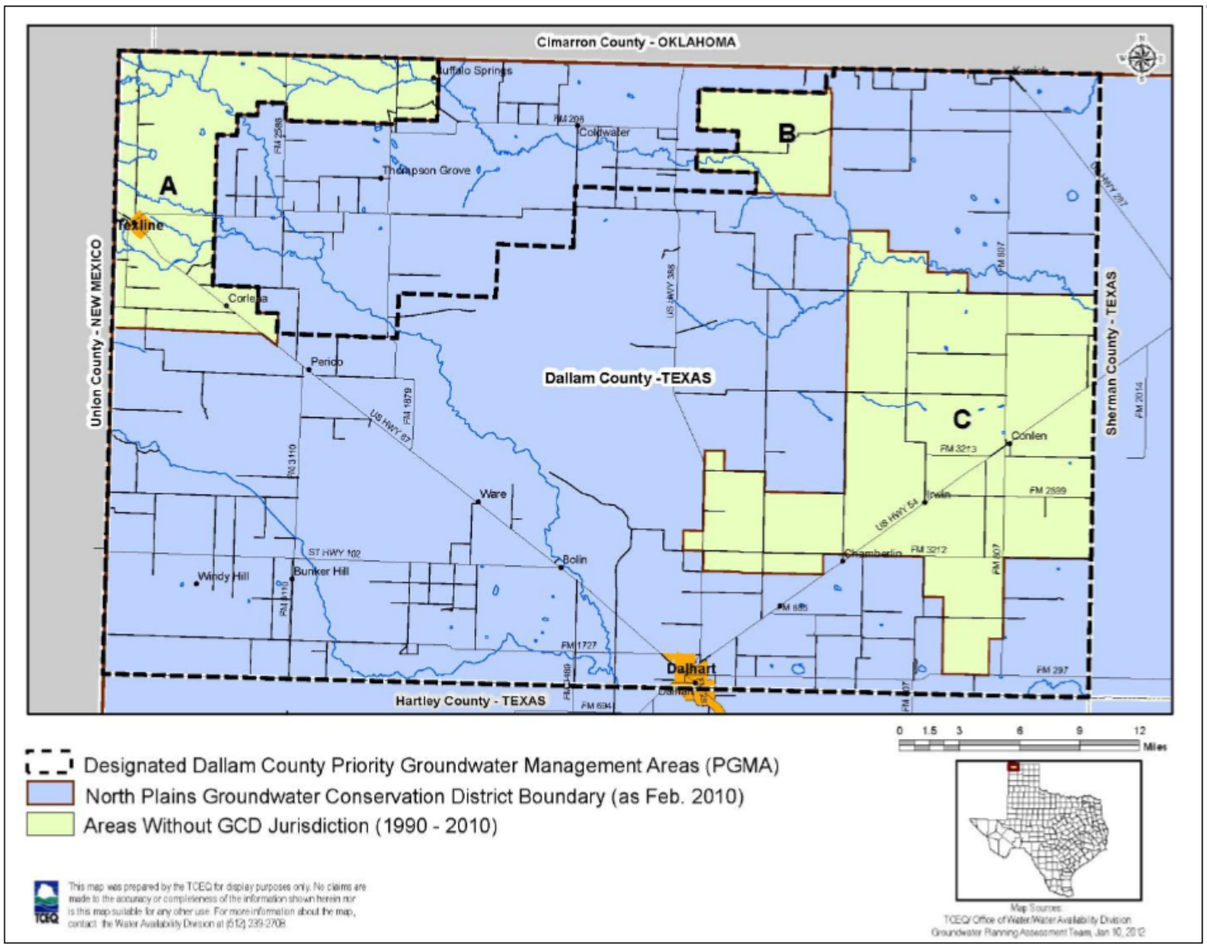
Groundwater District	Counties Served in PWPA	Aquifers
North Plains Groundwater Conservation District	Moore, Hutchinson, Sherman, Hartley, Dallam, Hansford, Ochiltree, Lipscomb	Ogallala Rita Blanca Dockum
Panhandle Groundwater Conservation District	Carson, Roberts, Gray, Donley, Armstrong, Potter, Hutchinson,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

For areas within the state that are not regulated by a groundwater conservation district, 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, who 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 Groundwater Conservation District (GCD). Otherwise, the TCEQ is required to create a GCD or to recommend that the area be added to an existing district. The TWDB works with the TCEQ to produce a legislative report every two years on the status of PGMAs in the state. The PGMA process is completely independent of the current GMA process and each process has different goals. The goal of the PGMA process is to establish GCDs in these designated areas so that there will be a regulating entity to address the identified groundwater issues. PGMAs are still relevant as long as there remain portions within these designated areas without GCDs. 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. Subsequently, the North Plains GCD approved the Order on March 9, 2010. 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. After further analysis of tax base issues, the TCEQ confirmed the previous recommendation. 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. To the PWPGs knowledge, there are no additional restrictions promulgated by the Dallam County Commissioners Court.

Figure 1-4: Dallam County PGMA Boundary



Source: (TCEQ)

1.5.2 Aquifers

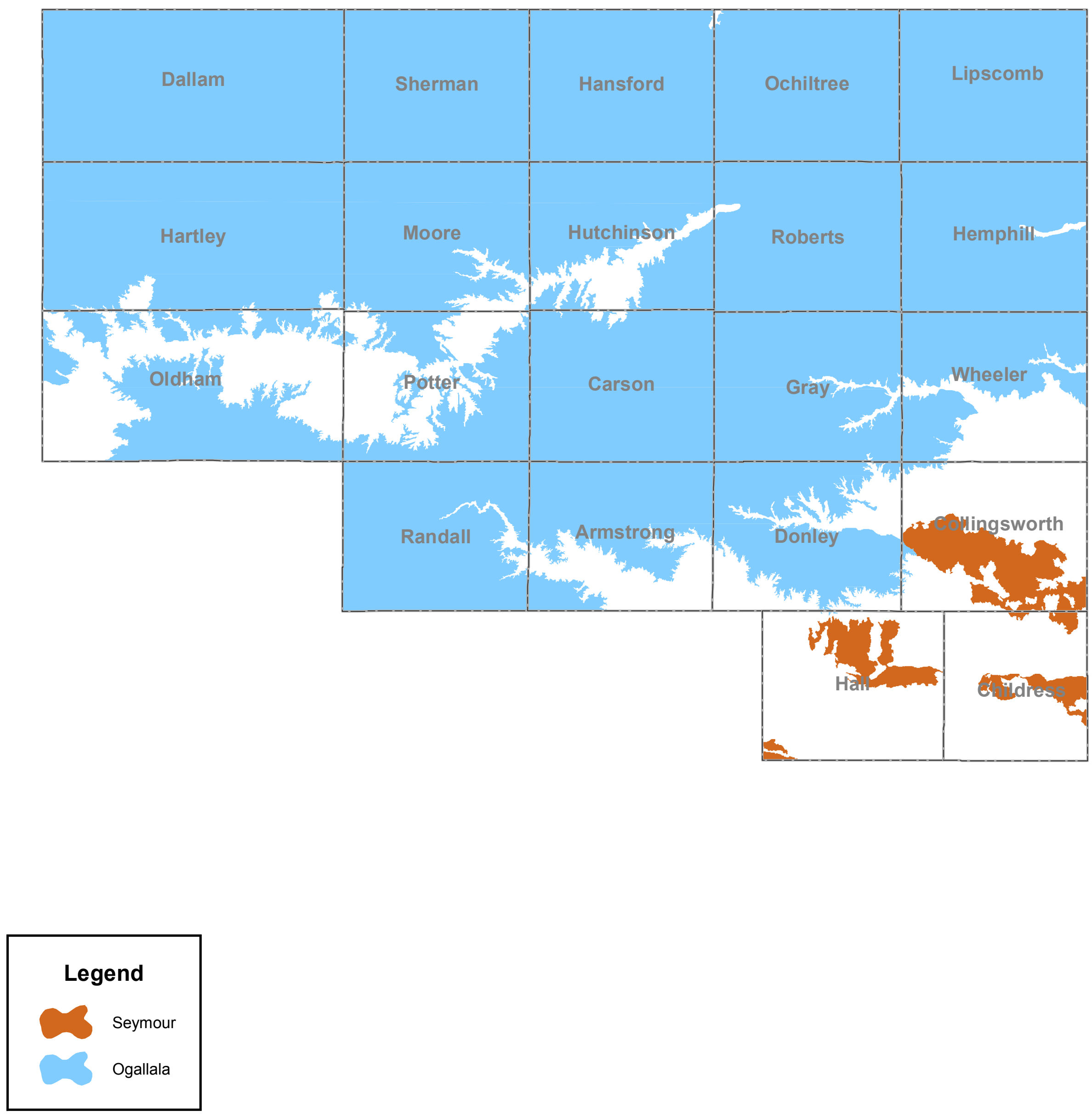
There are two major aquifers in the PWPA, the Ogallala and Seymour aquifers (Figure 1-5), and three minor aquifers, Blaine, Rita Blanca, and Dockum (Figure 1-6). The Whitehorse Formation is recognized by local residents as a regional supply source but has not been quantitatively characterized and is therefore not included as a distinct supply source in this plan. All aquifers serve as water sources for various uses in the PWPA.

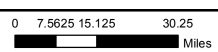
Ogallala Aquifer

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 approximately parallel 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 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. Previous estimates indicate that the long term average annual recharge rate is less than 3 inches per year. 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.





PANHANDLE WATER PLANNING AREA

MAJOR AQUIFERS IN PWPA

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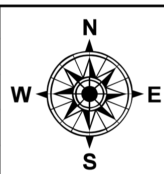
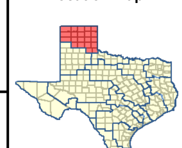
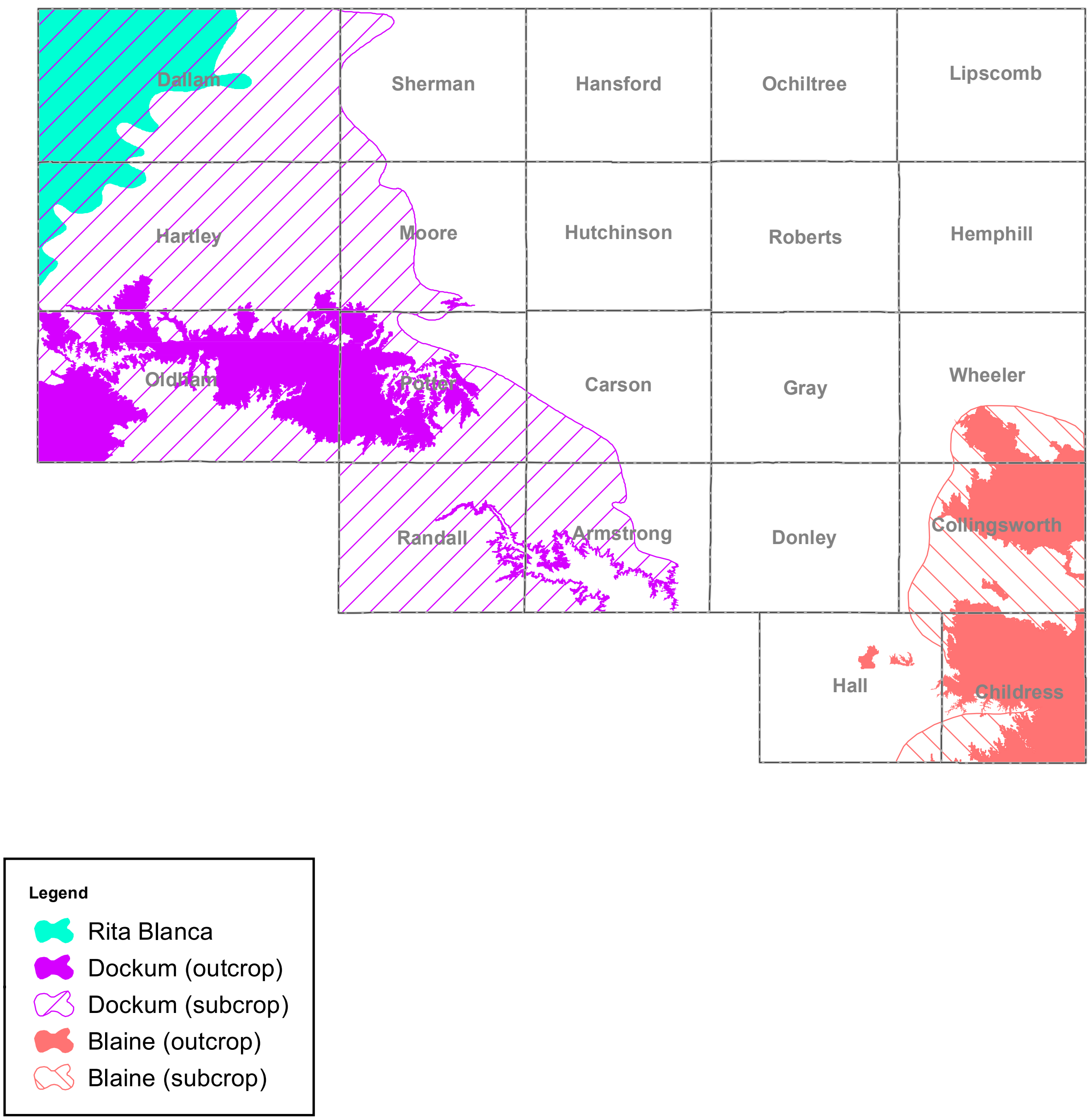


Location Map



FIGURE

1-5



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N W E S

PANHANDLE WATER PLANNING AREA

MINOR AQUIFERS IN PWPA

Location Map

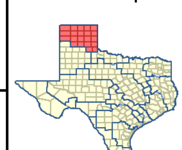


FIGURE 1-6

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 100 feet from predevelopment to 2000 and continue to drop into the future. Conservation efforts, implementation of efficiency technologies, crop research, reduced commodity prices and increased power costs have resulted in a reduction in the rate of water level declines.

Based on the storage amounts in using Northern Ogallala Groundwater Availability Model (Intera, 2010) and the Southern Ogallala GAM, the Ogallala aquifer has a total storage of about 250 million acre-feet within the 18 counties underlain by this aquifer in PWPA (Table 1-6). Historical estimates of water in storage in the Ogallala aquifer are about 246 million acre feet in 2000, which was based on an earlier versions of the GAM. In 2010, the Northern Ogallala GAM was updated using new well information and updated historical pumpage. This update included revisions to the base elevations of the aquifer, which resulted in some counties having less available storage and other counties having more storage. The counties with the greatest relative gains in storage are Dallam, Roberts, Lipscomb and Moore. The counties with less storage include the southern counties in the region: Armstrong, Donley and Potter. Overall, the Intera GAM shows greater total water in storage in the Ogallala aquifer today than estimated in 2000 with the 2004 Dutton model.

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.

Table 1-6: Estimated Groundwater Storage Volume of the Ogallala Aquifer in the PWPA

County	1990 Storage [1]	2000 GAM Storage [2]	2010 GAM Storage [2]	2010 GAM Storage [3]
	(million ac-ft)			
Armstrong	3.64	4.05	4.01	3.641
Carson	13.19	15.28	14.07	13.78
Childress	NA	NA	NA	NA
Collingsworth	NA	NA	NA	NA
Dallam	29.97	17.6	14.42	22.151
Donley	8.09	6.25	5.73	5.331
Gray	12.96	13.65	13.13	13.06
Hall	NA	NA	NA	NA
Hansford	23.27	21.69	20.41	20.99
Hartley	27.82	24.93	21.75	25.141
Hemphill	16.57	15.64	15.47	14.81
Hutchinson	10.54	11.11	10.55	11.07
Lipscomb	20.82	18.64	18.46	20.461
Moore	13.2	10.66	9.07	11.551
Ochiltree	18.57	19.8	19.10	19.77
Oldham	1.14	2.52	2.47	2.37
Potter	3.07	3.05	2.92	2.311
Randall	4.51	6.26	6.02	6.13
Roberts	27.62	27.49	27.08	31.121
Sherman	21.88	19.5	17.29	18.23
Wheeler	8.45	7.49	7.42	7.7
Total Storage	**265.31**	**245.61**	**229.37**	**249.62**

[1] Wyatt, 1996
[2] Dutton, 2004
[3] Intera, 2010
Notes:
1. The Intera 2010 Northern Ogallala GAM updated the aquifer base elevation, resulting in greater storage in some counties and less storage in others.
2. Data include results from both the Northern Ogallala and Southern Ogallala aquifers GAMs

NA = data not available or the Ogallala aquifer does not occur in these counties.

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 these scattered alluvial aquifers is estimated to be 3.18 million ac-ft based on 75 percent of the total storage. Annual effective recharge to the aquifer is approximately 215,200 ac-ft, or 5 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 gal/min and range from less than 100 gal/min to as much as 1,300 gal/min.

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).

According to a report published by the TWDB in 2003, the base of the Dockum Group aquifer is mudstones at elevations ranging from 1,200 ft. MSL in the south (Crockett County) to 3,200 ft. MSL in Oldham County, and to 3,400 ft. MSL in Dallam County. Saturated thicknesses range from 100 ft. to 2,000 ft. The water table ranges from approximately 3,800-4,000 ft. MSL in Oldham, Hartley, and Dallam counties to 3,200 ft. MSL or less in Potter, Carson, Armstrong, Moore and Sherman counties. 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. (Recharge reported in the 2001 plan is assumed for this update.) Estimates of the total volumes of water in storage are reported in Table 1-7.

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).

Table 1-7: Dockum Aquifer Storage and Recharge

County*	Storage[1] (ac-ft)	Annual Recharge[2] (ac-ft)
Armstrong	1,948,600	658
Carson	566,700	0
Dallam	6,561,800	0
Hartley	6,374,300	232
Moore	1,588,300	25
Oldham	6,544,400	5,349
Potter	3,051,500	2,312
Randall	3,974,800	217
Total	**30,610,400**	**8,793**

[1] TWDB, 2003
[2] Final Report Groundwater Availability Model for the Dockum GAM, October 2008
*The Dockum is absent or nearly so under the remaining counties in the PWPA.

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 (TWDB, 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 across 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. This plan and its implementation are not expected to have any impact to navigable waters or navigation within the state.

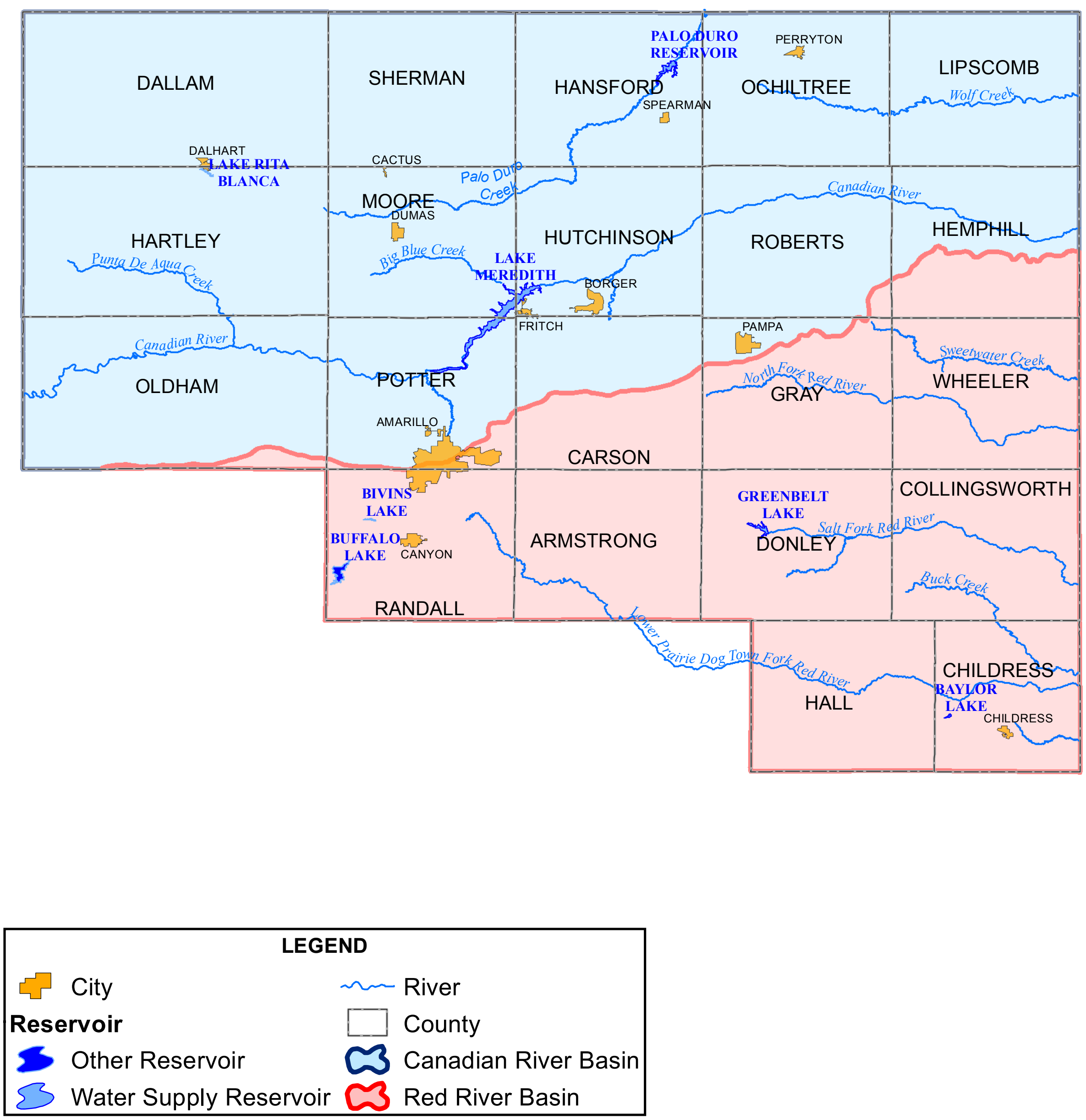
Surface Water Management and Classification

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. Individual surface water rights greater than 1,000 acre-feet per year for both the Canadian River Basin and the Red River Basin and actual use are shown in Table 1-8. The data show that permitted water rights total 177,690 acre-feet per year and reported use decreasing from 46,259 acre-feet per year in 2006 to 12,143 acre-feet per year in 2011.

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 2012 State of Texas Water Quality Inventory (TCEQ, 2012), 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. Nine segments in the PWPA were identified on the final 2012 303(d) list and are shown in Table 1-9. All nine segments are classified by TCEQ as low priority and may be scheduled for Total Maximum Daily Load (TMDL) development.

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.



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N W E S

PANHANDLE WATER PLANNING AREA

SURFACE WATER FEATURES IN PWPA

Location Map

FIGURE 1-7

Table 1-8: 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[1]	Use in 2011[1]
Canadian River Basin						
Hutchinson	CRMWA	Lake Meredith	Municipal	100,000	39,353	7,894
			Industrial	51,200	2,482	552
Hansford	Palo Duro River Authority	Palo Duro Reservoir	Municipal	10,460	0	0
Red River Basin						
Donley	Greenbelt MIWA	Greenbelt Reservoir	Municipal	14,530	4,424	3,697
			Industrial	500	0	0
			Irrigation	250	0	0
			Mining	750	0	0
Total				**177,690**	**46,259**	**12,143**

Source: TCEQ, 2014
[1] A "0" means that zero acre-feet of water was reported as used. A blank means that no report was submitted.
Notes:
Inter-regional water transfers: Approximately 50% of permitted amount of total water is authorized for use in Llano Estacado Planning Area from PWPA (Lake Meredith). Additionally, there are 99 water rights of <1,000 AF each in the region totaling 7,989 AF of permitted water.

Table 1-9: 2012 303d Listed Segments in the PWPA

		Constituents of Concern						
Water Body	**Segment Number**	**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						
Upper Prairie Dog Town Fork of Red River	0229		X					
Sweetwater Creek	0299A	X						

Source: TCEQ 2012

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 measured near

Canadian, Texas, approximately 22 miles upstream of the Texas-Oklahoma state line, averages 89 cubic feet per second (CFS), or 64,700 acre-feet per year.

In 2010, less than two percent of the water use in the Canadian River Basin was from surface water sources. Due to the scarcity of locally-developable surface water supplies, any additional water needed for the basin will likely come from groundwater or reuse of present supplies. Since the 2011 PWPA plan was completed, the region has experienced record low inflows to Lake Meredith and Palo Duro Reservoir and numerous water providers are considering groundwater options for future supplies.

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 used within the PWPA of the Red River Basin.

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.

According to the TWDB estimates of water use during 2010, about 2 percent of the total water used in the Red River Basin portion of the PWPA was surface water. Of this amount approximately 8,000 acre-feet was from imported water from the Canadian River Basin (Lake Meredith). Most of the remaining surface water use is associated with municipal use from Greenbelt Reservoir and local supplies for livestock use (TWDB, 2010).

1.5.5 Reuse Supplies

There is a total of about 18,000 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. 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 1-10 shows the seller, recipient and amount used.

Table 1-10: Reuse Supplies in the PWPA

Seller	Recipient	Current Use[1] (ac-ft/yr)
Amarillo	Xcel Energy	13,333
Borger	Manufacturing	1,045
Canyon	Irrigation	545
Childress	Irrigation	162
Memphis	Irrigation	100
Pampa	Golf Course	220
Panhandle	Irrigation	57
Tyson Foods	Irrigation	700
Wellington	Irrigation	53
Wheeler	Irrigation	51
Xcel Energy	Irrigation	1,500
Total		**17,766**

1. Data obtained from reported use or sales over the past 5 years.

1.6 Current Water Users 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. In 2010, agricultural water use accounted for 92 percent of total water use and includes both irrigation and livestock watering. Irrigated crop use accounts for 90 percent of the total water use, while livestock production accounts for 2 percent of the total and is forecast to nearly double during the planning period.

1.6.1 Municipal Use

The amount of water used for municipal purposes is closely tied to population centers. The TWDB estimates that during 2010, the total municipal water use in the PWPA was 77,832 ac-ft (Table 1-11), which is approximately 4 percent of total water use. Potter and Randall Counties, which contain the City of Amarillo, comprised 62 percent of the municipal water use in the PWPA, while five counties (Armstrong, Donley, Hemphill, Roberts, and Sherman) each comprise less than three percent.

Table 1-11: Historical and Projected Municipal Water Use for the PWPA, (ac-ft/yr)

County	2010	2020	2030	2040	2050	2060	2070
Armstrong	349	447	438	432	429	428	428
Carson	1,361	1,279	1,286	1,284	1,274	1,272	1,272
Childress	1,693	1,822	1,862	1,896	1,938	1,990	2,041
Collingsworth	622	716	737	749	774	794	812
Dallam	1,695	2,183	2,418	2,674	2,938	3,200	3,454
Donley	638	623	606	591	584	583	583
Gray	4,692	4,609	4,965	5,430	6,130	6,691	7,286
Hall	707	702	704	692	689	688	688
Hansford	1,090	1,120	1,164	1,208	1,251	1,304	1,357
Hartley	1,147	1,509	1,561	1,582	1,600	1,624	1,644
Hemphill	731	944	1,023	1,089	1,167	1,240	1,309
Hutchinson	5,600	5,148	5,221	5,193	5,180	5,173	5,171
Lipscomb	637	941	995	1,023	1,071	1,107	1,138
Moore	3,640	5,356	5,974	6,656	7,385	8,182	9,004
Ochiltree	2,261	3,075	3,252	3,456	3,696	3,969	4,268
Oldham	655	647	677	669	667	666	666
Potter	24,701	29,425	32,036	34,932	37,997	41,541	45,316
Randall	23,587	29,017	31,741	34,567	37,655	41,134	44,791
Roberts	168	273	276	272	271	271	271
Sherman	630	654	692	707	728	744	758
Wheeler	1,228	1,147	1,164	1,183	1,220	1,265	1,315
Total	**77,832**	**91,637**	**98,792**	**106,285**	**114,644**	**123,866**	**133,572**

Source: TWDB, 2013

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 the year 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 small diversions from Lake Meredith. Water usage by CRMWA member cities in 2011 is summarized in Table 1-12.

Table 1-12: Water Used by CRMWA Member Cities in the PWPA during 2011

City	Municipal Water Supplied by CRMWA (ac-ft/yr)		
	Surface Water CRMWA	Groundwater CRMWA	Total
Amarillo	3,354	25,086	28,440
Borger	354	3,283	3,638
Pampa	125	2,021	2,146
Total	**3,833**	**30,390**	**34,223**

TWDB projections for municipal water use by decade for 2010 through 2070 are located in Table 1-10. TWDB projected total municipal water use ranges from 91,637 acre-feet per year in 2020 to 133,572 acre-feet per year in 2070. Potter and Randall Counties make up the largest portion of projected municipal water use in the PWPA with approximately 62 percent of the total municipal water use by 2070. Collingsworth, Donley, Hall, Hemphill, Lipscomb, Oldham, Roberts, and Sherman Counties are projected to each use less than one percent of the total.

The amount of water from Lake Meredith available to the three member cities by the CRMWA is based on the available supply in the lake. According to CRMWA, the City of Amarillo is entitled to approximately 37 percent, Borger to 5 percent, and Pampa to 7 percent of the reservoir estimated yield. Just over 50 percent of the yield of Lake Meredith is contracted to cities in the Llano Estacado Region.

Greenbelt MIWA provides surface water from Greenbelt Reservoir for municipal, industrial, mining and irrigation uses. In 2011, Greenbelt MIWA supplied just over 2,100 acre-feet of water to the cities of Childress, Clarendon, Hedley, Memphis, and to the Red River Authority for use in the PWPA. Over 1,100 acre-feet were provided to entities for use in Region B. (TWDB, 2010)

1.6.2 Industrial Use

Industrial use includes mining, manufacturing, and power generation, and accounted for approximately 64,300 ac-ft in 2010. Table 1-13 contains the historical and projected industrial water use for counties in the PWPA.

Mining

Based on TWDB data, mining water use totaled approximately 3,893 acre-feet for the entire region in 2010, approximately 6 percent of the total industrial water used. Potter County had the highest use with 936 acre-feet (TWDB, 2013). 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 44,143 acre-feet for the entire region in 2010, approximately 69 percent of the total industrial water used. Hutchinson County had the highest use with 28,420 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, Moore and Potter are the only counties to have reported water use for power generation activities in 2010. Water use of 16,264 acre-feet accounts for approximately 25 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 most of the 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.

The TWDB projections for industrial water use in the PWPA are located in Table 1-13. Hutchinson and Potter Counties are projected to use the most water for industrial purposes, while Armstrong, Childress, Collingsworth, Dallam, Donley, Hall, and Hartley are projected to use little to no water for industrial purposes in 2020.

Table 1-13: TWDB Historical and Projected Industrial Water Use for the PWPA (ac-ft/yr)

County	2010	2020	2030	2040	2050	2060	2070
Armstrong	0	0	0	0	0	0	0
Carson	624	433	474	513	546	590	638
Childress	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	0
Dallam	6	9	9	10	10	11	11
Donley	0	0	0	0	0	0	0
Gray	488	5,834	6,604	6,829	7,493	7,441	7,496
Hall	0	0	0	0	0	0	0
Hansford	276	635	965	665	374	86	75
Hartley	2	12	12	11	10	9	8
Hemphill	754	2,320	1,769	1,250	738	229	74
Hutchinson	28,420	25,531	27,058	28,419	29,596	31,596	33,775
Lipscomb	376	1,245	913	607	309	201	196
Moore	9,658	9,268	9,565	10,054	10,484	11,194	11,952
Ochiltree	162	824	853	503	161	23	3
Oldham	407	475	563	639	671	737	808
Potter	21,477	36,041	38,414	40,940	43,287	48,437	53,122
Randall	508	589	638	684	722	784	852
Roberts	239	1,502	1,041	611	189	20	2
Sherman	38	35	207	151	98	44	20
Wheeler	865	3,268	2,329	1,413	503	139	119
Total	**64,300**	**88,021**	**91,414**	**93,299**	**95,191**	**101,541**	**109,151**

Source: TWDB, 2013

1.6.3 Agricultural Use

Land Use

Agricultural land use in the PWPA includes irrigated cropland, dryland cropland, and pastureland. Major crops include corn, cotton, hay, peanuts, sorghum, sunflower, soybeans, and wheat. According to 2012 Census of Agriculture estimates presented in Table 1-14, the number of farms has decreased over the last 10 years between 2002 through 2012, but the acres of harvested cropland have increased slightly during that time period. By 2012, total harvested cropland in the PWPA approximated 1,774,401 acres and was distributed between 2,276 farms. In 2012, approximately 71 percent of the harvested cropland was contained in seven counties (Carson, Dallam, Hansford, Hartley, Moore, Ochiltree, and Sherman) on 1,038 farms.

Table 1-14: Number of Farms and Acres of Harvested Cropland

County Name	2002		2007		2012	
	Farms	Acres	Farms	Acres	Farms	Acres
Armstrong	118	(D)	126	79,703	78	51,313
Carson	151	105,259	196	181,185	148	126,938
Childress	119	63,879	142	77,509	125	(D)
Collingsworth	215	89,709	171	98,829	150	81,282
Dallam	213	250,350	218	317,249	162	215,276
Donley	151	37,271	124	31,922	100	27,403
Gray	118	58,177	115	82,596	96	71,918
Hall	126	99,041	160	105,536	89	56,110
Hansford	147	127,477	155	249,487	176	222,287
Hartley	140	159,433	152	241,558	149	186,954
Hemphill	71	16,331	81	23,043	56	(D)
Hutchinson	61	(D)	68	97,920	53	59,259
Lipscomb	111	(D)	101	60,283	61	42,431
Moore	139	147,854	162	219,086	112	166,594
Ochiltree	179	(D)	230	263,068	168	172,086
Oldham	40	14,541	67	55,996	34	16,591
Potter	40	(D)	61	27,884	35	(D)
Randall	194	71,410	259	106,682	149	67,691
Roberts	22	15,535	34	28,223	24	(D)
Sherman	183	220,226	156	240,804	123	166,946
Wheeler	224	47,346	174	51,730	188	43,322
Total	**2,762**	**1,523,839**	**2,952**	**2,640,293**	**2,276**	**1,774,401**

Source: National Agricultural Statistics Service, Table 9, 2012, 2007, 2002 Census of Agriculture available at http://www.nass.usda.gov/census/; 2007 Texas Census of Agriculture available at http://www.agcensus.usda.gov/Publications/2007/index.asp
(D) Withheld to avoid disclosing data for individual farms

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. The 2010 demands shown in Table 1-15 best represent current irrigation water use. Irrigation for crop production represents the most significant use of water and accounts for approximately 91 percent of crop receipts within the PWPA in 2010. According to TWDB data, use of irrigation water totaled approximately 1,619,095 acre-feet in 2010. Five counties, Dallam, Hansford, Hartley, Moore, and Sherman, accounted for approximately 76 percent of the total irrigation water applied in 2010 (TWDB, 2013).

Table 1-15: Historical and Projected Irrigation Water Use for the PWPA (ac- ft/yr)

County	2010	2020	2030	2040	2050	2060	2070
Armstrong	4,396	4,194	3,990	3,708	3,296	2,884	2,472
Carson	60,069	55,702	52,838	48,776	43,356	37,937	32,517
Childress	9,456	7,308	7,026	6,601	5,868	5,134	4,401
Collingsworth	48,666	17,943	17,276	16,255	14,449	12,643	10,837
Dallam	363,839	369,864	347,524	318,795	283,373	247,952	212,530
Donley	25,523	24,080	23,203	21,847	19,419	16,992	14,564
Gray	22,721	21,291	20,104	18,539	16,479	14,419	12,359
Hall	34,122	10,134	9,806	9,274	8,243	7,213	6,182
Hansford	128,632	134,902	126,481	115,759	102,897	90,035	77,173
Hartley	340,554	345,365	325,882	300,290	266,924	233,559	200,193
Hemphill	4,549	1,907	1,814	1,685	1,498	1,311	1,124
Hutchinson	40,372	40,008	37,671	34,635	30,786	26,938	23,090
Lipscomb	31,415	20,009	19,014	17,650	15,689	13,728	11,767
Moore	162,595	143,028	134,395	123,290	109,591	95,892	82,193
Ochiltree	60,484	57,243	53,825	49,414	43,923	38,433	32,942
Oldham	4,186	3,937	3,768	3,524	3,133	2,741	2,350
Potter	1,191	3,427	3,292	3,091	2,748	2,404	2,061
Randall	18,419	18,000	17,156	15,976	14,201	12,426	10,650
Roberts	7,362	5,958	5,609	5,155	4,582	4,009	3,437
Sherman	236,631	220,966	207,757	190,687	169,499	148,312	127,125
Wheeler	13,913	8,203	7,983	7,433	6,607	5,781	4,955
Total	**1,619,095**	**1,513,469**	**1,426,414**	**1,312,384**	**1,166,561**	**1,020,743**	**874,922**

Source: TWDB 2013

Due to new technologies, economic considerations, and changing crop acreages the irrigation water use projections for future decades in the planning period will need to be reviewed and possibly revised with each plan update to accurately reflect changes in the farming community.

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 other agricultural uses in the region.

Estimating livestock water consumption consists of estimating water consumption for a livestock unit and the total number of livestock. The Texas Agricultural Statistics service provides current and historical numbers of livestock by livestock type and county. Texas A&M AgriLife, working together with representatives of the livestock industry, developed updated data on 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 livestock for each livestock type for each county.

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 kinds 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, sheep and lambs, and hogs and pigs.

Total livestock water use for the PWPA in 2010 was estimated at 32,295 acre-feet. Table 1-16 contains TWDB estimates of livestock water use by county supplied by surface and groundwater sources. Hansford County and Hartley County accounted for the most livestock water use in the region with Hansford using 3,759 acre-feet and Hartley using 5,778 acre-feet. Approximately 79 percent of the total livestock water use was supplied from groundwater sources.

The majority of current livestock water used in the PWPA is accounted for by feedlot cattle and swine production. The largest inventory of cattle on feed are in Hansford and Hartley counties. Other counties with more than 100,000 head feedlot capacity are: Dallam, Moore, Ochiltree, Randall and Sherman. Swine production is concentrated generally in counties along the northern portion of the PWPA.

Methods used to develop TWDB livestock water use projections were also evaluated in the PWPG agricultural water use study and new projections were developed (Table 1-17). Seven counties, Dallam, Hansford, Hartley, Moore, Ochiltree, Randall, and Sherman, used approximately 67 percent of the total livestock water use in the PWPA in 2010, and are projected to use more than 73 percent by 2070.

Table 1-16: Estimates of Livestock Water Use in the PWPA during 2010

County	Surface Water (ac-ft)	Groundwater (ac-ft)	Total
Armstrong	50	448	498
Carson	71	631	702
Childress	31	276	307
Collingsworth	14	465	479
Dallam	603	2,410	3,013
Donley	174	696	870
Gray	396	1,183	1,579
Hall	75	301	376
Hansford	1,128	2,631	3,759
Hartley	1,733	4,045	5,778
Hemphill	159	902	1,061
Hutchinson	122	368	490
Lipscomb	79	716	795
Moore	358	2,026	2,384
Ochiltree	144	1,300	1,444
Oldham	442	663	1,105
Potter	115	653	768
Randall	615	2,462	3,077
Roberts	48	273	321
Sherman	216	1,947	2,163
Wheeler	331	995	1,326
Total	**6,904**	**25,391**	**32,295**

Source: TWDB, 2010

Table 1-17: Historical and Projected Livestock Water Use in the PWPA (ac-ft/yr)

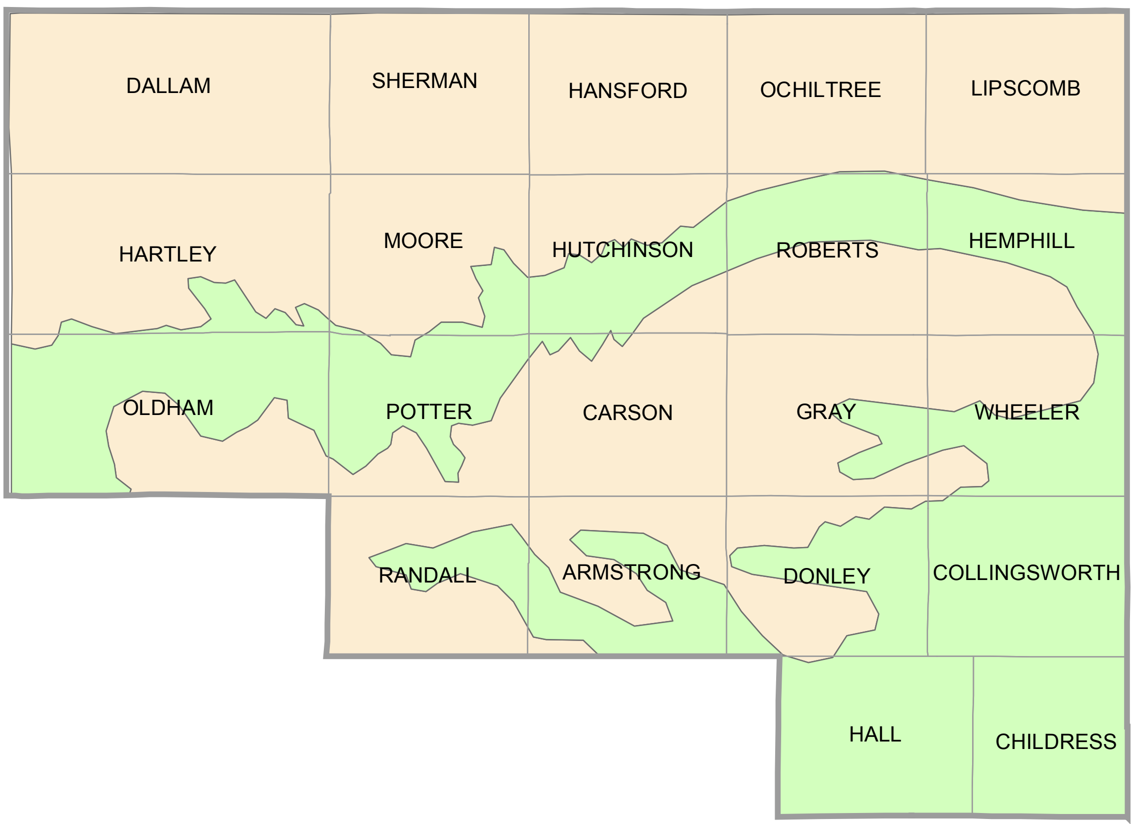
County	2010	2020	2030	2040	2050	2060	2070
Armstrong	498	645	649	652	656	659	663
Carson	702	692	696	700	704	709	713
Childress	307	490	493	495	497	500	503
Collingsworth	479	600	603	605	608	611	614
Dallam	3,013	4,437	4,669	4,920	5,191	5,485	5,803
Donley	870	1,330	1,332	1,333	1,335	1,337	1,339
Gray	1,579	1,352	1,378	1,407	1,438	1,473	1,511
Hall	376	336	337	339	340	341	343
Hansford	3,759	3,432	3,574	3,724	3,881	4,046	4,219
Hartley	5,778	6,498	6,977	7,498	8,066	8,684	9,359
Hemphill	1,061	1,275	1,279	1,284	1,289	1,295	1,302
Hutchinson	490	847	873	903	935	971	1,010
Lipscomb	795	947	969	993	1,020	1,050	1,083
Moore	2,384	3,676	3,906	4,155	4,424	4,716	5,032
Ochiltree	1,444	4,216	3,632	3,729	3,832	3,942	4,058
Oldham	1,105	1,229	1,231	1,234	1,237	1,240	1,243
Potter	768	481	482	484	486	488	491
Randall	3,077	2,654	2,665	2,677	2,690	2,704	2,719
Roberts	321	369	369	370	371	372	373
Sherman	2,163	3,449	3,631	3,825	4,034	4,257	4,497
Wheeler	1,326	1,577	1,680	1,682	1,684	1,687	1,689
Total	**32,295**	**40,532**	**41,425**	**43,009**	**44,718**	**46,567**	**48,564**

Source: TWDB 2013

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.



LEGEND

REGIONS

- High Plains
- Rolling Plains

0 7.625 15.25 30.5 Miles

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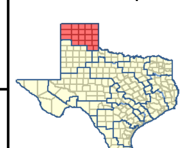
N W E S

PANHANDLE WATER PLANNING AREA

NATURAL REGIONS

Location Map



FIGURE

1-8

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.

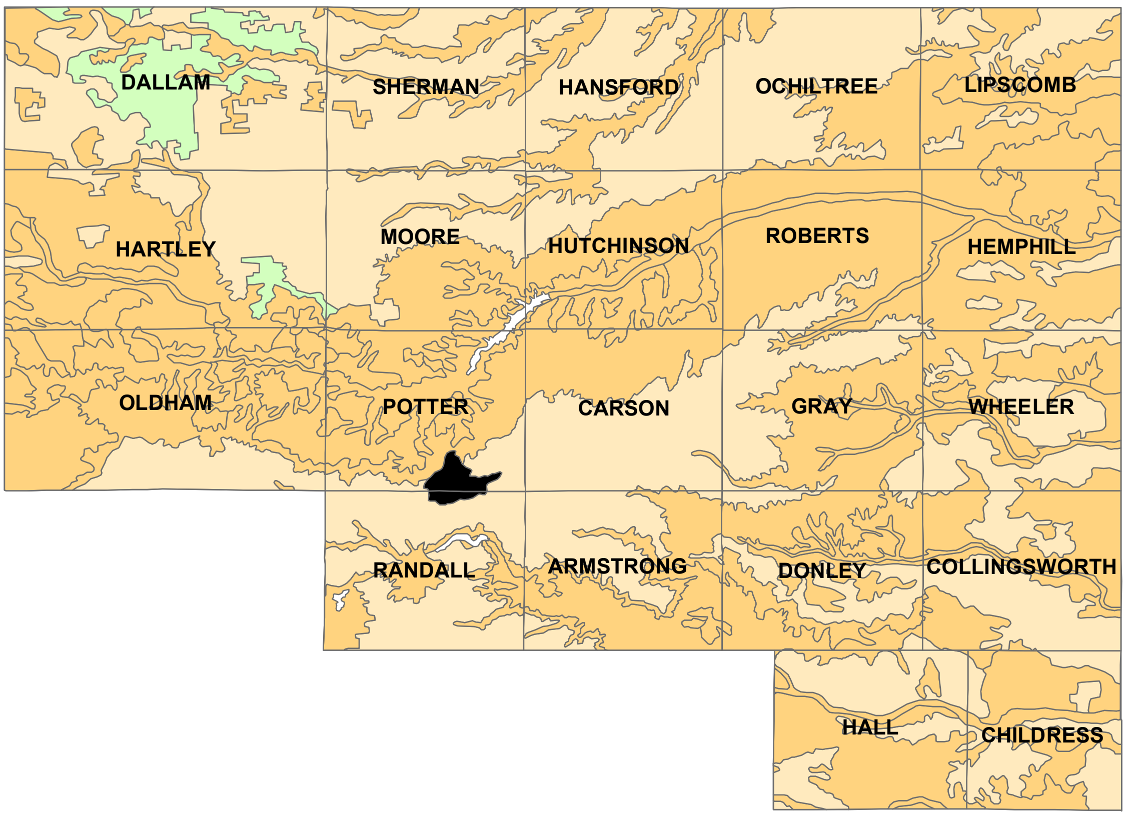
1.7.2 Regional Vegetation

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.



LEGEND

- Brush
- Crops
- Grass
- Urban

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N W E S

PANHANDLE WATER PLANNING AREA

REGIONAL VEGETATION

Location Map

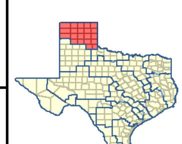


FIGURE 1-9

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 1 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 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.

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).

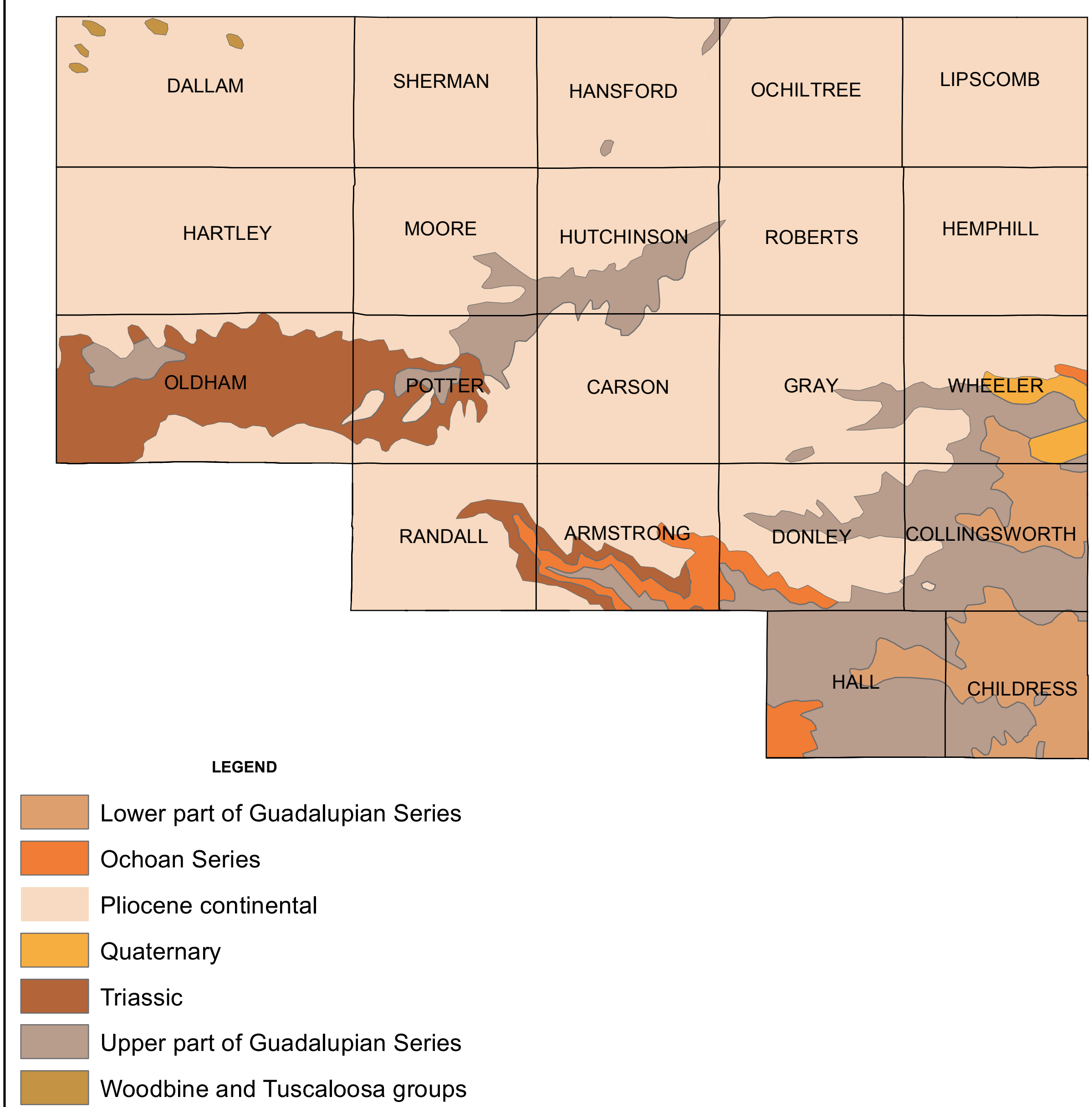
1.7.4 Mined Resources

Natural resources that are mined in the PWPA (Table 1-18) 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. 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 1-18: 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	
Hemphill					X	X	
Hutchinson	X	X			X	X	
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



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N W E S

PANHANDLE WATER PLANNING AREA

REGIONAL GEOLOGY

Location Map

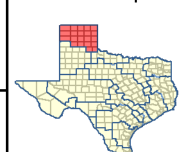


FIGURE 1-10

1.7.5 Soils

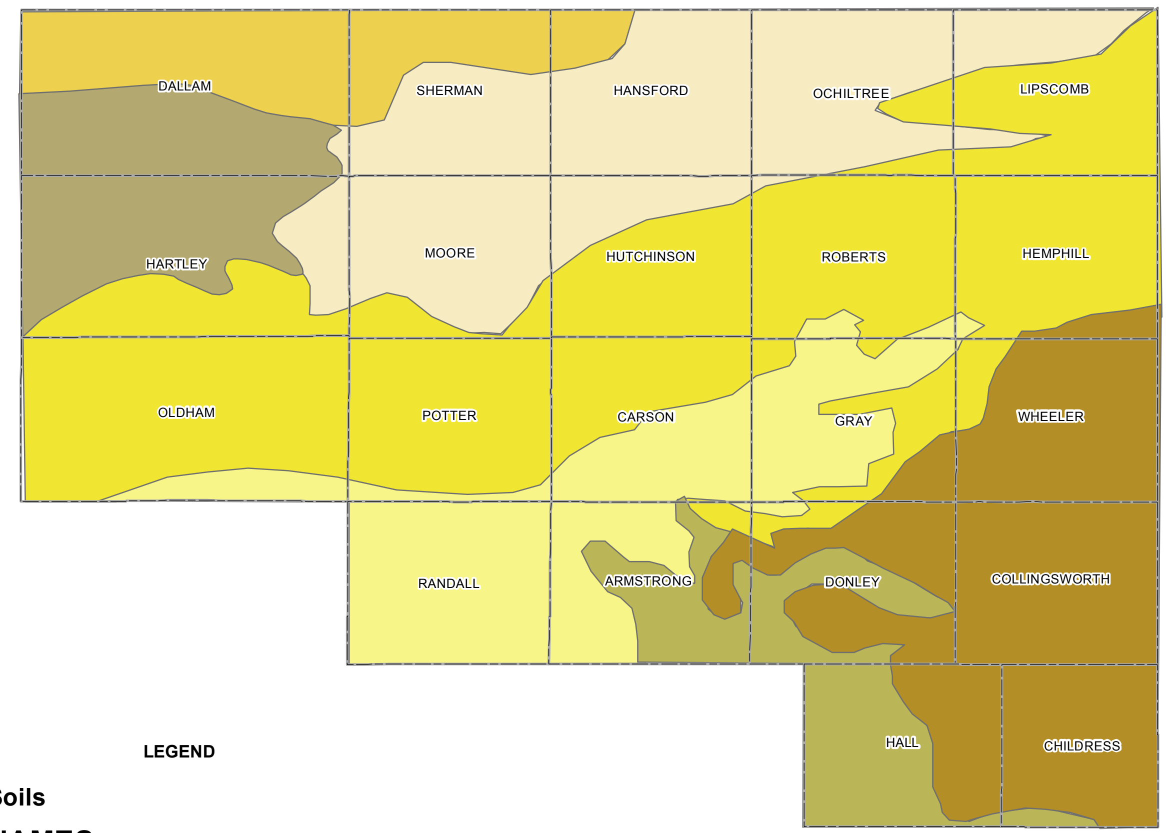
Soils of the High Plains formed under grass cover in Rocky Mountain outwash and sediment of variable sand, silt, clay, and lime content (Runkles, 1968). Calcium carbonate and, to some extent, gypsum are present in most soil profiles, and rainfall has been insufficient to leach these carbonates from the 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; and
- 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; and
- 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.



LEGEND

Soils

NAMES

- Dallam-Sunray-Dumas
- Mansker-Berda-Potter
- Miles-Springer-Woodward
- Pullman-Olton-Mansker
- Sherm-Gruver-Sunray
- Sunray-Conlen-Gruver
- Woodward-Quinlan-Vernon

0 7.625 15.25 30.5 Miles

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PANHANDLE WATER PLANNING AREA

Soil Associations

Location Map

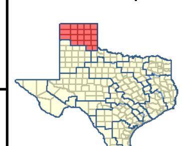


FIGURE 1-11

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.

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 wetlands 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 1-19).

Table 1-19: 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
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.

Special Water Resources

Special water resources are designated by the TWDB and include surface water resources that are located in one region and used in whole or in part in another region. In the PWPA, the TWDB has designated Lake Meredith and Greenbelt Reservoir as special water resources. Both of these lakes provide water to users outside of the PWPA. Descriptions of these resources and allocations of water are discussed in Chapter 3 of this plan.

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 1-20 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; 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.

Most water used in the PWPA is supplied from aquifers such as the Ogallala, making aquifer depletion a potentially major constraint on water sources 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 recent efforts to revisit 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.

Table 1-20: 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																								
American Peregrine Falcon	*Falco peregrinus anatum*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Bald Eagle	*Haliaeetus leucocephalus*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Interior Least Tern	*Sterna antilarrum athalossas*	E	E	B		B	F		F	F	B			B	B	B	B		B	B	B	B		F
Peregrine Falcon	*Falco peregrinus*		T	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Piping Plover	*Charadrius melodus*	T	T	F	F	F	F	F	F	B	F	F	F	F	F	F	F	F		F	F	F	F	F
Whooping Crane	*Grus americana*	E	E	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Lesser Prairie Chicken	*Tympanuchus pallidicinctus*	T			F	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F
Fish																								
Arkansas River Shiner	*Notropis girardi*	T	T		F			F		F		F	F	B	B	F	F	F	B	B	F	B		
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*		T			S																		
Mammals																								
Black Bear	*Ursus americanus*		T		S			S					S				S		S	S	S		S	
Gray Wolf	*Canis lupus*	E	E	B	B	B	B	B	B	B		B	B	B	B	B	B	B	B	B	B	B	B	B
Palo Duro Mouse	*Peromyscus truei comanche*		T	S																	S			
Texas Kangaroo Rat	*Dipodomys elator*		T			S																		
Black Footed Ferret	*Mustela nigripes*	E		F		F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	
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

Key:
F - Federal listings only (US Fish and Wildlife Service. 2014. Endangered Species List. http://www.fws.gov/endangered/)
S - State listings only (Texas Parks and Wildlife Department. 2014. Annotated County Lists of Rare Species. http://tpwd.texas.gov/gis/rtest/)
B - both Federal and State listings

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.

1.8.1 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. Entitles 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, 2016. 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, 46 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, this 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 14 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). The amount of real losses in the PWPA from the 46 public water suppliers totaled 1,239 million gallons or 3,800 acre-feet in 2010. Table 1-21 summarizes the water loss audit information that was collected by the TWDB for the 2010 year. Reductions in water loss is considered for municipal conservation in Chapter 5.

Table 1-21: Summary of TWDB Water Loss Audits

Total Water Loss	WUGS	SUDS/WSCs
≤ 10%	14	11
10% - 15%	4	1
15% - 20%	1	3
20% - 25%	1	2
≥ 25%	2	7

Source: 2010 Water Loss Audit Dataset from TWDB

1.8.2 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 has intensified over the last five years. For other watersheds, the drought began earlier. More discussion on drought and droughts of record is presented in Chapter 7.

1.8.3 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.

Surface water right holders that supply 1,000 acre-feet or more per year for non-irrigation use and 10,000 acre-feet per year for irrigation use are required to prepare a water conservation plan and submit it to TCEQ. In 2011, legislation was passed that requires all public water suppliers with greater than 3,300 connections to submit a conservation plan to the TWDB by May 1, 2014.

Drought contingency plans for retail public suppliers with greater than 3,300 connections were required to submit a copy of their plan to TCEQ by May 1, 2014. Retail public suppliers with less than 3,300 connections are required to complete a drought contingency plan and have this available upon request.

All Wholesale Water Providers were required to submit a drought contingency plan to the TCEQ by May 1, 2014.

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-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 salt water 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 fresh water 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. Eight irrigation strategies are considered based on water savings, cost to implement and impact to economy. 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.

1.10 Summary of Existing Local and Regional Water Plans

1.10.1 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 supplement 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.

1.10.2 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.

1.10.3 2011 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 nearly 430,000 acre-feet per year in 2010. There were 10 counties with 27 water user groups with projected water needs during the planning period. Collectively, the maximum projected need is just over 500,000 acre-feet per year in 2040. 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 and 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 314,283 acre-feet per year in 2020 and increasing to 572,120 acre-feet per year by 2060. Most of these savings were associated with recommendations for irrigated agriculture. Comparison of the 2011 Water Plan to this plan is presented in Chapter 11.

1.11 Existing Programs and Goals

1.11.1 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; and
- Healthy upland and wetland habitats to maximize waterfowl production and winter survival.

Agricultural Act of 2014

The 2014 Farm Bill, governing federal farm programs for the next 5 years, was signed into law in February 2014. The goal was to reduce farm program spending while maintaining some protection for agriculture. The Congressional Budget Office (CBO) projects federal spending on commodity and conservation programs will decrease $14.3 and $4 billion, respectively, while expenditures on crop insurance will increase $7 billion over the 2014-2023 time period. The nearly 1,000-page bill signaled a shift in policy away from previous farm bills that featured commodity programs to one that featured insurance-based protection. Commodity support programs including Direct Payments and the Countercyclical Program that were a part of the previous Farm Bill were replaced with Agricultural Risk Coverage which is a shallow revenue loss program and Price Loss Coverage while new subsidized crop insurance products Stacked Income Protection Plan (STAX) for cotton and Supplemental Coverage Option (SCO) for all program crops were added.

The changes in commodity programs and insurance are not anticipated to impact water use within the area. The primary source of conservation cost savings in the Farm Bill comes from the reduction in the nationwide cap on Conservation Reserve Program (CRP) acreage from 32 to 24 million acres by 2018. Approximately a million acres within the Panhandle Water Planning Area is presently in the CRP, some of which was irrigated prior to entering the program. Acreage exiting the CRP that could be returned to irrigation could significantly increase water use within the planning area.

Bio-Terrorism Preparedness and Response Act

Following the events of September 11th, Congress passed the Bio-Terrorism Preparedness and Response Act. Drinking water utilities serving more than 3,300 people were required and have completed vulnerability preparedness assessments and response plans for their water, wastewater, and stormwater facilities. The U.S. Environmental Protection Agency (EPA) funded the development of three voluntary guidance documents, which provide practical advice on improving security in new and existing facilities of all sizes. The guidance document for water utilities can be found through the American Water Works Association.

1.11.2 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. The two reaches pertinent to the states of Oklahoma and Texas are Reach I and Reach II. 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. Reach II is defined as the Red River from Denison Dam to the point where it crosses the Arkansas-Louisiana state boundary and all tributaries which contribute to the flow of the River with in this Reach.

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.

1.11.3 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).

Surface water rights

Surface water rights are administered by the TCEQ under Section 11 of the Texas Water Code. The TCEQ has the authority to revise existing water rights and grant new water rights if unappropriated water is available in the source basin. The issuance of new water rights permits by the TCEQ is based on the following criteria to determine the availability of supply:

- For non municipal, use at least 75 percent of the water can be expected to be available at least 75 percent of the time.
- For municipalities with no backup supply, 100 percent of the water can be expected to be available 100 percent of the time.
- For municipalities with a backup supply, a permit may be issued to use water that can be expected to be available less than 100 percent of the time.

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; and
- 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 (2012)

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 2012 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 2012 State Water Plan, public meetings were held across Texas.

List of References

(1) Ashworth, J.B. and J. Hopkins, *Aquifers of Texas*. Texas Water Development Board Report 345. Texas Water Development Board. Austin, Texas. November 1995.
(2) Chirase, N.K., S.H. Amosson, D.B. Parker, and T.H. Montgomery. *Quantity of Consumption of Grain and Water by Feedlot Cattle in ANRCP Counties. Section C, Agricultural Production Issues. In: Expert Panel to Identify Agricultural Science and Engineering Technical Issues and Data Resources for Risk Characterization Studies of Mixed Oxide Fuel Conversion Process* (eds. J.M. Sweeten, R.N. Clark, and B.A. Stewart). Final Report submitted to the Amarillo National Resource Center for Plutonium (ANRCP), Amarillo, Texas. October 14. 1997.
(3) Intera Inc. and Dutton, Alan. *Northern Ogallala Update to Support 2011 State Water Plan*, prepared for the Panhandle Water Planning Group, February 2010.
(4) Maderak, M.L., *Ground-Water Resources of Wheeler and Eastern Gray Counties*, Texas. Texas Water Development Board Report 170. Texas Water Development Board, Austin, Texas. May 1973.
(5) May, K. and E. Block. Personal Communication. Texas Natural Resource Conservation Commission, Austin, Texas, August 21 and August 28 1997.
(6) Runkles, J.R. *Agricultural resources related to water development in Texas*. Water Resources Institute, Texas Agricultural Experiment Station, Texas A& University, College Station, Texas. pp. 4.50-4.54.
(7) Texas A&M University (TAMU). Bioregions of Texas. [Online] August 12, 1999. Available URL: http://texastreeid.tamu.edu/content/texasEcoRegions/.
(8) Texas A&M University (TAMU). Checklist of the Vascular Plants of Texas, Ecological Summary. [Online] August 12, 1999. Available URL: http://www.csdl.tamu.edu/FLORA/tracy/
(9) Texas Commission on Environmental Quality (TCEQ). *Joint Groundwater Monitoring and Contamination Report*, June 1996. Texas Groundwater Protection Committee, Report SFR-56, Texas Natural Resource Conservation Commission.
(10) Texas Commission on Environmental Quality (TCEQ) Texas Clean Rivers Program, available online at. https://www.tceq.texas.gov/waterquality/clean-rivers
(11) Texas Commission on Environmental Quality (TCEQ) 2014. TCEQ Organization Chart, available online at http://www.tceq.state.tx.us/about/organization.
(12) Texas Parks and Wildlife Department (TPWD). The Texas Wetlands Plan. August 24, 1999.
(13) Texas Water Development Board, Historic Water Use Estimates, available online at http://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/index.asp.

Chapter 2 Current and Projected Population and Water Demand

2.1 Introduction

In October 2013, the Texas Water Development Board (TWDB) approved population and water demand projections for the Panhandle Water Planning Area (PWPA) for use in the 2016 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 use in Carson, Dallam, Hansford, Hutchinson, Moore, Ochiltree and Randall Counties based on local input. Changes were also made for the agricultural and industrial water demands. Due to the continuing changes in the agricultural sector in the region, a detailed study of the current and projected agricultural water use was conducted for this plan. Steam electric power water demands for Moore County were modified as the result of the expected closure of the facility in this county.

The TWDB distributes its population and demand projections by Water User Groups. A Water User Group is defined as one of the following:

- Cities with population of 500 or more,
- Individual utilities providing more than 0.25 million gallons per day (MGD) 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), or
- Livestock (aggregated on a county/basin basis).

Each Water User Group has an associated water demand. Only municipal Water User Groups have population projections.

To simplify the presentation of these data all projections in this chapter are aggregated by county where the water is used. Projections divided by Water User Group, county and basin may be found in the tables at the end of this chapter. The projections were developed by decade and cover the period from 2020 to 2070.

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.

This chapter documents historical and projected estimates of population and water demands of cities and counties in the PWPA, as well as the demands on designated wholesale water providers. Revisions to population and water demand projections discussed in this chapter have been approved by the TWDB.

2.2 Population

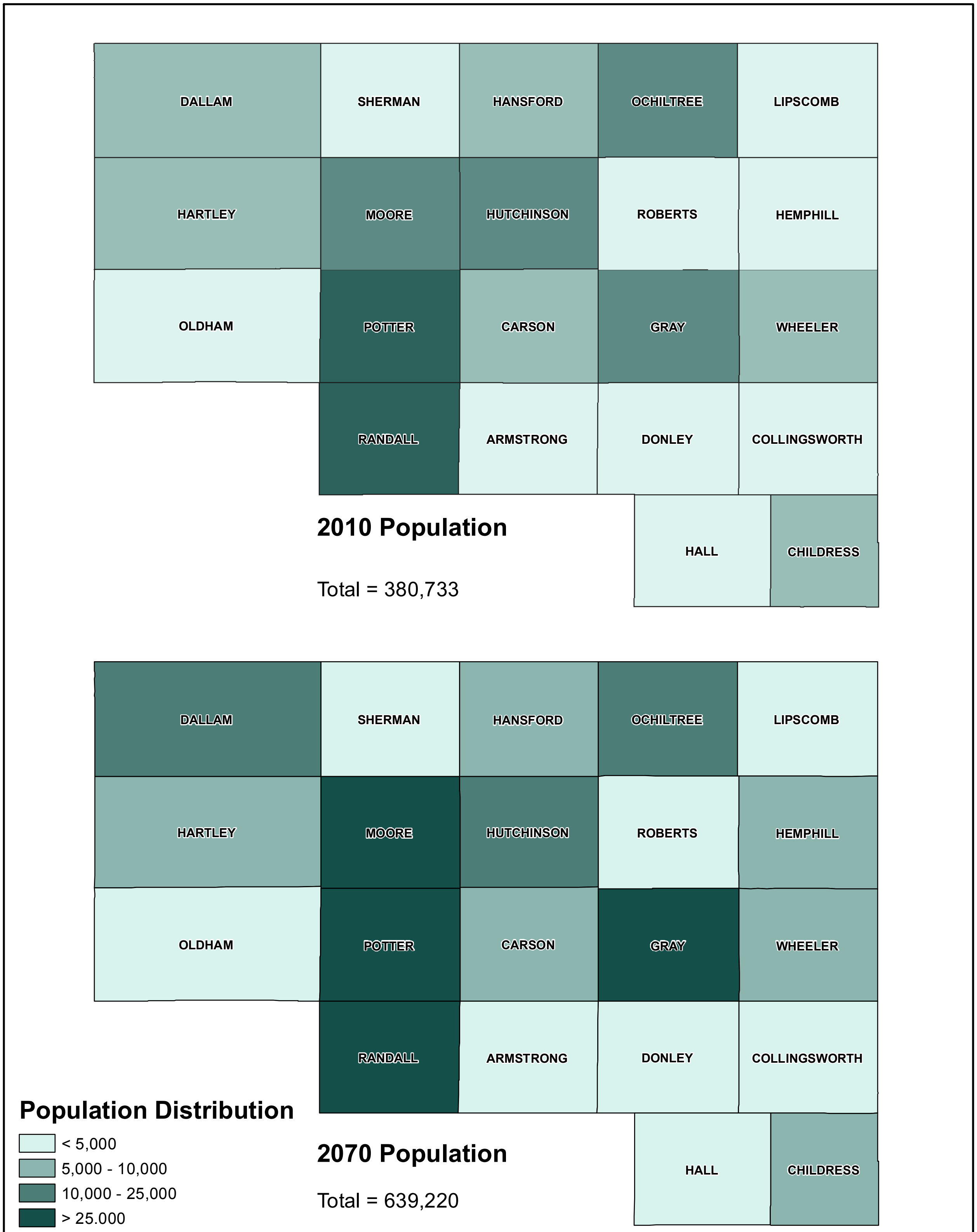
In 2010, the population of the State of Texas was approximately 25.1 million people. The population of the PWPA in 2010 was estimated to be 380,733. This represents approximately 1.5 percent of the state's population. Most of the region's population is located in Potter and Randall Counties, which contains Amarillo and surrounding areas. The remaining population in the PWPA is distributed among the other 19 counties, ranging from populations of 929 in Roberts County to 22,535 in Gray County.

Population projections for the PWPA are based on the 2010 U.S. Census. The projections use a standard methodology known as the cohort-component method. This method is based upon historical birth and survival rates of the region's population. It also accounts for the migration of people into and out of a community. For many communities, the migration rate can significantly affect the projected populations. For several counties in the Panhandle Region the TWDB assumed higher migration rates than historically recorded due to anticipated oil and gas development in the area. Surveys were sent to the municipalities to seek input on the projections. Based on the results of these surveys, several cities responded that significant long-term growth as estimated by the TWDB was not expected. These communities included Spearman, Perryton, Groom, Lake Tanglewood and Ochiltree County-Other. Two cities requested increases in population due to higher recent growth rates (Cactus) or new development (White Deer). Based on these responses, modifications to the draft TWDB projections were made for Carson, Hansford, Moore, Ochiltree and Randall Counties.

The population for the PWPA is projected to increase from the 380,733 in 2010 to 639,220 in 2070, or an average annual growth rate of 0.87 percent. As shown on Table 2-1, approximately 74 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 2010 population and 2070 population projections by county are shown in Figure 2-1.

Table 2-1: PWPA Population by County from 2010 to 2070

County Name	2010	2020	2030	2040	2050	2060	2070
Armstrong	1,901	1,911	1,911	1,911	1,911	1,911	1,911
Carson	6,182	6,354	6,520	6,632	6,632	6,632	6,632
Childress	7,041	7,269	7,546	7,776	8,001	8,225	8,443
Collingsworth	3,057	3,236	3,408	3,522	3,653	3,755	3,844
Dallam	6,703	7,744	8,720	9,747	10,759	11,733	12,671
Donley	3,677	3,788	3,788	3,788	3,788	3,788	3,788
Gray	22,535	24,439	27,046	30,168	34,186	37,388	40,730
Hall	3,353	3,393	3,487	3,487	3,487	3,487	3,487
Hansford	5,613	5,959	6,368	6,710	7,017	7,330	7,634
Hartley	6,062	6,281	6,631	6,817	6,950	7,069	7,164
Hemphill	3,807	4,209	4,609	4,948	5,297	5,609	5,895
Hutchinson	22,150	22,957	23,779	23,990	23,990	23,990	23,990
Lipscomb	3,302	3,599	3,858	4,011	4,211	4,350	4,465
Moore	21,904	25,768	29,372	33,210	37,106	41,170	45,330
Ochiltree	10,223	11,305	12,158	13,075	14,061	15,122	16,264
Oldham	2,052	2,230	2,376	2,376	2,376	2,376	2,376
Potter	121,073	134,031	148,960	164,757	180,486	197,638	215,701
Randall	120,725	134,269	150,044	165,835	182,010	199,219	217,095
Roberts	929	1,003	1,047	1,047	1,047	1,047	1,047
Sherman	3,034	3,294	3,571	3,720	3,853	3,949	4,020
Wheeler	5,410	5,587	5,809	6,019	6,239	6,478	6,733
Total	**380,733**	**418,626**	**461,008**	**503,546**	**547,060**	**592,266**	**639,220**



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PANHANDLE WATER PLANNING AREA

POPULATION PROJECTIONS FOR COUNTIES IN THE PWPA

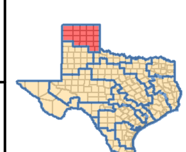
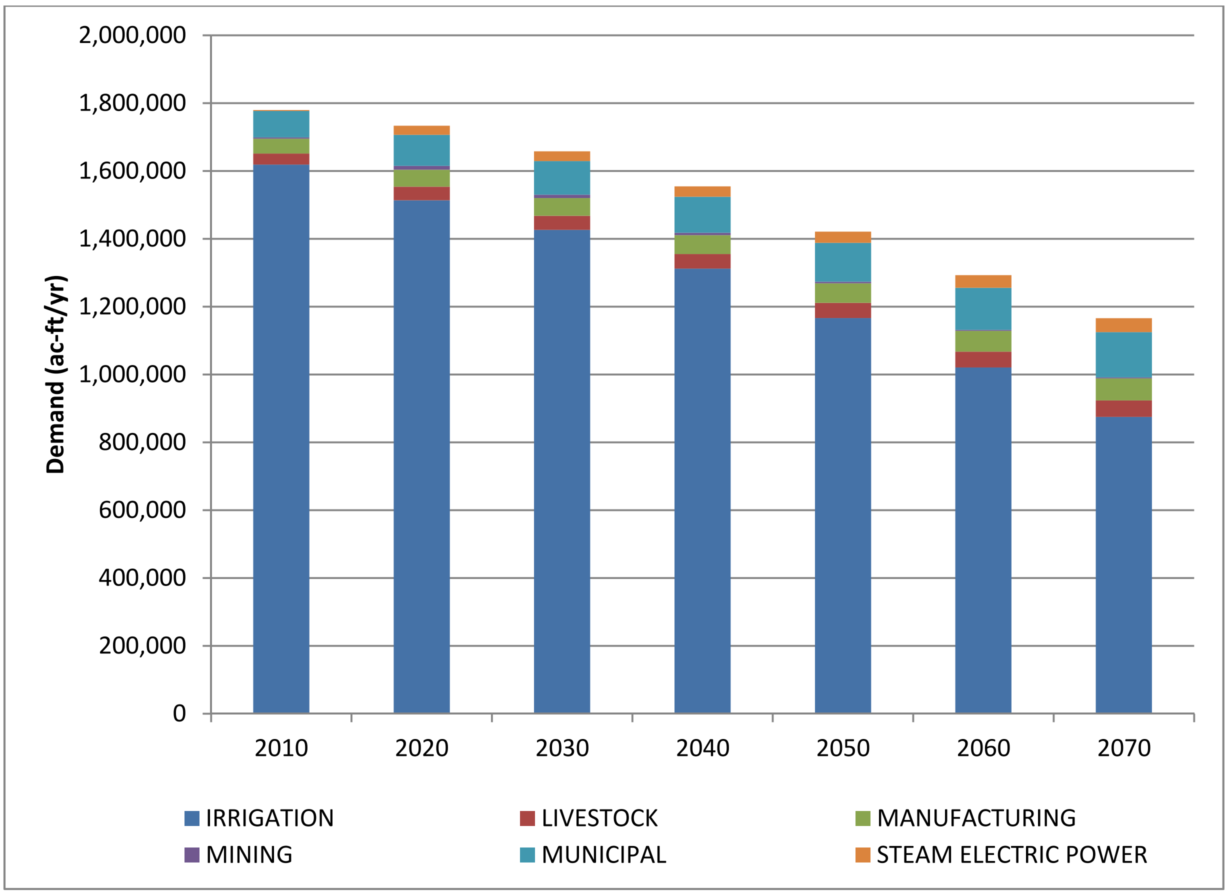


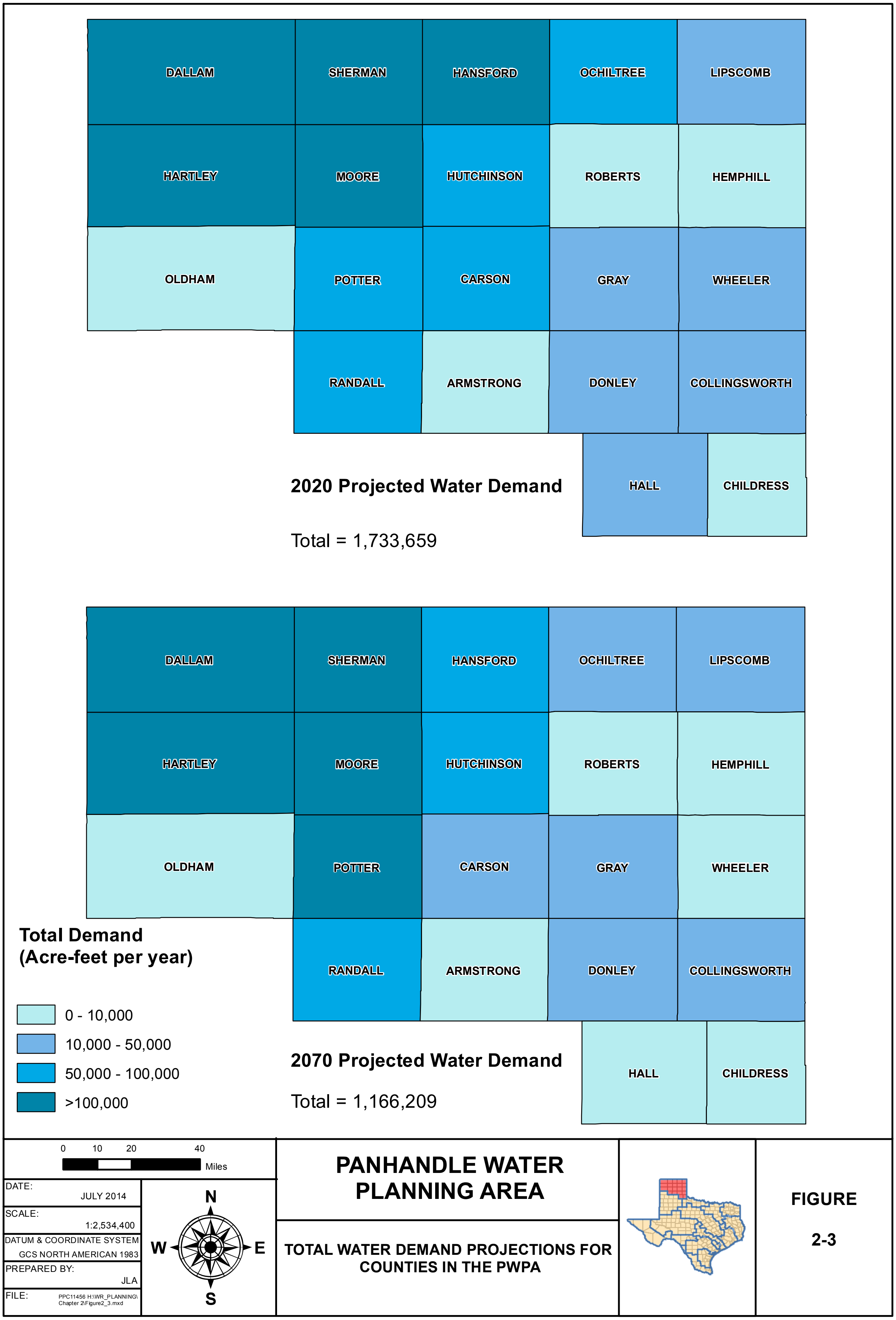
FIGURE 2-1

2.3 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. Water use of the remaining 18 counties totaled over 824,000 acre-feet and ranged from 5,243 acre-feet in Armstrong County to 178,277 acre-feet in Moore County. Projections for water demand indicate that total water usage in the PWPA will decrease from 1,733,659 acre-feet in 2020 to 1,166,209 acre-feet in 2070. (Figure 2-2) due to reductions in agricultural use. Most of the water use will continue to be used in the three counties noted above. Figure 2-3 shows the distribution of total water demands by county.

Figure 2-2: Total Water Use for PWPA from 2010 to 2070

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CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
2020 Projected Water Demand
Total = 1,733,659
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
Total Demand
(Acre-feet per year)
0 - 10,000
10,000 - 50,000
50,000 - 100,000
>100,000
2070 Projected Water Demand
Total = 1,166,209
0 10 20 40
Miles
DATE: JULY 2014
SCALE: 1:2,534,400
DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983
PREPARED BY: JLA
FILE: PPC11456 H:\WR_PLANNING\Chapter 2\Figure2_3.mxd
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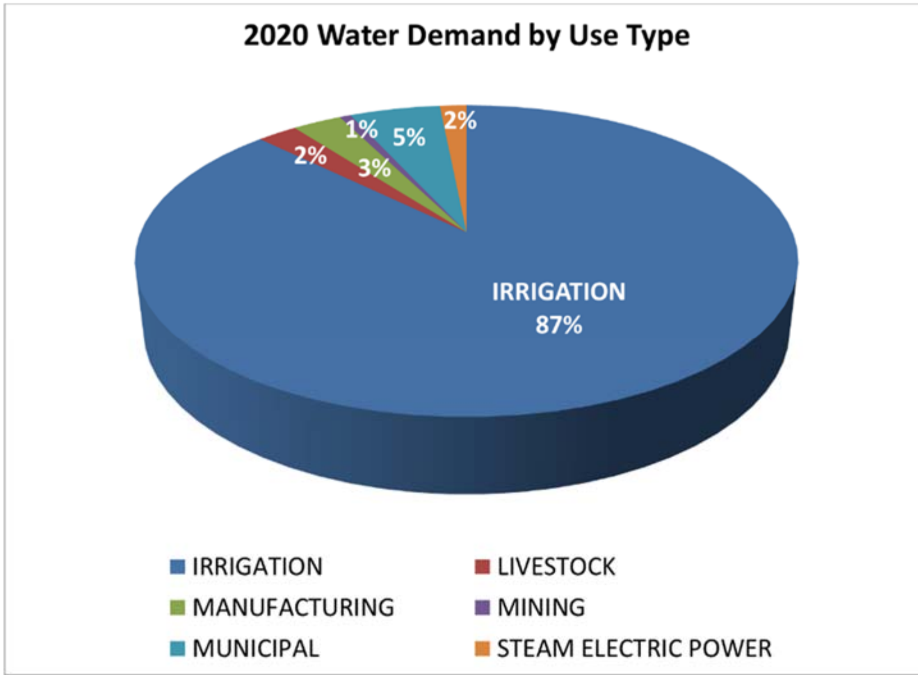
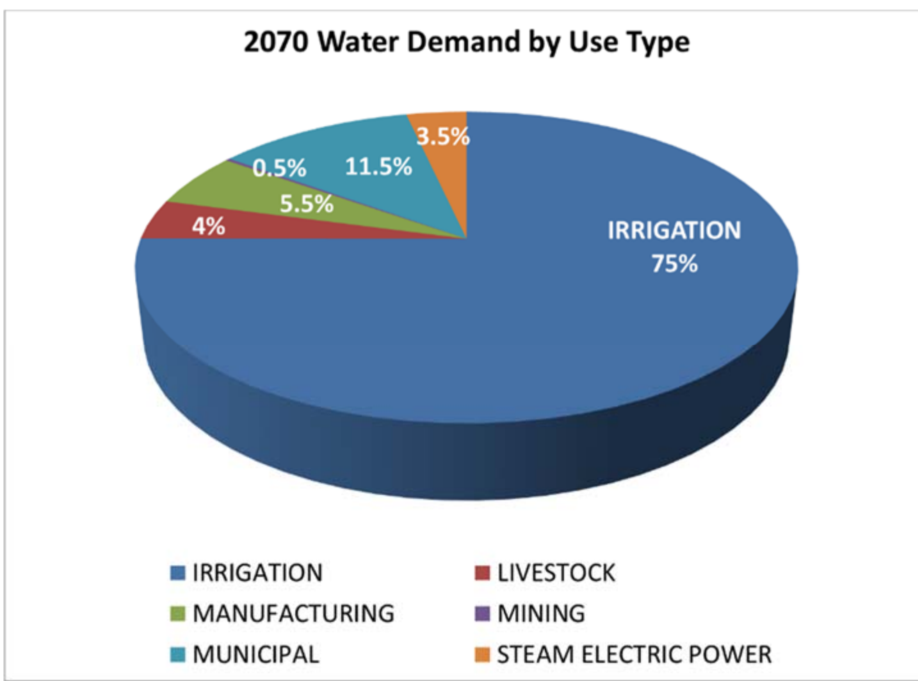
PANHANDLE WATER PLANNING AREA
TOTAL WATER DEMAND PROJECTIONS FOR COUNTIES IN THE PWPA
FIGURE 2-3

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, agricultural, steam-electric, and industrial water users.

Figure 2-4: Water Demand by Use Type





2.4 Municipal Water Demands

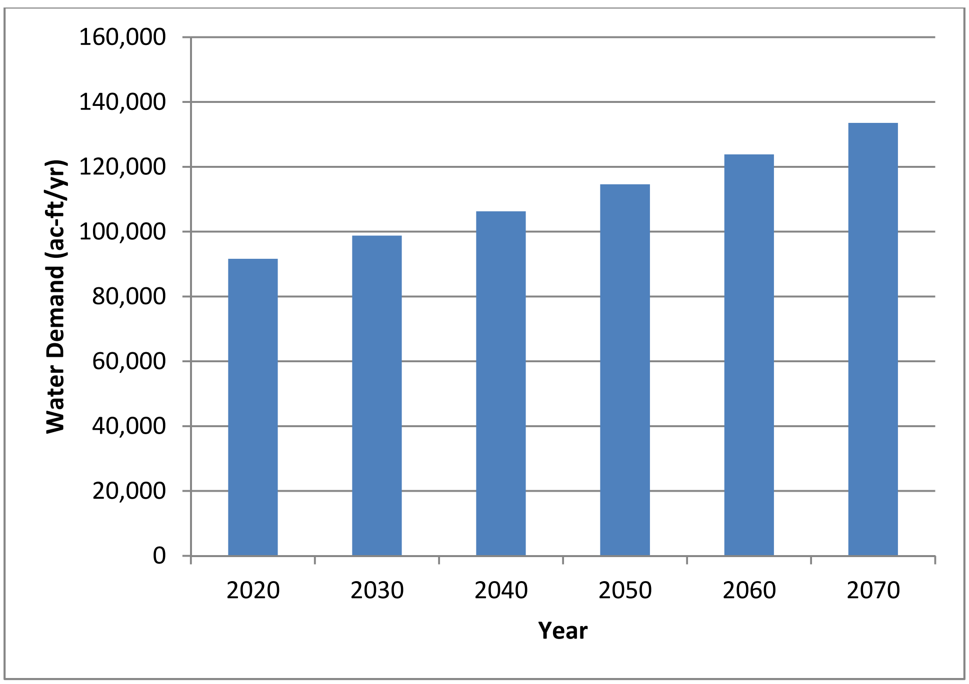
The distribution of municipal water use in the PWPA corresponds closely to the distribution of population centers in the PWPA. Projections of municipal water demands are calculated based on estimated changes in populations for cities and rural areas and on estimates of daily per capita water use. For 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 12,877 acre-feet per year by 2070.

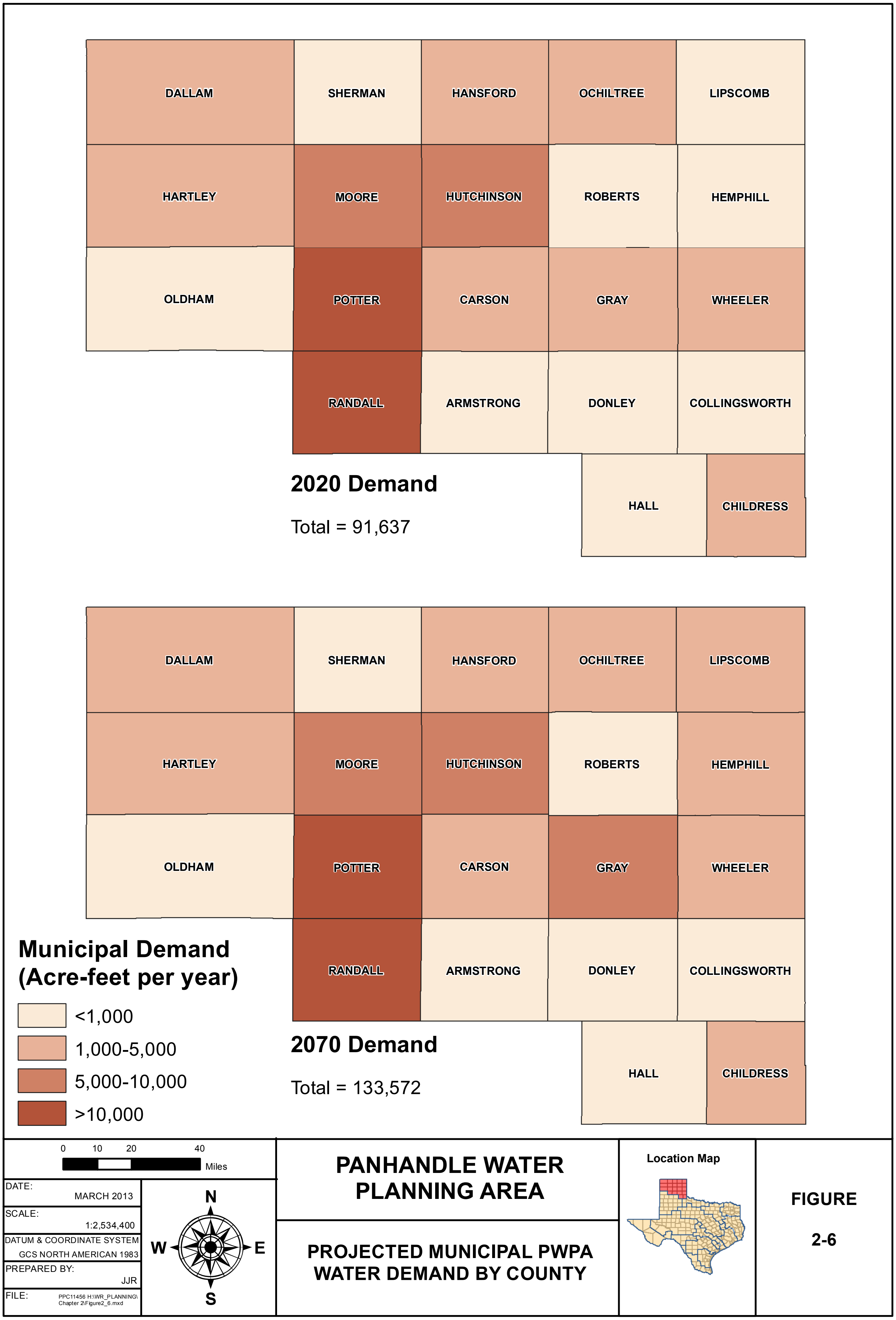
Table 2-2 Municipal Water Savings Incorporated into Demands

	Water Savings (ac-ft/ yr)					
County	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Armstrong	21	30	37	39	40	40
Carson	72	102	126	136	138	138
Childress	75	107	133	150	157	162
Collingsworth	37	56	71	76	80	82
Dallam	85	135	178	211	234	254
Donley	41	58	73	79	81	81
Gray	273	437	594	698	775	848
Hall	37	57	68	71	72	72
Hansford	64	100	124	139	148	155
Hartley	62	93	114	127	131	133
Hemphill	45	71	92	105	113	119
Hutchinson	277	399	476	489	497	497
Lipscomb	39	59	75	84	88	91
Moore	288	460	617	742	836	924
Ochiltree	121	184	240	279	305	330
Oldham	26	39	47	49	50	50
Potter	1,423	2,248	2,988	3,543	3,946	4,328
Randall	1,418	2,251	2,988	3,549	3,951	4,327
Roberts	11	16	20	21	22	22
Sherman	37	58	73	80	83	85
Wheeler	60	91	117	127	135	140
Total	**4,511**	**7,049**	**9,252**	**10,796**	**11,882**	**12,877**

Municipal water use in the PWPA accounts for approximately 5 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 91,637 acre-feet in 2020 to 133,572 acre-feet in 2070. This is approximately a 46 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 in the PWPA




DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
2020 Demand
Total = 91,637
2070 Demand
Total = 133,572
Municipal Demand (Acre-feet per year)
<1,000
1,000-5,000
5,000-10,000
>10,000
0 10 20 40
Miles
DATE: MARCH 2013
SCALE: 1:2,534,400
DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983
PREPARED BY: JJR
FILE: PPC11456 H:\WR_PLANNING\Chapter 2\Figure2_6.mxd
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PANHANDLE WATER PLANNING AREA
PROJECTED MUNICIPAL PWPA WATER DEMAND BY COUNTY
Location Map
FIGURE
2-6

2.5 Industrial Water Demands

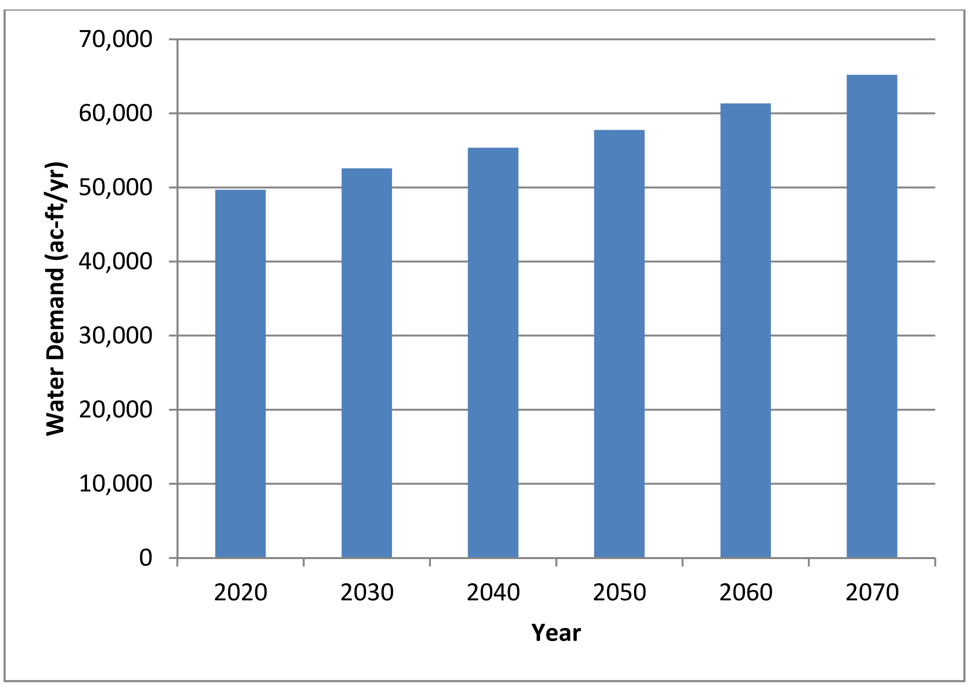
The TWDB defines industrial water use as water required in the production process of manufactured products, including water used by employees for drinking and sanitation purposes. The industrial use category includes manufacturing, steam power generation, and mining. Each of these categories is discussed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

2.5.1 Manufacturing

Most of the manufacturing industries in the PWPA are associated with agribusiness or energy production (oil and gas). There are eleven counties in the region with manufacturing water use. The larger users are located in Hutchinson, Moore and Potter Counties. Manufacturing demands are estimated by the TWDB based on historical reported use from 2004 to 2008, employment data and the historical rate of change.

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 49,695 acre-feet in 2020 to 65,194 acre-feet by 2070. Manufacturing water use represents 3 to 5 percent of the total water use in the PWPA over the planning period.

Figure 2-8: Projected Manufacturing Water Use in the PWPA




DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
2020 Projected Water Demand
Total = 88,021
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
Industrial Demand
(Acre-feet per year)
0
1 - 1,000
1,000 - 10,000
10,000 - 20,000
>20,000
2070 Projected Water Demand
Total = 109,151
0 10 20 40
Miles
DATE: JULY 2014
SCALE: 1:2,534,400
DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983
PREPARED BY: JLA
FILE: PPC11456 H:\WR_PLANNING\ Chapter 2\Figure2_3.mxd
N
W
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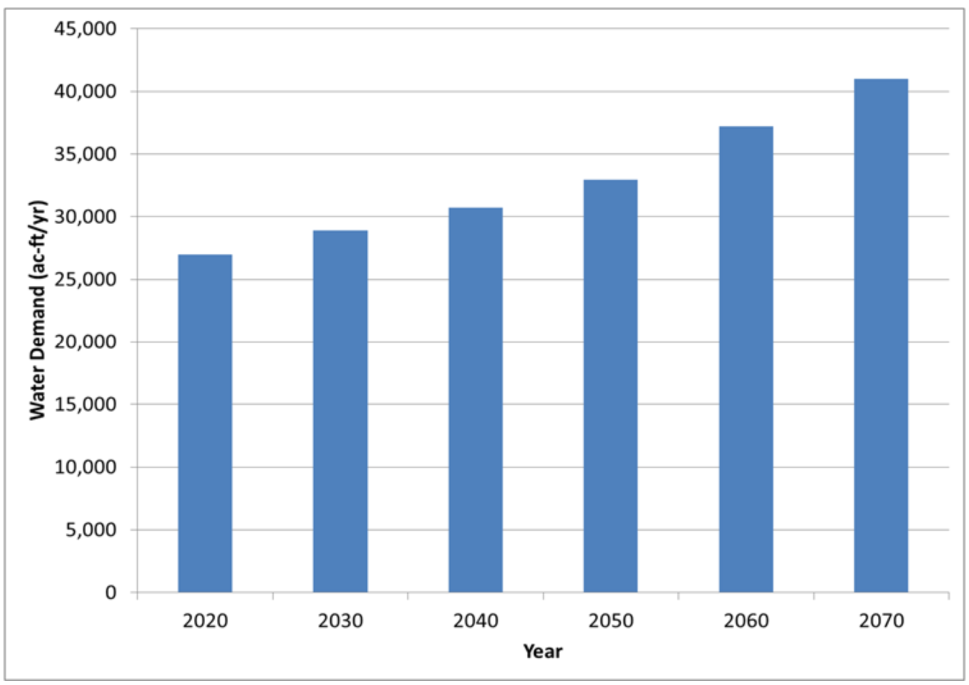
PANHANDLE WATER
PLANNING AREA
INDUSTRIAL WATER DEMAND PROJECTIONS FOR
COUNTIES IN THE PWPA
FIGURE
2-7

2.5.2 Steam Electric Power

Xcel Energy has power generation plants located in Moore and Potter counties that account for nearly all of the current water use by power generators in the PWPA. During this round of planning the amount projected water use by Xcel Energy in Moore County was set to zero (0) after 2020. In addition to the Xcel Energy facilities there is a proposed new coal plant in Gray County that is planned to support wind generation in the Panhandle. Water demands for this facility were developed by the Bureau of Economic Geology (BEG) as part of a study contracted by the TWDB [1]. These demands are included in this planning update.

Considering existing and proposed facilities, water demand for power generation in the PWPA is projected to increase from 26,996 acre-feet in 2020 to 40,989 acre-feet by 2070. This represents between 2 to 3 percent of the total water use in the PWPA over the planning period. Figure 2-9 illustrates the projected water demands of steam power generators in the PWPA.

Figure 2-9: Projected Steam Power Water Use in the PWPA

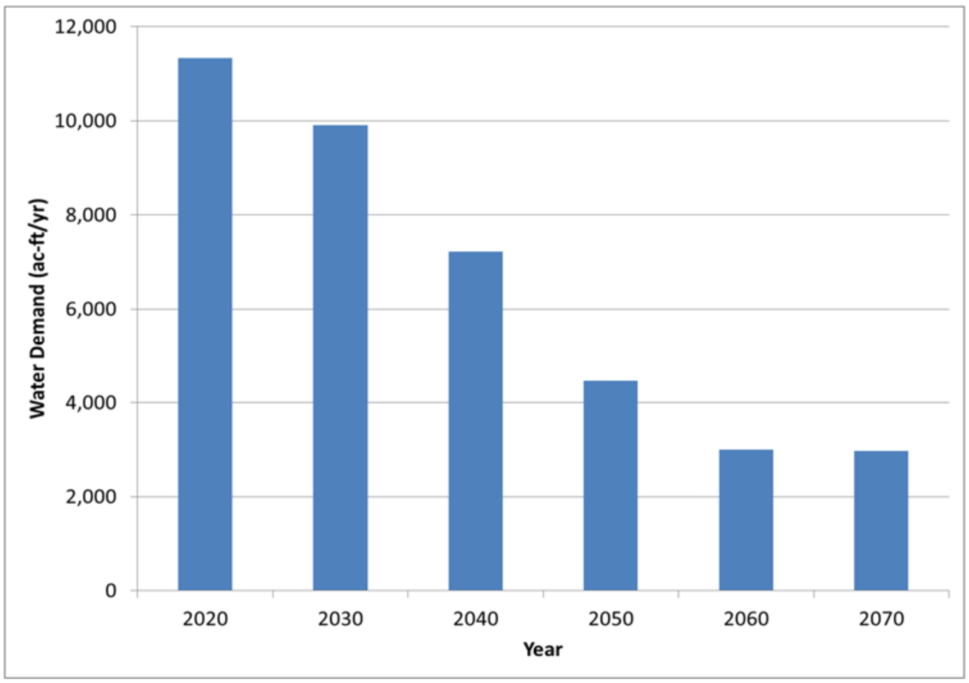


2.5.3 Mining

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 titled "Current and Projected Water Use in the Texas Mining and Oil and Gas Industry" (2). Mining demands for the 2016 regional plan are based on an additional study titled "Oil and Gas Water Use: Update to the 2011 Mining Water Use Report" by the Bureau of Economic Geology (BEG) (3).

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 2-10 shows the projected water demands for mining in the PWPA.

Figure 2-10: Projected Mining Water Use in the PWPA



2.6 Agricultural Water Demands

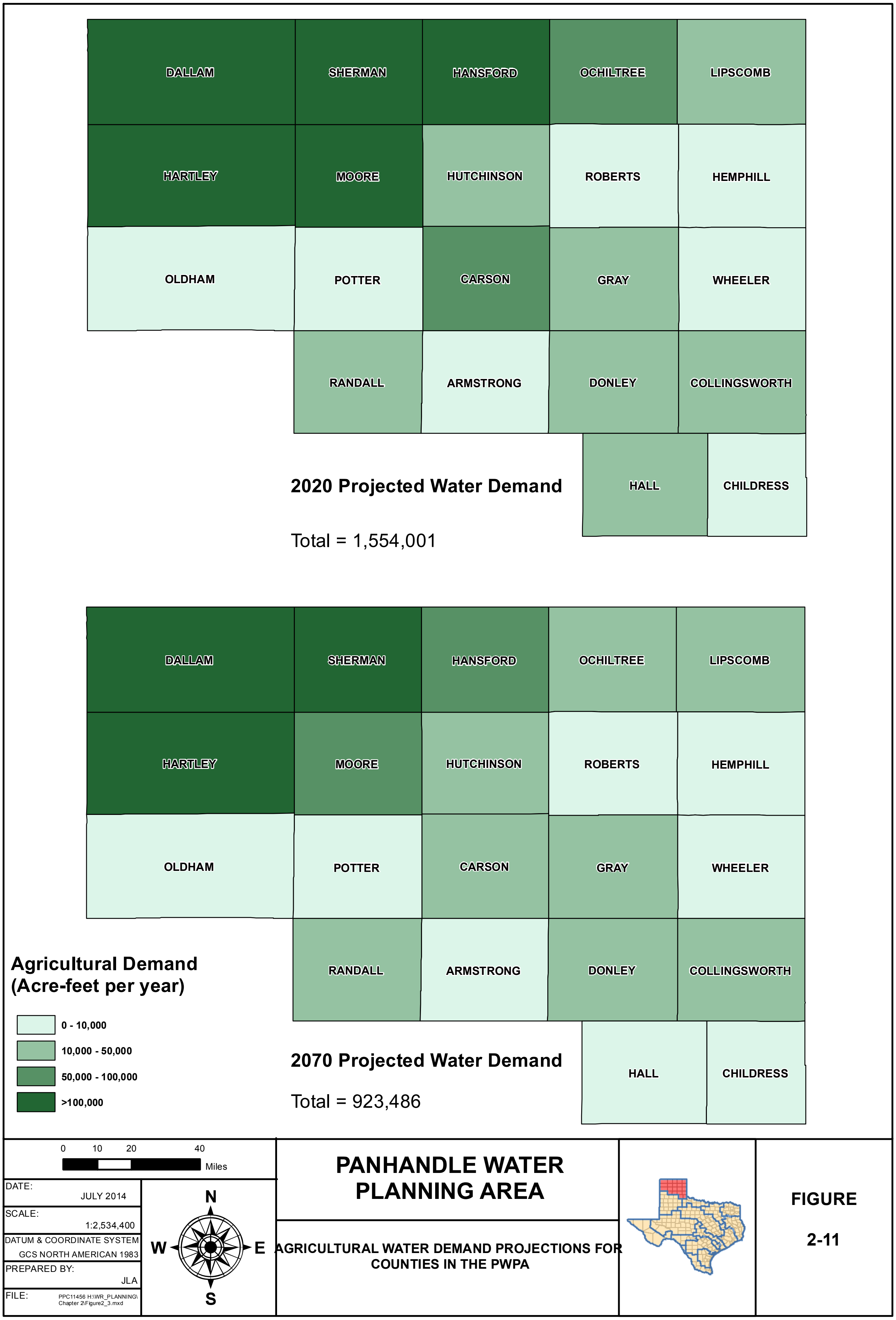
Agricultural water demands include water used for irrigation purposes and water for livestock production. It does not include water for processing agricultural or livestock products. This demand is included under manufacturing.

Agricultural water use accounts for approximately than 90 percent of the total water demand in the PWPA. Figure 2-11 shows the agricultural water use by county in the region. The largest agricultural water users are in Dallam, Hartley, Moore and Sherman Counties.

2.6.1 Irrigation Water Demands

Irrigation water use accounts for the majority of the water used in the PWPA. The PWPG contracted with Texas A&M AgriLife Research and Extension Center at Amarillo (Texas A&M Agrilife) to develop updated agricultural water demands, including irrigated agriculture and livestock water demands. The 2016 RWP irrigation estimates were developed using the Texas A&M AgriLife model. The model is effectively a water balance model using the parameters of irrigation water pumped, crop ET, effective rainfall and soil profile water used within the respective crop growing seasons. The irrigation model is computed on a per crop per county basis and then summed over the regional counties (21) for the irrigation demand total. Based on local information of irrigated farms and property transfers, the total regional irrigated acreage of 1,218,664 for 2020 in the 2011 Water Plan increased to 1,350,942 acres for this plan (a 10.9% increase). The agricultural demand report is provided in Appendix B.

Considering the current irrigated acreages by crop type, irrigation equipment, energy prices for irrigation wells, and the shifts in crop demands, the irrigation water demands for 2020 in the PWPA are projected to be 1.51 million acre-feet per year. This is an increase of about 200,000 acre-feet from the 2011 water plan. However, it is less than the historical use in 2011. This is because the adopted irrigation water demands consider an average water use over the historic period from 2006 to 2010. Since the primary source of water for irrigation is the Ogallala Aquifer, an average water demand for irrigation is recommended for long-term planning to better assess the impacts on the water source. 2011 was an extremely dry year with higher than average irrigation water use. As with the 2011 plan, irrigated water needs are projected to decline over time due to increases in conservation and conversion of acreages to other uses. By 2070, the updated irrigation water demands are projected to be 874,922 acre-feet per year. Figure 2-12 shows the total projected irrigation water demand in the PWPA.


DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
2020 Projected Water Demand
Total = 1,554,001
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
HALL
CHILDRESS
2070 Projected Water Demand
Total = 923,486
Agricultural Demand
(Acre-feet per year)
0 - 10,000
10,000 - 50,000
50,000 - 100,000
>100,000
0 10 20 40
Miles
DATE: JULY 2014
SCALE: 1:2,534,400
DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983
PREPARED BY: JLA
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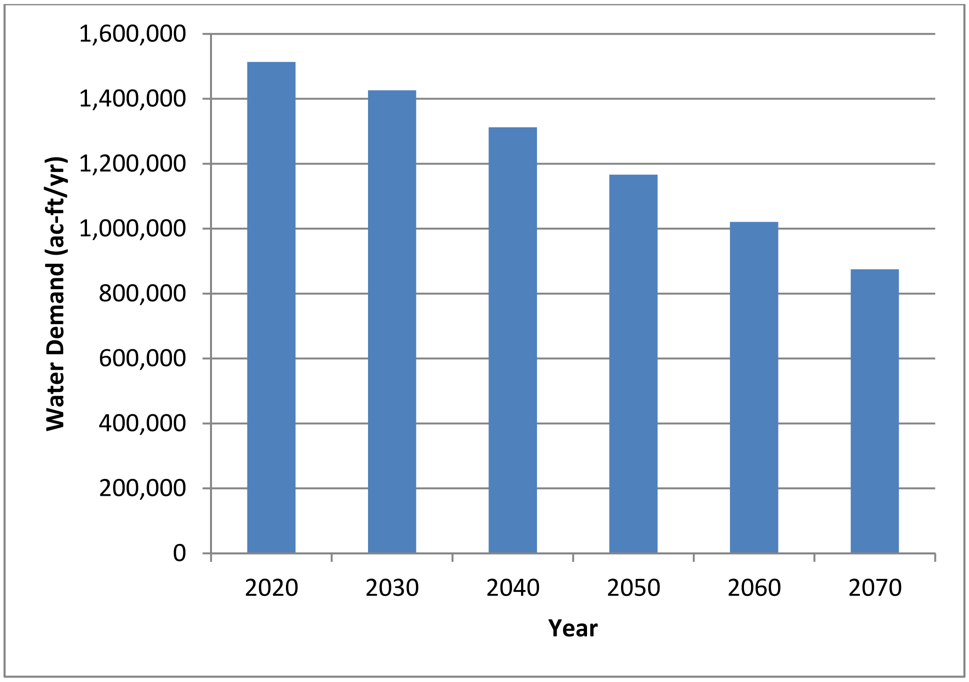
PANHANDLE WATER
PLANNING AREA
AGRICULTURAL WATER DEMAND PROJECTIONS FOR
COUNTIES IN THE PWPA
FIGURE
2-11

Figure 2-12: Projected Water Use for Irrigation in the PWPA



2.6.2 Livestock Water Demands

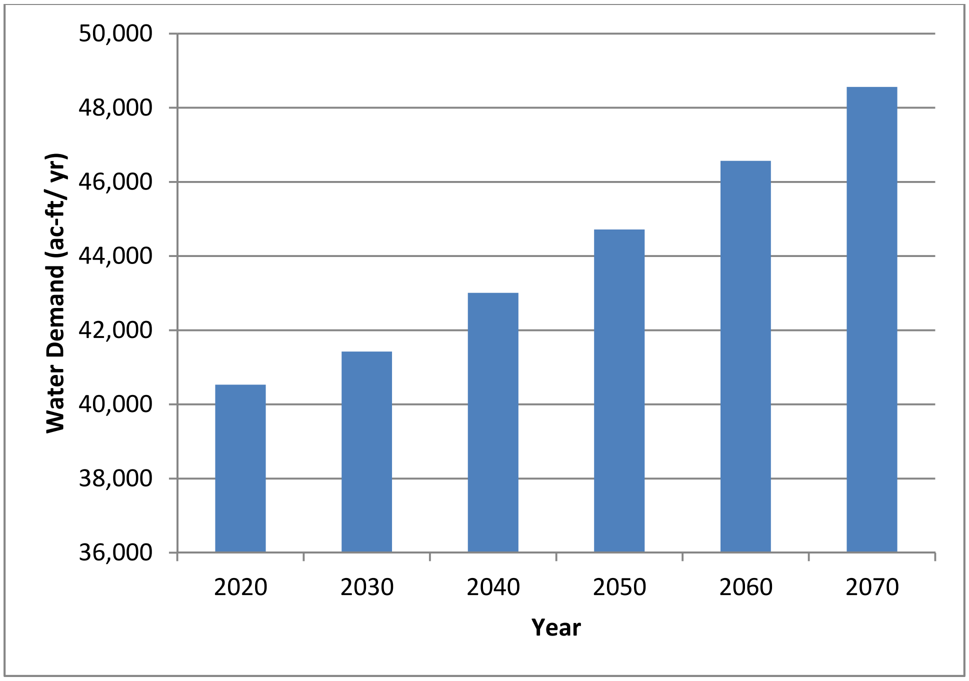
Livestock water use is part of the total agricultural demand in the PWPA. While comprising only about 2 percent of the region's current water use, livestock production is an important component of the overall economy of the PWPA. Changes to types of livestock production impact not only this demand sector 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 B.

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 40,532 acre-feet in 2020 and increasing to 48,564 acre-feet per year by 2070. The largest livestock water use group is the fed cattle industry with an annual usage of about 22,290 acre-feet per year by 2070. The forecasted expansion of the dairy industry results in a water usage estimate by 2070 of just over 12,000 acre-feet per year. These two user groups account for 71 percent of projected livestock water use in 2070. Overall, water use in the PWPA livestock sector is predicted to increase 20 percent from 2020 to 2070.

Figure 2-13 shows the projected livestock demand in the PWPA. Figure 2-14 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 B.

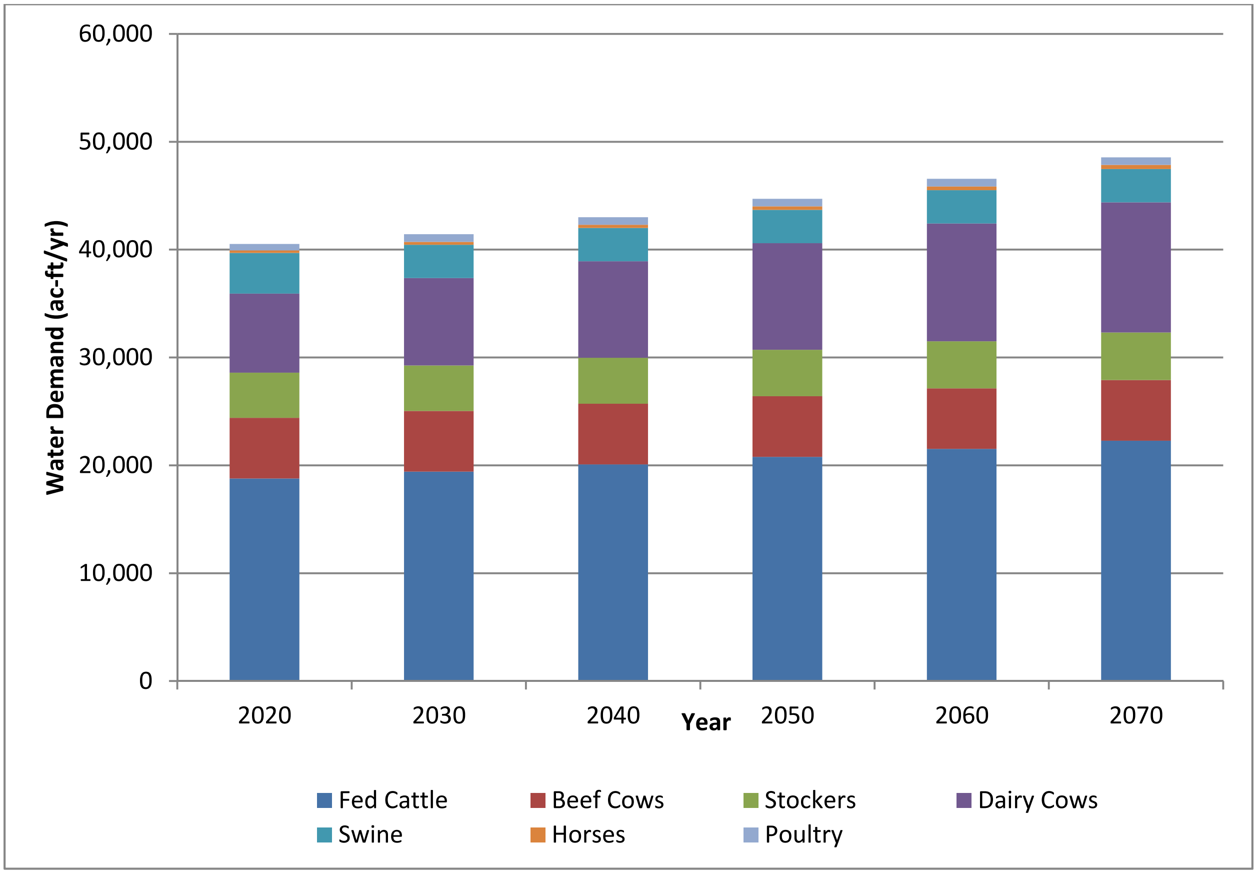
Figure 2-13: Projected Livestock Water Demands for PWPA



2.6.3 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.

Figure 2-14: Projected Livestock Water Demands by Animal Category



2.7 Wholesale Water Providers

The category of Wholesale Water Provider (WWP) was created to include major providers of water for municipal and industrial use in the regional planning process. The PWPG has designated six WWPs in the region. These include the Canadian River Municipal Water Authority (CRMWA), cities of Amarillo, Borger, and Cactus, Greenbelt Municipal and Industrial Water Authority (Greenbelt MIWA) and Palo Duro River Authority (PDRA). Descriptions of each of these wholesale water providers are provided in Section 1.4 of this plan.

Of the six wholesale water providers, PDRA is not currently providing water to customers but each of these entities expect to provide wholesale water during the planning period. 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 wholesale water providers. These demands include current contractual obligations and expected future demands of existing customers. For many of the wholesale providers, the contracts are simply to provide water to meet the entity's needs.

2.7.1 City of Amarillo

In 2020, the City of Amarillo is projected to provide 81,492 acre-feet of water to the City of Amarillo, the City of Canyon, Texas Parks and Wildlife Department (Palo Duro State Park), and industrial use by ASARCO, Tyson, and Xcel Energy. All of the water from Amarillo to Xcel Energy in 2020 is assumed to be treated wastewater. By 2070, Amarillo is expected to provide approximately 121,518 acre-feet per year to existing customers. Most of the increase in projected demand on Amarillo is associated with growth of the city and local manufacturing needs. As the surrounding County-Other in Potter and Randall Counties continue 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	47,731	52,110	56,810	61,860	67,631	73,739
Manufacturing - Potter Co	6,799	7,323	7,834	8,276	8,884	9,535
City of Canyon	1,000	1,000	1,000	1,000	0	0
Manufacturing - Randall Co	550	550	550	550	550	550
Palo Duro State Park	25	25	25	25	25	25
Steam Electric Power	25,387	26,804	28,408	30,011	34,115	37,669
Total	**81,492**	**87,812**	**94,627**	**101,722**	**111,205**	**121,518**

2.7.2 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 60 percent of the current demand on Greenbelt MIWA is to 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
City of Childress	1,624	1,658	1,686	1,722	1,768	1,814
City of Chillicothe	65	63	60	61	62	62
City of Clarendon	378	369	361	356	356	356
City of Crowell	138	134	132	131	131	131
City of Memphis	100	100	100	100	100	100

Customers	Demands (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Childress County-Other	178	184	189	194	200	204
Donley County-Other	95	95	95	95	95	95
Foard County-Other	50	50	50	50	50	50
Hall County-Other	92	92	92	92	92	92
Hardeman County-Other	60	60	60	60	60	60
Hardeman County Manufacturing	276	294	313	332	332	332
City of Quanah	397	391	388	394	397	400
Total	**3,453**	**3,490**	**3,526**	**3,587**	**3,643**	**3,696**

2.7.3 Canadian River Municipal Water Authority (CRMWA)

CRMWA is the largest wholesale water provider in the PWPA. In 2020 CRMWA is projected to supply nearly 100,000 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 120,000 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	1,818	1,827	1,836	4,680	4,680	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	1,534	1,950	2,300	2,750	2,750	2,750
City of O'Donnell	137	139	142	146	150	153
City of Plainview	2,761	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	460	477	483	496	507	517
City of Brownfield	1,380	1,500	1,600	1,750	1,750	1,750
Total	**100,450**	**108,814**	**114,138**	**121,457**	**121,549**	**121,633**

2.7.4 City of Borger

The City of Borger provides wholesale water to industrial customers in Hutchinson and Carson Counties and retail services to its city customers and Hutchinson County-Other. Currently, the industrial demands on Borger total about 6 MGD, which accounts for about 25 percent of the manufacturing demand in Hutchinson County (assuming a peaking factor of 1.25). It is expected that Borger will continue to provide water for 25 percent of the projected manufacturing demands. The City also provides water to a carbon plant in Carson County. Borger has a contract to supply water to TCW Supply. This contract is met through a complex agreement of trading water supplies with several of its industrial customers such that the net demand on the City of Borger is zero.

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

Customers	Demands (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Borger	3,215	3,254	3,234	3,229	3,225	3,224
Manufacturing - Hutchinson Co.	6,337	6,707	7,062	7,371	7,885	8,435
Manufacturing Carson Co.	450	450	450	450	450	450
Hutchinson County-Other	56	57	57	55	52	49
TCW Supply	0	0	0	0	0	0
Total	**10,058**	**10,468**	**10,803**	**11,105**	**11,612**	**12,158**

2.7.5 City of Cactus

The City of Cactus provides wholesale water to manufacturers in Moore County and retail water to its municipal customers. The City has a contract for 3.2 MGD with a meat packing plant in Moore County and also provides water to the Etter Community outside the city limits.

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	1,108	1,242	1,382	1,532	1,686
Moore County-Other	98	108	119	132	146	160
Moore County Manufacturing	3,168	3,342	3,513	3,664	3,913	4,178
Total	**4,251**	**4,558**	**4,874**	**5,178**	**5,591**	**6,024**

List of References

(1) Bureau of Economic Geology, *Water Demand Projections for Power Generation in Texas*, prepared for the Texas Water Development Board, August 2008.

(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

TWDB Population and Demand Projections

Texas Water Development Board
2016 Regional Water Plan Population Projections for 2010-2070
Region A

WATER USER GROUP	COUNTY NAME	P2010[1]	P2020	P2030	P2040	P2050	P2060	P2070
CLAUDE	ARMSTRONG	1,196	1,203	1,203	1,203	1,203	1,203	1,203
COUNTY-OTHER	ARMSTRONG	705	708	708	708	708	708	708
	ARMSTRONG Total	1,901	1,911	1,911	1,911	1,911	1,911	1,911
COUNTY-OTHER	CARSON	1,662	2,164	2,196	2,239	2,239	2,239	2,239
GROOM	CARSON	574	574	574	574	574	574	574
HI TEXAS WATER COMPANY[2]	CARSON	494	-	-	-	-	-	-
PANHANDLE	CARSON	2,452	2,491	2,583	2,631	2,631	2,631	2,631
WHITE DEER	CARSON	1,000	1,125	1,167	1,188	1,188	1,188	1,188
	CARSON Total	6,182	6,354	6,520	6,632	6,632	6,632	6,632
CHILDRESS	CHILDRESS	6,105	6,303	6,543	6,743	6,938	7,132	7,321
COUNTY-OTHER	CHILDRESS	936	966	1,003	1,033	1,063	1,093	1,122
	CHILDRESS Total	7,041	7,269	7,546	7,776	8,001	8,225	8,443
COUNTY-OTHER	COLLINGSWORTH	868	918	967	1,000	1,037	1,066	1,091
WELLINGTON	COLLINGSWORTH	2,189	2,318	2,441	2,522	2,616	2,689	2,753
	COLLINGSWORTH Total	3,057	3,236	3,408	3,522	3,653	3,755	3,844
COUNTY-OTHER	DALLAM	1,015	1,172	1,319	1,475	1,628	1,776	1,918
DALHART	DALLAM	5,181	5,986	6,741	7,534	8,317	9,069	9,794
TEXLINE	DALLAM	507	586	660	738	814	888	959
	DALLAM Total	6,703	7,744	8,720	9,747	10,759	11,733	12,671
CLARENDON	DONLEY	2,026	2,088	2,088	2,088	2,088	2,088	2,088
COUNTY-OTHER	DONLEY	1,651	1,700	1,700	1,700	1,700	1,700	1,700
	DONLEY Total	3,677	3,788	3,788	3,788	3,788	3,788	3,788
COUNTY-OTHER	GRAY	3,763	4,080	4,516	5,037	5,707	6,243	6,800
MCLEAN	GRAY	778	844	934	1,042	1,181	1,291	1,407
PAMPA	GRAY	17,994	19,515	21,596	24,089	27,298	29,854	32,523
	GRAY Total	22,535	24,439	27,046	30,168	34,186	37,388	40,730
COUNTY-OTHER	HALL	1,063	1,075	1,105	1,105	1,105	1,105	1,105
MEMPHIS	HALL	2,290	2,318	2,382	2,382	2,382	2,382	2,382
	HALL Total	3,353	3,393	3,487	3,487	3,487	3,487	3,487
COUNTY-OTHER	HANSFORD	1,051	1,148	1,273	1,381	1,471	1,562	1,648
GRUVER	HANSFORD	1,194	1,306	1,447	1,570	1,673	1,777	1,873
SPEARMAN	HANSFORD	3,368	3,505	3,648	3,759	3,873	3,991	4,113
	HANSFORD Total	5,613	5,959	6,368	6,710	7,017	7,330	7,634
COUNTY-OTHER	HARTLEY	3,313	3,465	3,708	3,837	3,929	4,011	4,077
DALHART	HARTLEY	2,749	2,816	2,923	2,980	3,021	3,058	3,087
	HARTLEY Total	6,062	6,281	6,631	6,817	6,950	7,069	7,164
CANADIAN	HEMPHILL	2,649	3,016	3,381	3,691	4,010	4,295	4,556
COUNTY-OTHER	HEMPHILL	1,158	1,193	1,228	1,257	1,287	1,314	1,339

Texas Water Development Board
2016 Regional Water Plan Population Projections for 2010-2070
Region A

WATER USER GROUP	COUNTY NAME	P2010[1]	P2020	P2030	P2040	P2050	P2060	P2070
	HEMPHILL Total	3,807	4,209	4,609	4,948	5,297	5,609	5,895
BORGER	HUTCHINSON	13,251	13,734	14,226	14,352	14,352	14,352	14,352
COUNTY-OTHER	HUTCHINSON	369	2,920	3,024	3,051	3,051	3,051	3,051
FRITCH	HUTCHINSON	2,109	2,186	2,265	2,285	2,285	2,285	2,285
HI TEXAS WATER COMPANY[2]	HUTCHINSON	2,450	-	-	-	-	-	-
STINNETT	HUTCHINSON	1,881	1,950	2,020	2,038	2,038	2,038	2,038
TCW SUPPLY INC	HUTCHINSON	2,090	2,167	2,244	2,264	2,264	2,264	2,264
	HUTCHINSON Total	22,150	22,957	23,779	23,990	23,990	23,990	23,990
BOOKER	LIPSCOMB	1,502	1,740	1,948	2,071	2,232	2,344	2,436
COUNTY-OTHER	LIPSCOMB	1,800	1,859	1,910	1,940	1,979	2,006	2,029
	LIPSCOMB Total	3,302	3,599	3,858	4,011	4,211	4,350	4,465
CACTUS	MOORE	3,179	4,232	4,824	5,455	6,095	6,763	7,444
COUNTY-OTHER	MOORE	2,100	2,413	2,752	3,111	3,476	3,857	4,247
DUMAS	MOORE	14,691	16,897	19,260	21,777	24,331	26,995	29,725
FRITCH	MOORE	8	10	11	12	14	15	17
SUNRAY	MOORE	1,926	2,216	2,525	2,855	3,190	3,540	3,897
	MOORE Total	21,904	25,768	29,372	33,210	37,106	41,170	45,330
BOOKER	OCHILTREE	14	22	33	45	58	74	92
COUNTY-OTHER	OCHILTREE	1,407	1,555	1,671	1,796	1,930	2,074	2,229
PERRYTON	OCHILTREE	8,802	9,728	10,454	11,234	12,073	12,974	13,943
	OCHILTREE Total	10,223	11,305	12,158	13,075	14,061	15,122	16,264
COUNTY-OTHER	OLDHAM	1,168	1,269	1,352	1,352	1,352	1,352	1,352
VEGA	OLDHAM	884	961	1,024	1,024	1,024	1,024	1,024
	OLDHAM Total	2,052	2,230	2,376	2,376	2,376	2,376	2,376
AMARILLO	POTTER	105,486	116,775	129,782	143,546	157,250	172,193	187,931
COUNTY-OTHER	POTTER	15,587	17,256	19,178	21,211	23,236	25,445	27,770
	POTTER Total	121,073	134,031	148,960	164,757	180,486	197,638	215,701
AMARILLO	RANDALL	85,209	94,816	106,024	117,243	128,735	140,962	153,663
CANYON	RANDALL	13,303	14,803	16,553	18,305	20,099	22,008	23,991
COUNTY-OTHER	RANDALL	21,356	23,762	26,571	29,383	32,263	35,328	38,510
HAPPY	RANDALL	61	68	76	84	93	101	111
LAKE TANGLEWOOD	RANDALL	796	820	820	820	820	820	820
	RANDALL Total	120,725	134,269	150,044	165,835	182,010	199,219	217,095
COUNTY-OTHER	ROBERTS	332	390	424	423	423	423	423
MIAMI	ROBERTS	597	613	623	624	624	624	624
	ROBERTS Total	929	1,003	1,047	1,047	1,047	1,047	1,047
COUNTY-OTHER	SHERMAN	1,017	1,104	1,197	1,246	1,291	1,323	1,347
STRATFORD	SHERMAN	2,017	2,190	2,374	2,474	2,562	2,626	2,673

Texas Water Development Board
2016 Regional Water Plan Population Projections for 2010-2070
Region A

WATER USER GROUP	COUNTY NAME	P2010[1]	P2020	P2030	P2040	P2050	P2060	P2070
	SHERMAN Total	3,034	3,294	3,571	3,720	3,853	3,949	4,020
COUNTY-OTHER	WHEELER	1,908	1,969	2,048	2,121	2,200	2,283	2,373
SHAMROCK	WHEELER	1,910	1,973	2,051	2,126	2,203	2,288	2,378
WHEELER	WHEELER	1,592	1,645	1,710	1,772	1,836	1,907	1,982
	WHEELER Total	5,410	5,587	5,809	6,019	6,239	6,478	6,733
	Region A Total	**380,733**	**418,626**	**461,008**	**503,546**	**547,060**	**592,266**	**639,220**

[1] 2010 Census Data.

[2] Hi Texas Water Company was a Water User Group in the 2011 Plan and were counted in the 2010 population estimate, but were incorporated into county other in the 2020-2070 population projections.

2016 Regional Water Plan
Municipal Water Demand Projections for 2020-2070 in acre-feet
Region A

WATER USER GROUP	COUNTY NAME	D2020	D2030	D2040	D2050	D2060	D2070
CLAUDE	ARMSTRONG	358	353	348	346	345	345
COUNTY-OTHER	ARMSTRONG	89	85	84	83	83	83
	ARMSTRONG Total	**447**	**438**	**432**	**429**	**428**	**428**
COUNTY-OTHER	CARSON	284	281	280	277	276	276
GROOM	CARSON	179	176	174	173	173	173
PANHANDLE	CARSON	572	581	582	577	576	576
WHITE DEER	CARSON	244	248	248	247	247	247
	CARSON Total	**1,279**	**1,286**	**1,284**	**1,274**	**1,272**	**1,272**
CHILDRESS	CHILDRESS	1,624	1,658	1,686	1,722	1,768	1,814
COUNTY-OTHER	CHILDRESS	198	204	210	216	222	227
	CHILDRESS Total	**1,822**	**1,862**	**1,896**	**1,938**	**1,990**	**2,041**
COUNTY-OTHER	COLLINGSWORTH	191	197	200	207	212	217
WELLINGTON	COLLINGSWORTH	525	540	549	567	582	595
	COLLINGSWORTH Total	**716**	**737**	**749**	**774**	**794**	**812**
COUNTY-OTHER	DALLAM	141	151	166	183	199	214
DALHART	DALLAM	1,815	2,014	2,228	2,447	2,666	2,878
TEXLINE	DALLAM	227	253	280	308	335	362
	DALLAM Total	**2,183**	**2,418**	**2,674**	**2,938**	**3,200**	**3,454**
CLARENDON	DONLEY	378	369	361	356	356	356
COUNTY-OTHER	DONLEY	245	237	230	228	227	227
	DONLEY Total	**623**	**606**	**591**	**584**	**583**	**583**

2016 Regional Water Plan
Municipal Water Demand Projections for 2020-2070 in acre-feet
Region A

WATER USER GROUP	COUNTY NAME	D2020	D2030	D2040	D2050	D2060	D2070
COUNTY-OTHER	GRAY	693	752	827	930	1,015	1,105
MCLEAN	GRAY	205	222	243	274	299	326
PAMPA	GRAY	3,711	3,991	4,360	4,926	5,377	5,855
	GRAY Total	**4,609**	**4,965**	**5,430**	**6,130**	**6,691**	**7,286**
COUNTY-OTHER	HALL	319	322	320	319	319	319
MEMPHIS	HALL	383	382	372	370	369	369
	HALL Total	**702**	**704**	**692**	**689**	**688**	**688**
COUNTY-OTHER	HANSFORD	138	145	157	167	176	186
GRUVER	HANSFORD	310	336	360	380	404	425
SPEARMAN	HANSFORD	672	683	691	704	724	746
	HANSFORD Total	**1,120**	**1,164**	**1,208**	**1,251**	**1,304**	**1,357**
COUNTY-OTHER	HARTLEY	655	687	700	711	725	737
DALHART	HARTLEY	854	874	882	889	899	907
	HARTLEY Total	**1,509**	**1,561**	**1,582**	**1,600**	**1,624**	**1,644**
CANADIAN	HEMPHILL	786	866	934	1,009	1,079	1,145
COUNTY-OTHER	HEMPHILL	158	157	155	158	161	164
	HEMPHILL Total	**944**	**1,023**	**1,089**	**1,167**	**1,240**	**1,309**
BORGER	HUTCHINSON	3,215	3,254	3,234	3,229	3,225	3,224
COUNTY-OTHER	HUTCHINSON	312	319	321	320	320	319
FRITCH	HUTCHINSON	437	441	436	434	433	433
STINNETT	HUTCHINSON	446	452	448	447	446	446
TCW SUPPLY INC	HUTCHINSON	738	755	754	750	749	749
	HUTCHINSON Total	**5,148**	**5,221**	**5,193**	**5,180**	**5,173**	**5,171**
BOOKER	LIPSCOMB	496	547	576	618	648	674
COUNTY-OTHER	LIPSCOMB	445	448	447	453	459	464
	LIPSCOMB Total	**941**	**995**	**1,023**	**1,071**	**1,107**	**1,138**
CACTUS	MOORE	985	1,108	1,242	1,382	1,532	1,686
COUNTY-OTHER	MOORE	327	360	397	439	486	534
DUMAS	MOORE	3,538	3,941	4,388	4,866	5,391	5,933
FRITCH	MOORE	2	3	3	3	3	4
SUNRAY	MOORE	504	562	626	695	770	847
	MOORE Total	**5,356**	**5,974**	**6,656**	**7,385**	**8,182**	**9,004**
BOOKER	OCHILTREE	7	10	13	17	21	26
COUNTY-OTHER	OCHILTREE	239	248	260	278	298	320
PERRYTON	OCHILTREE	2,829	2,994	3,183	3,401	3,650	3,922
	OCHILTREE Total	**3,075**	**3,252**	**3,456**	**3,696**	**3,969**	**4,268**
COUNTY-OTHER	OLDHAM	375	392	388	388	387	387

2016 Regional Water Plan
Municipal Water Demand Projections for 2020-2070 in acre-feet
Region A

WATER USER GROUP	COUNTY NAME	D2020	D2030	D2040	D2050	D2060	D2070
VEGA	OLDHAM	272	285	281	279	279	279
	OLDHAM Total	**647**	**677**	**669**	**667**	**666**	**666**
AMARILLO	POTTER	26,342	28,680	31,270	34,014	37,188	40,568
COUNTY-OTHER	POTTER	3,083	3,356	3,662	3,983	4,353	4,748
	POTTER Total	**29,425**	**32,036**	**34,932**	**37,997**	**41,541**	**45,316**
AMARILLO	RANDALL	21,389	23,430	25,540	27,846	30,443	33,171
CANYON	RANDALL	3,633	3,982	4,343	4,736	5,179	5,643
COUNTY-OTHER	RANDALL	3,665	4,002	4,359	4,748	5,187	5,651
HAPPY	RANDALL	11	12	13	14	15	16
LAKE TANGLEWOOD	RANDALL	319	315	312	311	310	310
	RANDALL Total	**29,017**	**31,741**	**34,567**	**37,655**	**41,134**	**44,791**
COUNTY-OTHER	ROBERTS	49	51	49	49	49	49
MIAMI	ROBERTS	224	225	223	222	222	222
	ROBERTS Total	**273**	**276**	**272**	**271**	**271**	**271**
COUNTY-OTHER	SHERMAN	184	194	197	204	208	212
STRATFORD	SHERMAN	470	498	510	524	536	546
	SHERMAN Total	**654**	**692**	**707**	**728**	**744**	**758**
COUNTY-OTHER	WHEELER	290	291	293	302	313	325
SHAMROCK	WHEELER	350	353	357	369	383	398
WHEELER	WHEELER	507	520	533	549	569	592
	WHEELER Total	**1,147**	**1,164**	**1,183**	**1,220**	**1,265**	**1,315**
	Region A Total	**91,637**	**98,792**	**106,285**	**114,644**	**123,866**	**133,572**

2016 Regional Water Plan
Irrigation Water Demand Projections for 2020 -2070 in acre-feet
Region A

	2020	2030	2040	2050	2060	2070
ARMSTRONG	4,194	3,990	3,708	3,296	2,884	2,472
CARSON	55,702	52,838	48,776	43,356	37,937	32,517
CHILDRESS	7,308	7,026	6,601	5,868	5,134	4,401
COLLINGSWORTH	17,943	17,276	16,255	14,449	12,643	10,837
DALLAM	369,864	347,524	318,795	283,373	247,952	212,530
DONLEY	24,080	23,203	21,847	19,419	16,992	14,564
GRAY	21,291	20,104	18,539	16,479	14,419	12,359
HALL	10,134	9,806	9,274	8,243	7,213	6,182
HANSFORD	134,902	126,481	115,759	102,897	90,035	77,173
HARTLEY	345,365	325,882	300,290	266,924	233,559	200,193
HEMPHILL	1,907	1,814	1,685	1,498	1,311	1,124
HUTCHINSON	40,008	37,671	34,635	30,786	26,938	23,090
LIPSCOMB	20,009	19,014	17,650	15,689	13,728	11,767
MOORE	143,028	134,395	123,290	109,591	95,892	82,193
OCHILTREE	57,243	53,825	49,414	43,923	38,433	32,942
OLDHAM	3,937	3,768	3,524	3,133	2,741	2,350
POTTER	3,427	3,292	3,091	2,748	2,404	2,061
RANDALL	18,000	17,156	15,976	14,201	12,426	10,650
ROBERTS	5,958	5,609	5,155	4,582	4,009	3,437
SHERMAN	220,966	207,757	190,687	169,499	148,312	127,125
WHEELER	8,203	7,983	7,433	6,607	5,781	4,955
Region A Total	**1,513,469**	**1,426,414**	**1,312,384**	**1,166,561**	**1,020,743**	**874,922**

2016 Regional Water Plan
Livestock Water Demand Projections for 2020-2070 in acre-feet
Region A

	2020	2030	2040	2050	2060	2070
ARMSTRONG	645	649	652	656	659	663
CARSON	692	696	700	704	709	713
CHILDRESS	490	493	495	497	500	503
COLLINGSWORTH	600	603	605	608	611	614
DALLAM	4,437	4,669	4,920	5,191	5,485	5,803
DONLEY	1,330	1,332	1,333	1,335	1,337	1,339
GRAY	1,352	1,378	1,407	1,438	1,473	1,511
HALL	336	337	339	340	341	343
HANSFORD	3,432	3,574	3,724	3,881	4,046	4,219
HARTLEY	6,498	6,977	7,498	8,066	8,684	9,359
HEMPHILL	1,275	1,279	1,284	1,289	1,295	1,302
HUTCHINSON	847	873	903	935	971	1,010
LIPSCOMB	947	969	993	1,020	1,050	1,083
MOORE	3,676	3,906	4,155	4,424	4,716	5,032
OCHILTREE	4,216	3,632	3,729	3,832	3,942	4,058
OLDHAM	1,229	1,231	1,234	1,237	1,240	1,243
POTTER	481	482	484	486	488	491
RANDALL	2,654	2,665	2,677	2,690	2,704	2,719
ROBERTS	369	369	370	371	372	373
SHERMAN	3,449	3,631	3,825	4,034	4,257	4,497
WHEELER	1,577	1,680	1,682	1,684	1,687	1,689
Region A Total	**40,532**	**41,425**	**43,009**	**44,718**	**46,567**	**48,564**

2016 Regional Water Plan

Manufacturing Water Demand Projections for 2020-2070 in acre-feet

Region A

	2020	2030	2040	2050	2060	2070
ARMSTRONG	0	0	0	0	0	0
CARSON	419	460	499	532	576	624
CHILDRESS	0	0	0	0	0	0
COLLINGSWORTH	0	0	0	0	0	0
DALLAM	9	9	10	10	11	11
DONLEY	0	0	0	0	0	0
GRAY	4,350	4,418	4,463	4,481	4,301	4,129
HALL	0	0	0	0	0	0
HANSFORD	58	61	63	65	70	74
HARTLEY	5	5	5	5	5	5
HEMPHILL	6	6	6	6	6	6
HUTCHINSON	25,347	26,827	28,249	29,483	31,540	33,741
LIPSCOMB	147	155	161	167	180	193
MOORE	9,052	9,549	10,038	10,469	11,179	11,937
OCHILTREE	0	0	0	0	0	0
OLDHAM	0	0	0	0	0	0
POTTER	9,713	10,461	11,191	11,823	12,691	13,622
RANDALL	589	638	684	722	784	852
ROBERTS	0	0	0	0	0	0
SHERMAN	0	0	0	0	0	0
WHEELER	0	0	0	0	0	0
Region A Total	**49,695**	**52,589**	**55,369**	**57,763**	**61,343**	**65,194**

2016 Regional Water Plan

Mining Water Demand Projections for 2020-2070 in acre-feet

Region A

	2020	2030	2040	2050	2060	2070
ARMSTRONG	0	0	0	0	0	0
CARSON	14	14	14	14	14	14
CHILDRESS	0	0	0	0	0	0
COLLINGSWORTH	0	0	0	0	0	0
DALLAM	0	0	0	0	0	0
DONLEY	0	0	0	0	0	0
GRAY	75	74	67	60	53	47
HALL	0	0	0	0	0	0
HANSFORD	577	904	602	309	16	1
HARTLEY	7	7	6	5	4	3
HEMPHILL	2,314	1,763	1,244	732	223	68
HUTCHINSON	184	231	170	113	56	34
LIPSCOMB	1,098	758	446	142	21	3
MOORE	16	16	16	15	15	15
OCHILTREE	824	853	503	161	23	3
OLDHAM	475	563	639	671	737	808
POTTER	941	1,149	1,341	1,453	1,631	1,831
RANDALL	0	0	0	0	0	0
ROBERTS	1,502	1,041	611	189	20	2
SHERMAN	35	207	151	98	44	20
WHEELER	3,268	2,329	1,413	503	139	119
Region A Total	**11,330**	**9,909**	**7,223**	**4,465**	**2,996**	**2,968**

2016 Regional Water Plan
Steam Electric Water Demand Projections for 2020-2070 in acre-feet
Region A

	2020	2030	2040	2050	2060	2070
ARMSTRONG	0	0	0	0	0	0
CARSON	0	0	0	0	0	0
CHILDRESS	0	0	0	0	0	0
COLLINGSWORTH	0	0	0	0	0	0
DALLAM	0	0	0	0	0	0
DONLEY	0	0	0	0	0	0
GRAY	1,409	2,112	2,299	2,952	3,087	3,320
HALL	0	0	0	0	0	0
HANSFORD	0	0	0	0	0	0
HARTLEY	0	0	0	0	0	0
HEMPHILL	0	0	0	0	0	0
HUTCHINSON	0	0	0	0	0	0
LIPSCOMB	0	0	0	0	0	0
MOORE	200	0	0	0	0	0
OCHILTREE	0	0	0	0	0	0
OLDHAM	0	0	0	0	0	0
POTTER	25,387	26,804	28,408	30,011	34,115	37,669
RANDALL	0	0	0	0	0	0
ROBERTS	0	0	0	0	0	0
SHERMAN	0	0	0	0	0	0
WHEELER	0	0	0	0	0	0
Region A Total	**26,996**	**28,916**	**30,707**	**32,963**	**37,202**	**40,989**

Chapter 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, GMAs and RWPGs for the purpose of water supply planning. 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 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 was based on the percent change between the 2050 to 2060 MAG values, then extrapolated to 2070.

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 3-1). 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 of the PWPA counties, with the exception of Childress, Collingsworth and Hall Counties. These counties are located within GMA 6. In 2009, the GMA 1 adopted desired future conditions (DFCs) for the combined Ogallala/ Rita Blanca aquifer system. The adopted DFCs for the Ogallala/Rita Blanca have not changed since they were adopted in 2009 and 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. 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. For the Blaine, the DFC states that 50 percent of the volume in storage shall remain in 50 years in Wheeler County.

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.

GMA 6 has divided the Seymour into separate sections (Pods) for DFC designation purposes. The DFC for the portions of Seymour Pods 1, 2 and 3 that are located in Childress, Collingsworth and Hall Counties (Mesquite GCD) requires that 50 percent of current volume will remain in 50 years. For the portions of Seymour Pods 3 and 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 portion of Seymour Pod 1 located in the Gateway GCD in Childress County was designated to be non-relevant.

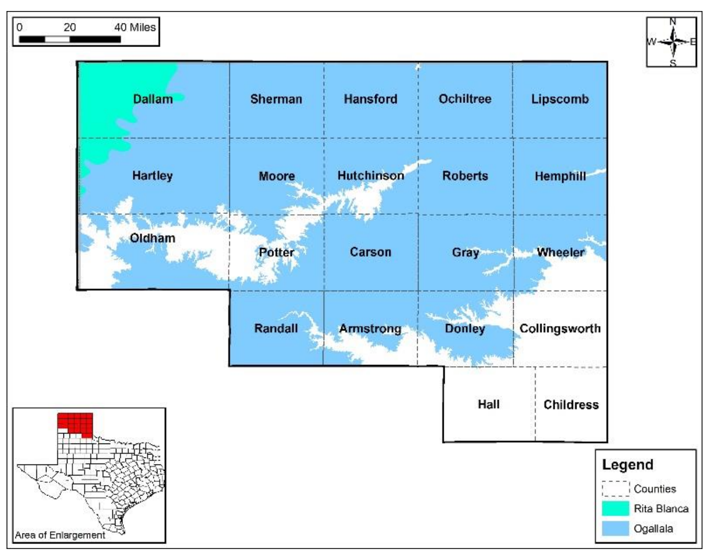
The Blaine aquifer DFC adopted within the Mesquite GCD, which includes Collingsworth, Hall and selected parcels of Childress County that were added by individual land owner petition in 2007, requires that 80 percent of current volume stored in the aquifer shall remain in 50 years. The DFC for the Blaine aquifer adopted within the Gateway GCD, which manages all of Childress County except for the tracts added via landowner petition to the Mesquite GCD, requires that total water decline will be no more than two feet over the 50-year planning period.

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

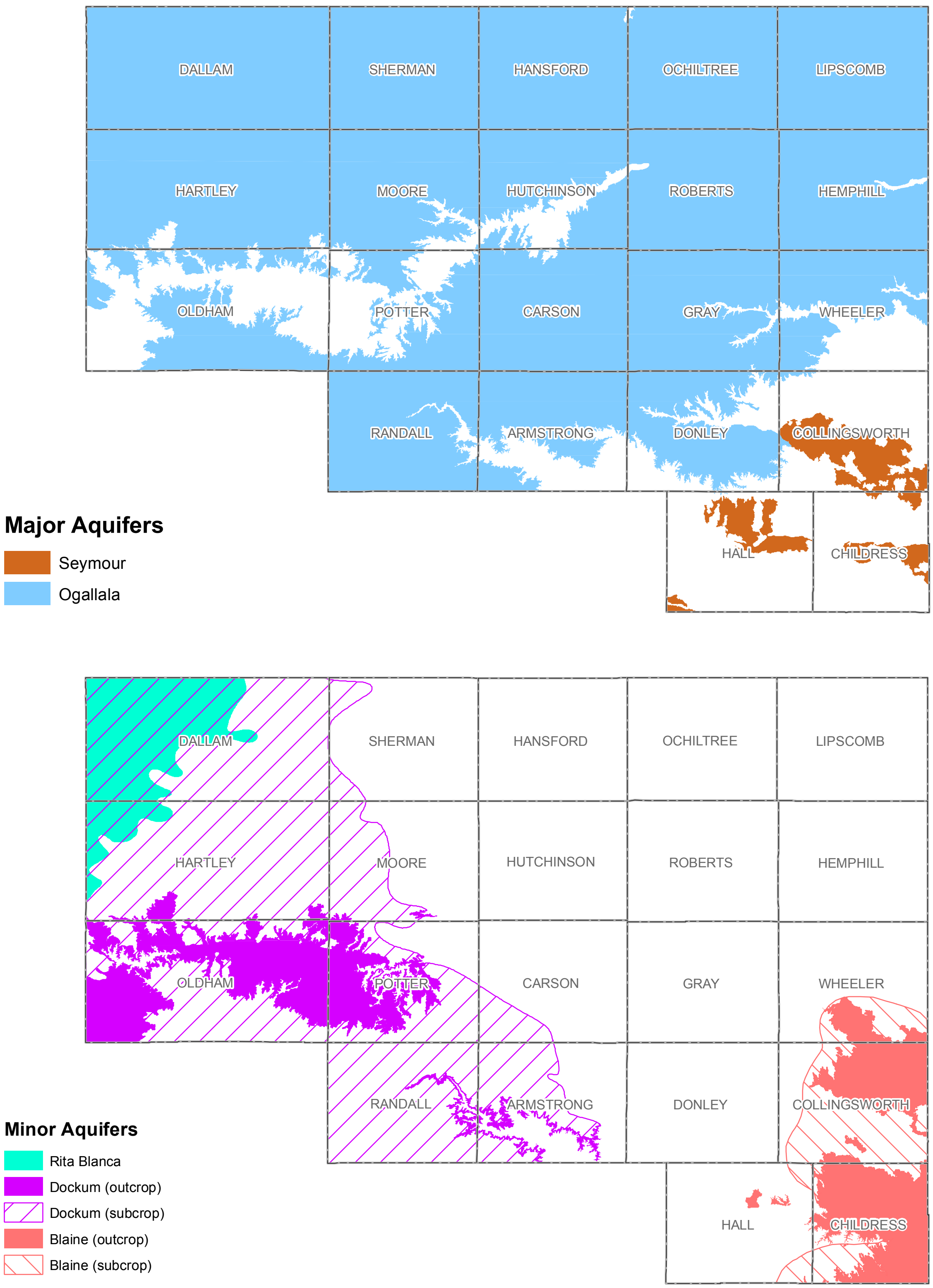
In previous planning cycles, the availability of water from the Northern Ogallala/Rita Blanca aquifer was determined using the Northern Ogallala Groundwater Availability Model (GAM) (Dutton, Reedy and Mace, 2001; Dutton 2004). In 2010, an updated version of the Northern Ogallala GAM was completed (Intera, 2010) to help support regional planning. This GAM was subsequently adopted by GMA 1 for purposes of assessing the DFCs and MAGs. As requested by GMA 1, GAM Run 12-005 MAG was completed in 2012 and the MAG values were adopted by the GMA. Available supplies of groundwater from the Dockum aquifer were determined using the Dockum GAM (GAM10-019_Final_MAG_v2).

The volumes of water available from the Seymour and Blaine aquifers were determined using the GAM analyses. In 2004, a model for the Seymour aquifer was completed (Intera, 2010). This model was utilized to determine availability for the 2006 (GAM Run 04-22) and 2011 planning cycles. To determine the MAG values, GAM Run 10-056 MAG (for the Blaine) and GAM Run 10-058 (for the Seymour) were completed in December 2011. These GAM runs are the basis of the supply for the 2016 Regional Water Plan.

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. 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.



0 10 20 40 Miles

DATE: APRIL 2015

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DATUM & COORDINATE SYSTEM GCS NORTH AMERICAN 1983

PREPARED BY: JJR

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N W E S

PANHANDLE WATER PLANNING AREA

MAJOR AND MINOR AQUIFERS

Location Map

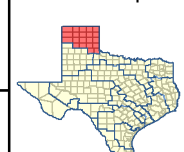


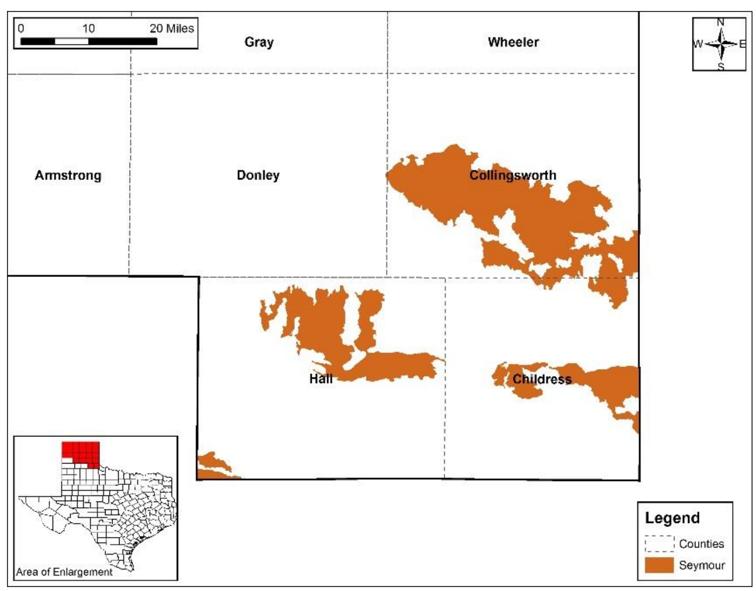
FIGURE 3-1

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 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 3,310,163 acre-feet per year in 2020 to 1,915,780 acre-feet per year by 2070. Figure 3-2 maps the MAGs by county for planning decades 2020, 2040 and 2070.

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).

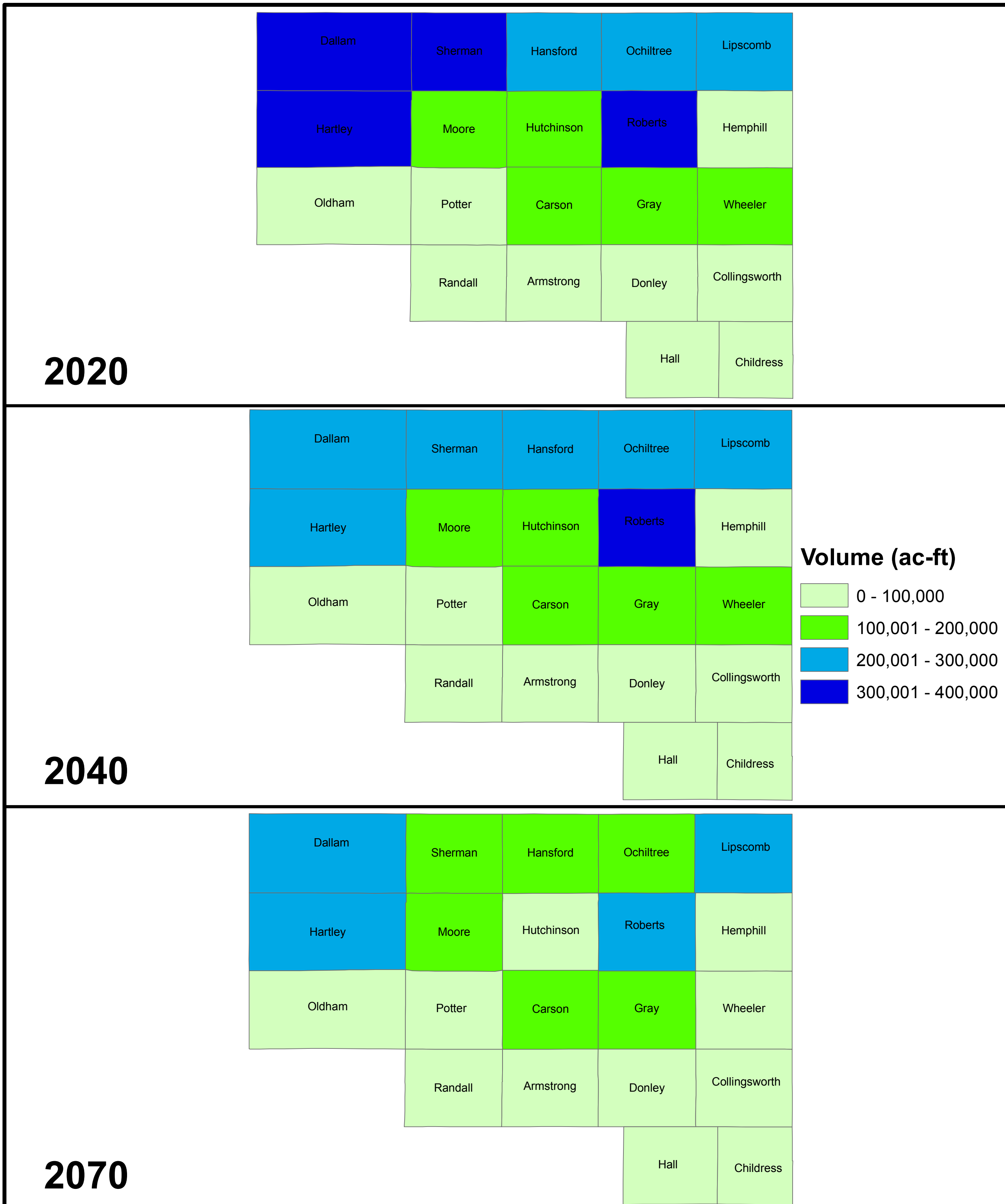
Table 3-1: Modeled Available Groundwater in the Ogallala/Rita Blanca Aquifer (ac-ft/yr)

County	Basin	2020	2030	2040	2050	2060	2070
Armstrong	Red	45,367	41,079	37,416	34,161	31,328	28,730
Carson	Canadian	81,718	73,958	66,324	59,324	53,120	47,565
	Red	89,424	80,108	71,529	63,665	56,289	49,768
Dallam	Canadian	352,474	309,076	270,317	234,813	203,491	176,347
Donley	Red	74,540	70,208	64,373	58,707	53,537	48,822
Gray	Canadian	39,813	36,848	33,749	30,659	27,766	25,146
	Red	120,860	109,180	98,784	89,135	80,128	72,031
Hansford	Canadian	262,271	240,502	218,405	197,454	177,536	159,627
Hartley	Canadian	389,548	337,001	291,094	250,966	216,098	186,074
Hemphill	Canadian	22,931	22,969	23,262	23,412	23,642	23,874
	Red	18,828	19,429	19,515	19,577	19,517	19,457
Hutchinson	Canadian	136,433	124,573	112,149	100,575	90,438	81,323
Lipscomb	Canadian	283,794	273,836	256,406	237,765	219,100	201,900
Moore	Canadian	199,354	173,987	147,617	123,573	103,113	86,041
Ochiltree	Canadian	246,475	224,578	203,704	183,227	164,265	147,265
Oldham	Canadian	19,360	18,722	17,694	16,406	15,198	14,079
	Red	3,122	2,885	2,772	2,306	2,269	2,233
Potter	Canadian	22,044	20,621	18,960	17,318	15,450	13,783
	Red	4,828	2,917	1,815	1,596	1,406	1,239
Randall	Red	85,614	82,398	75,698	68,881	58,384	49,487
Roberts	Canadian	372,950	350,415	321,680	290,903	261,482	235,037
	Red	17,951	18,202	17,565	16,609	15,557	14,572
Sherman	Canadian	300,908	263,747	229,122	197,480	169,172	144,922
Wheeler	Red	119,556	114,817	107,697	100,289	93,117	86,458
Total		**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**	**1,915,780**

Source: 2012 GAM Run 12-005 MAG Report developed by TWDB.

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 MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070 (GR10-058_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 28,762 acre-feet per year in 2020, and decrease to 21,229 acre-feet per year by 2070.



N W E S

Region A - Panhandle Regional Water Planning Area

Modeled Available Groundwater in the Ogallala Aquifer

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DATE	April, 2015
SCALE	1:0
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3-2

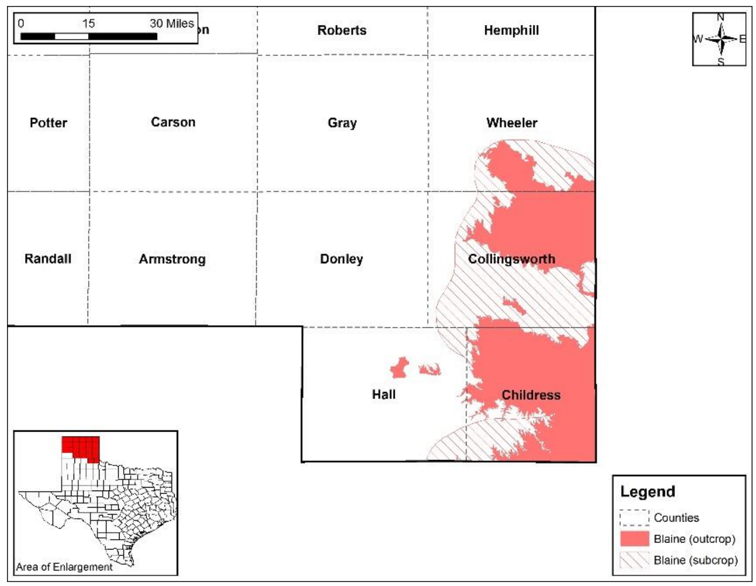
FIGURE

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

County	Basin	2020	2030	2040	2050	2060	2070
Childress	Red	732	717	712	712	712	712
Collingsworth	Red	16,010	14,250	13,348	11,329	10,241	9,257
Hall	Red	12,020	11,462	10,866	11,085	11,172	11,260
Total		**28,762**	**26,429**	**24,926**	**23,126**	**22,125**	**21,229**

Source: 2011 GAM Run 10-058 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).

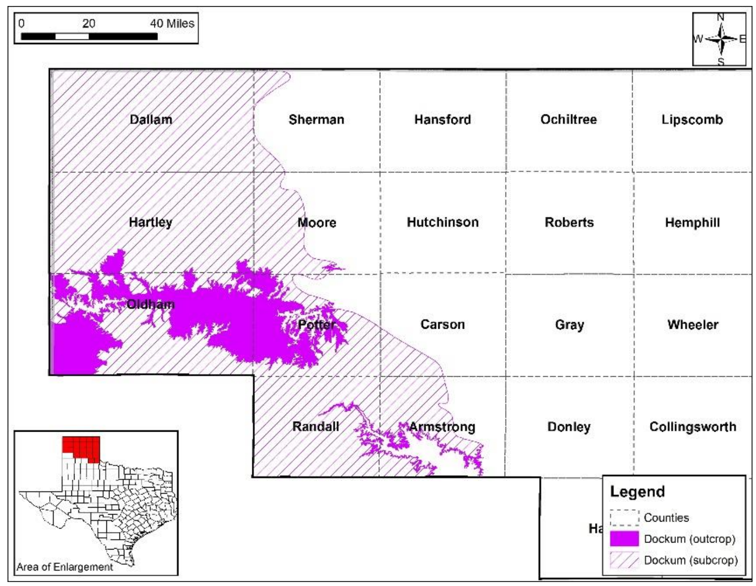
Table 3-3 presents the MAG volumes (in acre-feet per year) by county, aquifer and river basin for planning years 2020 through 2070. As shown on Table 3-3, the total Blaine MAGs in the PWPA range from 311,088 acre-feet per year in 2020, decreasing to 308,501 acre-feet per year by 2070.

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

County	Basin	2020	2030	2040	2050	2060	2070
Childress	Red	15,206	15,206	15,206	15,206	15,206	15,206
Collingsworth	Red	185,376	185,376	185,376	185,376	185,376	185,376
Hall	Red	11,509	11,509	11,509	11,509	11,509	11,509
Wheeler	Red	98,997	98,997	98,997	98,997	97,695	96,410
Total		**311,088**	**311,088**	**311,088**	**311,088**	**309,786**	**308,501**

Source: 2011 GAM Run 10-056 and GAM Run 10-020 MAG Reports 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 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 are 21,223 acre-feet per year for the entire 50-year planning cycle.

Other Aquifers

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 generally coming 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	582	582	582	582	582	582
Carson	Canadian	20	20	20	20	20	20
	Red	263	263	263	263	263	263
Dallam	Canadian	4,034	4,034	4,034	4,034	4,034	4,034
Hartley	Canadian	3,567	3,567	3,567	3,567	3,567	3,567
Moore	Canadian	5,395	5,395	5,395	5,395	5,395	5,395
Oldham	Canadian	2,868	2,868	2,868	2,868	2,868	2,868
	Red	104	104	104	104	104	104
Potter	Canadian	1,525	1,525	1,525	1,525	1,525	1,525
	Red	155	155	155	155	155	155
Randall	Red	2,119	2,119	2,119	2,119	2,119	2,119
Sherman	Canadian	591	591	591	591	591	591
Total		**21,223**	**21,223**	**21,223**	**21,223**	**21,223**	**21,223**

Source: 2011 GAM Run 10-019 MAG Report developed by TWDB

In order 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. Average well depth from recent driller's logs (2003-2013) 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.

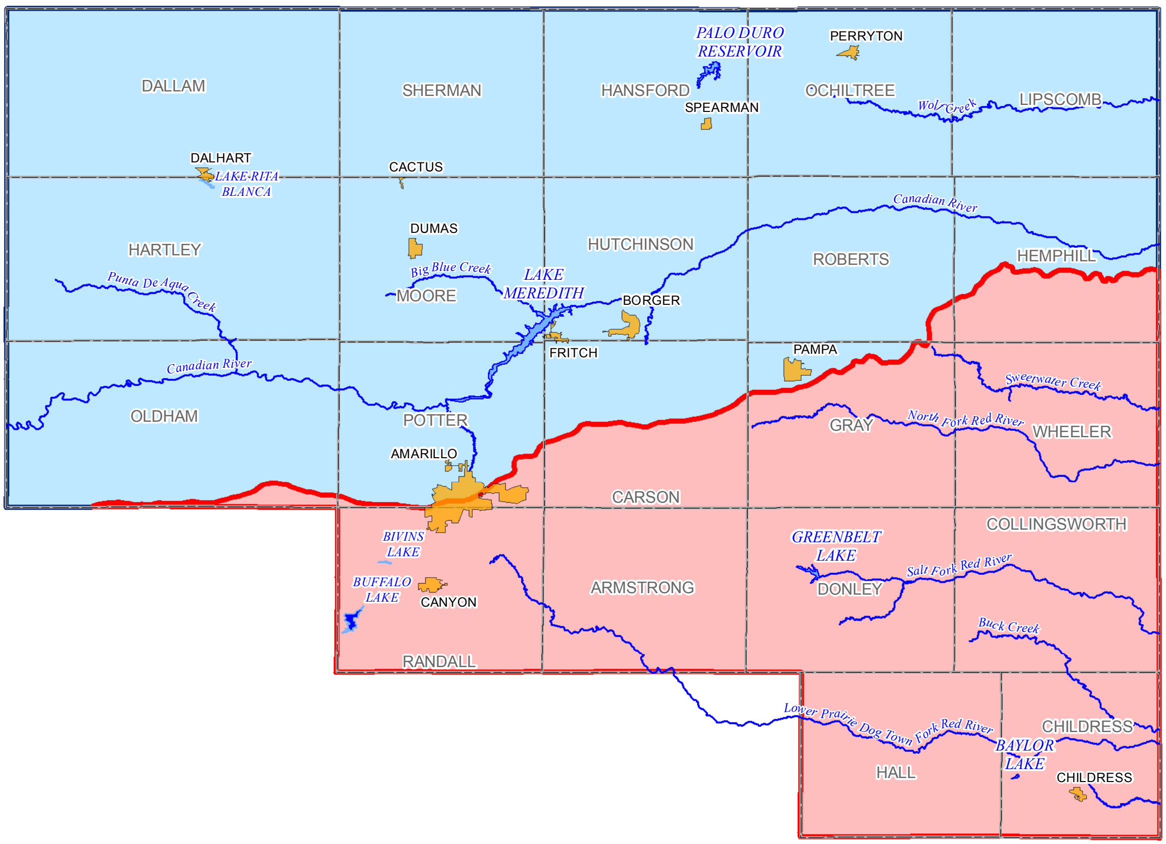
Table 3-5 presents the groundwater availability volumes derived using this methodology. Note that all of these counties are located in the Red River basin.

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

County	Supply
Armstrong	370
Childress	233
Collingsworth	309
Donley	479
Hall	1,086
Wheeler	276

3.1.3 Water Supply Reservoirs

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



LEGEND

CITY	RIVER
RESERVOIR	COUNTY
OTHER RESERVOIR	CANADIAN RIVER BASIN
WATER SUPPLY RESERVOIR	RED RIVER BASIN

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SCALE: 1:2,217,600

DATUM & COORDINATE SYSTEM: GCS NORTH AMERICAN 1983

PREPARED BY: DLB

FILE: PPC07480 H:\WR_PLANNING\WORKING\20090512_Figures\Chapter3\Figure3_5.mxd

N W E S

PANHANDLE WATER PLANNING AREA

SURFACE WATER SUPPLIES IN PWPA

Location Map

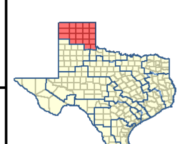


FIGURE 3-3

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 can be diverted directly from the lake, 4.030 ac-ft/yr diverted from Lelia Lake Creek, and 250 diverted directly from Salt Fork of the Red River.

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. The 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.

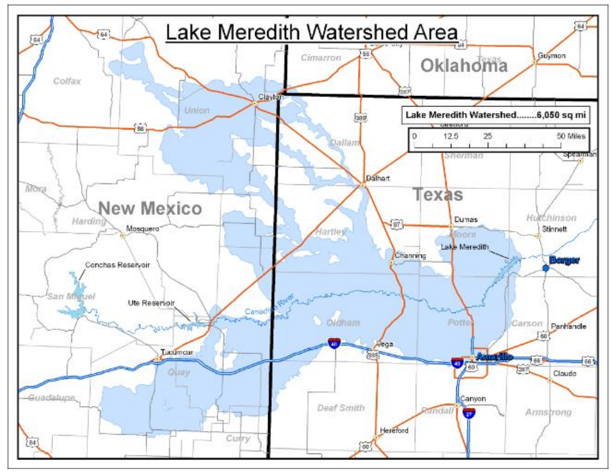
All three reservoirs in the PWPA are currently in the critical drought period. In 2011, Lake Meredith recorded the lowest historical inflow at approximately 6,300 acre-feet. Both Lake Meredith and Palo Duro Reservoir, which are located in the Canadian River Basin, are at less than 10 percent full as of October 2014. Greenbelt Reservoir, located in the Red River Basin, is approximately 15 percent full.

The TWDB guidelines specify that surface water supplies are to be determined using the Water Availability Models (WAMs) for the respective river basins. Challenges with the use of the WAM models for supply determination in the PWPA are that these models do not include the hydrology of the on-going drought and the continuation of the drought will impact the available supplies. To better represent reservoir supplies alternate methodologies were used to estimate reservoir yields and available supplies for Lake Meredith and Greenbelt Reservoir for the 2016 Regional Plan. The yield estimates from the 2011 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 are presented below. Additional information on the WAMs can be found in Appendix C.

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)



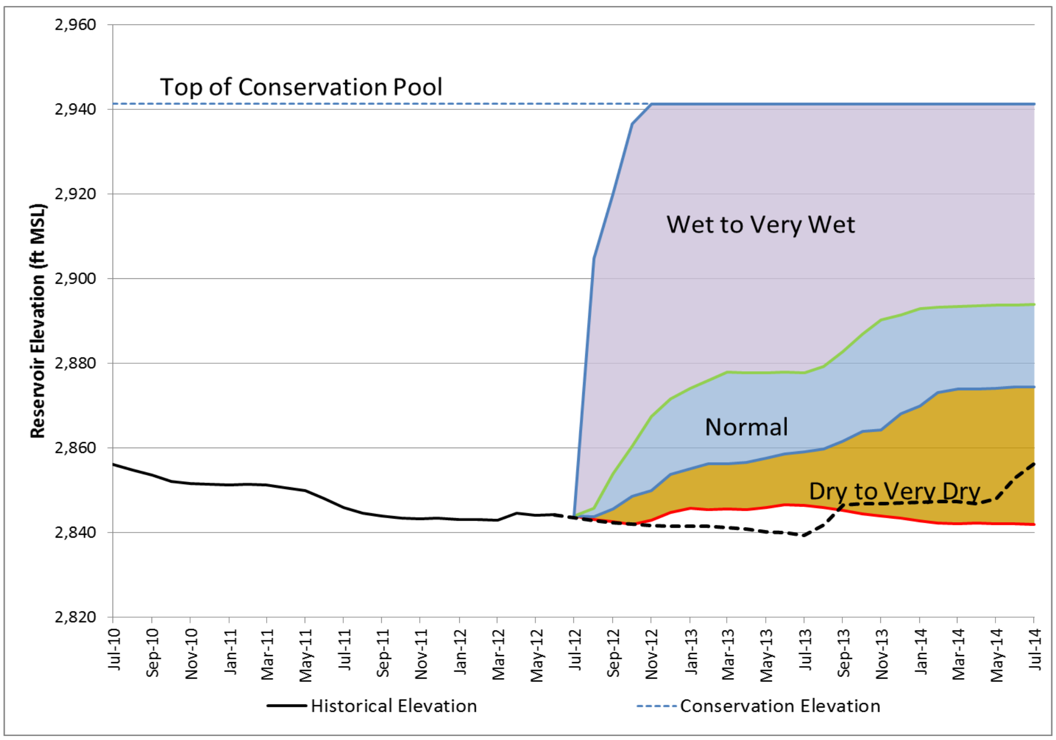
Source: http://www.CRMWA.com

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 for Lake Meredith, firm yield and safe yield analyses were conducted using the hydrology of the Canadian WAM through September 2004 and calculated inflows to the lake from October 2004 to March 2012. As expected, the minimum content of the lake occurred at the end of the simulation, indicating the reservoir was still in the critical drought. To assess the potential impacts of continuing drought, a conditional reliability assessment was conducted. A conditional reliability assessment starts with current conditions and analyzes all sequences of available historical hydrology over a specific future time period. Based on statistics of the output, a level of risk for each possible outcome is assigned. This method reveals the reliable supply based on historical hydrology sequences. For Lake Meredith, this analysis was conducted for a two-year period with the starting elevation in July 2012. Two demand scenarios were considered: 1) no diversions and 2) average historical diversions over the previous decade (55,000 acre-feet per year). The results found that even for the no diversion scenario, the lake elevations do not recover within two years under worst case conditions. The plot of the no diversions scenario is shown on Figure 3-4. This figure also shows that the historical elevations over the projected future simulation period (July 2012 – July 2014) were less than the minimum predicted elevation until September 2013, indicating the lake has little to no reliable supply.

Figure 3-4: Conditional Reliability Assessment for Lake Meredith with No Diversions



Based on the updated analyses, projections of conservation storage, firm yield, safe yield and reliable supply for Lake Meredith during the planning period are shown in Table 3-7.

Table 3-7: Projected Yield and Available Supply 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)	37,505	37,505	37,505	37,505	37,505	37,505
Safe Yield (ac-ft/yr)	32,928	32,928	32,928	32,928	32,928	32,928
Available Supply[2] (ac-ft/yr)	0	0	0	0	0	0

[1] Limited by provisions of the Canadian River Compact.
[2] Available supply is the amount of water assumed available to users for regional water planning.

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 dam began impounding water in January 1991 and was over 80% full (by depth) in 2000. However, due to continued drought and reduced inflows, the reservoir was less than 5% full in October 2014.

The original conservation storage capacity of the reservoir was estimated to be 60,897 acre-feet. A study by Freese and Nichols (1974) estimated the yield to be approximately 8,700 acre-feet per year. The most recent yield studies for the Palo Duro Reservoir show that it is currently in its critical period. The firm yield with the Canadian River Basin WAM estimated the yield of about 4,000 acre-feet year considering a hydrology through September 2004. 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 near gages or mass balance.

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.

Based on a linear interpolation of the most recent yield estimate, the projected firm yield of Palo Duro Reservoir is expected to decrease from 3,917 acre-feet in 2020 to 3,792 acre-feet in 2050 and down 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. The available supply from Palo Duro Reservoir is limited during the beginning of the planning period by the lack of a delivery system.

Table 3-8: Projected Yield 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).

Similar to Lake Meredith, Greenbelt Reservoir experienced declining water levels in response to the recent drought. To address the Greenbelt MIWA's concerns, a reliability analysis was conducted for Greenbelt Reservoir in 2011 (Freese, 2011). This study evaluated the firm and safe yields of the reservoir using inflows from the Red River WAM through 1998 and calculated inflows through 2010. It also conducted a reliability assessment to determine the potential future response of the reservoir under different inflow conditions.

The yield studies found that the reservoir was in critical drought conditions at the end of the simulation (2010), indicating continuing drought would impact the yield estimates. The study also 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 reliability analysis found that the reservoir was able to sustain a demand of 3,850 acre-feet per year over a projected future 5-year period with a minimum storage content of about 1,000 acre-feet. Based on these results, it is recommended that the supply from the reservoir be limited to 3,850 acre-feet per year. A summary of the yield analyses and reliable supply is shown in Table 3-9.

Table 3-9: Projected Yield and Available Supply 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)	8,164	8,031	7,898	7,765	7,630	7,495
Safe Yield (ac-ft/yr)	6,728	6,592	6,456	6,320	6,181	6,042
Reliable Supply (ac-ft/yr)	3,850	3,768	3,686	3,604	3,522	3,440

3.1.4 Run of the River Supplies

According to the TCEQ water rights database there are 107 water rights permit holders in the PWPA representing a total of 185,663 acre-feet per year (TCEQ 2014). Three water rights permits are associated with water supply reservoirs, which are discussed in Section 3.1.3 and further documented in Appendix C. These represent a total of 177,690 acre-feet per year, or approximately 96 percent of the total water rights allocated in the PWPA. The remaining 103 water rights represent the run of the river supplies, which are diversions directly from a stream or river. Table 3-10 summarizes these rights by county in the PWPA. The permitted diversions total 7,973 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 listing of the water rights and the methodology to assess the available supply are included in Appendix C.

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

3.1.5 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, without a right for diversion.

In 1982, the low water dam was rebuilt, and was reworked in 1992 to become a flood control structure (R.N. Clark, Personal Communication). 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)
Buffalo Lake	Tierra Blanca Creek	Red	flood control, promotion of wildlife	n/a	1938	18,121
Lake Tanglewood	Palo Duro Creek	Red	recreation	n/a	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 earthfill 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 an artificial 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 basins. These are ephemeral wetlands which are an important element of surface hydrology and ecological diversity. Most playas are seasonally flooded basins, receiving their water only from rainfall or snowmelt. Moisture loss occurs by evaporation and filtration through the soil to underlying aquifers. In some years there is little to water in area playa lakes.

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 5,457 playa lakes are located in the PWPA, covering approximately one percent of the surface area (NRCS, 2009). Playa basins 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, and are generally circular to oval in shape. Typically, the soil in the playas is the Randall Clay.

Playa basins also supply important habitat for resident wildlife. The basins 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. Table 3-12 shows the estimated acreage and water storage for playa lakes in the PWPA.

A number of other small reservoirs are currently used for private storage and diversion purposes. In order to use any of the minor reservoirs for water supply purposes, water rights for diverting the water for a specific use would be needed. Other issues may be associated with diverting water from playa lakes. Therefore, these surface water sources have not been included as sources of available water supplies.

3.1.6 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. 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**	**341,068**

[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	57	58	58	58	58	58
Childress	162	166	169	172	177	181
Collingsworth	53	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	1,045	1,045	1,045	1,045	1,045	1,045
Lipscomb	0	0	0	0	0	0
Moore	0	0	0	0	0	0
Ochiltree						
Oldham						
Potter	27,587	29,004	30,608	32,211	36,315	39,869
Randall	545	597	651	710	777	846
Roberts	0	0	0	0	0	0
Sherman	0	0	0	0	0	0
Wheeler	51	52	53	55	57	59
Total	**29,820**	**31,296**	**32,959**	**34,628**	**38,807**	**42,438**

3.1.7 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 and self-contained storage facilities (old gravel pits, etc.) for mining. The amounts of available supplies for these uses are based on data collected by the TWDB on historical water use. A summary of the local supplies by county is shown in Table 3-14.

3.1.8 Summary of Water Supplies in the PWPA

The available water supplies in the PWPA total over 3,700,000 acre-feet per year in 2020, decreasing to 2,300,000 acre-feet per year by 2070. 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**

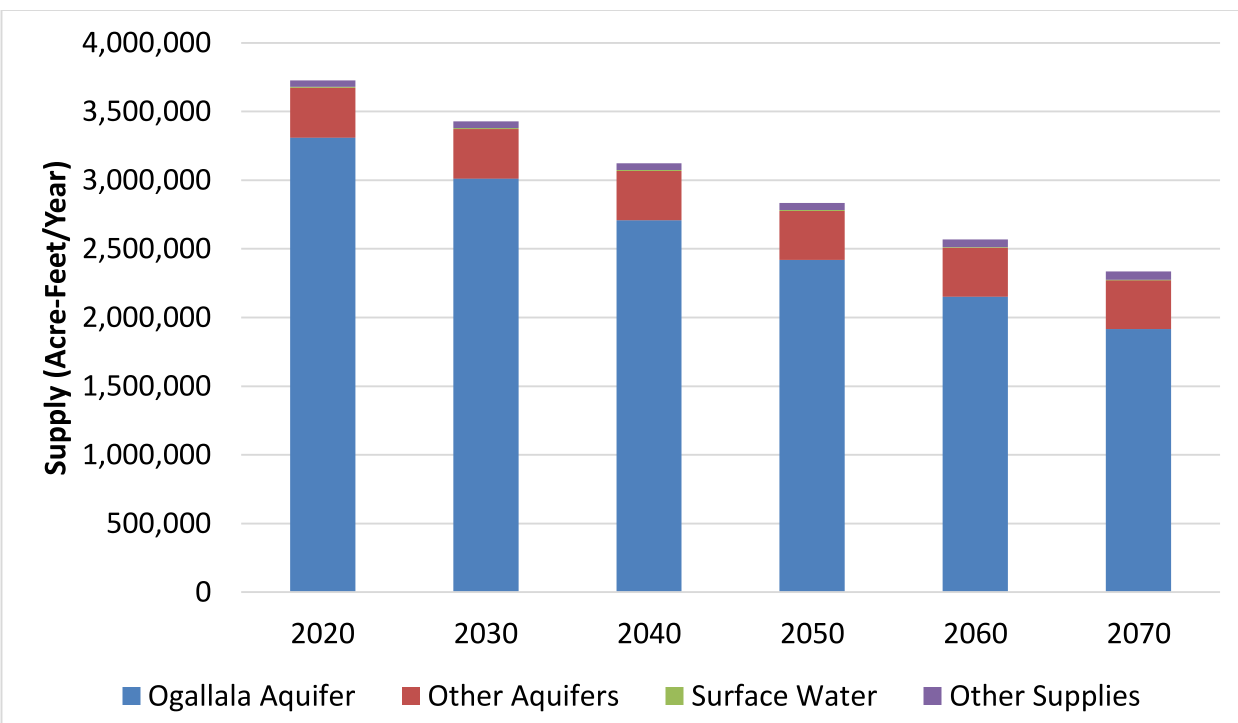
The supplies shown in Table 3-15 and Figure 3-7 represent the amount of water supply that is located in the PWPA and includes supplies that are currently developed and potential future supplies that could be developed. For reservoirs, the supply used for planning purposes is shown. For groundwater, the PWPG adopted availabilities are shown (MAGs for major and minor aquifers and adopted supplies for Other Aquifer). These values do not consider infrastructure constraints, contractual agreements, or the economic feasibility of developing these sources. Nor do they consider the ultimate location of use (e.g., exports to Regions O and B). These values are reported by its source location (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)

Source	2020	2030	2040	2050	2060	2070
Lake Meredith (available supply)	0	0	0	0	0	0
Greenbelt Lake (available supply)	3,850	3,782	3,714	3,646	3,578	3,440
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
Total Surface Water	**10,305**	**10,195**	**10,085**	**9,976**	**9,866**	**9,686**
Ogallala Aquifer	3,310,163	3,012,056	2,707,647	2,418,801	2,151,403	1,915,780
Seymour Aquifer	28,762	26,429	24,926	23,126	22,125	21,229
Blaine Aquifer	311,088	311,088	311,088	311,088	309,786	308,501
Dockum Aquifer	21,223	21,223	21,223	21,223	21,223	21,223
Other Aquifers	2,753	2,753	2,753	2,753	2,753	2,753
Total Groundwater	**3,673,989**	**3,373,549**	**3,067,637**	**2,776,991**	**2,507,290**	**2,269,486**
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	29,820	31,296	32,959	34,628	38,807	42,438
Total Supply in PWPA	**3,730,897**	**3,431,823**	**3,127,464**	**2,838,378**	**2,572,746**	**2,338,393**

*No current infrastructure

Figure 3-5: 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 groundwater 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 1.7 million acre-feet.

Figure 3-6 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 2010 and 2060). In 2010 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 3-6: Ogallala Simulated Saturated Thickness Based on Modeled Available Groundwater

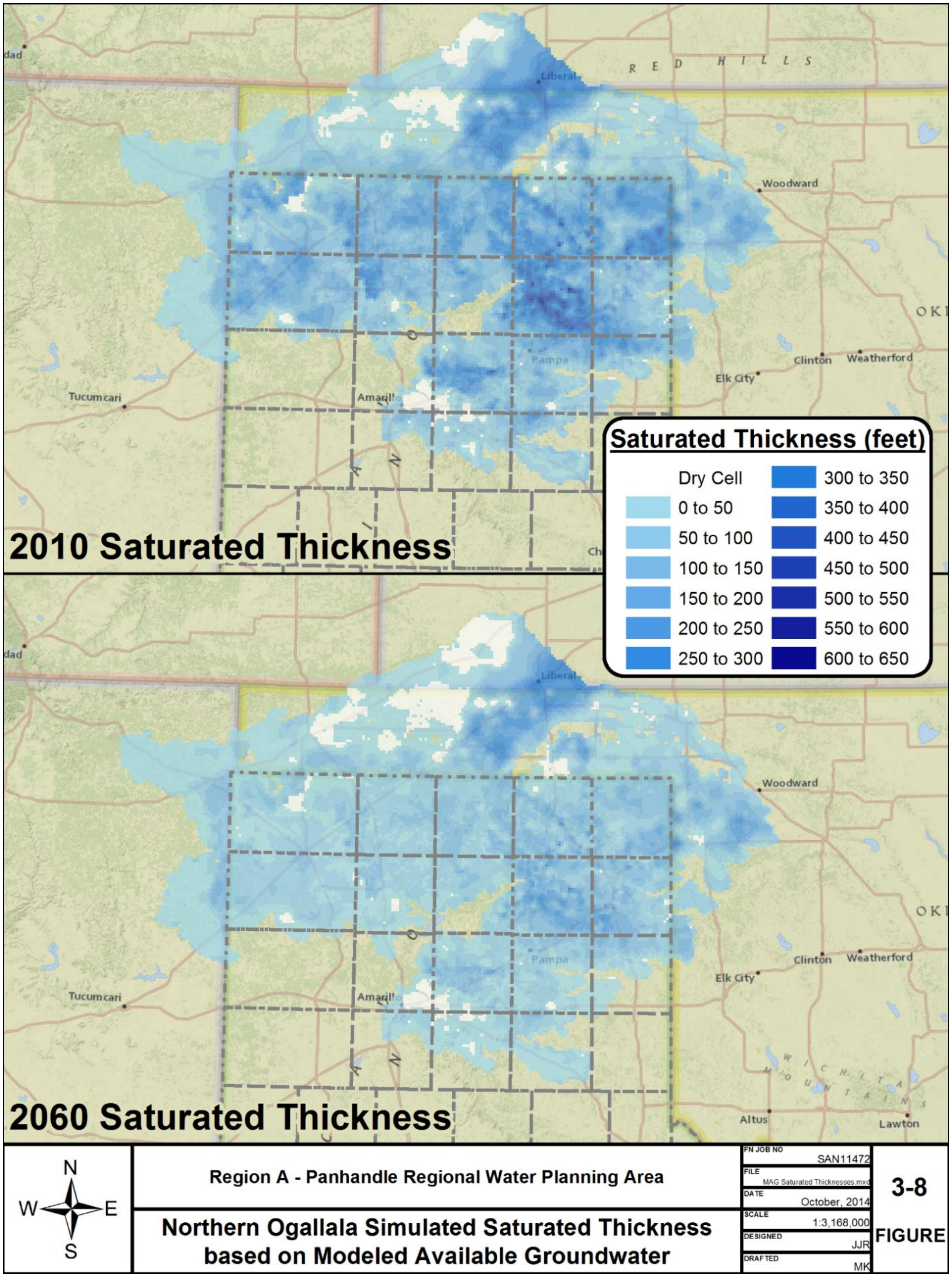
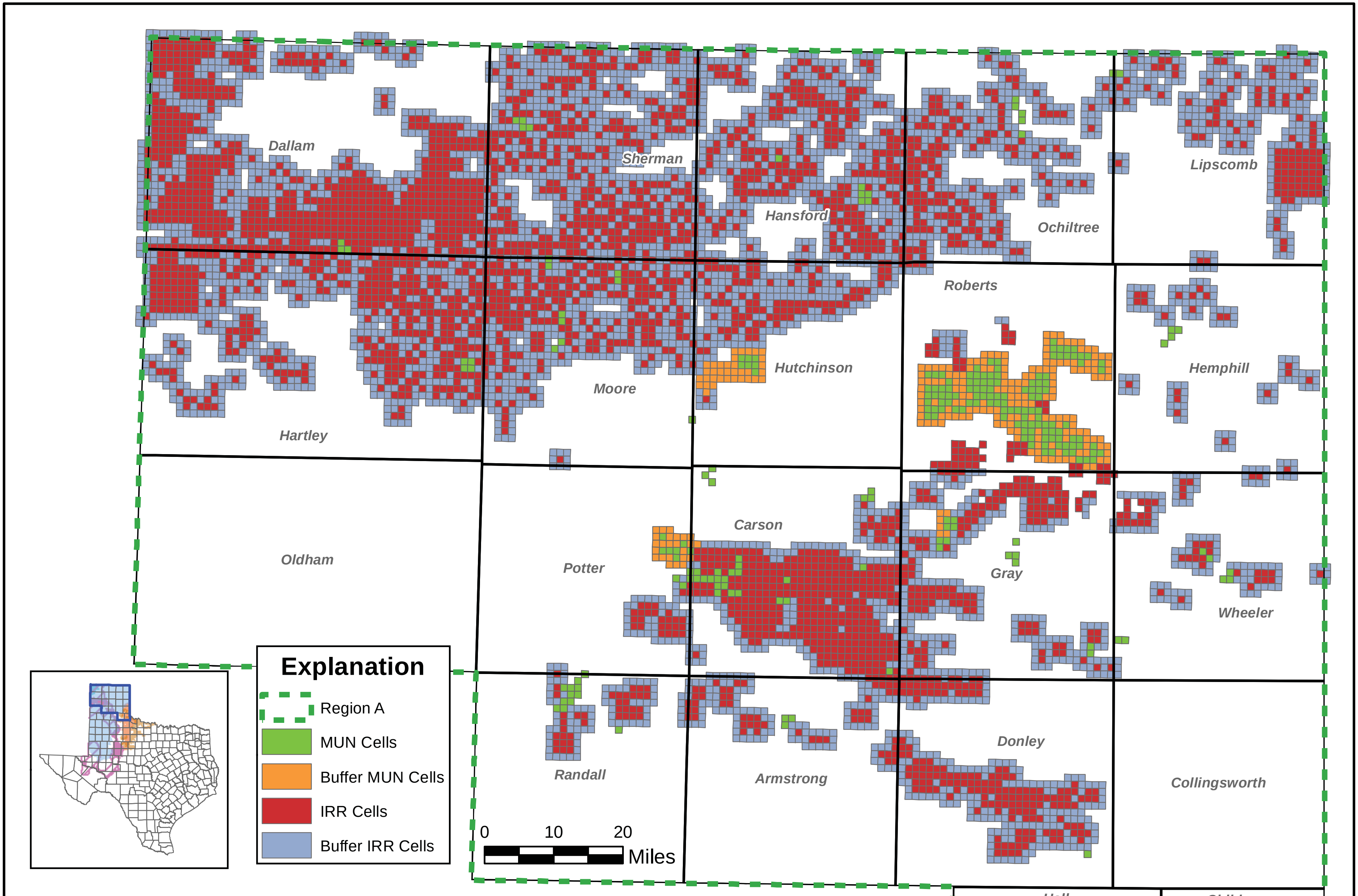


Table 3-16: Projected Total Production from the Ogallala Aquifer within PWPA (ac-ft/yr)

County	2020	2030	2040	2050	2060	2070
Armstrong	5,118	4,909	4,624	4,213	3,803	3,395
Carson	68,586	64,203	58,686	52,080	45,799	39,521
Dallam	370,979	349,106	320,885	285,998	251,134	216,284
Donley	24,884	23,985	22,607	20,165	17,728	15,292
Gray	29,832	29,210	27,747	26,331	24,210	22,206
Hansford	137,450	129,545	118,717	105,764	92,832	80,185
Hartley	349,030	330,078	305,027	272,246	239,522	206,850
Hemphill	6,025	5,464	4,887	4,271	3,654	3,388
Hutchinson	67,690	66,740	65,137	62,494	60,559	58,834
Lipscomb	22,966	21,715	20,097	17,913	15,910	14,008
Moore	160,321	152,833	143,148	130,877	118,977	107,174
Ochiltree	64,937	61,141	56,681	51,191	45,946	40,850
Oldham	4,492	4,441	4,265	3,904	3,577	3,257
Potter	27,848	55,223	57,345	59,230	63,800	67,889
Randall	25,967	24,913	23,711	22,035	20,500	19,000
Roberts	108,341	115,898	120,335	126,659	137,220	136,715
Sherman	224,020	211,203	194,286	173,275	152,273	131,316
Wheeler	12,597	11,557	10,111	8,412	7,268	6,472
Total	**1,711,083**	**1,662,163**	**1,558,297**	**1,427,058**	**1,304,712**	**1,172,636**

Note: The demands on the Ogallala aquifer shown above represent the expected demands less supplies from other sources. This differs from the allocated supplies from the Ogallala aquifer. Allocated supplies may be greater in some counties and less in other counties, pending availability and infrastructure constraints.

To assist with the allocation of Ogallala water to irrigation and municipal users, the Northern Ogallala GAM was used. This model simulation was designed to meet the adopted DFCs spatially and over time (i.e., pumping was limited such that the DFC was met for each grid cell each decade). This is a more conservative approach to allocating groundwater but it provides better defined geographical constraints than county-wide availability values. 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 3-7. 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.



Region A - Panhandle Regional Water Planning Area

Irrigation and Municipal Pumping Cells in the Ogallala/Rita Blanca Aquifer GAM

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FIGURE

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 Wholesale Water Provider Supplies and Allocation to Users

As part of the water allocation process, water developed by wholesale water providers is distributed to its customers, which are then assigned to the appropriate water user group. Generally, if the wholesale 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 wholesale provider exceeded its developed supplies, then the supplies were reduced proportionally to all customers. This reduction in supply was applied to each of the wholesale provider's sources as appropriate. In the PWPA, only Greenbelt MIWA was shown to have sufficient supplies to meet its customers' demands. Any surplus water from Greenbelt MIWA's sources was assigned to the wholesale provider. Table 3-17 shows the water supplies available to wholesale 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. 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. 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 in Region B and the Red River Authority that provides water to county-other in Region B. Approximately 34,000 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 water imported and exported from the region.

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

		Supply (ac-ft/yr)					
Wholesale Provider	**Source**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Amarillo	Ogallala - Randall County	2,263	1,735	1,372	1,100	890	680
	Ogallala - Potter County	9,467	7,388	7,123	6,735	6,200	5,664
	Ogallala - Carson County	10,948	9,378	7,883	6,669	5,760	4,850
	Ogallala - Deaf Smith	100	100	100	100	50	0
	CRMWA	28,029	27,841	24,313	20,782	18,754	16,729
	Total	**50,807**	**46,442**	**40,791**	**35,386**	**31,654**	**27,923**
CRMWA	Lake Meredith	0	0	0	0	0	0
	Ogallala - Roberts County	69,000	60,463	55,502	50,483	45,590	40,697
Borger	Ogallala - Hutchinson County	4,667	3,802	3,249	2,803	2,434	2,064
	Ogallala - Carson County	561	457	391	337	293	248
	Direct Reuse	1,045	1,045	1,045	1,045	1,045	1,045
	CRMWA	3,829	3,829	3,439	2,938	2,650	2,363
	Total	**10,102**	**9,133**	**8,124**	**7,123**	**6,422**	**5,720**
Cactus	Ogallala - Moore County	1,733	1,359	1,053	794	677	559
Greenbelt MIWA	Ogallala - Donley County	1,900	1,615	1,373	1,167	992	843
	Greenbelt Reservoir	3,850	3,768	3,686	3,604	3,522	3,440
	Total	**5,750**	**5,383**	**5,059**	**4,771**	**4,514**	**4,283**

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

Source	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Exports:						
Lake Meredith	0	0	0	0	0	0
Greenbelt Reservoir	660	695	731	777	805	831
Ogallala (Donley County)	326	297	272	251	227	204
Ogallala (Roberts County)	34,658	27,778	26,857	24,818	22,431	20,039
Total	**35,644**	**28,770**	**27,860**	**25,846**	**23,463**	**21,074**
Imports:						
Ogallala (Deaf Smith County)	300	300	300	300	250	200
Ogallala (Swisher County)	10	12	12	13	12	10

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	437	441	436	434	433	433
	Moore	5	5	5	5	5	5
	Potter	6,042	5,162	4,340	3,667	3,168	2,668
	Randall	4,906	4,216	3,543	3,002	2,592	2,182
Dallam	Hartley	614	530	440	361	294	234
Donley	Hall	476	437	409	334	296	259
	Childress	596	552	509	468	433	397
Hartley	Moore	2,171	2,174	2,066	1,896	1,700	1,504
Lipscomb	Ochiltree	7	10	11	10	10	9
Potter	Randall	2,938	2,312	2,392	2,372	2,275	2,174
Roberts	Gray	2,484	1,015	893	1,945	1,755	1,566
	Hutchinson	3,829	3,829	3,439	2,938	2,650	2,363
	Potter	17,440	17,169	15,018	12,839	11,825	10,527
	Randall	10,589	10,672	9,295	7,943	6,929	6,202

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 94 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 1,570,000 acre-feet per year and projected to decrease to 1,320,000 by the year 2040 and ultimately to 921,000 acre-feet per year in 2070. These supply volumes are shown in Table 3-20.

The developed supply is less than 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 on Figure 3-8.

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]	0	0	0	0	0	0
Greenbelt Lake[1]	1,652	1,748	1,838	1,934	2,037	2,137
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	**4,190**	**4,286**	**4,376**	**4,472**	**4,575**	**4,675**
Ogallala Aquifer[1]	1,476,344	1,353,859	1,225,504	1,087,569	954,839	825,590
Seymour Aquifer	18,915	18,253	17,211	15,277	13,409	11,578
Blaine Aquifer	16,515	15,899	14,964	13,336	11,699	10,063
Dockum Aquifer	7,730	7,719	7,710	7,700	7,691	7,683
Other Aquifer	2,317	2,317	2,317	2,317	2,252	2,149
Total Groundwater	**1,521,821**	**1,398,047**	**1,267,706**	**1,126,199**	**989,890**	**857,063**
Local Supply	16,783	16,783	16,783	16,783	16,783	16,783
Direct Reuse	29,820	31,296	32,959	34,628	38,807	42,438
Total Other Supplies	**46,603**	**48,079**	**49,742**	**51,411**	**55,590**	**59,221**
Total Supply	**1,572,614**	**1,450,412**	**1,321,824**	**1,182,082**	**1,050,055**	**920,959**

[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 WWP and are not reported in this table.
[2] There is no currently available supply from Palo Duro Reservoir because there is no infrastructure.

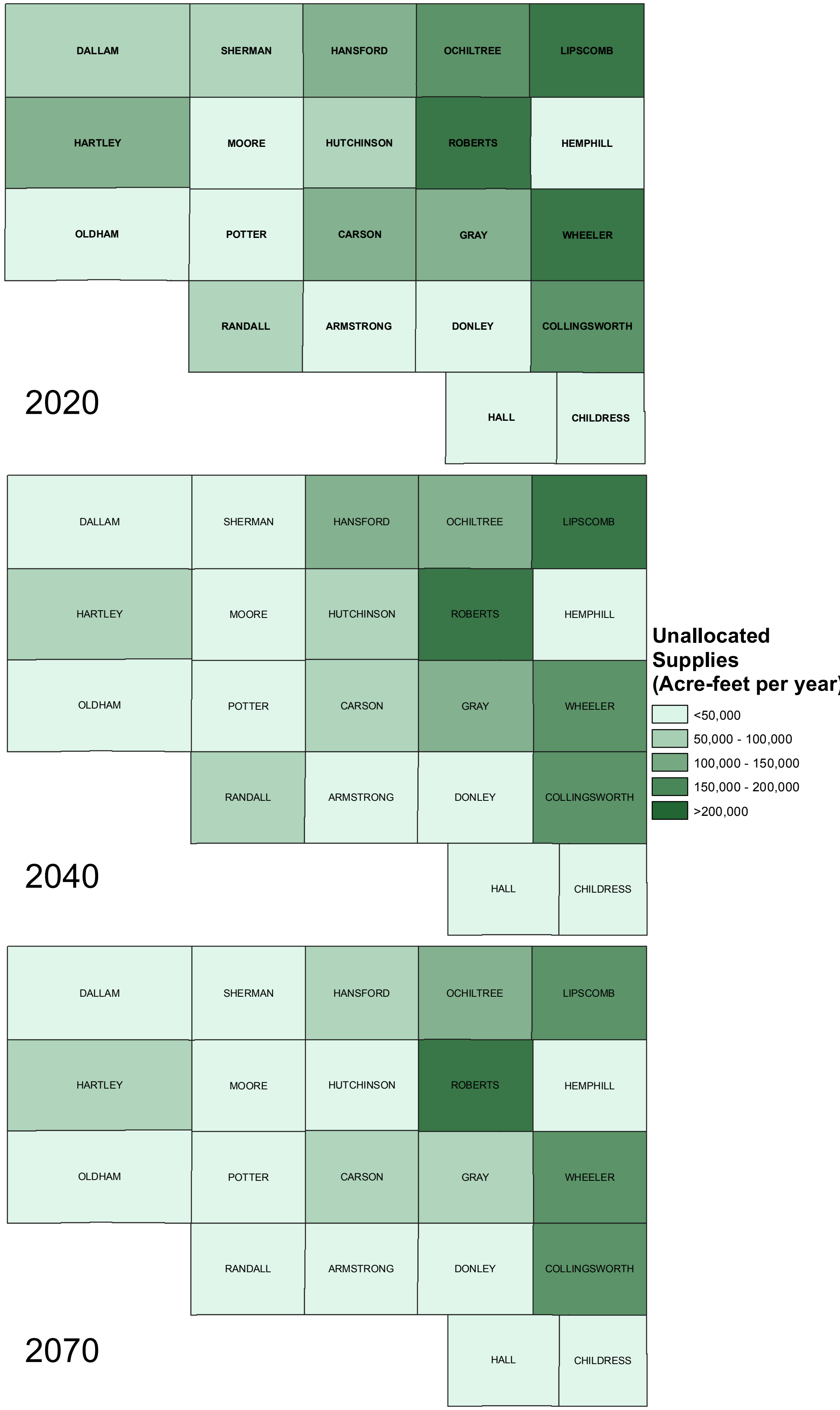
Table 3-21: Unallocated Water Supplies in PWPA (ac-ft/yr)

Source	2020	2020	2030	2040	2050	2060
Lake Meredith	0	0	0	0	0	0
Greenbelt Lake	1,538	1,325	1,117	893	680	472
Palo Duro Reservoir	3,917	3,875	3,833	3,792	3,750	3,708
Ogallala Aquifer	1,799,145	1,630,434	1,455,326	1,306,476	1,174,168	1,070,157
Seymour Aquifer	9,847	8,176	7,715	7,849	8,716	9,651
Blaine Aquifer	294,573	295,189	296,124	297,752	298,087	298,438
Dockum Aquifer	13,448	13,459	13,469	13,479	13,488	13,497
Other Aquifer	436	436	436	436	501	604
Total Groundwater	**2,117,449**	**1,947,694**	**1,773,070**	**1,625,992**	**1,494,960**	**1,392,347**
Other Supplies	**0**	**0**	**0**	**0**	**0**	**0**
Total Unallocated Supply	**2,122,904**	**1,952,908**	**1,778,048**	**1,630,719**	**1,499,446**	**1,396,527**

Note: The amount shown for unallocated supplies accounts for water that is used outside of the PWPA.

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

County	2020	2030	2040	2050	2060	2070
Armstrong	41,039	37,009	33,676	30,872	28,486	26,334
Carson	101,451	89,331	78,817	70,652	63,483	57,833
Childress	8,367	8,634	9,054	9,787	10,521	11,254
Collingsworth	182,929	181,837	181,955	181,734	182,452	183,274
Dallam	61,797	52,917	45,342	38,414	32,800	31,350
Donley	49,706	46,178	41,616	38,317	35,481	33,034
Gray	129,790	115,883	103,842	92,658	82,980	74,380
Hall	14,176	13,946	13,882	15,132	16,249	17,368
Hansford	128,561	114,723	103,537	95,870	89,105	84,046
Hartley	118,912	101,397	85,939	72,818	61,596	55,163
Hemphill	35,670	36,869	37,823	38,654	39,444	39,885
Hutchinson	70,452	60,846	51,148	43,203	35,899	29,427
Lipscomb	260,727	252,020	236,304	220,082	203,545	188,366
Moore	49,204	33,079	17,938	8,923	6,933	6,531
Ochiltree	181,999	164,385	148,448	133,902	120,651	109,195
Oldham	19,373	18,579	17,606	16,211	15,292	14,457
Potter	12,766	11,763	9,460	8,199	6,753	5,693
Randall	61,158	59,421	54,361	49,680	41,246	34,408
Roberts	313,559	300,622	277,095	251,458	226,686	204,806
Sherman	76,666	52,350	34,654	24,181	17,074	13,978
Wheeler	204,602	201,119	195,551	189,972	182,770	175,745
Total	**2,122,904**	**1,952,908**	**1,778,048**	**1,630,719**	**1,499,446**	**1,396,527**



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PANHANDLE WATER PLANNING AREA

UNALLOCATED SUPPLIES IN PWPA

Location Map

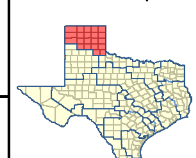


FIGURE 3-8

Attachment 3-1

WATER USER GROUP EXISTING WATER SUPPLIES

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR)					
		2020	2030	2040	2050	2060	2070
ARMSTRONG COUNTY							
RED BASIN							
CLAUDE	A | OGALLALA AQUIFER | ARMSTRONG COUNTY	463	405	354	311	273	235
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 | OGALLALA AQUIFER | ARMSTRONG COUNTY	493	497	500	504	507	511
LIVESTOCK	A | OTHER AQUIFER FRESH/BRACKISH | ARMSTRONG COUNTY	30	30	30	30	30	30
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	122	122	122	122	122	122
IRRIGATION	A | OGALLALA AQUIFER | ARMSTRONG COUNTY	4,194	3,990	3,708	3,296	2,884	2,472
RED BASIN TOTAL EXISTING SUPPLY		**5,402**	**5,144**	**4,814**	**4,363**	**3,916**	**3,470**
ARMSTRONG COUNTY TOTAL EXISTING SUPPLY		**5,402**	**5,144**	**4,814**	**4,363**	**3,916**	**3,470**
CARSON COUNTY							
CANADIAN BASIN							
WHITE DEER	A | OGALLALA AQUIFER | CARSON COUNTY	106	107	107	107	107	107
COUNTY-OTHER	A | OGALLALA AQUIFER | CARSON COUNTY	249	237	228	225	208	185
MANUFACTURING	A | OGALLALA AQUIFER | CARSON COUNTY	25	28	30	32	35	37
MINING	A | OGALLALA AQUIFER | CARSON COUNTY	14	14	14	14	14	14
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	59	59	59	59	59	59
LIVESTOCK	A | OGALLALA AQUIFER | CARSON COUNTY	460	463	466	469	473	476
IRRIGATION	A | OGALLALA AQUIFER | CARSON COUNTY	14,483	13,738	12,682	11,273	9,864	8,454
CANADIAN BASIN TOTAL EXISTING SUPPLY		**15,396**	**14,646**	**13,586**	**12,179**	**10,760**	**9,332**
RED BASIN							
GROOM	A | OGALLALA AQUIFER | CARSON COUNTY	326	342	344	338	326	314
PANHANDLE	A | OGALLALA AQUIFER | CARSON COUNTY	483	60	0	0	0	0
WHITE DEER	A | OGALLALA AQUIFER | CARSON COUNTY	138	141	141	140	140	140
COUNTY-OTHER	A | OGALLALA AQUIFER | CARSON COUNTY	215	205	197	194	180	160
MANUFACTURING	A | OGALLALA AQUIFER | CARSON COUNTY	1,102	995	927	871	824	777
LIVESTOCK	A | OGALLALA AQUIFER | CARSON COUNTY	98	99	100	101	102	103
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	75	75	75	75	75	75
IRRIGATION	A | DIRECT REUSE	57	58	58	58	58	58
IRRIGATION	A | OGALLALA AQUIFER | CARSON COUNTY	40,885	38,765	35,759	31,748	27,738	23,728
IRRIGATION	A | RED RUN-OF-RIVER	277	277	277	277	277	277
RED BASIN TOTAL EXISTING SUPPLY		**43,656**	**41,017**	**37,878**	**33,802**	**29,720**	**25,632**
CARSON COUNTY TOTAL EXISTING SUPPLY		**59,052**	**55,663**	**51,464**	**45,981**	**40,480**	**34,964**
CHILDRESS COUNTY							
RED BASIN							
CHILDRESS	A | GREENBELT LAKE/RESERVOIR	1,087	1,161	1,228	1,301	1,379	1,457
CHILDRESS	A | OGALLALA AQUIFER | DONLEY COUNTY	537	497	458	421	389	357
COUNTY-OTHER	A | GREENBELT LAKE/RESERVOIR	119	129	138	147	156	164
COUNTY-OTHER	A | OGALLALA AQUIFER | DONLEY COUNTY	59	55	51	47	44	40
COUNTY-OTHER	A | OTHER AQUIFER FRESH/BRACKISH | CHILDRESS COUNTY	20	20	20	20	20	20
COUNTY-OTHER	A | SEYMOUR AQUIFER | CHILDRESS COUNTY	20	20	20	20	20	20
LIVESTOCK	A | BLAINE AQUIFER | CHILDRESS COUNTY	216	216	216	216	216	216

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
CHILDRESS COUNTY							
RED BASIN							
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	49	49	49	49	49	49
LIVESTOCK	A | SEYMOUR AQUIFER | CHILDRESS COUNTY	240	240	240	240	240	240
IRRIGATION	A | BLAINE AQUIFER | CHILDRESS COUNTY	6,995	6,713	6,288	5,555	4,821	4,088
IRRIGATION	A | DIRECT REUSE	162	166	169	172	177	181
IRRIGATION	A | OTHER AQUIFER FRESH/BRACKISH | CHILDRESS COUNTY	213	213	213	213	213	213
IRRIGATION	A | RED RUN-OF-RIVER	19	19	19	19	19	19
IRRIGATION	A | SEYMOUR AQUIFER | CHILDRESS COUNTY	100	100	100	100	100	100
RED BASIN TOTAL EXISTING SUPPLY		**9,836**	**9,598**	**9,209**	**8,520**	**7,843**	**7,164**
CHILDRESS COUNTY TOTAL EXISTING SUPPLY		**9,836**	**9,598**	**9,209**	**8,520**	**7,843**	**7,164**
COLLINGSWORTH COUNTY							
RED BASIN							
WELLINGTON	A | SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	0	0	0	0	0	0
COUNTY-OTHER	A | BLAINE AQUIFER | COLLINGSWORTH COUNTY	8	8	8	8	8	8
COUNTY-OTHER	A | OTHER AQUIFER FRESH/BRACKISH | COLLINGSWORTH COUNTY	25	25	25	25	25	25
COUNTY-OTHER	A | SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	204	204	204	204	204	204
LIVESTOCK	A | BLAINE AQUIFER | COLLINGSWORTH COUNTY	275	275	275	283	283	283
LIVESTOCK	A | OTHER AQUIFER FRESH/BRACKISH | COLLINGSWORTH COUNTY	276	276	276	276	276	276
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	29	29	29	29	29	29
LIVESTOCK	A | SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	26	26	26	26	26	26
IRRIGATION	A | BLAINE AQUIFER | COLLINGSWORTH COUNTY	8,972	8,638	8,128	7,225	6,322	5,419
IRRIGATION	A | DIRECT REUSE	53	54	55	57	58	60
IRRIGATION	A | OTHER AQUIFER FRESH/BRACKISH | COLLINGSWORTH COUNTY	8	8	8	8	8	8
IRRIGATION	A | RED RUN-OF-RIVER	851	851	851	851	851	851
IRRIGATION	A | SEYMOUR AQUIFER | COLLINGSWORTH COUNTY	8,972	8,638	8,128	7,225	6,322	5,419
RED BASIN TOTAL EXISTING SUPPLY		**19,699**	**19,032**	**18,013**	**16,217**	**14,412**	**12,608**
COLLINGSWORTH COUNTY TOTAL EXISTING SUPPLY		**19,699**	**19,032**	**18,013**	**16,217**	**14,412**	**12,608**
DALLAM COUNTY							
CANADIAN BASIN							
DALHART	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	1,306	1,220	1,112	993	872	744
TEXLINE	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	227	253	280	262	236	201
COUNTY-OTHER	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	141	151	166	183	199	214
MANUFACTURING	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	9	9	10	10	11	11
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	2,488	2,488	2,488	2,488	2,488	2,488
LIVESTOCK	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	1,949	2,181	2,432	2,703	2,997	3,315
IRRIGATION	A | DOCKUM AQUIFER | DALLAM COUNTY	3,026	3,026	3,026	3,026	3,026	3,026
IRRIGATION	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	287,439	252,823	221,543	192,895	167,090	141,286
CANADIAN BASIN TOTAL EXISTING SUPPLY		**296,585**	**262,151**	**231,057**	**202,560**	**176,919**	**151,285**

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
DALLAM COUNTY TOTAL EXISTING SUPPLY		**296,585**	**262,151**	**231,057**	**202,560**	**176,919**	**151,285**
DONLEY COUNTY							
RED BASIN							
CLARENDON	A | GREENBELT LAKE/RESERVOIR	253	258	263	269	278	286
CLARENDON	A | OGALLALA AQUIFER | DONLEY COUNTY	125	111	98	87	78	70
COUNTY-OTHER	A | GREENBELT LAKE/RESERVOIR	64	66	69	72	74	76
COUNTY-OTHER	A | OGALLALA AQUIFER | DONLEY COUNTY	201	199	196	193	191	189
LIVESTOCK	A | OGALLALA AQUIFER | DONLEY COUNTY	664	666	667	669	671	673
LIVESTOCK	A | OTHER AQUIFER FRESH/BRACKISH | DONLEY COUNTY	383	383	383	383	383	383
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	283	283	283	283	283	283
IRRIGATION	A | OGALLALA AQUIFER | DONLEY COUNTY	24,080	23,203	21,847	19,419	16,992	14,564
IRRIGATION	A | RED RUN-OF-RIVER	166	166	166	166	166	166
RED BASIN TOTAL EXISTING SUPPLY		**26,219**	**25,335**	**23,972**	**21,541**	**19,116**	**16,690**
DONLEY COUNTY TOTAL EXISTING SUPPLY		**26,219**	**25,335**	**23,972**	**21,541**	**19,116**	**16,690**
GRAY COUNTY							
CANADIAN BASIN							
PAMPA	A | OGALLALA AQUIFER | GRAY COUNTY	1,531	1,224	976	791	637	483
PAMPA	A | OGALLALA AQUIFER | ROBERTS COUNTY	2,484	1,015	893	1,945	1,755	1,566
COUNTY-OTHER	A | OGALLALA AQUIFER | GRAY COUNTY	450	488	537	604	659	717
MANUFACTURING	A | OGALLALA AQUIFER | GRAY COUNTY	4,371	4,370	4,465	4,465	4,275	4,085
MINING	A | OGALLALA AQUIFER | GRAY COUNTY	7	7	7	6	5	5
STEAM ELECTRIC POWER	A | OGALLALA AQUIFER | GRAY COUNTY	1,409	2,112	2,299	2,952	3,087	3,320
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	199	199	199	199	199	199
LIVESTOCK	A | OGALLALA AQUIFER | GRAY COUNTY	141	141	141	141	141	141
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	5,315	5,006	4,599	4,064	3,528	2,992
CANADIAN BASIN TOTAL EXISTING SUPPLY		**16,128**	**14,783**	**14,337**	**15,388**	**14,507**	**13,729**
RED BASIN							
MCLEAN	A | OGALLALA AQUIFER | GRAY COUNTY	245	240	244	185	164	144
COUNTY-OTHER	A | OGALLALA AQUIFER | GRAY COUNTY	243	264	290	326	356	388
MANUFACTURING	A | OGALLALA AQUIFER | GRAY COUNTY	229	230	235	235	225	215
MINING	A | OGALLALA AQUIFER | GRAY COUNTY	68	67	60	54	48	42
LIVESTOCK	A | OGALLALA AQUIFER | GRAY COUNTY	1,174	1,174	1,174	1,174	1,174	1,174
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	600	600	600	600	600	600
IRRIGATION	A | OGALLALA AQUIFER | GRAY COUNTY	15,700	14,822	13,664	12,139	10,615	9,091
IRRIGATION	A | RED RUN-OF-RIVER	55	55	55	55	55	55
RED BASIN TOTAL EXISTING SUPPLY		**18,314**	**17,452**	**16,322**	**14,768**	**13,237**	**11,709**
GRAY COUNTY TOTAL EXISTING SUPPLY		**34,442**	**32,235**	**30,659**	**30,156**	**27,744**	**25,438**
HALL COUNTY							
RED BASIN							
MEMPHIS	A | GREENBELT LAKE/RESERVOIR	67	70	73	76	78	80
MEMPHIS	A | OGALLALA AQUIFER | DONLEY COUNTY	361	324	299	226	191	156

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
HALL COUNTY							
RED BASIN							
COUNTY-OTHER	A | GREENBELT LAKE/RESERVOIR	62	64	67	69	72	74
COUNTY-OTHER	A | OGALLALA AQUIFER | DONLEY COUNTY	115	113	110	108	105	103
COUNTY-OTHER	A | SEYMOUR AQUIFER | HALL COUNTY	142	142	142	142	142	142
LIVESTOCK	A | OTHER AQUIFER FRESH/BRACKISH | HALL COUNTY	300	300	300	300	300	300
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	91	91	91	91	91	91
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 FRESH/BRACKISH | HALL COUNTY	786	786	786	786	721	618
IRRIGATION	A | RED RUN-OF-RIVER	52	52	52	52	52	52
IRRIGATION	A | SEYMOUR AQUIFER | HALL COUNTY	9,196	8,868	8,336	7,305	6,340	5,412
RED BASIN TOTAL EXISTING SUPPLY		**11,287**	**10,925**	**10,371**	**9,270**	**8,207**	**7,143**
HALL COUNTY TOTAL EXISTING SUPPLY		**11,287**	**10,925**	**10,371**	**9,270**	**8,207**	**7,143**
HANSFORD COUNTY							
CANADIAN BASIN							
GRUVER	A | OGALLALA AQUIFER | HANSFORD COUNTY	371	338	249	184	132	81
SPEARMAN	A | OGALLALA AQUIFER | HANSFORD COUNTY	672	683	691	421	258	112
COUNTY-OTHER	A | OGALLALA AQUIFER | HANSFORD COUNTY	200	200	200	200	200	200
MANUFACTURING	A | OGALLALA AQUIFER | HANSFORD COUNTY	90	91	93	101	111	120
MINING	A | OGALLALA AQUIFER | HANSFORD COUNTY	577	904	602	309	16	1
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	2,617	2,617	2,617	2,617	2,617	2,617
LIVESTOCK	A | OGALLALA AQUIFER | HANSFORD COUNTY	815	957	1,107	1,264	1,429	1,602
IRRIGATION	A | CANADIAN RUN-OF-RIVER	22	22	22	22	22	22
IRRIGATION	A | OGALLALA AQUIFER | HANSFORD COUNTY	134,902	126,481	115,759	102,897	90,035	77,173
CANADIAN BASIN TOTAL EXISTING SUPPLY		**140,266**	**132,293**	**121,340**	**108,015**	**94,820**	**81,928**
HANSFORD COUNTY TOTAL EXISTING SUPPLY		**140,266**	**132,293**	**121,340**	**108,015**	**94,820**	**81,928**
HARTLEY COUNTY							
CANADIAN BASIN							
DALHART	A | OGALLALA-RITA BLANCA AQUIFER | DALLAM COUNTY	614	530	440	361	294	234
COUNTY-OTHER	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	655	687	700	711	725	737
MANUFACTURING	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	5	5	5	5	5	5
MINING	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	7	7	6	5	4	3
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	3,193	3,193	3,193	3,193	3,193	3,193
LIVESTOCK	A | DOCKUM AQUIFER | HARTLEY COUNTY	1,161	1,161	1,161	1,161	1,161	1,161
LIVESTOCK	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	2,144	2,623	3,144	3,712	4,330	5,005
IRRIGATION	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	268,060	232,514	201,640	174,225	150,144	126,063
CANADIAN BASIN TOTAL EXISTING SUPPLY		**275,839**	**240,720**	**210,289**	**183,373**	**159,856**	**136,401**
HARTLEY COUNTY TOTAL EXISTING SUPPLY		**275,839**	**240,720**	**210,289**	**183,373**	**159,856**	**136,401**

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
HEMPHILL COUNTY							
CANADIAN BASIN							
CANADIAN	A | OGALLALA AQUIFER | HEMPHILL COUNTY	786	866	934	1,009	1,079	1,145
COUNTY-OTHER	A | OGALLALA AQUIFER | HEMPHILL COUNTY	132	132	132	132	132	132
MANUFACTURING	A | OGALLALA AQUIFER | HEMPHILL COUNTY	6	6	6	6	6	6
MINING	A | OGALLALA AQUIFER | HEMPHILL COUNTY	926	705	498	293	89	27
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	248	248	248	248	248	248
LIVESTOCK	A | OGALLALA AQUIFER | HEMPHILL COUNTY	509	512	515	518	521	525
IRRIGATION	A | OGALLALA AQUIFER | HEMPHILL COUNTY	1,316	1,251	1,162	1,033	904	775
CANADIAN BASIN TOTAL EXISTING SUPPLY		**3,923**	**3,720**	**3,495**	**3,239**	**2,979**	**2,858**
RED BASIN							
COUNTY-OTHER	A | OGALLALA AQUIFER | HEMPHILL COUNTY	90	90	90	90	90	90
MINING	A | OGALLALA AQUIFER | HEMPHILL COUNTY	1,388	1,058	746	439	134	41
LIVESTOCK	A | OGALLALA AQUIFER | HEMPHILL COUNTY	345	346	348	350	353	356
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	173	173	173	173	173	173
IRRIGATION	A | OGALLALA AQUIFER | HEMPHILL COUNTY	591	563	523	465	407	349
RED BASIN TOTAL EXISTING SUPPLY		**2,587**	**2,230**	**1,880**	**1,517**	**1,157**	**1,009**
HEMPHILL COUNTY TOTAL EXISTING SUPPLY		**6,510**	**5,950**	**5,375**	**4,756**	**4,136**	**3,867**
HUTCHINSON COUNTY							
CANADIAN BASIN							
BORGER	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	794	594	643	648	528	434
BORGER	A | OGALLALA AQUIFER | ROBERTS COUNTY	2,329	2,129	1,639	1,238	1,050	863
FRITCH	A | OGALLALA AQUIFER | CARSON COUNTY	437	441	436	434	433	433
STINNETT	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	501	467	448	332	281	230
TCW SUPPLY INC	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	663	504	379	284	214	180
COUNTY-OTHER	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	455	448	441	433	426	421
MANUFACTURING	A | CANADIAN RUN-OF-RIVER	2	2	2	2	2	2
MANUFACTURING	A | DIRECT REUSE	1,045	1,045	1,045	1,045	1,045	1,045
MANUFACTURING	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	22,810	23,220	23,663	24,122	25,406	26,778
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 | CANADIAN LIVESTOCK LOCAL SUPPLY	281	281	281	281	281	281
LIVESTOCK	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	566	592	622	654	690	729
IRRIGATION	A | CANADIAN RUN-OF-RIVER	96	96	96	96	96	96
IRRIGATION	A | OGALLALA AQUIFER | HUTCHINSON COUNTY	40,008	37,671	34,635	30,786	26,938	23,090
CANADIAN BASIN TOTAL EXISTING SUPPLY		**71,671**	**69,421**	**66,300**	**62,168**	**59,046**	**56,116**
HUTCHINSON COUNTY TOTAL EXISTING SUPPLY		**71,671**	**69,421**	**66,300**	**62,168**	**59,046**	**56,116**
LIPSCOMB COUNTY							
CANADIAN BASIN							
BOOKER	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	496	547	499	361	300	240
COUNTY-OTHER	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	473	473	473	473	473	473
MANUFACTURING	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	147	155	140	98	83	69
MINING	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	1,098	758	446	142	21	3
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	110	110	110	110	110	110

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
LIPSCOMB COUNTY							
CANADIAN BASIN							
LIVESTOCK	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	837	859	883	910	940	973
IRRIGATION	A | CANADIAN RUN-OF-RIVER	66	66	66	66	66	66
IRRIGATION	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	20,009	19,014	17,650	15,689	13,728	11,767
CANADIAN BASIN TOTAL EXISTING SUPPLY		**23,236**	**21,982**	**20,267**	**17,849**	**15,721**	**13,701**
LIPSCOMB COUNTY TOTAL EXISTING SUPPLY		**23,236**	**21,982**	**20,267**	**17,849**	**15,721**	**13,701**
MOORE COUNTY							
CANADIAN BASIN							
CACTUS	A | OGALLALA AQUIFER | MOORE COUNTY	402	331	268	212	185	156
DUMAS	A | OGALLALA AQUIFER | MOORE COUNTY	1,132	790	573	318	162	7
DUMAS	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	2,116	2,130	2,030	1,869	1,679	1,489
FRITCH	A | OGALLALA AQUIFER | CARSON COUNTY	5	5	5	5	5	5
SUNRAY	A | OGALLALA AQUIFER | MOORE COUNTY	609	330	125	62	18	0
COUNTY-OTHER	A | OGALLALA AQUIFER | MOORE COUNTY	307	332	363	399	444	489
COUNTY-OTHER	A | OGALLALA-RITA BLANCA AQUIFER | HARTLEY COUNTY	55	44	36	27	21	15
MANUFACTURING	A | OGALLALA AQUIFER | MOORE COUNTY	7,175	7,203	7,284	6,024	5,032	4,191
MINING	A | OGALLALA AQUIFER | MOORE COUNTY	16	16	16	15	15	15
STEAM ELECTRIC POWER	A | OGALLALA AQUIFER | MOORE COUNTY	200	0	0	0	0	0
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	1,000	1,000	1,000	1,000	1,000	1,000
LIVESTOCK	A | OGALLALA AQUIFER | MOORE COUNTY	2,676	2,906	3,155	3,424	3,716	4,032
IRRIGATION	A | CANADIAN RUN-OF-RIVER	7	7	7	7	7	7
IRRIGATION	A | OGALLALA AQUIFER | MOORE COUNTY	143,028	134,395	123,290	109,591	92,003	76,015
CANADIAN BASIN TOTAL EXISTING SUPPLY		**158,728**	**149,489**	**138,152**	**122,953**	**104,287**	**87,421**
MOORE COUNTY TOTAL EXISTING SUPPLY		**158,728**	**149,489**	**138,152**	**122,953**	**104,287**	**87,421**
OCHILTREE COUNTY							
CANADIAN BASIN							
BOOKER	A | OGALLALA AQUIFER | LIPSCOMB COUNTY	7	10	11	10	10	9
PERRYTON	A | OGALLALA AQUIFER | OCHILTREE COUNTY	2,351	2,031	1,745	1,524	1,309	1,136
COUNTY-OTHER	A | OGALLALA AQUIFER | OCHILTREE COUNTY	263	273	286	306	328	352
MINING	A | OGALLALA AQUIFER | OCHILTREE COUNTY	824	853	503	161	23	3
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	421	421	421	421	421	421
LIVESTOCK	A | OGALLALA AQUIFER | OCHILTREE COUNTY	3,795	3,211	3,308	3,411	3,521	3,637
IRRIGATION	A | OGALLALA AQUIFER | OCHILTREE COUNTY	57,243	53,825	49,414	43,923	38,433	32,942
CANADIAN BASIN TOTAL EXISTING SUPPLY		**64,904**	**60,624**	**55,688**	**49,756**	**44,045**	**38,500**
OCHILTREE COUNTY TOTAL EXISTING SUPPLY		**64,904**	**60,624**	**55,688**	**49,756**	**44,045**	**38,500**
OLDHAM COUNTY							
CANADIAN BASIN							
VEGA	A | OGALLALA AQUIFER | OLDHAM COUNTY	90	90	90	90	90	90
VEGA	O | OGALLALA AQUIFER | DEAF SMITH COUNTY	200	200	200	200	200	200
COUNTY-OTHER	A | DOCKUM AQUIFER | OLDHAM COUNTY	387	387	387	387	387	387
COUNTY-OTHER	A | OGALLALA AQUIFER | OLDHAM COUNTY	214	210	211	211	211	211
MINING	A | DOCKUM AQUIFER | OLDHAM COUNTY	283	283	283	283	283	283

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
OLDHAM COUNTY							
CANADIAN BASIN							
MINING	A | OGALLALA AQUIFER | OLDHAM COUNTY	173	257	330	361	425	493
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	626	626	626	626	626	626
LIVESTOCK	A | DOCKUM AQUIFER | OLDHAM COUNTY	430	430	430	430	430	430
LIVESTOCK	A | OGALLALA AQUIFER | OLDHAM COUNTY	356	356	356	356	356	356
IRRIGATION	A | DOCKUM AQUIFER | OLDHAM COUNTY	372	372	372	372	372	372
IRRIGATION	A | OGALLALA AQUIFER | OLDHAM COUNTY	2,699	2,567	2,377	2,072	1,766	1,461
CANADIAN BASIN TOTAL EXISTING SUPPLY		**5,830**	**5,778**	**5,662**	**5,388**	**5,146**	**4,909**
RED BASIN							
COUNTY-OTHER	A | OGALLALA AQUIFER | OLDHAM COUNTY	73	77	76	76	76	76
MINING	A | OGALLALA AQUIFER | OLDHAM COUNTY	19	23	26	27	29	32
LIVESTOCK	A | OGALLALA AQUIFER | OLDHAM COUNTY	119	119	119	119	119	119
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	209	209	209	209	209	209
IRRIGATION	A | OGALLALA AQUIFER | OLDHAM COUNTY	866	829	775	689	603	517
RED BASIN TOTAL EXISTING SUPPLY		**1,286**	**1,257**	**1,205**	**1,120**	**1,036**	**953**
OLDHAM COUNTY TOTAL EXISTING SUPPLY		**7,116**	**7,035**	**6,867**	**6,508**	**6,182**	**5,862**
POTTER COUNTY							
CANADIAN BASIN							
AMARILLO	A | OGALLALA AQUIFER | CARSON COUNTY	3,643	3,112	2,617	2,211	1,911	1,610
AMARILLO	A | OGALLALA AQUIFER | POTTER COUNTY	3,151	2,452	2,364	2,233	2,056	1,879
AMARILLO	A | OGALLALA AQUIFER | RANDALL COUNTY	753	576	455	365	295	225
AMARILLO	A | OGALLALA AQUIFER | ROBERTS COUNTY	6,803	6,992	6,146	5,279	4,931	4,433
AMARILLO	O | OGALLALA AQUIFER | DEAF SMITH COUNTY	33	33	33	33	16	0
COUNTY-OTHER	A | DOCKUM AQUIFER | POTTER COUNTY	900	900	900	900	900	900
COUNTY-OTHER	A | OGALLALA AQUIFER | POTTER COUNTY	800	800	800	800	800	800
MANUFACTURING	A | OGALLALA AQUIFER | POTTER COUNTY	219	191	169	154	137	122
MANUFACTURING	A | OGALLALA AQUIFER | ROBERTS COUNTY	924	836	724	612	547	476
MINING	A | OGALLALA AQUIFER | POTTER COUNTY	640	781	912	988	1,109	1,245
STEAM ELECTRIC POWER	A | DIRECT REUSE	25,387	26,804	28,408	30,011	34,115	37,669
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	500	500	500	500	500	500
LIVESTOCK	A | DOCKUM AQUIFER | POTTER COUNTY	13	13	13	13	13	13
LIVESTOCK	A | OGALLALA AQUIFER | POTTER COUNTY	50	50	50	50	50	50
IRRIGATION	A | DIRECT REUSE	555	617	711	760	727	700
IRRIGATION	A | OGALLALA AQUIFER | POTTER COUNTY	1,305	1,033	803	586	451	317
CANADIAN BASIN TOTAL EXISTING SUPPLY		**45,676**	**45,690**	**45,605**	**45,495**	**48,558**	**50,939**
RED BASIN							
AMARILLO	A | OGALLALA AQUIFER | CARSON COUNTY	2,399	2,049	1,722	1,456	1,257	1,059
AMARILLO	A | OGALLALA AQUIFER | POTTER COUNTY	2,074	1,614	1,557	1,470	1,353	1,237
AMARILLO	A | OGALLALA AQUIFER | RANDALL COUNTY	496	379	300	240	194	149
AMARILLO	A | OGALLALA AQUIFER | ROBERTS COUNTY	4,480	4,603	4,046	3,476	3,246	2,919
AMARILLO	O | OGALLALA AQUIFER | DEAF SMITH COUNTY	22	22	22	22	11	0
COUNTY-OTHER	A | OGALLALA AQUIFER | POTTER COUNTY	700	700	700	700	700	500

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
POTTER COUNTY							
RED BASIN							
MANUFACTURING	A | OGALLALA AQUIFER | POTTER COUNTY	1,238	1,085	957	871	776	692
MANUFACTURING	A | OGALLALA AQUIFER | ROBERTS COUNTY	5,233	4,738	4,102	3,472	3,101	2,699
MINING	A | OGALLALA AQUIFER | POTTER COUNTY	301	368	429	465	522	586
LIVESTOCK	A | OGALLALA AQUIFER | POTTER COUNTY	50	50	50	50	50	50
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	62	62	62	62	62	62
IRRIGATION	A | DIRECT REUSE	1,645	1,583	1,489	1,440	1,473	1,500
IRRIGATION	A | OGALLALA AQUIFER | POTTER COUNTY	103	96	89	83	76	70
RED BASIN TOTAL EXISTING SUPPLY		**18,803**	**17,349**	**15,525**	**13,807**	**12,821**	**11,523**
POTTER COUNTY TOTAL EXISTING SUPPLY		**64,479**	**63,039**	**61,130**	**59,302**	**61,379**	**62,462**
RANDALL COUNTY							
RED BASIN							
AMARILLO	A | OGALLALA AQUIFER | CARSON COUNTY	4,906	4,217	3,544	3,002	2,592	2,181
AMARILLO	A | OGALLALA AQUIFER | POTTER COUNTY	4,242	3,322	3,202	3,032	2,790	2,548
AMARILLO	A | OGALLALA AQUIFER | RANDALL COUNTY	1,014	780	617	495	401	306
AMARILLO	A | OGALLALA AQUIFER | ROBERTS COUNTY	9,162	9,473	8,325	7,167	6,693	6,011
AMARILLO	O | OGALLALA AQUIFER | DEAF SMITH COUNTY	45	45	45	45	23	0
CANYON	A | DOCKUM AQUIFER | RANDALL COUNTY	218	207	197	187	178	169
CANYON	A | OGALLALA AQUIFER | RANDALL COUNTY	1,500	1,425	1,354	1,286	1,222	1,161
CANYON	A | OGALLALA AQUIFER | ROBERTS COUNTY	906	761	616	493	0	0
HAPPY	A | DOCKUM AQUIFER | RANDALL COUNTY	5	5	6	6	6	7
HAPPY	O | OGALLALA AQUIFER | SWISHER COUNTY	10	12	12	13	12	10
LAKE TANGLEWOOD	A | OGALLALA AQUIFER | RANDALL COUNTY	147	115	87	63	44	26
COUNTY-OTHER	A | DOCKUM AQUIFER | RANDALL COUNTY	689	689	689	689	689	689
COUNTY-OTHER	A | OGALLALA AQUIFER | RANDALL COUNTY	2,316	2,316	2,316	2,316	2,316	2,316
COUNTY-OTHER	A | OGALLALA AQUIFER | ROBERTS COUNTY	23	19	15	12	10	8
MANUFACTURING	A | OGALLALA AQUIFER | RANDALL COUNTY	50	50	50	50	50	50
MANUFACTURING	A | OGALLALA AQUIFER | ROBERTS COUNTY	498	419	339	271	226	183
LIVESTOCK	A | DOCKUM AQUIFER | RANDALL COUNTY	230	230	230	230	230	230
LIVESTOCK	A | OGALLALA AQUIFER | RANDALL COUNTY	1,112	1,123	1,135	1,148	1,162	1,177
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	1,312	1,312	1,312	1,312	1,312	1,312
IRRIGATION	A | DIRECT REUSE	545	597	651	710	777	846
IRRIGATION	A | OGALLALA AQUIFER | RANDALL COUNTY	18,000	17,156	15,976	14,201	12,426	10,650
IRRIGATION	A | RED RUN-OF-RIVER	217	217	217	217	217	217
RED BASIN TOTAL EXISTING SUPPLY		**47,147**	**44,490**	**40,935**	**36,945**	**33,376**	**30,097**
RANDALL COUNTY TOTAL EXISTING SUPPLY		**47,147**	**44,490**	**40,935**	**36,945**	**33,376**	**30,097**
ROBERTS COUNTY							
CANADIAN BASIN							
MIAMI	A | OGALLALA AQUIFER | ROBERTS COUNTY	541	541	541	459	393	326
COUNTY-OTHER	A | OGALLALA AQUIFER | ROBERTS COUNTY	60	60	60	60	60	60
MINING	A | OGALLALA AQUIFER | ROBERTS COUNTY	1,457	1,010	593	183	19	2
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	124	124	124	124	124	124

Water User Group (WUG) Existing Water Supply

REGION A	SOURCE REGION | SOURCE NAME	EXISTING SUPPLY (ACRE-FEET PER YEAR) 2020	2030	2040	2050	2060	2070
ROBERTS COUNTY							
CANADIAN BASIN							
LIVESTOCK	A | OGALLALA AQUIFER | ROBERTS COUNTY	338	338	338	338	338	338
IRRIGATION	A | CANADIAN RUN-OF-RIVER	72	72	72	72	72	72
IRRIGATION	A | OGALLALA AQUIFER | ROBERTS COUNTY	5,588	5,257	4,825	4,281	3,737	3,193
CANADIAN BASIN TOTAL EXISTING SUPPLY		**8,180**	**7,402**	**6,553**	**5,517**	**4,743**	**4,115**
RED BASIN							
COUNTY-OTHER	A | OGALLALA AQUIFER | ROBERTS COUNTY	5	5	5	5	5	5
MINING	A | OGALLALA AQUIFER | ROBERTS COUNTY	45	31	18	6	1	0
LIVESTOCK	A | OGALLALA AQUIFER | ROBERTS COUNTY	10	10	10	10	10	10
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	15	15	15	15	15	15
IRRIGATION	A | OGALLALA AQUIFER | ROBERTS COUNTY	298	280	258	229	200	172
RED BASIN TOTAL EXISTING SUPPLY		**373**	**341**	**306**	**265**	**231**	**202**
ROBERTS COUNTY TOTAL EXISTING SUPPLY		**8,553**	**7,743**	**6,859**	**5,782**	**4,974**	**4,317**
SHERMAN COUNTY							
CANADIAN BASIN							
STRATFORD	A | OGALLALA AQUIFER | SHERMAN COUNTY	1,251	1,251	1,251	1,107	920	733
COUNTY-OTHER	A | OGALLALA AQUIFER | SHERMAN COUNTY	184	194	197	204	208	212
MINING	A | OGALLALA AQUIFER | SHERMAN COUNTY	35	207	151	98	44	20
LIVESTOCK	A | CANADIAN LIVESTOCK LOCAL SUPPLY	1,052	1,052	1,052	1,052	1,052	1,052
LIVESTOCK	A | OGALLALA AQUIFER | SHERMAN COUNTY	2,397	2,579	2,773	2,982	3,205	3,445
IRRIGATION	A | CANADIAN RUN-OF-RIVER	32	32	32	32	32	32
IRRIGATION	A | OGALLALA AQUIFER | SHERMAN COUNTY	220,966	207,757	190,687	169,499	148,312	127,125
CANADIAN BASIN TOTAL EXISTING SUPPLY		**225,917**	**213,072**	**196,143**	**174,974**	**153,773**	**132,619**
SHERMAN COUNTY TOTAL EXISTING SUPPLY		**225,917**	**213,072**	**196,143**	**174,974**	**153,773**	**132,619**
WHEELER COUNTY							
RED BASIN							
SHAMROCK	A | OGALLALA AQUIFER | WHEELER COUNTY	957	912	872	820	765	710
WHEELER	A | OGALLALA AQUIFER | WHEELER COUNTY	323	271	225	184	157	139
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 FRESH/BRACKISH | 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 | OGALLALA AQUIFER | WHEELER COUNTY	803	803	803	803	803	803
LIVESTOCK	A | OTHER AQUIFER FRESH/BRACKISH | WHEELER COUNTY	28	28	28	28	28	28
LIVESTOCK	A | RED LIVESTOCK LOCAL SUPPLY	845	845	845	845	845	845
IRRIGATION	A | BLAINE AQUIFER | WHEELER COUNTY	15	15	15	15	15	15
IRRIGATION	A | DIRECT REUSE	51	52	53	55	57	59
IRRIGATION	A | OGALLALA AQUIFER | WHEELER COUNTY	8,203	7,983	7,433	6,607	5,781	4,955
IRRIGATION	A | OTHER AQUIFER FRESH/BRACKISH | WHEELER COUNTY	226	226	226	226	226	226
IRRIGATION	A | RED RUN-OF-RIVER	603	603	603	603	603	603
RED BASIN TOTAL EXISTING SUPPLY		**15,726**	**14,471**	**12,920**	**11,093**	**9,823**	**8,906**

Water User Group (WUG) Existing Water Supply

REGION A		EXISTING SUPPLY (ACRE-FEET PER YEAR)					
	SOURCE REGION | SOURCE NAME	2020	2030	2040	2050	2060	2070
WHEELER COUNTY TOTAL EXISTING SUPPLY		15,726	14,471	12,920	11,093	9,823	8,906
	REGION A TOTAL EXISTING SUPPLY	1,572,614	1,450,412	1,321,824	1,182,082	1,050,055	920,959

Chapter 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, wholesale 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 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.

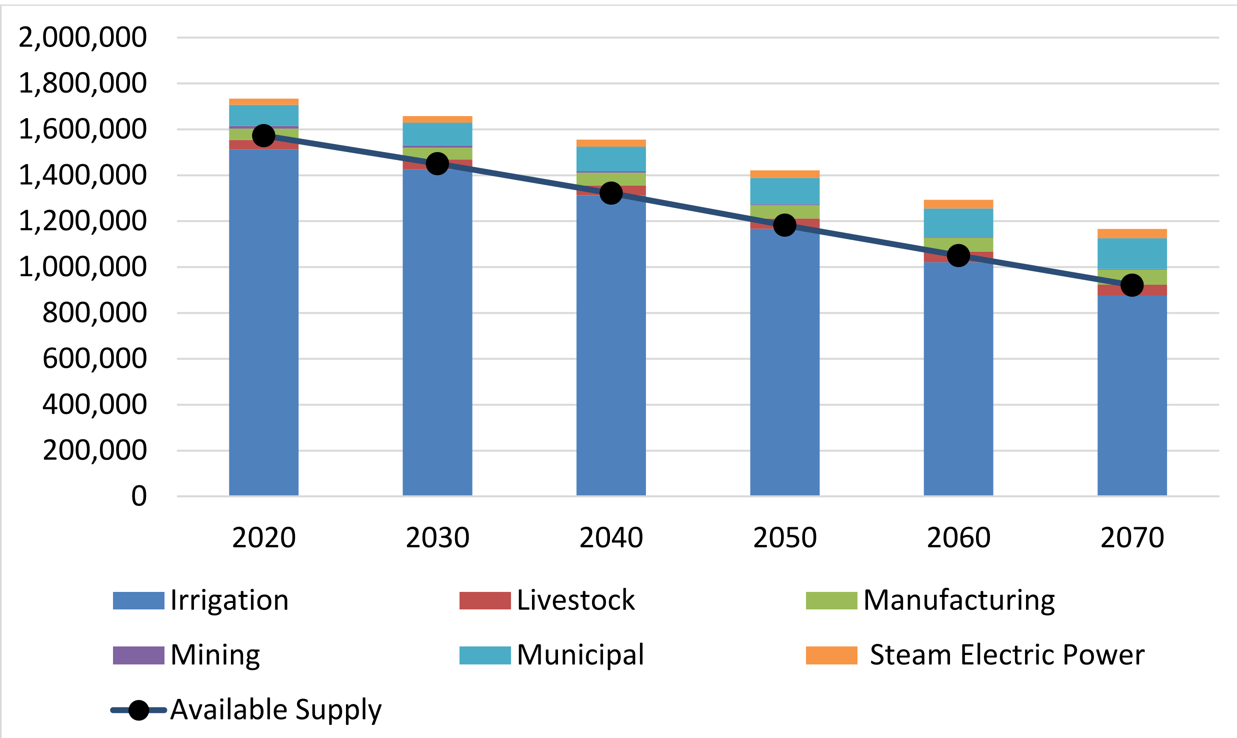
Considering only developed and connected supplies for the PWPA, on a regional basis there is a projected regional need of over 160,000 acre-feet per year in 2020, increasing to a maximum need of nearly 245,000 in 2070. This is shown in Table 4-1 and graphically on Figure 4-1.

Table 4-1: Comparison of Supplies and Demands for the PWPA

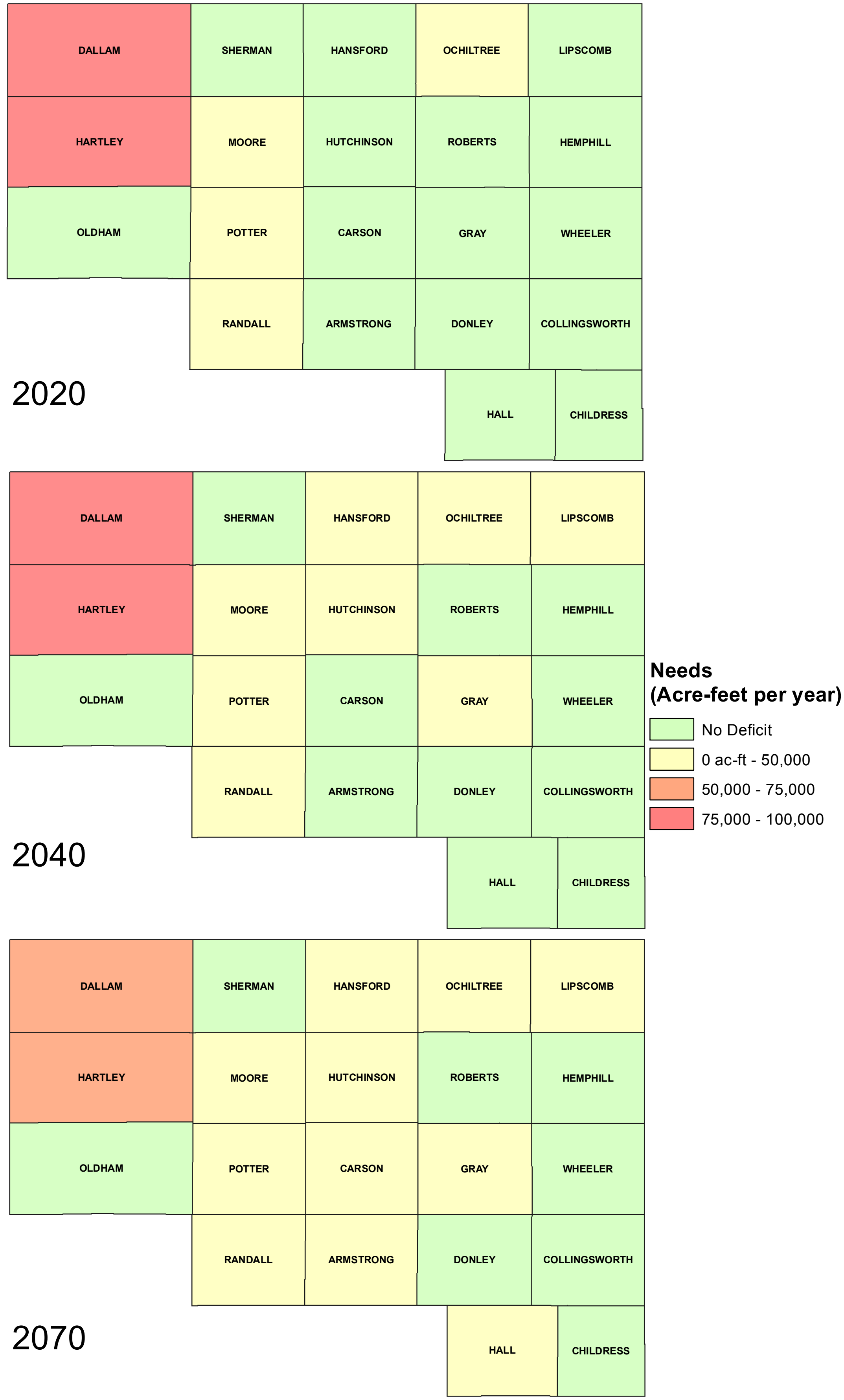
	2020	2030	2040	2050	2060	2070
Supply (Acre-feet)	1,572,614	1,450,412	1,321,824	1,182,082	1,050,055	920,959
Demand (Acre-feet)	1,733,659	1,658,045	1,554,977	1,421,114	1,292,717	1,166,209
Surplus/Need (ac-ft)	**-161,045**	**-207,633**	**-233,153**	**-239,032**	**-242,662**	**-245,250**

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/year)



On a county-basis, there are thirteen counties with needs over the planning period. These include Armstrong, Carson, Dallam, Gray, Hall, Hansford, Hartley, Hutchinson, Lipscomb, Moore, Ochiltree, Potter, and Randall. 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.



0 12.5 25 50 Miles

DATE: OCTOBER 2014
SCALE: 1:3,168,000
DATUM & COORDINATE SYSTEM: GCS NORTH AMERICAN 1983
PREPARED BY: JJR
FILE: PPC11456 H:\WR_PLANNING\Chapter4\Figure4-2.mxd

N E S W

PANHANDLE WATER PLANNING AREA

NEEDS IN PWPA

Location Map

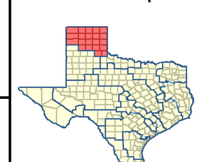


FIGURE 4-2

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

	2020	2030	2040	2050	2060	2070
County	**Surplus/Need**					
Armstrong	116	67	22	-18	-55	-93
Carson	946	369	191	101	-28	-176
Childress	216	217	217	217	219	219
Collingsworth	440	416	404	386	364	345
Dallam	-79,908	-92,469	-95,342	-88,952	-79,729	-70,513
Donley	186	194	201	203	204	204
Gray	1,356	-816	-1,546	-1,384	-2,280	-3,214
Hall	115	78	66	-2	-35	-70
Hansford	177	109	-16	-388	-651	-896
Hartley	-77,545	-93,712	-99,092	-93,227	-84,020	-74,803
Hemphill	64	65	67	64	61	58
Hutchinson	137	-1,402	-2,850	-4,329	-5,632	-6,930
Lipscomb	94	91	-6	-240	-365	-483
Moore	-2,600	-4,351	-6,003	-8,931	-15,697	-20,760
Ochiltree	-454	-938	-1,414	-1,856	-2,322	-2,771
Oldham	828	796	801	800	798	795
Potter	-4,895	-11,185	-18,317	-25,216	-31,491	-38,528
Randall	-3,113	-7,710	-12,969	-18,323	-23,672	-28,915
Roberts	451	448	451	369	302	234
Sherman	813	785	773	615	416	219
Wheeler	1,531	1,315	1,209	1,079	951	828
Total	**-161,045**	**-207,633**	**-233,153**	**-239,032**	**-242,662**	**-245,250**

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

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-three water user groups (accounting for basin and county designations) with identified needs during the planning period. Of these, there are twenty-five cities and county other water users in fourteen counties that are projected to experience a water need before 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 Randall Counties.

Total needs for all water user groups are projected to be approximately 170,800 acre feet per year in 2020, increasing to 241,400 acre feet per year in 2040 and approximately 252,600 acre-feet per year by the year 2070. Of this amount, irrigation represents approximately 92 percent in the 2020 projections and over 59 percent of the total need in 2070 with needs ranging from 156,700 to 148,500 acre-feet per year. The needs attributed to the other water use categories total approximately 104,100 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. To account for the level of accuracy of the data, a need is defined as a demand greater than the current supply by more than or equal to 10 acre-feet per year.

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

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

Irrigation

Irrigation needs are identified for Dallam, Hartley, and Moore Counties. All of these counties rely heavily on the Ogallala for irrigation supplies. Needs are observed in two counties starting in 2020.

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

COUNTY	2020	2030	2040	2050	2060	2070
Dallam	79,399	91,675	94,226	87,452	77,836	68,218
Hartley	77,305	93,368	98,650	92,699	83,415	74,130
Moore					3,882	6,171
Total	**156,704**	**185,043**	**192,876**	**180,151**	**165,133**	**148,519**

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/year)

	2020	2030	2040	2050	2060	2070
Amarillo	4,508	12,441	21,815	31,334	39,862	49,182
Booker	0	0	79	264	359	451
Borger	92	531	952	1,343	1,647	1,927
Cactus	583	777	974	1,170	1,347	1,530
Canyon	1,009	1,589	2,176	2,770	3,779	4,313
Claude	0	0	0	35	72	110
County-Other-Hall	0	3	1	0	0	0
County-Other Moore	0	0	0	13	21	30
County-Other Potter	683	956	1,262	1,583	1,953	2,548
County-Other Randall	637	978	1,339	1,731	2,172	2,638
Dalhart	749	1,138	1,558	1,982	2,399	2,807
Dumas	290	1,021	1,785	2,679	3,550	4,437
Gruver	0	0	111	196	272	344
Lake Tanglewood	172	200	225	248	266	284
McLean	0	0	0	89	135	182
Memphis	0	0	0	68	100	133
Pampa	0	1,752	2,491	2,190	2,985	3,806
Panhandle	89	521	582	577	576	576
Perryton	478	963	1,438	1,877	2,341	2,786
Spearman	0	0	0	283	466	634
Stinnett	0	0	0	115	165	216
Sunray	0	232	501	633	752	847
TCW Supply	75	251	375	466	535	569
Texline	0	0	0	46	99	161
Wellington	525	540	549	567	582	595
Wheeler	184	249	308	365	412	453
Total	**10,074**	**24,142**	**38,521**	**52,624**	**66,847**	**81,559**

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 wholesale 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/year)

	2020	2030	2040	2050	2060	2070
Hutchinson	0	860	1,739	2,614	3,487	4,416
Lipscomb	0	0	21	69	97	124
Moore	1,877	2,346	2,754	4,445	6,147	7,746
Potter	2,099	3,611	5,239	6,714	8,130	9,633
Randall	41	169	295	401	508	619
Total	**4,017**	**6,986**	**10,048**	**14,243**	**18,369**	**22,538**

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 Wholesale Water Providers

There are six wholesale water providers located in the PWPA. Of these entities, four are projected to have needs within the planning period: CRMWA, City of Amarillo, City of Borger, and City of Cactus. Much of the early needs are associated with the loss of Lake Meredith as a reliable supply and infrastructure constraints associated with 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 wholesale water providers in the PWPA. Greenbelt MIWA and the Palo Duro River Authority do not show a water need. However, both water providers are considering developing water management strategies to help meet their customers' needs and prepare for potential impacts to current water sources associated with the ongoing drought.

Table 4-7: Projected Needs for Wholesale Providers in the PWPA (ac-ft/yr)

Wholesale Provider	2020	2030	2040	2050	2060	2070
Amarillo	5,298	14,566	25,428	36,325	45,436	55,926
Borger	0	1,335	2,679	3,982	5,190	6,438
Cactus	2,518	3,199	3,821	4,384	4,914	5,465
CRMWA	31,450	48,351	58,636	70,974	75,959	80,936

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. Further review of 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 are no recommended direct reuse projects in the PWPA.

4.3.1 Summary of Second Tier Water Needs for Water User Groups

After the implementation of conservation strategies, the PWPA has a projected water need of 105,400 acre-feet per year in 2020. Most of this is associated with irrigated agriculture that has not fully realized the benefits of conservation. By 2050, there is no projected water need for irrigation. On a regional basis, the majority of the need after 2030 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 diminish. By 2070, the projected need in the PWPA is over 93,000 acre-feet per year. All of this need is for municipal and manufacturing use. 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 (ac-ft/yr)

Use Type	2020	2030	2040	2050	2060	2070
Municipal	7,194	20,748	34,783	48,398	62,255	76,594
Manufacturing	4,941	3,375	4,809	8,543	12,669	16,838
Mining	0	0	0	0	0	0
Steam Electric Power	0	0	0	0	0	0
Livestock	0	0	0	0	0	0
Irrigation	93,289	71,708	8,174	0	0	0
Total	**105,424**	**95,831**	**47,766**	**56,941**	**74,924**	**93,432**

Attachment 4-1

WATER USER GROUP (NEEDS)/SURPLUS

Water User Group (WUG) Needs/Surplus

REGION A	WUG (NEEDS)/SURPLUS (ACRE-FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
ARMSTRONG COUNTY						
RED BASIN						
CLAUDE	105	52	6	(35)	(72)	(110)
COUNTY-OTHER	11	15	16	17	17	17
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
CARSON COUNTY						
CANADIAN BASIN						
WHITE DEER	0	0	0	0	0	0
COUNTY-OTHER	88	76	68	67	51	28
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
RED BASIN						
GROOM	147	166	170	165	153	141
PANHANDLE	(89)	(521)	(582)	(577)	(576)	(576)
WHITE DEER	0	0	0	0	0	0
COUNTY-OTHER	92	85	77	75	61	41
MANUFACTURING	708	563	458	371	283	190
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
CHILDRESS COUNTY						
RED BASIN						
CHILDRESS	0	0	0	0	0	0
COUNTY-OTHER	20	20	19	18	18	17
LIVESTOCK	15	12	10	8	5	2
IRRIGATION	181	185	188	191	196	200
COLLINGSWORTH COUNTY						
RED BASIN						
WELLINGTON	(525)	(540)	(549)	(567)	(582)	(595)
COUNTY-OTHER	46	40	37	30	25	20
LIVESTOCK	6	3	1	6	3	0
IRRIGATION	913	913	915	917	918	920
DALLAM COUNTY						
CANADIAN BASIN						
DALHART	(509)	(794)	(1,116)	(1,454)	(1,794)	(2,134)
TEXLINE	0	0	0	(46)	(99)	(161)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	(79,399)	(91,675)	(94,226)	(87,452)	(77,836)	(68,218)
DONLEY COUNTY						
RED BASIN						
CLARENDON	0	0	0	0	0	0
COUNTY-OTHER	20	28	35	37	38	38
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	166	166	166	166	166	166

Water User Group (WUG) Needs/Surplus

REGION A	WUG (NEEDS)/SURPLUS (ACRE-FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
GRAY COUNTY						
CANADIAN BASIN						
PAMPA	304	(1,752)	(2,491)	(2,190)	(2,985)	(3,806)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	238	173	225	208	189	162
MINING	0	0	0	0	0	0
STEAM ELECTRIC POWER	0	0	0	0	0	0
LIVESTOCK	205	202	199	196	193	189
IRRIGATION	0	0	0	0	0	0
RED BASIN						
MCLEAN	40	18	1	(89)	(135)	(182)
COUNTY-OTHER	0	0	0	0	0	0
MANUFACTURING	12	9	12	11	10	9
MINING	0	0	0	0	0	0
LIVESTOCK	557	534	508	480	448	414
IRRIGATION	0	0	0	0	0	0
HALL COUNTY						
RED BASIN						
MEMPHIS	45	12	0	(68)	(100)	(133)
COUNTY-OTHER	0	(3)	(1)	0	0	0
LIVESTOCK	70	69	67	66	65	63
IRRIGATION	0	0	0	0	0	0
HANSFORD COUNTY						
CANADIAN BASIN						
GRUVER	61	2	(111)	(196)	(272)	(344)
SPEARMAN	0	0	0	(283)	(466)	(634)
COUNTY-OTHER	62	55	43	33	24	14
MANUFACTURING	32	30	30	36	41	46
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	(240)	(344)	(442)	(528)	(605)	(673)
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	(77,305)	(93,368)	(98,650)	(92,699)	(83,415)	(74,130)
HEMPHILL COUNTY						
CANADIAN BASIN						
CANADIAN	0	0	0	0	0	0
COUNTY-OTHER	17	20	23	23	23	23
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
RED BASIN						
COUNTY-OTHER	47	45	44	41	38	35

Water User Group (WUG) Needs/Surplus

REGION A	WUG (NEEDS)/SURPLUS (ACRE-FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
HEMPHILL COUNTY						
RED BASIN						
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	0	0	0	0	0	0
HUTCHINSON COUNTY						
CANADIAN BASIN						
BORGER	(92)	(531)	(952)	(1,343)	(1,647)	(1,927)
FRITCH	0	0	0	0	0	0
STINNETT	55	15	0	(115)	(165)	(216)
TCW SUPPLY INC	(75)	(251)	(375)	(466)	(535)	(569)
COUNTY-OTHER	143	129	120	113	106	102
MANUFACTURING	10	(860)	(1,739)	(2,614)	(3,487)	(4,416)
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	0	0	(77)	(257)	(348)	(434)
COUNTY-OTHER	28	25	26	20	14	9
MANUFACTURING	0	0	(21)	(69)	(97)	(124)
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	(583)	(777)	(974)	(1,170)	(1,347)	(1,530)
DUMAS	(290)	(1,021)	(1,785)	(2,679)	(3,550)	(4,437)
FRITCH	3	2	2	2	2	1
SUNRAY	105	(232)	(501)	(633)	(752)	(847)
COUNTY-OTHER	35	16	2	(13)	(21)	(30)
MANUFACTURING	(1,877)	(2,346)	(2,754)	(4,445)	(6,147)	(7,746)
MINING	0	0	0	0	0	0
STEAM ELECTRIC POWER	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	7	7	7	7	(3,882)	(6,171)
OCHILTREE COUNTY						
CANADIAN BASIN						
BOOKER	0	0	(2)	(7)	(11)	(17)
PERRYTON	(478)	(963)	(1,438)	(1,877)	(2,341)	(2,786)
COUNTY-OTHER	24	25	26	28	30	32
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	18	5	9	11	11	11
COUNTY-OTHER	299	282	286	286	287	287
MINING	0	0	0	0	0	0

Water User Group (WUG) Needs/Surplus

REGION A	WUG (NEEDS)/SURPLUS (ACRE-FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
OLDHAM COUNTY						
CANADIAN BASIN						
LIVESTOCK	503	501	499	497	495	492
IRRIGATION	0	0	0	0	0	0
RED BASIN						
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	8	8	7	6	5	5
IRRIGATION	0	0	0	0	0	0
POTTER COUNTY						
CANADIAN BASIN						
AMARILLO	(1,501)	(4,129)	(7,241)	(10,389)	(13,215)	(16,315)
COUNTY-OTHER	(271)	(446)	(642)	(847)	(1,084)	(1,336)
MANUFACTURING	(314)	(542)	(786)	(1,007)	(1,220)	(1,445)
MINING	0	0	0	0	0	0
STEAM ELECTRIC POWER	0	0	0	0	0	0
LIVESTOCK	164	163	161	160	158	155
IRRIGATION	181	37	0	0	0	7
RED BASIN						
AMARILLO	(987)	(2,719)	(4,767)	(6,840)	(8,703)	(10,742)
COUNTY-OTHER	(412)	(510)	(620)	(736)	(869)	(1,212)
MANUFACTURING	(1,785)	(3,069)	(4,453)	(5,707)	(6,910)	(8,188)
MINING	0	0	0	0	0	0
LIVESTOCK	30	30	30	29	29	29
IRRIGATION	0	0	1	121	323	519
RANDALL COUNTY						
RED BASIN						
AMARILLO	(2,020)	(5,593)	(9,807)	(14,105)	(17,944)	(22,125)
CANYON	(1,009)	(1,589)	(2,176)	(2,770)	(3,779)	(4,313)
HAPPY	4	5	5	5	3	1
LAKE TANGLEWOOD	(172)	(200)	(225)	(248)	(266)	(284)
COUNTY-OTHER	(637)	(978)	(1,339)	(1,731)	(2,172)	(2,638)
MANUFACTURING	(41)	(169)	(295)	(401)	(508)	(619)
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	762	814	868	927	994	1,063
ROBERTS COUNTY						
CANADIAN BASIN						
MIAMI	317	316	318	237	171	104
COUNTY-OTHER	12	10	12	12	12	12
MINING	0	0	0	0	0	0
LIVESTOCK	103	103	102	101	100	99
IRRIGATION	0	0	0	0	0	0
RED BASIN						
COUNTY-OTHER	4	4	4	4	4	4
MINING	0	0	0	0	0	0
LIVESTOCK	15	15	15	15	15	15
IRRIGATION	0	0	0	0	0	0

Water User Group (WUG) Needs/Surplus

REGION A	WUG (NEEDS)/SURPLUS (ACRE-FEET PER YEAR)					
	2020	2030	2040	2050	2060	2070
SHERMAN COUNTY						
CANADIAN BASIN						
STRATFORD	781	753	741	583	384	187
COUNTY-OTHER	0	0	0	0	0	0
MINING	0	0	0	0	0	0
LIVESTOCK	0	0	0	0	0	0
IRRIGATION	32	32	32	32	32	32
WHEELER COUNTY						
RED BASIN						
SHAMROCK	607	559	515	451	382	312
WHEELER	(184)	(249)	(308)	(365)	(412)	(453)
COUNTY-OTHER	95	94	92	83	72	60
MINING	0	0	0	0	0	0
LIVESTOCK	118	15	13	11	8	6
IRRIGATION	895	896	897	899	901	903

Chapter 5 Water Management Strategies

There are 34 water users and five wholesale water providers 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 104,000 acre-feet of needs for municipal and manufacturing water use. This chapter identifies the potential water management strategies that could be implemented to meet these needs.

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 six wholesale providers 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.

Subchapter 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 potential feasible strategies have 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. This subchapter identifies the potentially feasible strategies for water users and wholesale water providers 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, or recommended or alternative for an entity. A list of the potentially feasible 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/WWP needs. A comprehensive list of the potential strategy types identified is included below.

- Water conservation and drought management
- Wastewater reuse
- 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 water rights
    - Yield enhancement
    - Water quality improvements
- New supply development
    - Surface water resources
    - Groundwater resources

- Brush control
- Precipitation enhancement
- Desalination
- Water right cancellation
- Aquifer storage and recovery
- Interbasin transfers

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. 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 and voluntary redistribution), 4) new groundwater supply development, 5) brush control, and 6) precipitation enhancement.

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

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. On the contrary, 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 were evaluated, all other municipal water user groups were evaluated) 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 (direct 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 are 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.

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 wholesale water providers 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.

Voluntary Redistribution

Voluntary redistribution is transfer 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.

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.

Aquifer Storage and Recovery (ASR)

Aquifer storage and recovery is a type of strategy that utilizes suitable geologic formations to store water until needed. It can be used for both treated groundwater and surface water. 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 is considered for CRMWA.

5A.1.4 New Groundwater Development

As previously discussed, groundwater accounted for approximately 98 percent of the total water use in the PWPA in 2010. Over much of the region, there is available groundwater for future development. Towards the southeast portion of 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 Potter counties. Also, there is little groundwater available for future development in heavily irrigated areas in Dallam, Hartley, Moore, and Sherman counties. 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	1,799,145
Seymour Aquifer	9,847
Blaine Aquifer	294,573
Dockum Aquifer	13,448
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.1.5 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. There are three primary species of brush in the PWPA that are eligible for funding from the WSEP as shown in Table 5A-3.

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

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.

5A.1.6 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.

In accordance with state guidance, the potentially feasible strategies were evaluated with respect to:

- 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; and
- Other relevant factors.

The other 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 Panhandle Water Planning Area (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 2013 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 5.5 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 user's distribution system. There may be additional costs to actually deliver the water to the end users of the water that are not represented in these estimates.

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. A water management strategy may have a positive or negative effect on a 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 actually 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 (such as mining), 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 issues affect water use options and treatment requirements. For the evaluations of the strategies, it was assumed that the final water product 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.

5A.3 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.

5A.3.1 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 E.

Subchapter 5B Water Conservation

Water conservation is a demand management strategy that pro-actively 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 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 conservations 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.

5B.1 Municipal Conservation

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% 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.

If a public water supplier serves over 5,000 people, they are additionally required to the 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.

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
- Landscape 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). 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 a 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.

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 2% of the total water demands. Per person cost 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. .

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% 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% losses and WSCs with losses greater than or equal to 25%. If no water loss data was available, this strategy was considered for an entity with a gpcd over 140. A constant 5% savings rate was assumed until an entity's gpcd was equal to 140. Costs were estimated at $10 per person per year.

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/household/year. It is assumed that 75 percent of the households would respond to this measure by not wasting water. Costs for this strategy would be those costs associated with enforcement.

Landscape Ordinance

Local officials would implement an ordinance that would promote residential plantings that conserve water for all new construction. This strategy is assumed to be implemented by 2030 and would only apply to new construction for both residential and commercial properties. This BMP would save 1,000 gallons per increased number of households per year. Costs for this strategy would be those costs associated with enforcement.

Time of Day Watering Limit

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/household/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.

5B.1.3 Evaluation of Municipal Conservation Strategies

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 Municipal Conservation Summary

It is estimated that the municipal conservation strategy outlined in this memorandum will save, on a regional basis, nearly 3,700 acre-feet in 2020 and over 5,400 acre-feet in 2070. The annual cost for this strategy is over $1.73 million in 2020 increasing to approximately $2.43 million in 2070. The combined unit cost across the region is approximately $470 per acre-foot in 2020 and $447 per acre-foot in 2070. The unit costs varies 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. Conservation programs are typically funded through the city's annual operating budget. Capital costs shown in Table 5B-1 represent an estimate of the total capital expenditures over 50 years. However, these costs may differ for each entity; therefore, all capital expenditures for conservation are considered consistent.

Table 5B-1: Municipal Water Conservation Savings and Cost by Water User Group

	Conservation Savings (Ac-ft/yr)						Conservation Cost							Conservation Unit Cost ($/Ac-ft)					
WUG	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**Capital Cost**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Amarillo	1,734	1,935	2,122	2,316	2,534	2,762	$0	$432,980	$501,809	$547,028	$592,633	$641,811	$693,285	$250	$259	$258	$256	$253	$251
Booker	15	17	18	19	20	21	$0	$9,846	$10,448	$10,819	$11,298	$11,650	$11,952	$648	$618	$603	$583	$570	$559
Borger	104	107	106	106	106	106	$0	$42,769	$44,122	$44,394	$44,394	$44,394	$44,394	$410	$414	$417	$417	$418	$418
Cactus	32	36	41	45	50	55	$0	$16,638	$18,266	$20,001	$21,761	$23,598	$25,471	$519	$504	$491	$479	$469	$460
Canadian	64	70	76	82	88	93	$2,294,900	$43,454	$48,108	$52,060	$56,128	$59,761	$63,089	$681	$683	$684	$682	$679	$675
Canyon	127	142	156	171	187	203	$0	$76,793	$104,961	$108,132	$111,379	$114,834	$118,424	$604	$737	$693	$653	$615	$583
Childress	132	135	138	141	145	148	$4,098,000	$85,363	$88,423	$90,973	$93,460	$95,933	$98,343	$646	$654	$661	$664	$664	$663
Clarendon	14	13	13	13	13	13	$0	$10,742	$10,742	$10,742	$10,742	$10,742	$10,742	$787	$798	$807	$813	$813	$813
Claude	29	29	28	28	28	28	$721,800	$20,338	$20,338	$20,338	$20,338	$20,338	$20,338	$698	$707	$716	$719	$721	$721
County - Other (Hall)	25	26	26	26	26	26	$660,000	$18,706	$19,089	$19,089	$19,089	$19,089	$19,089	$735	$741	$745	$747	$747	$747
County - Other (Moore)	14	15	17	19	21	23	$0	$11,636	$12,568	$13,555	$14,559	$15,607	$16,679	$857	$826	$797	$770	$744	$723
County - Other (Potter)	266	291	318	347	379	413	$13,409,600	$225,014	$249,520	$275,440	$301,259	$329,424	$359,068	$846	$858	$866	$869	$869	$869
County - Other (Randall)	143	158	173	189	207	225	$0	$70,346	$78,070	$85,803	$93,723	$102,152	$110,903	$493	$496	$496	$496	$494	$492
Dalhart	79	86	93	100	107	113	$0	$29,206	$31,576	$33,914	$36,180	$38,349	$40,423	$369	$367	$365	$363	$360	$357
Dumas	133	152	171	190	210	231	$0	$80,584	$109,861	$114,416	$119,039	$123,861	$128,802	$606	$722	$671	$628	$590	$558
Fritch	37	38	37	37	37	37	$1,367,000	$32,999	$34,019	$34,287	$34,312	$34,325	$34,351	$889	$902	$916	$920	$922	$921
Groom	5	5	5	5	5	5	$0	$6,579	$6,579	$6,579	$6,579	$6,579	$6,579	$1,252	$1,267	$1,277	$1,281	$1,281	$1,281
Gruver	23	25	26	28	30	31	$964,600	$21,652	$23,449	$25,018	$26,331	$27,657	$28,881	$958	$953	$947	$943	$932	$924
Lake Tanglewood	25	24	24	24	24	24	$492,000	$15,455	$15,455	$15,455	$15,455	$15,455	$15,455	$625	$632	$638	$640	$642	$642
Mclean	17	18	20	23	25	27	$669,900	$15,761	$16,909	$18,286	$20,058	$21,460	$22,939	$938	$926	$912	$887	$869	$852
Memphis	34	23	14	14	14	14	$470,000	$34,555	$35,371	$11,551	$11,551	$11,551	$11,551	$1,029	$1,535	$803	$805	$806	$806
Miami	17	18	17	17	17	17	$373,200	$12,816	$12,943	$12,956	$12,956	$12,956	$12,956	$734	$737	$743	$746	$746	$746
Pampa	146	161	178	202	220	240	$0	$85,322	$114,089	$118,601	$124,409	$129,036	$133,867	$584	$707	$665	$615	$586	$559
Panhandle	47	48	48	48	48	48	$1,559,800	$36,760	$37,933	$38,545	$38,545	$38,545	$38,545	$777	$787	$796	$802	$803	$803
Perryton	85	90	96	103	111	119	$0	$31,752	$33,749	$35,894	$38,201	$40,679	$43,343	$374	$373	$372	$370	$367	$364
Shamrock	30	31	31	32	33	35	$1,301,900	$30,156	$31,150	$32,107	$33,088	$34,172	$35,320	$997	$1,015	$1,029	$1,026	$1,021	$1,015
Spearman	24	24	25	25	26	27	$0	$14,639	$15,032	$15,337	$15,651	$15,975	$16,311	$619	$619	$619	$617	$612	$606
Stinnett	37	38	37	37	37	37	$1,212,200	$29,863	$30,755	$30,985	$30,985	$30,985	$30,985	$809	$819	$831	$832	$834	$834
Stratford	39	42	43	44	45	46	$1,489,900	$32,923	$35,269	$36,544	$37,666	$38,482	$39,081	$838	$844	$852	$853	$852	$849
Sunray	37	42	46	52	57	63	$1,822,300	$33,254	$37,194	$41,401	$45,673	$50,135	$54,687	$896	$896	$893	$886	$877	$870
TCW Supply Inc.	58	59	59	59	59	59	$1,346,700	$32,629	$33,611	$33,866	$33,866	$33,866	$33,866	$563	$566	$570	$573	$574	$574
Texline	18	20	22	24	26	28	$464,500	$12,472	$13,415	$14,410	$15,379	$16,322	$17,227	$709	$683	$662	$643	$627	$612
Vega	22	23	23	23	23	23	$608,100	$17,253	$18,056	$18,056	$18,056	$18,056	$18,056	$790	$787	$797	$802	$802	$802
Wellington	44	45	46	47	49	50	$1,533,900	$34,555	$36,123	$37,156	$38,354	$39,285	$40,101	$794	$804	$812	$811	$809	$807
Wheeler	15	15	16	16	17	18	$0	$9,524	$9,703	$9,873	$10,049	$10,244	$10,451	$638	$631	$624	$615	$605	$593
White Deer	20	21	21	21	21	21	$704,400	$19,344	$19,879	$20,147	$20,147	$20,147	$20,147	$950	$957	$968	$971	$971	$971
Region A Total	**3,690**	**4,022**	**4,333**	**4,675**	**5,044**	**5,431**	**$37,564,700**	**$1,734,672**	**$1,958,580**	**$2,053,755**	**$2,173,289**	**$2,297,452**	**$2,425,696**	**$470**	**$487**	**$474**	**$465**	**$455**	**$447**

5B.2 Agricultural Water Conservation

Agriculture is the largest user of water in the PWPA, and accounted for 92% of the total water use in the PWPA in 2010. Most of the Counties in the PWPA can meet the agricultural demands. There are three counties showing needs in irrigation: Dallam, Hartley and Moore. These needs are projected to reach 155,688 acre-feet per year in 2020 and peak at 192,876 acre-feet per year deficit in 2040. 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 eight agricultural water conservation strategies considered include irrigation scheduling, irrigation equipment changes, soil management, advances in plant breeding, precipitation enhancement, conversion to dryland farming and changes to crop types and crop varieties that use less water. These strategies are summarized in Section 5B.2.1 and evaluated in detail in Appendix D. 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 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-2. A synopsis of the potential water savings associated with all eight 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 D.

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% of the water applied for each crop.

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 $3.00 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 $5.00 per acre annual cost was assumed for irrigation scheduling. Irrigation scheduling costs can be reduced if the producer choses to buy the soil moisture probe. Typically, the cost of a soil moisture probe ranges from $1,300 to $2,650, depending on the company and level of sophistication of the probe.

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. Short season hybrids may be seeded earlier to possible avoid insect threat, and have the potential of planting a third crop in two years either by planting a short season variety prior to or following a wheat crop (Howell et al., 1996). Early planting of the short season hybrids can also help avoid high evaporative demand periods and save water. The seasonal evapotranspiration for short season corn hybrids was found to be generally 5 inches less than that of long season hybrids (Howell et al., 1998). The water use of short season grain sorghum is about 0.6 inches less than that of long season varieties. In this analysis, the water savings from adopting short season corn and short season grain sorghum are assumed to be 4.1 and 3.0 acre-inches per acre, respectively.

The implementation cost of this water conservation strategy was assumed to be the compensation needed to account for the loss in yield and profitability of employing the strategy. Howell et al. (1998) reported that the yield from short season hybrids was about 15% less than that from the full season hybrids. A partial budget analysis considering the loss in revenue versus the reduction in pumping cost, fertilizer, and harvest expense indicates that approximately half of the revenue reduction is profit loss (Texas A&M AgriLife Crop and Livestock Budgets, 2014). In this analysis, the loss of revenue from short season corn and grain sorghum is estimated as 15% of the average revenue for the last 5 years and the implementation cost is assumed to be half of that amount. The average revenue was calculated using the average corn and grain sorghum yield and the average price received in Northern High Plains for last 5 years (USDA, 2014). It should be noted that the reduction in gross receipts and associated expenditures is expected to have a negative impact on the regional economy.

Irrigation Equipment Changes

Current irrigation methods practiced in the Texas Panhandle include conventional furrow irrigation (CF), 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 CF, MESA, LESA, LEPA, and SDI is 60, 78, 88, 95, and 97%, 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 establishing new MESA and LESA systems in CF irrigated fields and converting MESA and LESA to LEPA to improve its 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 3.5 and 1.3 acre-inches per acre for conversion of furrow to MESA/LESA and MESA/LESA to LEPA, respectively. It should be noted that water savings from this strategy vary by county and over time as the amount of water pumped changes.

Initial investment in irrigation equipment varies depending on the dealer and spacing between sprinkler drops or tape in the case of SDI. In consultation with industry representatives and other secondary sources, the cost of adding a quarter-mile (125 acres) sprinkler system was estimated to be $75,000-$80,000. The estimates to convert a MESA or LESA quarter-mile sprinkler system to LEPA ranged from $7,000-$10,000, depending on the spacing of the drops. The estimates for installing a SDI system ranged from $1,200-$1,500 per acre, depending primarily on whether drip tapes were spaced 80 inches or 40 inches apart.

The implementation cost of this strategy is estimated using the costs associated with the irrigation equipment required for each of the systems and their respective adoption rate. The assumed adoption percentage of the irrigation systems during each decade was used along with the acreage and average water use to estimate the amount of irrigation applied using these systems during the baseline period and future periods. These irrigation amounts were multiplied with the cost per acre-inch to get the total cost of irrigation during the baseline and future time periods. The difference in cost between successive time periods is the cost of implementation for this strategy.

Change in Crop Type

Selection 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% 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. In this analysis, it is assumed that shifting from corn to low water use crops can save 7.8 to 8.6 acre-inches per acre depending on the crop choice.

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 and that of irrigated cropland with fair water availability. This per acre cost of adoption is then multiplied by the assumed acreage of adoption to get the total cost, which is then expressed as the cost per acre-foot of water savings. The value of irrigated cropland with fair water availability in the region ranges from $1,800 to $2,500 per acre. The average of these two prices ($2,150) was used as the average land value for irrigated cropland with fair water availability in the region.

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% on the soil surface (CTIC, 2014). Conservation tillage can reduce evaporation, increase rainfall infiltration, 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. Different tillage practices such as minimum tillage, reduced tillage, no-till; ridge tillage, vertical tillage, and strip tillage are often interchangeably used with the term conservation tillage. In this analysis, the water savings from adopting effective soil management strategy is assumed to be 1.75 acre-inches per acre.

The initial capital investment in equipment may impede the adoption of soil management practices. The purchase price of conservation tillage equipment capable of doing strip till or vertical tillage varies considerably depending on the size and company that made it. For example, a six-row strip till implement costs approximately $32,000, whereas a 24-row prices out at $116,500 (Texas A&M AgriLife Crop and Livestock Budgets, 2014). A 14-foot vertical tillage implement costs $39,000, where a 40-foot version priced out at $116,500. The appropriate size of conservation implements depends upon the equipment compliment of the producer.

The implementation cost is estimated as the difference between the cost of conventional tillage and conservation tillage. It is assumed that the average conventionally tilled field will be disked once, chiseled once, and cultivated three times during the year. This will be followed by two herbicide applications; one pre-plant and one post-plant. In the case of conservation tillage (strip tillage is assumed as it is most common in the region), it is assumed that the field is chiseled once and cultivated two times. There are three herbicide applications in conservation tillage. The cost of conventional and conservation tillage are calculated as $87.75 and $85.16 per acre, respectively.

Precipitation Enhancement

Precipitation enhancement, commonly known as cloud seeding or weather modification, is a process in which clouds are inoculated with condensation agents (such as silver iodide) to enhance rainfall formation. Currently, cloud seeding is conducted in almost one-fifth of the land area of Texas, covering about 31 million acres. In 2012, the weather modification programs in Texas conducted 162 missions, treating 353 thunderstorms. Analysis showed that the treated storms lived 40% longer, covered 47% more area, and produced 124% more rain than the untreated storms. The estimated increase in water availability was 1,517,266 acre-feet at a cost of $11/acre-foot (TDLR, 2014). Precipitation enhancement can help conserve groundwater by reducing the irrigation requirement. It can also increase reservoir levels and could have a positive impact on dryland farms and ranches, including hail suppression. This analysis assumes a water savings of one acre-inch per acre for all irrigated acreage in the region by precipitation enhancement.

The strategy of precipitation enhancement is adopted only by the counties in the Panhandle Groundwater Conservation District (PGCD), which are Carson, Donley, Gray, Roberts, Wheeler and parts of Armstrong, Hutchinson, and Potter Counties. In consultation with PGCD personnel, the cost of adoption of this strategy per acre feet of water saved is estimated as $6.28 in the 2006 plan. Since this was a local estimate of the cost it was determined to be more accurate than the TDRL cost for the area. This 2006 PGCD value was adjusted to 2014 dollars (USDA, 2014). The cost of adoption of this strategy per acre-foot of water saved is estimated to be $8.11

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. Other highly drought tolerant crops like canola, safflower, mustard, camelina, jatropha, castor, guar, and rapeseed are currently being evaluated for suitability and profitability, but sustained markets and returns on investments are still valid concerns. This analysis assumes 13.9 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.

The cost of implementing this water conservation strategy is evaluated in terms of reduced land values. Land that has sufficient water available for irrigation is worth much more compared to dry cropland. The cost of adoption for one acre of land is estimated as the difference between the average land value in the region for irrigated cropland and that of dryland. This per acre cost of adoption is then multiplied by the assumed acreage of adoption to get the total cost. The land values reported by the Texas chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA, 2013) provided the average land value for irrigated and dry cropland in the region. The value of irrigated cropland with fair water availability in the region ranges from $1,800 to $4,000 per acre. The average of these two values ($2,900) was used as the average land value for irrigated cropland availability in the region. The average land value of dry cropland ranged from $500 to $700 per acre in the western parts of the region and from $700 to $1,100 in the Eastern parts of the region resulting in an overall average of $750 per acre. The cost assumed in the analysis to retire an acre of irrigated land was the difference in the irrigated cropland value and dry cropland value. In addition to the implementation cost, the loss in gross receipts from the conversion of irrigated to dryland crop production was estimated.

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% and the second round of varieties will reduce the water use an additional 15% 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%.

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 2016 planning effort for each of the strategies is presented in Table 5B-2.

Table 5B-2: Possible Water Management Strategies for Reducing Irrigation Demands

Water Management Strategy	Annual Regional Water Savings (ac-in/ac/yr)	Assumed Baseline Use 2013	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%	20%	35%	50%	75%	85%	90%	95%
Irrigation Equipment Changes	Furrow to MESA or LESA 3.5	87%	90%	91.5%	93%	94.5%	96%	98%
	MESA or LESA to LEPA or SDI 1.3	75%	80%	85%	90%	95%	100%	100%
Change in crop type	7.8-8.6	10%	15%	20%	25%	30%	35%	40%
Change in crop variety	4.10 (corn) 3.0 (sorghum)	40%	50%	60%	70%	70%	70%	70%
Conversion to Dryland	13.9	0%	2.5%	5%	5%	5%	5%	5%
Soil Management	1.75	70%	75%	80%	85%	90%	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%
Precipitation Enhancement	1.0	38%	38%	38%	38%	38%	38%	38%

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 the forthcoming sections. The year 2013 was selected as the baseline for evaluating strategies. Baseline adoption rates for strategies were estimated using secondary data sources and future adoption rates (2020 – 2070) were identified under the guidance of the PWPG Agriculture committee, Table 5B-2. Since final implementation rates of conservation strategies do not occur until 2070, the water savings, direct cost and net cost of all strategies were evaluated over a 60-year planning horizon (2020 – 2079). A five-year average (2006 – 2010) of Farm Service Agency (FSA) irrigated acreage for the region was used to establish a baseline from which effectiveness of alternative conservation strategies were measured. FSA irrigated acreage estimates were increased in some counties based on local knowledge to account for farms known not to be registered with FSA. The five-year average of irrigated acreage was used to dampen distortions resulting from acreage shifts between crops caused by volatile crop prices. Water availability was assumed to remain constant in measuring the impacts 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:

- change in crop type, irrigation scheduling, and changes in irrigation equipment
- changes in crop variety, irrigation scheduling, and changes in irrigation equipment
- change 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 $9.10 per acre-inch (Texas A&M AgriLife Crop and Livestock Budgets, 2014). All costs were evaluated in September 2013 dollars. The loss in gross receipts was estimated by strategy, where warranted. The impact on the regional economy resulting from a change in gross receipts was not estimated but is discussed.

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-3 shows the total estimated water savings and costs associated with proposed individual irrigation water conservation strategies and the three potential combination for the region.

Table 5B-3: Estimated Water Savings and Costs for Proposed Conservation Strategies

Water Management Strategy	Cumulative Water Savings (WS)	Implementation Cost (IC)	IC/WS	Cost Savings	Net Cost/WS	Loss in Gross Receipts
	ac-ft	$1,000	$/ac-ft	$1,000	$/ac-ft	$1,000
Irrigation Scheduling	4,685,325	209,396	$44.69	511,637	($64.51)	-
Change in Crop Variety	3,064,326	602,294	$196.55	-	$196.55	1,204,587
Irrigation Equipment Changes	3,643,928	55,638	$15.27	397,917	($93.93)	-
Change in Crop Type	6,394,663	199,934	$31.27	-	$31.27	3,006,360
Soil Management	1,970,123	-34,989	($17.76)	215,137	($126.99)	-
Precipitation Enhancement	813,923	6,601	$8.11	88,880	($101.09)	-
Irrigated to Dryland Farming	4,156,337	145,226	$34.94	-	$34.94	2,805,477
Advances in Plant Breeding	13,821,966	113,322	$8.20	1,509,359	($102.63)	-
Combinations						
Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	13,602,712	265,034	$19.48	1,485,416	($89.72)	3,006,360
Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	10,325,042	867,328	$84.00	1,127,495	($25.20)	1,204,587
Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	22,928,545	378,356	$16.50	2,503,797	($92.70)	3,006,360

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 includes: change in crop type, advances in plant breeding, irrigation scheduling, and changes in irrigation equipment. Counties without a need are recommended to adopt conservation measures of: advances in plant breeding, irrigation scheduling, and changes in irrigation equipment. A change in crop type is not recommended as the negative economic impact may deter potential irrigators from implementation if there is no need. Table 5B-4 through 5B-7 show the county by county savings for each of the individual strategies. Table 5B-8 shows the savings associated with the recommended strategies which accounts for potential overestimation of water savings. Dallam, Hartley and Moore are represented with the recommended combination of four conservation measures, whereas the remaining counties are evaluated with only three conservation strategies. Table 5B-9 shows the costs based on $16.50 per acre-foot as shown in the previous Table 5B-3. On a regional basis the PWPA is projected to save approximately 482,700 acre-feet per year at a cost of $8.0 million per year.

Weather Modification (Precipitation Enhancement) is only a recommended strategy for counties in the Panhandle Groundwater Conservation District (PGCD), which are Carson, Donley, Gray, Roberts, Wheeler and parts of Armstrong, Hutchinson, and Potter Counties. Table 5B-10 shows the estimate water savings for those counties.

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-4: Estimated Water Savings from Irrigation Scheduling by County in the PWPA

County	Water savings from Irrigation Scheduling (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	66	132	242	287	309	331
Carson	0	844	1,688	3,094	3,656	3,938	4,219
Childress	0	107	215	393	465	501	537
Collingsworth	0	269	538	986	1,166	1,255	1,345
Dallam	0	5,547	11,094	20,338	24,036	25,885	27,734
Donley	0	362	723	1,325	1,566	1,687	1,807
Gray	0	319	638	1,169	1,382	1,488	1,594
Hall	0	152	303	556	657	708	758
Hansford	0	2,018	4,036	7,399	8,744	9,417	10,089
Hartley	0	5,179	10,358	18,990	22,442	24,169	25,895
Hemphill	0	29	57	105	124	134	143
Hutchinson	0	599	1,199	2,198	2,597	2,797	2,997
Lipscomb	0	300	600	1,100	1,300	1,400	1,500
Moore	0	2,143	4,286	7,858	9,287	10,001	10,716
Ochiltree	0	857	1,713	3,141	3,713	3,998	4,284

County	Water savings from Irrigation Scheduling (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Oldham	0	59	118	215	255	274	294
Potter	0	51	102	187	221	238	255
Randall	0	269	537	985	1,164	1,254	1,344
Roberts	0	89	178	327	387	416	446
Sherman	0	3,290	6,580	12,064	14,257	15,354	16,450
Wheeler	0	124	247	454	536	577	618
Total	**0**	**22,671**	**45,342**	**83,127**	**98,241**	**105,798**	**113,355**

Table 5B-5: Estimated Water Savings from Irrigation Equipment Changes by County in the PWPA

County	Water savings from Irrigation Equipment Changes (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	67.4	109.3	154	176.5	236.3	266.3
Carson	0	895.6	1451	2045	2344.3	3138.7	3536.7
Childress	0	117.5	190.4	268.3	307.5	411.8	464
Collingsworth	0	288.5	467.4	658.7	755.1	1011	1139.2
Dallam	0	5947	9634.6	13578.5	15566.3	20840.8	23483.7
Donley	0	387.2	627.3	884	1013.4	1356.8	1528.9
Gray	0	342.3	554.6	781.7	896.1	1199.7	1351.9
Hall	0	162.9	264	372	426.5	571	643.4
Hansford	0	2169.1	3514.1	4952.6	5677.6	7601.3	8565.3
Hartley	0	5553	8996.4	12679.1	14535.2	19460.3	21928.2
Hemphill	0	30.7	49.7	70	80.3	107.5	121.1
Hutchinson	0	643.3	1042.2	1468.8	1683.8	2254.3	2540.2
Lipscomb	0	321.7	521.2	734.6	842.1	1127.5	1270.4
Moore	0	2299.7	3725.8	5250.9	6019.5	8059.2	9081.3
Ochiltree	0	920.4	1491.1	2101.5	2409.1	3225.5	3634.5
Oldham	0	63.3	102.6	144.5	165.7	221.8	250
Potter	0	55.1	89.3	125.8	144.2	193.1	217.6
Randall	0	289.4	468.9	660.8	757.6	1014.3	1142.9
Roberts	0	95.8	155.2	218.7	250.8	335.7	378.3
Sherman	0	3552.9	5756	8112.1	9299.7	12450.8	14029.8
Wheeler	0	131.9	213.7	301.1	345.2	462.2	520.8
Total	**0**	**24,335**	**39,425**	**55,563**	**63,697**	**85,280**	**96,095**

Table 5B-6: Estimated Water Savings from Changes in Crop Type by County in the PWPA

County	Water savings from Changes in Crop Type (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	40.7	81.5	122.2	163	203.7	244.5
Carson	0	1033	2066	3099	4132	5165.1	6198.1
Childress	0	5.4	10.8	16.2	21.6	27	32.3
Collingsworth	0	29.6	59.1	88.7	118.3	147.9	177.4
Dallam	0	8341.3	16682.6	25023.9	33365.2	41706.5	50047.8
Donley	0	94.7	189.4	284.1	378.8	473.6	568.3
Gray	0	424.3	848.7	1273	1697.3	2121.7	2546
Hall	0	0	0	0	0	0	0
Hansford	0	2955.9	5911.8	8867.7	11823.7	14779.6	17735.5
Hartley	0	6842.3	13684.7	20527	27369.4	34211.7	41054
Hemphill	0	2.9	5.9	8.8	11.7	14.6	17.6
Hutchinson	0	836.2	1672.4	2508.6	3344.9	4181.1	5017.3
Lipscomb	0	233.1	466.2	699.2	932.3	1165.4	1398.5
Moore	0	3325.2	6650.4	9975.5	13300.7	16625.9	19951.1
Ochiltree	0	1229	2458	3687	4916	6145	7374
Oldham	0	9.8	19.6	29.3	39.1	48.9	58.7
Potter	0	0.4	0.9	1.3	1.8	2.2	2.7
Randall	0	66.4	132.7	199.1	265.4	331.8	398.1
Roberts	0	144.5	289	433.6	578.1	722.6	867.1
Sherman	0	4773.2	9546.4	14319.6	19092.8	23866	28639.2
Wheeler	0	62.8	125.5	188.3	251.1	313.8	376.6
Total	**0**	**30,451**	**60,902**	**91,352**	**121,803**	**152,254**	**182,705**

Table 5B-7: Estimated Water Savings from Advances in Plant Breeding by County in the PWPA

County	Water savings from Advances in Plant Breeding for Drought Tolerance (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	102.6	250	492.9	553.2	572.4	572.4
Carson	0	2823.3	4858.2	10591	11788.1	11912.7	11912.7
Childress	0	177.6	326.4	695.9	776.9	788.9	788.9
Collingsworth	0	70.2	195.2	387	419.6	437.6	437.6
Dallam	0	19444.8	33500.2	72707.8	81256.3	82122.9	82122.9
Donley	0	209.7	366.6	796.4	885.2	895.6	895.6
Gray	0	899	1470.6	3251.7	3623.7	3648.2	3648.2
Hall	0	135.2	219	485.5	541.4	544.6	544.6
Hansford	0	6644	12325.8	26201.7	29258.9	29730.8	29730.8
Hartley	0	15812.3	27154.1	59014.1	65927.3	66614.5	66614.5
Hemphill	0	6.2	21.4	40.1	44.1	46.5	46.5
Hutchinson	0	1843.7	3190.9	6919	7729.1	7814.2	7814.2
Lipscomb	0	451.6	848.6	1799.5	2007.1	2041.3	2041.3
Moore	0	7445.6	13209.1	28559.6	31762.5	32170.6	32170.6
Ochiltree	0	2842.6	5121.3	11017.6	12259.5	12431	12431
Oldham	0	23.1	196.7	339.9	363.3	395.7	395.7
Potter	0	3.2	51	80.7	90.7	99.9	99.9
Randall	0	184	892.8	1607.9	1747.7	1871.1	1871.1
Roberts	0	313.5	496.1	1106.5	1235.2	1240.4	1240.4
Sherman	0	11572.4	20447.4	44120.8	49226.2	49843.9	49843.9
Wheeler	0	197.5	355.4	763.3	851.1	862.9	862.9
Total	**0**	**71,202**	**125,497**	**270,979**	**302,347**	**306,086**	**306,086**

Table 5B-8: Estimated Water Savings from the Recommended Combination by County[1,2]

County	Water savings from Recommended Combination[1] (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	206	425	721	800	869	900
Carson	0	3,980	6,910	12,747	14,010	14,774	15,146
Childress	0	351	632	1,100	1,220	1,324	1,378
Collingsworth	0	548	1,037	1,647	1,843	2,104	2,250
Dallam[2]	0	34,218	61,174	106,343	121,011	132,167	140,612
Donley	0	836	1,484	2,436	2,729	3,065	3,259
Gray	0	1,361	2,301	4,216	4,648	4,929	5,078
Hall	0	392	679	1,145	1,280	1,419	1,499
Hansford	0	9,447	17,175	31,242	34,401	36,373	37,260
Hartley[2]	0	29,197	52,161	90,476	103,095	113,047	120,509
Hemphill	0	57	111	174	196	224	239
Hutchinson	0	2,692	4,694	8,578	9,459	10,010	10,281
Lipscomb	0	936	1,702	2,945	3,268	3,555	3,706
Moore[2]	0	13,308	24,120	41,895	47,571	52,037	55,406
Ochiltree	0	4,030	7,195	13,177	14,476	15,292	15,670
Oldham	0	127	360	567	617	694	723
Potter	0	95	209	319	359	413	441
Randall	0	647	1,641	2,637	2,890	3,221	3,356
Roberts	0	435	717	1,339	1,475	1,550	1,590
Sherman[2]	0	20,156	36,498	63,651	72,285	78,846	83,721
Wheeler	0	395	706	1,230	1,364	1,480	1,542
Total	**0**	**123,414**	**221,931**	**388,585**	**438,997**	**477,393**	**504,566**

1. The recommended combination includes Irrigation Scheduling, Irrigation Equipment Changes and Advances in Plant Breeding.
2. The recommended combination for Dallam, Hartley, Moore and Sherman Counties includes Changes in Crop Type, Irrigation Scheduling, Irrigation Equipment Changes and Advances in Plant Breeding.

Table 5B-9: Estimated Cost for the Recommended Combination by County in the PWPA[1,2]

County	Capital Cost[3]	Cost for Recommended Combination[1] ($/yr)					
		2020	2030	2040	2050	2060	2070
Armstrong	$154,200	$3,399	$7,013	$11,897	$13,200	$14,339	$14,850
Carson	$2,047,700	$65,670	$114,015	$210,326	$231,165	$243,771	$249,909
Childress	$268,700	$5,792	$10,428	$18,150	$20,130	$21,846	$22,737
Collingsworth	$659,600	$9,042	$17,111	$27,176	$30,410	$34,716	$37,125
Dallam[2]	$13,596,900	$564,597	$1,009,371	$1,754,660	$1,996,682	$2,180,756	$2,320,098
Donley	$885,200	$13,794	$24,486	$40,194	$45,029	$50,573	$53,774
Gray	$782,700	$22,457	$37,967	$69,564	$76,692	$81,329	$83,787
Hall	$372,500	$6,468	$11,204	$18,893	$21,120	$23,414	$24,734
Hansford	$4,959,300	$155,876	$283,388	$515,493	$567,617	$600,155	$614,790
Hartley[2]	$12,696,300	$481,751	$860,657	$1,492,854	$1,701,068	$1,865,276	$1,988,399
Hemphill	$70,100	$941	$1,832	$2,871	$3,234	$3,696	$3,944
Hutchinson	$1,470,800	$44,418	$77,451	$141,537	$156,074	$165,165	$169,637
Lipscomb	$735,600	$15,444	$28,083	$48,593	$53,922	$58,658	$61,149
Moore[2]	$5,258,000	$219,582	$397,980	$691,268	$784,922	$858,611	$914,199
Ochiltree	$2,104,300	$66,495	$118,718	$217,421	$238,854	$252,318	$258,555
Oldham	$144,700	$2,096	$5,940	$9,356	$10,181	$11,451	$11,930
Potter	$126,000	$1,568	$3,449	$5,264	$5,924	$6,815	$7,277
Randall	$661,700	$10,676	$27,077	$43,511	$47,685	$53,147	$55,374
Roberts	$219,000	$7,178	$11,831	$22,094	$24,338	$25,575	$26,235
Sherman[2]	$8,123,100	$332,574	$602,217	$1,050,242	$1,192,703	$1,300,959	$1,381,397
Wheeler	$301,500	$6,518	$11,649	$20,295	$22,506	$24,420	$25,443
Total	**$55,637,900**	**$2,036,331**	**$3,661,862**	**$6,411,653**	**$7,243,451**	**$7,876,985**	**$8,325,339**

1. The recommended combination includes Irrigation Scheduling, Irrigation Equipment Changes and Advances in Plant Breeding.
2. The recommended combination for Dallam, Hartley, Moore and Sherman Counties includes Changes in Crop Type, Irrigation Scheduling, Irrigation Equipment Changes and Advances in Plant Breeding.
3. The capital costs shown is associated with Irrigation Equipment Changes. Only annual costs are assumed for the other strategy types. (See Appendix D for detailed breakdowns of supplies and costs.)

Table 5B-10: Estimated Water Savings from Weather Modification (Precipitation Enhancement) by County in the PWPA

County	Water savings from Precipitation Enhancement (acre-feet/yr)						
	Baseline	2020	2030	2040	2050	2060	2070
Armstrong	0	402	402	402	402	402	402
Carson	0	4,850	4,850	4,850	4,850	4,850	4,850
Childress	0	0	0	0	0	0	0
Collingsworth	0	0	0	0	0	0	0
Dallam	0	0	0	0	0	0	0
Donley	0	1,866	1,866	1,866	1,866	1,866	1,866
Gray	0	1,858	1,858	1,858	1,858	1,858	1,858
Hall	0	0	0	0	0	0	0
Hansford	0	0	0	0	0	0	0
Hartley	0	0	0	0	0	0	0
Hemphill	0	0	0	0	0	0	0
Hutchinson	0	2,960	2,960	2,960	2,960	2,960	2,960
Lipscomb	0	0	0	0	0	0	0
Moore	0	0	0	0	0	0	0
Ochiltree	0	0	0	0	0	0	0
Oldham	0	0	0	0	0	0	0
Potter	0	216	216	216	216	216	216
Randall	0	0	0	0	0	0	0
Roberts	0	469	469	469	469	469	469
Sherman	0	0	0	0	0	0	0
Wheeler	0	944	944	944	944	944	944
Total	**0**	**13,565**	**13,565**	**13,565**	**13,565**	**13,565**	**13,565**

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-11 summarizes two scenarios: a pumping rate of less than and greater than 700 gallons per minute.

Table 5B-11: Estimated Costs of Irrigation Wells in the PWPA

Pumping Rate (gpm)	Approximate Well Depth (ft.)	Approximate Well Casing Diameter (in.)	Approximate Pumping Unit Diameter (in.)	Well Cost	Pumping Equipment Cost	Total Cost
Less than 700	375	12¾	4 - 6	$33,750	$25,500	$59,250
Greater than 700	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

The TCEQ defines water conservation as "a strategy or combination of strategies for reducing the volume of water withdrawn from a water supply source, for reducing the loss or waste of water, for maintaining or improving the efficiency in the use of water, for increasing the recycling and reuse of water, and for preventing the pollution of water."

The TCEQ 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. Water conservation plans are also required for all water users applying for a State water right, and 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 TWDB. All updated water conservation plans were to be submitted to the Executive Director of the TCEQ by May 1, 2014.

In the PWPA, eight 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. Presently, these water users are not required to develop water conservation plans unless the user is seeking State funding; however, a wholesale water provider may request that its customers prepare a conservation plan to assist in meeting the goals and targets of the wholesale water provider's plan. A list of the users in the PWPG required to submit water conservation plans is shown in Table 5B-12.

Table 5B-12: Water Users in the PWPA Required to Prepare Water Conservation Plans

Municipal and Industrial Water Users	Irrigation Water Users
City of Amarillo	None in Region A
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 482,699 acre-feet per year by 2070. This represents a reduction of 60 percent of the projected demands. These strategies are specific to 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/

Subchapter 5C Water Management Strategies for Wholesale Water Providers

There are six wholesale water providers located in the PWPA. Of these entities, five are projected to have needs within the planning period: CRMWA, Amarillo, Borger, Cactus and PDRA. The other wholesale provider, Greenbelt MIWA is planning to develop projects to secure additional supplies for its customers. 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 wholesale 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 69,000 acre-feet per year in 2020, decreasing to 40,700 acre-feet per year by 2070 as groundwater becomes depleted within CRMWA's current well fields. Current demands on CRMWA are estimated at approximately 100,450 acre-feet per year in 2020 and increase to over 121,630 acre-feet per year by 2070. This results in near-term needs of 31,450 acre-feet per year and long-term needs of about 81,000 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
- Conjunctive use of groundwater with Lake Meredith
    - Brush control in Lake Meredith watershed
    - Aquifer storage and recovery

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

Customers	Demands (ac-ft/yr)					
	2020	2030	2040	2050	2060	2070
Region A:						
City of Pampa	1,818	1,827	1,836	4,680	4,680	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	1,534	1,950	2,300	2,750	2,750	2,750
City of O'Donnell	137	139	142	146	150	153
City of Plainview	2,761	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	460	477	483	496	507	517
City of Brownfield	1,380	1,500	1,600	1,750	1,750	1,750
Total	**100,450**	**108,814**	**114,138**	**121,457**	**121,549**	**121,633**
Sources	**Current Water Supply (ac-ft/yr)**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Lake Meredith	0	0	0	0	0	0
Roberts County Groundwater[1]	69,000	60,463	55,502	50,483	45,590	40,697
Total Current Supply	69,000	60,463	55,502	50,483	45,590	40,697
Need	**Need (ac-ft/yr)**					
Current Customers	31,450	48,351	58,636	70,974	75,959	80,936

[1] Groundwater supply over time is based on a 1 MGD reduction per year of well field capacity and a 1.25% peaking factor.

Each of the three strategies identified for CRMWA is recommended for implementation. 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.

5C.1.1 Expanded Development of Roberts County Well Field

Due to continued lack of inflow for Lake Meredith, CRMWA is proceeding to expand their groundwater production and delivery capacity. CRMWA holds water rights to 444,833 acres in Roberts and adjacent counties. Presently, only a fraction of these rights are developed. The current capacity of the transmission system (CRMWA I) from the Robert 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. CRMWA plans to develop a second pipeline with a capacity of 54 MGD, which would have the ability to deliver about 58,000 acre-feet per year. For planning purposes, this strategy would likely provide 48,000 acre-feet per year without additional local storage during the lower demand months. With CRMWA II the total capacity from the Roberts County well field is increased to 117 MGD, which is the full capacity of its existing Lake Meredith system. It is assumed that a new 67-mile 54 inch pipeline (CRMWA II) would be constructed from Roberts County to the terminal storage reservoir northeast of Amarillo. Infrastructure needed to develop the water and transmission is detailed in the cost estimates in Appendix E.

Time Intended to Complete

Continued expansion of the Robert 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 2020 with the transmission system on line by 2024. Additional wells may 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 76,000 acre-feet per year. This includes the development of 28,000 acre-feet per year of new groundwater supply for the existing pipeline and an additional 48,000 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 $275 million.

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.

5C.1.2 Conjunctive Use of Roberts County Well Field and Lake Meredith

The conjunctive use strategy for CRMWA utilizes the Authority's primary sources (Lake Meredith and Robert County groundwater) in a manner that most efficiently manages and delivers water supply to its customers. CRMWA's system is designed to utilize and deliver both sources of water. However, due to limitations in supply availability and delivery systems, the current supply available to CRMWA is limited to groundwater from Roberts County. This strategy recognizes the interdependence and use of these sources and identifies additional infrastructure to manage these sources. The conjunctive use strategy consists of three major components:

- Supply from Lake Meredith in years when available
- Control of invasive brush within the Lake Meredith watershed
- Aquifer Storage and Recovery of supplies in excess of demands

Each of these components are discussed individually, but together comprise the Conjunctive Use Strategy.

5C.1.2.1 Supply from Lake Meredith

With the on-going drought, the reliability of water from Lake Meredith has been severely impacted. There were several years in which CRMWA used very little to no water from this source. For planning purposes, the reliable supply is assumed to be zero. However, when there are inflows to the lake and water levels recover, CRMWA does plan to utilize this source for water supply to reduce groundwater pumping. Depending upon the ultimate end user, water from the two sources may need to be blended to meet water quality standards. Since both systems are currently in place, there are no infrastructure improvements associated with this strategy.

Time Intended to Complete

This strategy would be implemented immediately provided there is sufficient water in Lake Meredith to withdraw. Due to the uncertainty of inflows to Lake Meredith and the nature of conjunctive use, the conjunctive use operations may include extended periods of only groundwater use.

Quantity, Reliability and Cost

For purposes of planning, it is assumed that up to 40,000 acre-feet of surface water would be used conjunctively with the Roberts County groundwater in any one year. On a decadal average, the amount of additional water is estimated to be 10,000 acre-feet per year. The reliability of this supply is moderate if it is operated conjunctively with CRMWA's groundwater supplies. There are no capital costs associated with this strategy.

Environmental Issues

Potential environmental issues may be associated with reduced lake levels. However, CRMWA does not intend to operate the lake when levels are very low; therefore, environmental issues are expected to be low.

Impact on Water Resources and Other Management Strategies

This strategy would help prolong CRMWA's groundwater supplies with the use of renewable surface water. It also would provide a beneficial use of water that otherwise would have been lost to evaporation. This strategy would reduce pumping costs associated with the *Expanded Development of Roberts County Well Field* strategy.

Impact on Agriculture and Natural Resources

This strategy does not have any impacts to agriculture or natural resources.

Other Relevant Factors

There are no other identified relevant factors.

5C.1.2.2 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, nearly $3.5 million has been spent with 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. This strategy recommends that CRMWA continue with its program with support from the State Water Supply Enhancement Program to control salt cedar in the Lake Meredith watershed.

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. For this plan, it is assumed that the water made available from Lake Meredith in the Conjunctive Use strategy includes water made available from brush control. Therefore, the total supply from brush control would range between 0 and less than 10,000 acre-feet per year. The reliability during drought is low. The annual costs are estimated at $200,000.

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 the Conjunctive Use strategy.

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.

5C.1.2.3 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 by 54 MGD to 119 MGD. The average annual supply from this system (including CRMWA II) is estimated at 117,000 acre-feet per year, based on system peaking factor of 1.15. This results in an average delivery of 104 MGD.

During non-peak periods, the capacity of the CRMWA transmission system is underutilized; yet during peak demand months, the ability to meet all of 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 or Robert 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 all 11 member cities will be beneficiaries of the project. Each member city will utilize their existing well fields and treatment capacity. 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 the Roberts County well field to the ASR wells or the surface, ground, or blended water may be delivered to the customer's treatment facility and pumped back to the customer's well field for storage. Defined improvements will be determined during the feasibility study sponsored by CRMWA during 2016. All of the supplies associated with the ASR project component of the Conjunctive Use Strategy are assigned to CRMWA and are not allocated to individual member cities. 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.

<u>Time to Implement</u>

Supply will be available for the ASR project after CRMWA II is online in 2023.

<u>Quantity, Reliability and Cost</u>

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 from the ASR project is 16,400 acre-feet per year. The source of this water would be Lake Meredith or the Ogallala aquifer in Roberts County. Under conjunctive use, it is assumed that an average decadal supply of 10,000 acre-feet per year is available from Lake Meredith. Therefore, the amount of additional supply from the Roberts County well field for ASR on an average decadal basis is estimated at 6,400 acre-feet per year. However, the actual amounts used by source will vary by year based on demands and available supply in 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 at a later time. It was assumed for each member city that 20,000 feet of additional well field piping is needed along with pump improvements and injection wells. The strategy as a whole is estimated to cost $68 million.

<u>Environmental Issues</u>

Potential environmental impacts include water quality concerns for the receiving aquifer. This will be mitigated by pre-treatment of the water before injection and storage.

<u>Impact on Water Resources and Other Management Strategies</u>

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.

5C.1.3 Summary for CRMWA

The recommended strategies for CRMWA would provide up to 97,000 acre-feet per year. CRMWA is planning to initiate well capacity replacement in 2020 and transmission expansion by 2024. 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	31,450	48,351	58,636	70,974	75,959	80,936
Recommended Strategies	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Region A Customer Conservation	1,377	1,526	1,664	1,814	1,973	2,141
Region O Customer Conservation	2,849	2,981	3,110	3,320	3,557	3,807
Replace Well Capacity for CRMWA I[1]	0	9,000	13,000	19,000	23,000	28,000
Expand GW and delivery capacity (CRMWA II) [1]		48,000	48,000	48,000	48,000	48,000
Conjunctive Use[2]	10,000	16,400	16,400	16,400	16,400	16,400
Total from Strategies	**14,226**	**77,907**	**82,174**	**88,534**	**92,930**	**98,348**

[1] This is part of the Expanded Development of Roberts County Well Field strategy.
[2] Supply from Conjunctive Use includes supply from Lake Meredith, Brush Control and ASR.

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	$24.80	-	$1.68	$1.68	$4.31	$4.31	$2.93
Expand GW and delivery capacity (CRMWA II)	$250.30	-	$32.47	$32.47	$11.52	$11.52	$11.52
Conjunctive Use	$67.65	$0.20	$7.40	$7.40	$1.74	$1.74	$1.74
Total	**$342.75**	**$0.20**	**$41.55**	**$41.55**	**$17.57**	**$17.57**	**$16.19**

5C.2 City of Amarillo

The City of Amarillo provides municipal water to city customers in Randall and Potter Counties, 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 with Xcel Energy for 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 fully 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 of year of water. The total estimated current supply for the City is 50,807 acre-feet per year of potable water and 25,387 acre-feet of reuse supply. Potable water supplies are projected to decrease to 27,923 acre-feet per year as groundwater supplies decline. Reuse is expected is increase over time and is supplied to Xcel Energy for steam electric power use.

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 2020 with a shortfall of about 5,300 acre-feet per year and increasing to nearly 56,000 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.

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	47,731	52,110	56,810	61,860	67,631	73,739
Manufacturing - Potter County	6,799	7,323	7,834	8,276	8,884	9,535
City of Canyon	1,000	1,000	1,000	1,000	0	0
Manufacturing - Randall County	550	550	550	550	550	550
Palo Duro State Park	25	25	25	25	25	25
Steam Electric Power–Potter County	25,387	26,804	28,408	30,011	34,115	37,669
Total Demand	**81,492**	**87,812**	**94,627**	**101,722**	**111,205**	**121,518**
Sources	**Current Water Supply (ac-ft/yr)**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Randall County	2,263	1,735	1,372	1,100	890	680
Ogallala - Potter County	9,467	7,388	7,123	6,735	6,199	5,664
Ogallala - Carson County	10,948	9,378	7,882	6,669	5,760	4,850
Ogallala - Roberts County (CRMWA)	28,029	27,841	24,313	20,782	18,754	16,729
Meredith (CRMWA)	0	0	0	0	0	0
Ogallala - Deaf Smith	100	100	100	100	50	0
Reuse	25,387	26,804	28,408	30,011	34,115	37,669
Total Current Supply (W/O Reuse)	**50,807**	**46,442**	**40,791**	**35,386**	**31,653**	**27,923**
Need	**5,298**	**14,566**	**25,428**	**36,325**	**45,436**	**55,926**

The recommended water management strategies for Amarillo include conservation strategies, purchase of additional supply from CRMWA, expansion of their Potter and Carson County well fields, and development of the Roberts County Well Field. The city is considering direct reuse as an alternate strategy.

Recommended Strategies

- Implement conservation strategies (See Section 5B.1)
- Obtain contractual supplies from CRMWA (this is evaluated with CRMWA strategies)
- Develop Phase 2 of the Potter County Well Field (Ogallala aquifer)
- Purchase and Develop Additional Groundwater in Carson County
- Develop Roberts County Well Field (Ogallala aquifer)

Alternate Strategies

- Develop Direct Potable Reuse Supply

5C.2.1 Develop Phase II of the Potter County Well Field (Ogallala aquifer)

The City of Amarillo has unused groundwater rights in the Ogallala aquifer in Potter County that were not developed as part of the Phase 1 well field. However, due to limitation of the MAG in Potter County, the supply from this strategy is also limited. For the purposes of this plan, 6,000 acre-feet per year is available in 2020, decreasing to 4,000 acre-feet per year by 2070. If the MAG values are changed in the future water plans, the quantities available to Amarillo may increase. This well field strategy assumes that approximately 12 new wells will be drilled in Potter County. The wells will be drilled to a depth of 600 feet and produce approximately 850 gallons per minute. This project includes 40 miles of well field piping ranging from 8- to 54-inches in diameter, and 5-miles of 54-inch pipeline to transport the water to existing infrastructure. Additional pumping capacity and storage are also included. These infrastructure improvements were provided by Amarillo and include the infrastructure to develop up to 15 MGD of additional supply.

Time Intended to Complete

Phase II of the Potter County Well Field is anticipated to be online by 2020.

Quantity, Reliability and Cost

Approximately 6,000 acre-feet of additional water will be obtained from the Potter County well field in 2020 declining to 4,000 acre-feet by 2070. In Potter County, the reliability of Ogallala supplies are moderate to low since there is significant use of this supply. In the vicinity of Amarillo's well field, the reliability should be moderate as determined by previous studies. The total capital cost for the Potter County Phase II well field is $53.4 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. Since this well field is connecting to existing transmission infrastructure there is likely to be very little, if any, environmental issues of 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 competing for groundwater supplies in Potter County, and competition may increase as the supply is depleted. This strategy utilized most of undeveloped Ogallala groundwater, such that there is little available supply for other strategies.

Impact on Agriculture and Natural Resources

The increased demands on the Ogallala will continue to deplete the storage in the aquifer. The development of the proposed well fields are expected to have minimal impact on the agriculture and other natural resources since Amarillo already owns the water rights. 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.

5C.2.2 Purchase and Develop Additional Groundwater in Carson County

The City of Amarillo has an existing well field in the Ogallala aquifer in Carson County. The city plans to purchase and develop additional water rights near the existing well field to maintain the current capacity of water source. While Amarillo intends to develop this strategy over time with the addition of one or two wells every couple of years, this strategy is formulated on the ultimate development. It is assumed that Amarillo could develop up to 10 MGD of additional water supply over time. To provide this quantity of water, it is assumed that approximately 18 new wells will be drilled in Carson County. The wells will be drilled to a depth of 800 feet and produce approximately 750 gallons per minute. This project includes 95,000 feet of well field piping ranging from 8- to 30-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, 5-miles of 42-inch pipeline and associated pumping facilities upgrades are included in the cost estimates.

Time Intended to Complete

This project was assumed to be online in 2040.

Quantity, Reliability and Cost

Approximately 11,200 acre-feet per year of additional water will be obtained from the Carson County well field. In Carson County, the reliability of Ogallala supplies is moderate since there is currently competition for this supply with irrigators. The total capital cost for the Carson County well field is $37.5 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 Carson County 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 are expected to have low 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.

5C.2.3 Develop Roberts County Well Field (Ogallala aquifer)

The City of Amarillo has unused groundwater rights in the Ogallala aquifer in Roberts County. 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. It is assumed that the Roberts County strategy will be implemented in two phases, with Phase 1 being developed by 2070. This well field strategy assumes that approximately 18 new wells will be drilled in southeastern Roberts County. The wells will be drilled to a depth of 600 feet and produce approximately 800 gallons per minute. This project includes 18 miles of well field piping ranging from 12- to 42-inches in diameter, and 75-miles of 42-inch pipeline to transport the water from Roberts County to Amarillo.

Time Intended to Complete

The Roberts County well field will be developed as additional supplies are needed. This is expected to occur by 2070.

Quantity, Reliability and Cost

Approximately 11,200 acre-feet per year of additional water will be obtained from the Roberts County well field. 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 $170 million. These costs could potentially be less if Amarillo and CRMWA 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.

5C.2.4 Direct Potable Reuse

The City of Amarillo is considering a project to treat their wastewater effluent to potable water status. This is an alternative strategy for the City of Amarillo. The city currently has a contract with Xcel Energy for 100% of its reuse. This strategy is only feasible if Xcel agrees to Amarillo retaining some of its effluent for its own use. The strategy would include treating up to 8 MGD at the existing wastewater treatment plan with pre-treatment and reverse osmosis to produce 5.45 MGD of finished water. The water would then be transported approximately 7 miles to the balancing reservoir. The reject water 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 could be permitted and constructed by 2030.

Quantity, Reliability and Cost

Direct potable reuse would have moderate to high reliability since Amarillo is producing a greater amount of wastewater than necessary for this strategy. The capital cost for this project is approximately $63.6 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 expected to be less than projected in Chapter 2. Also, there is a potential strategy to sell reuse water to manufacturing in Potter County. This strategy, if implemented, could impact the supplies available to Potter County manufacturing, but this impact cannot be assessed at this time due to the uncertainty of the future steam electric power needs.

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 also would require a modification to the agreement with Xcel Energy for purchase of Amarillo's wastewater.

5C.2.5 Summary of Recommended Strategies for Amarillo

The recommended strategies for Amarillo would provide up to 62,000 acre-feet per year and fully meet the City's needs. Amarillo is planning to initiate Phase II of their Potter County Well field by 2020. The recommended strategies and quantities are shown in Table 5C-5. The total capital cost for Amarillo is $261 million and the annual costs for the strategies are summarized in Table 5C-6.

Table 5C-5: Recommended Water Management Strategies for Amarillo (ac-ft/yr)

	2020	2030	2040	2050	2060	2070
Need	5,298	14,566	25,428	36,325	45,436	55,926
Recommended Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation	1,734	1,935	2,122	2,316	2,534	2,762
Supplies from CRMWA	19,596	23,596	25,687	29,218	31,246	33,271
Potter County Well Field – Phase 2	6,000	5,600	5,200	4,800	4,400	3,967
Carson County Well Field			11,200	11,200	11,200	11,200
Roberts County Well Field						11,200
Total from Strategies	**27,330**	**31,131**	**44,209**	**47,534**	**49,380**	**62,400**
Alternate Strategy	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Direct Reuse	0	6,100	6,100	6,100	6,100	6,100

Table 5C-6: Summary of Costs for Recommended Strategies for Amarillo

Recommended Strategies	**Capital Cost**	**Annual Costs ($ Million)**					
		2020	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation	-	$0.43	$0.50	$0.55	$0.59	$0.64	$0.69
Supplies from CRMWA[1]	-	-	-	-	-	-	-
Potter County Well Field Phase 2	$53.4	$5.64	$5.64	$1.18	$1.18	$1.18	$1.18
Carson County Well Field	$37.5			$4.94	$4.94	$1.80	$1.80
Roberts County Well Field	$170.2						$17.2
Total from Strategies	**$261.10**	**$6.07**	**$6.14**	**$6.67**	**$6.71**	**$3.62**	**$20.87**
Alternate Strategy	**Capital Cost**	**Annual Costs ($ Million)**					
		2020	**2030**	**2040**	**2050**	**2060**	**2070**
Direct Reuse	$63.57	-	$8.34	$8.34	$3.02	$3.02	$3.02

[1] Purchase of additional supplies from CRMWA does not include additional infrastructure and the purchase costs are already negotiated

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 Counties. 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. Borger needs to develop additional supplies to meet needs.

Table 5C-7: Summary of Demands, Supplies and Needs for the City of Borger

Customers	Demands (ac-ft/yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Borger	3,215	3,254	3,234	3,229	3,225	3,224
Manufacturing - Hutchinson Co.	6,337	6,707	7,062	7,371	7,885	8,435
Manufacturing - Carson Co.	450	450	450	450	450	450
Hutchinson County-other	56	57	57	55	52	49
Total Demand	**10,058**	**10,468**	**10,803**	**11,105**	**11,612**	**12,158**
Sources	**Current Water Supply (ac-ft/yr)**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Hutchinson Co.	4,667	3,802	3,249	2,803	2,434	2,064
Ogallala - Carson Co.[1]	561	457	391	337	293	248
Reuse[2]	1,045	1,045	1,045	1,045	1,045	1,045
Lake Meredith (CRMWA)	0	0	0	0	0	0
Ogallala - Roberts Co.	3,829	3,829	3,439	2,938	2,650	2,363
Total Current Supply	**10,102**	**9,133**	**8,124**	**7,123**	**6,422**	**5,720**
Need	**93**	**1,342**	**2,679**	**3,982**	**5,190**	**6,438**

[1]Supply from the Carson County well field is used only for manufacturing use in Carson County.

[2]Reuse supply is only available to manufacturing users in Hutchinson County.

The recommended strategies include implementing conservation measures, obtaining contractual supplies from CRMWA and developing additional groundwater from the Ogallala in Hutchinson County. Table 5C-8 shows the amount of water supply associated with each of the recommended strategies. The yield of the City of Borger's well field is expected to decline over time. It is anticipated that Borger will continue to operate the groundwater system at levels similar to current pumpage. The City is currently developing additional groundwater in Hutchinson County and expects to have these supplies online in 2015.

Recommended Strategies

- Implement conservation strategies (See Section 5B.1)
- Obtain contractual supplies from CRMWA (this is evaluated with CRMWA strategies)
- Develop additional groundwater well (Ogallala aquifer)

After the City of Borger implements conservation and receives its full contracted amount of water from CRMWA, the City would need to develop approximately 6,000 acre-feet of water. This is expected to come from new and expanded groundwater sources.

5C.3.1 Develop additional groundwater well (Ogallala aquifer)

The City of Borger has 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 14 miles of 24-inch pipeline to transport the water to the City of Borger. The City currently has sufficient treatment capacity to treat the annual supply of 6,000 acre-feet.

Time Intended to Complete

The City has been actively developing a new well field southwest of the current well field since 2012. Production wells, pipelines, pumps, and storage facilities have been constructed and the project should be on-line in 2015.

Quantity, Reliability and Cost

Approximately 6,000 acre-feet per year of additional water will be obtained from the Hutchinson County well field. Reliability of groundwater in Hutchinson County is moderate to high, depending on location and competing interests. The capital costs for expanding the Hutchinson County well field are estimated at $29.5 million. Actual costs may differ.

Environmental Issues

The environmental impacts from groundwater development are expected to be low. The project is nearly complete.

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 Hutchinson 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.

5C.3.2 Summary of Recommended Strategies for Borger

The recommended strategies for the City of Borger would provide up to 10,806 acre-feet per year by 2070. The City of Borger has initiated development of their new well field to be completed by 2015. 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. 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
Need	93	1,342	2,679	3,982	5,190	6,438
Recommended Strategies	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation	104	107	106	106	106	106
Supplies from CRMWA	3,447	3,484	3,633	4,130	4,414	4,700
Additional Ogallala – Hutchinson Co.	6,000	6,000	6,000	6,000	6,000	6,000
Total from Strategies	**9,551**	**9,591**	**9,739**	**10,236**	**10,520**	**10,806**

Table 5C-9: Summary of Costs for Recommended Strategies for Borger

Recommended Strategies	Capital Cost ($ Million)	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Conservation	-	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Supplies from CRMWA[1]	-	-	-	-	-	-	-
Additional Ogallala – Hutchinson Co.	$29.46	$3.12	$3.12	$0.95	$0.95	$0.95	$0.95
Total from Strategies	**$29.46**	**$3.2**	**$3.2**	**$1.0**	**$1.0**	**$1.0**	**$1.0**

[1] Purchase of additional supplies from CRMWA does not include additional infrastructure and the purchase costs are already negotiated

5C.4 City of Cactus

The City of Cactus provides water to municipal and manufacturing customers in Moore County. Cactus currently obtains all of its supplies from the Ogallala aquifer in Moore County. Cactus is also a member of the Palo Duro River Authority. Table 5C-10 lists the projected demands by customer, current supplies, and recommended strategies for Cactus to meet the projected water needs.

Table 5C-10: Summary of Demands, Supplies, and Needs for the City of Cactus

Customers	Demands (ac-ft/yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
City of Cactus	985	1108	1242	1382	1532	1686
Moore County-Other	98	108	119	132	146	160
Moore County Manufacturing	3,168	3,342	3,513	3,664	3,913	4,178
Total Demand	**4,251**	**4,558**	**4,874**	**5,178**	**5,591**	**6,024**
Sources	**Current Water Supply (ac-ft/yr)**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Ogallala - Moore County	1,733	1,359	1,053	794	677	559
Total Current Supply	**1,733**	**1,359**	**1,053**	**794**	**677**	**559**
Need	**2,518**	**3,199**	**3,821**	**4,384**	**4,914**	**5,465**

The recommended strategies for the City of Cactus include water conservation and the development of new wells in the Ogallala Aquifer in Moore County. At this time Palo Duro reservoir is considered an alternative 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

5C.4.1 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 8 new wells producing approximately 850 gpm at a depth of 600 feet. The location of the new well field is unknown. For planning purposes, this strategy assumes 3 miles of 24-inch pipeline to connect to existing infrastructure.

Time Intended to Complete

Cactus will need to develop approximately 2,500 acre-feet of additional supplies by 2020 increasing to 5,500 by 2070.

Quantity, Reliability and Cost

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 capital cost for new wells is $18.2 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.

5C.4.2 Palo Duro Reservoir

Cactus is one of the six member cities of the Palo Duro River Authority. The project would involve a transmission system to connect the six member cities to the reservoir. Cactus would be responsible for a share of the cost necessary to connect the City of Cactus and not the whole system. This strategy is evaluated in Section 5C.6 for PDRA.

5C.4.3 Summary of Recommended Strategies for Cactus

Recommended Strategies

The City of Cactus is expected to experience needs in 2020 of 2,500 acre-feet increasing to over 5,400 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 5,500 acre-feet as shown in Table 5C-11. The total capital cost for the recommended strategies as shown in Table 5C-12 is $18.2 million.

Alternative Strategy

As a member of the PDRA, Cactus is interested in developing a regional transmission system to use water from Palo Duro Reservoir. 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 $61.9 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
Need	**2,518**	**3,199**	**3,821**	**4,384**	**4,914**	**5,465**
Recommended Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation	32	36	41	45	50	55
New Well Field -Ogallala Aquifer	5,500	5,500	5,500	5,500	5,500	5,500
Total from Strategies	**5,532**	**5,536**	**5,541**	**5,545**	**5,550**	**5,555**
Alternate Strategy	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Lake Palo Duro Project	0	0	1,744	1,744	1,744	1,744

Table 5C-12: Summary of Costs for Recommended Strategies

Recommended Strategies	**Capital Cost ($ Million)**	**Annual Costs ($ Million)**					
		2020	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation	-	$0.02	$0.02	$0.02	$0.02	$0.02	$0.03
New Well Field -Ogallala Aquifer	$18.2	$2.31	$2.31	$0.8	$0.8	$0.8	$0.8
Total from Strategies	**$0.00**	**$0.31**	**$0.31**	**$2.12**	**$2.12**	**$2.12**	**$2.12**
Alternate Strategy:							
Lake Palo Duro Project	$66.7	-	$7.07	$7.07	$1.49	$1.49	$1.49

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 3,850 acre-feet per year in 2020 and declining to 3,440 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 3,700 acre-feet per year over the planning period. Considering both the reservoir supplies and local groundwater supplies, Greenbelt MIWA is not expected to have any water Needs during the planning period.

Table 5C-13: Summary of Demands and Supplies for the Greenbelt MIWA

Customers	Demands (ac-ft/yr)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
City of Childress	1,624	1,658	1,686	1,722	1,768	1,814
City of Chillicothe	65	63	60	61	62	62
City of Clarendon	378	369	361	356	356	356
City of Crowell	138	134	132	131	131	131
City of Memphis	100	100	100	100	100	100
Childress County-Other	178	184	189	194	200	204
Donley County-Other	95	95	95	95	95	95
Foard County-Other	50	50	50	50	50	50
Hall County-Other	92	92	92	92	92	92
Hardeman County-Other	60	60	60	60	60	60
Hardeman County Manufacturing	276	294	313	332	332	332
City of Quanah	397	391	388	394	397	400
TOTAL	**3,453**	**3,490**	**3,526**	**3,587**	**3,643**	**3,696**
Sources	**Supply (ac-ft/yr)**					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Ogallala - Donley County	1,900	1,615	1,373	1,167	992	843
Greenbelt Reservoir	3,850	3,768	3,686	3,604	3,522	3,440
Total	**5,750**	**5,383**	**5,059**	**4,771**	**4,514**	**4,283**
Surplus or (Need)	2,297	1,893	1,533	1,184	871	587

While the projections indicate Greenbelt MIWA can meet its projected demands, 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

5C.5.1 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 13 miles to the Greenbelt Water Treatment Plant site. The strategy would include a pump station and ground storage tank and associated electrical and instrumentation. This would be in-lieu of sending the groundwater to the existing Greenbelt Reservoir. It was assumed that the Greenbelt MIWA would purchase the groundwater rights necessary to provide 2,000 acre-feet annually.

Time Intended to Complete

It was assumed that this project could be online by 2020 if the water rights were able to be purchased from willing sellers.

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 for a new well is $12.6 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 well is located north of 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. It is assumed that nay water rights purchased would be on a willing buyer- willing sell basis.

Other Relevant Factors

Greenbelt MIWA will need to seek a groundwater permit from the Panhandle GCD.

5C.5.2 Summary of Recommended Strategies for Greenbelt MIWA

Water Conservation by Greenbelt MIWA customers in PWPA will provide approximately 140 acre-feet in 2020 increasing to 160 acre-feet by 2070. New wells in the Ogallala aquifer can provide an additional 2,000 acre-feet per years and could be completed by 2020. Table 5C-14 shows the amount of supply from the recommended strategies. The total capital costs for the recommended strategies is $12.6 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
Need	0	0	0	0	0	0
Recommended Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Conservation of Customers	146	149	151	154	158	162
Donley County Groundwater	2,000	2,000	2,000	2,000	2,000	2,000
Total from Strategies	**2,146**	**2,149**	**2,151**	**2,154**	**2,158**	**2,162**

Table 5C-15: Summary of Costs for Recommended Strategies

Recommended Strategies	Capital Cost	Annual Costs					
		2020	2030	2040	2050	2060	2070
Donley County Groundwater	$12.62	$1.26	$1.26	$0.20	$0.20	$0.20	$0.20
Total from Strategies	**$12.62**	**$1.26**	**$1.26**	**$0.20**	**$0.20**	**$0.20**	**$0.20**

5C.6 Palo Duro River Authority (PDRA)

The PDRA owns and operates the Palo Duro Reservoir in Hansford County, a potential future water supply source for cities in the PWPA. The PDRA was authorized to serve Hansford and Moore Counties and the City of Stinnett. The lake was completed in 1991, but the infrastructure to transport and treat the water has not been constructed. As such, the PDRA currently does not provide water to any member city. The PDRA has six member cities that are interested in Palo Duro Reservoir as an alternative strategy. All six cities are projected to have water Needs over the planning period: Cactus, Dumas, Gruver, Spearman, Stinnett and Sunray.

To meet the water supply needs of its member cities, PDRA could build a proposed transmission system to deliver water from the Palo Duro Reservoir to these cities by 2030. Based on the projected needs and existing supplies, the amount of water each city is expected to receive from the Palo Duro Reservoir is presented in Table 5C-16. Some of this water will be used by the cities for municipal and industrial sales. The PDRA's water rights and the Canadian River Compact allow use of water from the reservoir for manufacturing needs if the water is supplied through a municipality.

Table 5C-16: Distribution of Water from Palo Duro Reservoir

Water User	Year 2030	
	Peak (MGD)	Supply (ac-ft/yr)
Cactus	3.1	1,744
Dumas	2.42	1,356
Gruver	0.48	271
Spearman	0.21	116
Sunray	0.48	271
Stinnett	0.21	116
Total	**6.9**	**3,875**

Note: Peak (MGD) was estimated based on a peaking factor of 2. Pipelines and pump stations were sized for peak flows.

For regional planning purposes, the supply from the reservoir has been allocated to avoid exceeding the firm yield. However, the Palo Duro River Authority would operate the reservoir on an overdraft basis, using groundwater to supplement supply during drought conditions. It is assumed that these cities could supplement their use of the Palo Duro Reservoir water with groundwater. This would allow the cities to conserve their groundwater resources when there is sufficient water in the reservoir. It would also allow them to increase the usage of the reservoir because they are not depending on it for water supply in dry years.

Recommended Strategy

- None

Alternative Strategy

- Develop Palo Duro Reservoir transmission system

5C.6.1 Develop Palo Duro Reservoir Transmission System

The Palo Duro transmission system is an alternative strategy for the Palo Duro River Authority that would move water from Palo Duro Reservoir to the six member cities. While the member cities plan to meet projected needs with groundwater, these cities are interested in keeping this project listed as an alternative strategy for their supply in this plan.

Time Intended to Complete

The Palo Duro Reservoir transmission system could be completed by 2030.

Quantity, Reliability and Cost

The quantity of water should be sufficient. Reliability of the water in Palo Duro Reservoir is low. The reservoir is in drought of record conditions and the current capacity is 1.6 percent. The reliable supply is likely less than shown in Chapter 3, which was estimated using the Canadian River WAM model. The total capital cost for the transmission system is $139.6 million. Table C-19 shows the breakdown of supply and capital cost for the participating cities.

Environmental Issues

The environmental impacts associated with the construction of the transmission system are expected to be low. Once the specific pipeline route is established, a detailed evaluation to determine environmental impacts, if any, will need to be performed. Diverting water from the reservoir may result in lower lake levels, which could impact aquatic habitats. It is likely that diversions would be less during periods of low lake levels.

Impact on Water Resources and Other Management Strategies

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.

Impact on Agriculture and Natural Resources

The recommended strategy is expected to have positive impacts on agriculture as there is less competition for groundwater. Impacts to other natural resources are expected to be minimal.

Other Relevant Factors

There are no other identified relevant factors.

5C.6.2 Summary of Alternative Strategies for PDRA

Connection of the six member cities to Palo Duro Reservoir will cost approximately $139.5 million dollars with the cost split by the infrastructure necessary to provide the supply.

Table 5C-17: Alternative Water Management Strategies for PDRA (ac-ft/yr)

	2020	2030	2040	2050	2060	2070
Need	873	2,031	3,371	4,961	6,386	7,791
Alternate Strategies	**Supply from Strategy**					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Customer Conservation	248	279	309	340	373	407
Palo Duro Delivery System		3,875	3,875	3,875	3,875	3,875
Total from Strategies	**248**	**4,154**	**4,184**	**4,215**	**4,248**	**4,282**

Table 5C-18: Summary of Costs for Alternative Strategy

Alternate Strategies	Capital Cost	Annual Costs ($ Million)					
		2020	2030	2040	2050	2060	2070
Palo Duro Delivery System	$139.57	-	$14.76	$14.76	$3.09	$3.09	$3.09

Table 5C-19: Summary of Palo Duro Strategy Customer Distribution

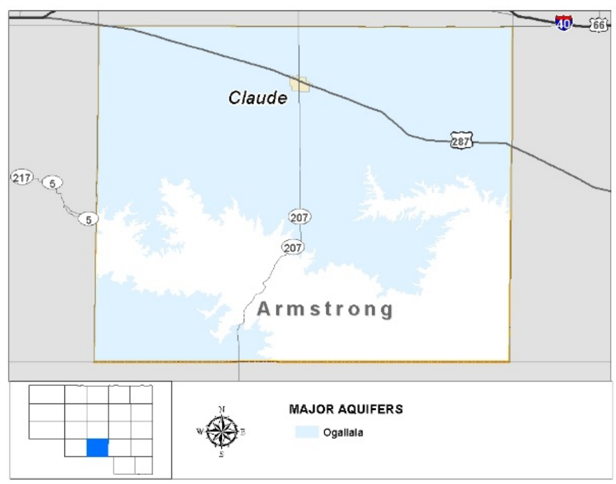
Participating City	Annual Supply Amount (ac-ft/yr)	Capital Cost ($ Millions)
Cactus	1,744	$66.72
Dumas	1,356	$45.55
Sunray	271	$9.36
Gruver	116	$5.62
Spearman	271	$4.78
Stinnett	116	$7.54
Total	**3,875**	**$139.57**

Subchapter 5D Water Management Strategies for Water Users by County

There are twenty-one counties in the PWPA, of which seven show no needs after conservation. 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 wholesale 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 E and a summary evaluation matrix is included as Attachment 5-2.

Water Conservation is recommended for municipal (only County-Other users with needs were evaluated, all other municipal water user groups were evaluated) 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 this subchapter, but are included in the county summary sections.

5D.1 Armstrong County



Armstrong County is located along the southern edge of the Northern Ogallala aquifer. The City of Claude, with a population of 1,203, is the largest city in the county. Water users in Armstrong County obtain their current water supplies from the Ogallala aquifer, with a small amount coming from the Dockum aquifer. The City of Claude is the only entity shown to have a need over the planning period.

5D.1.1 Claude

The City of Claude currently obtains its water supply from four wells in the Ogallala aquifer. Due to declining water levels, Claude is projected to have a water need of 110 acre-feet per year by 2070.

For this plan the potentially feasible water management strategies for Claude are:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Wells

Drill Additional Groundwater Wells

The City has plans to drill 2 new supplemental wells in the Ogallala aquifer. The City of Claude currently owns 640 acres of water rights south, south-west and south-east of town. This strategy assumes that 2 new wells would be drilled to provide up to 400 acre-feet per year of supplemental supplies. These wells would produce water from approximately 275 feet below surface. For the purpose of this plan, the new wells are assumed to be drilled near the City's existing wells 3 ½ miles southeast of town. These 2 new wells will provide approximately 400 acre-feet per year. Minimal treatment such as chlorine disinfection will be required.

Time Intended to Complete

The City of Claude intends to complete these wells when funding becomes available. For purposes of this plan, the strategy would be completed by 2040.

Quantity, Reliability, and Cost

Each well would have a depth of 275 and an average 240 gpm capacity. The two wells can produce 400 acre-feet per year. There is sufficient water from the Ogallala to support this strategy. The reliability would be moderate due to competition for water from this source. The costs are estimated at $2.9 million.

Environmental Issues

No significant environmental impact is expected for additional groundwater development. Once the specific locations of the 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, the recommended conservation strategies will help to demands on this source.

Impact on Agriculture and Natural Resources

No significant impact on agricultural or natural resources is expected for this strategy. The city already owns the water rights.

Other Relevant Factors

The water quality in the Ogallala aquifer varies from fresh water in the north with TDS less than 400 milligrams per liter, to high TDS in the south in excess of standard drinking water parameters. The water quality of Claude's existing well field is good and it is expected that the expansion will provide high quality water.

Table 5D-1 shows the capital cost and annual supplies expected from the recommended strategies.

Table 5D-1: Recommended Water Strategies for Claude (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	35	72	110
Recommended Strategies							
Municipal Conservation	$2.3	29	29	28	28	28	28
New Wells	$2.9			400	400	400	400
Total	**$5.2**	**29**	**29**	**428**	**428**	**428**	**428**

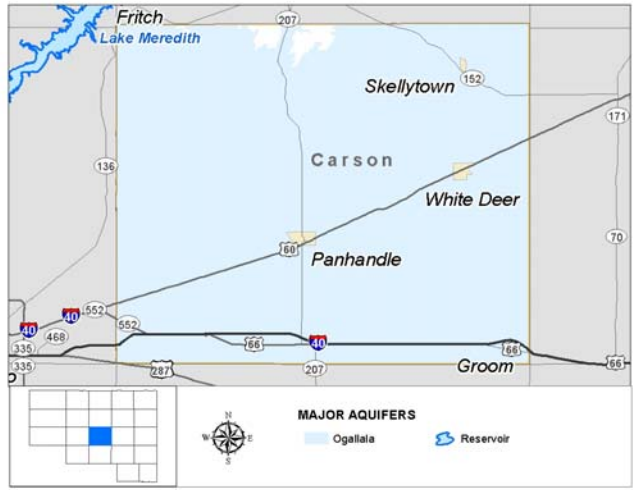
5D.1.2 Armstrong County Summary

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. For Claude, it is also recommended to expand its well field to replace lost capacity associated with declining water levels. A summary of the recommended water management plan for Armstrong County is shown in Table 5D-2.

Table 5D-2: Armstrong County Water Management Plan

Water User Group	Current Supplies	Need	Recommended Water Management Strategies
Claude	Ogallala aquifer	Yes	Municipal conservation, New well
County-Other	Ogallala and Other aquifers	No	None
Irrigation	Ogallala aquifers	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.2 Carson County



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. The City of Amarillo also operates a large well field in western Carson County and has plans for expansion. The City of Panhandle, with a population of nearly 2,500, is the largest city in the county. 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 2020 and reaching a peak need of 582 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

Drill Additional Groundwater Well

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 2 new wells and associated well field piping will be necessary to meet the City's water needs. These 2 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 2020. 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, 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 $3.2 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-3: Recommended Water Strategies for Panhandle (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		89	521	582	577	576	576
Recommended Strategies							
Municipal Conservation	$1.6	47	48	48	48	48	48
New Wells	$3.2	600	600	600	600	600	600
Total	**$4.8**	**647**	**648**	**648**	**648**	**648**	**648**

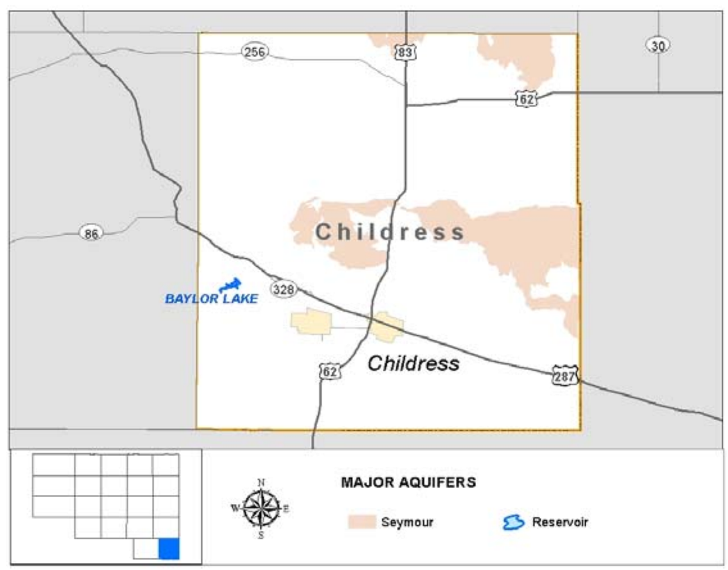
5D.2.2 Carson County Summary

Carson County has a total projected water need of 582 acre-feet per year, all of which is associated with the City of Panhandle. 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. 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-4: 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, Precipitation enhancement
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, New wells
Steam Electric	None	-	-
White Deer	Ogallala aquifer	No	Municipal conservation

5D.3 Childress County



Childress County is located in the far southeastern part of the PWPA. The City of Childress is the largest city in the county with a 2020 population of 6,303. 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.

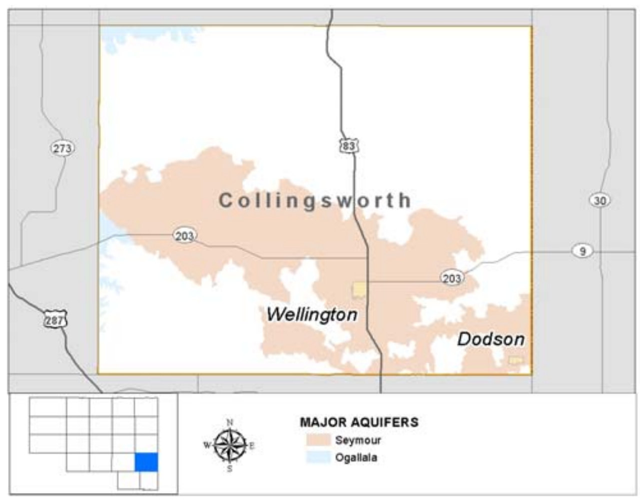
While the county is not water rich, it does not have a projected need over the planning period. Conservation is recommended for the City of Childress and irrigation. A summary of the water plan for Childress County is shown in Table 5D-5.

Table 5D-5: Childress County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Childress	Greenbelt Reservoir	No	Municipal conservation
County-Other	Seymour aquifer and Greenbelt Reservoir	No	None
Irrigation	Blaine, Seymour and Whitehorse aquifers and reuse	No	Irrigation conservation
Livestock	Seymour aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Local supply	No	None
Steam Electric	None	-	-

5D.4 Collingsworth County

Collingsworth County is located on the southeastern border of the PWPA. 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.



Collingsworth County does not have a projected need over the planning period. However, the City of Wellington is planning to develop additional groundwater supplies to improve the reliability of its current sources.

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
- Nitrate Treatment of Seymour Aquifer Supplies

Drill Additional Groundwater Well

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 180 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 180 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 $2.6 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 500 acre-feet of treated water that meets current drinking water standards. The capital cost is estimated at $3.7 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-6.

Table 5D-6: Recommended Strategies for City of Wellington (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		525	540	549	567	582	595
Recommended Strategies							
Municipal Conservation	$1.5	44	45	46	47	49	50
New Wells	$2.6	180	180	180	180	180	180
Nitrate Treatment	$3.7	500	500	500	500	500	500
Total	**$7.8**	**724**	**725**	**726**	**727**	**729**	**730**

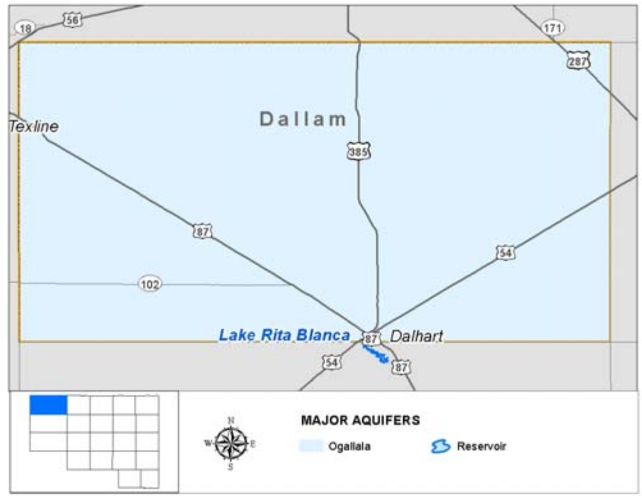
5D.4.2 Collingsworth County Summary

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 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
Wellington	Seymour aquifer	Yes	Additional Seymour Aquifer, Nitrate Treatment, Municipal conservation
County-Other	Blaine, Seymour and Other aquifers	No	None
Irrigation	Ogallala, Blaine and Seymour aquifers, reuse and Red River water rights	No	Irrigation conservation
Livestock	Ogallala, Blaine, Seymour and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Steam Electric	None	-	-

5D.5 Dallam County



Dallam County is located in the far northwestern part of the PWPA. Dalhart is the largest city in Dallam County with a total population of approximately 8,800, of which about two-thirds are located in Dallam County. The remaining population is in Hartley 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 irrigated agriculture in Dallam County. The recommended strategies to meet the needs for 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 2,800 acre-feet per year by 2070. To meet this need, the strategies considered include:

- Municipal Conservation (see Section 5B.1)
- Develop Additional Groundwater Well

Develop Additional Groundwater Well

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 possibly drilling one additional well to develop the needed supply from the Ogallala aquifer. A new booster station and ground storage would be needed at the well field, along with a 2-mile pipeline from the booster station to the city's existing water line.

Time Intended to Complete

This strategy would be implemented by 2020.

Quantity, Reliability, and Cost

Assuming a similar well production as Dalhart's existing wells, this strategy could provide an average annual supply of 2,700 acre-feet per year. The reliability would be moderate due to the competition from other water users. The capital costs are estimated at $2.9 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-8: Recommended Water Strategies for Dalhart (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		749	1,138	1,558	1,982	2,399	2,807
Recommended Strategies							
Municipal Conservation	$0	79	86	93	100	107	113
New wells	$2.9	2,700	2,700	2,700	2,700	2,700	2,700
Total	**$2.9**	**2,779**	**2,786**	**2,793**	**2,800**	**2,807**	**2,813**

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 2050. The potential strategies to meet this need include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well

Drill Additional Groundwater Well

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 150 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 150 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 $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 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-9: Recommended Water Strategies for Texline (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	46	99	161
Recommended Strategies							
Municipal Conservation	$0.5	18	20	22	24	26	28
New Wells	$1.1	0	0	0	150	150	150
Total	**$1.6**	**18**	**20**	**22**	**174**	**176**	**178**

5D.5.3 Dallam County Irrigation

The irrigation needs in Dallam County peak at over 94,000 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 is shown in Table 5D-10. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-10: Recommended Water Strategies for Dallam County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		79,399	91,675	94,226	87,452	77,836	68,218
Recommended Strategies							
Irrigation Conservation	$13.6	34,218	61,174	106,343	121,011	132,167	140,612
Total	**$13.6**	**34,218**	**61,174**	**106,343**	**121,011**	**132,167**	**140,612**

[1] Irrigation conservation costs are determined on an annual basis as shown in 5B.2

5D.5.4 Dallam County Summary

Dallam County has a total projected water need of over 95,000 acre-feet per year. 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 irrigated agriculture can be met through conservation. There is a projected unmet water need for Irrigation of about 45,000 acre-feet in 2020, which decreases to zero by 2040. After 2040, 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-11. The unmet needs are shown in Table 5D-12.

Table 5D-11: Dallam County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Dalhart	Ogallala aquifer	No	Municipal conservation, Additional Ogallala
Texline	Ogallala aquifer	Yes	New wells, Municipal conservation
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala/Rita Blanca and Dockum aquifers and reuse	Yes	Irrigation conservation
Livestock	Ogallala/ Rita Blanca aquifer and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	None	-	-
Steam Electric	None	-	-

Table 5D-12: Unmet Water Needs in Dallam County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(45,181)	(30,501)	0	0	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 population of about 2,000. The majority of the water supply for Donley County is obtained from these two sources. A small amount of local supply is used for agricultural purposes. Current sources of supply are shown to be adequate for all users. It is recommended that conservation be implemented for Clarendon and irrigation to preserve existing supplies for future use.

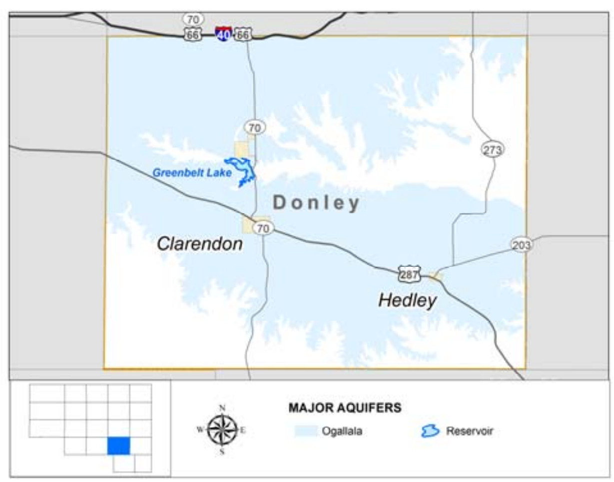
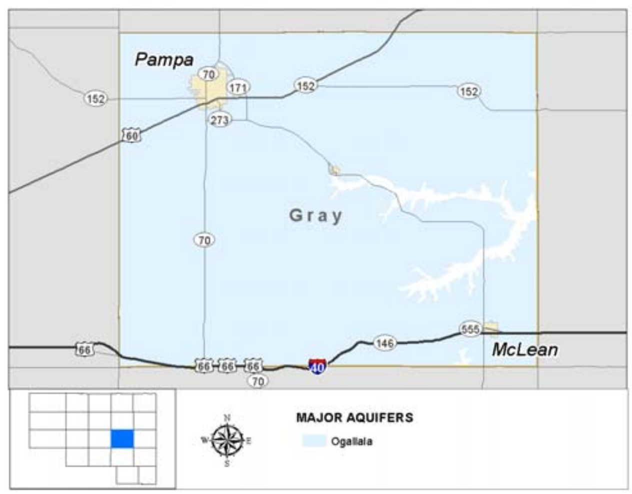


Table 5D-13: Donley County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Clarendon	Greenbelt reservoir	No	Municipal conservation
County-Other	Ogallala aquifer and Greenbelt reservoir	No	None
Irrigation	Ogallala aquifer and Red River water rights	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.7 Gray County



The Ogallala aquifer underlies most of Gray County. This water resource is the primary source for most users in the county. The City of Pampa, which is the largest city in the county, is a member city of CRMWA. CRMWA provides water from its Roberts County well field and Lake Meredith (when available) to Pampa. Only about 20 percent of the total available supply from the Ogallala in Gray County is currently developed.

There is sufficient developed supplies to meet most of the demands in the county. Only McLean and Pampa are identified with projected water needs. Most of Pampa's need is associated with the need for CRMWA, which is addressed with the wholesale water provider in Chapter 5C.

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 2020. The potentially feasible strategies for McLean include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well

Drill Additional Groundwater Well

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 260 gpm with well depths of about 180 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 2020.

Quantity, Reliability, and Cost

This strategy would provide McLean with an additional 200 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 $790,000, which provides a unit cost of $1.37 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 200 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-14: Recommended Water Strategies for McLean (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	89	135	182
Recommended Strategies							
Municipal Conservation	$0.7	17	18	20	23	25	27
New wells	$0.79	200	200	200	200	200	200
Total	**$1.49**	**217**	**218**	**220**	**223**	**225**	**227**

5D.7.2 Pampa

The City of Pampa provides water to customers in Gray County, including TDCJ, and Titan Specialties and other manufactories. 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 approximately 1,700 acre-feet is projected by 2030 and increasing to about 3,800 acre-feet 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 Wells

Drill Additional Groundwater Well

This strategy includes four new wells and associated well field piping. The new wells would be drilled to provide 2,000 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 2020.

Quantity, Reliability, and Cost

The new wells will provide 2,000 acre-feet 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 $8.6 million. The units cost of this additional water is estimated at $1.50 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.

Table 5D-15: Recommended Water Strategies for Pampa (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	1,752	2,491	2,190	2,985	3,806
Recommended Strategies							
Municipal Conservation	$0	146	161	178	202	220	240
New Wells	$8.6	2,000	2,000	2,000	2,000	2,000	2,000
CRMWA Supplies[1]	$0	181	1,125	1,142	2,967	3,119	3,309
TOTAL	**$8.6**	**2,327**	**3,286**	**3,320**	**5,169**	**5,339**	**5,549**

[1] CRMWA supply costs are evaluated in 5C.1

5D.7.3 Gray County Summary

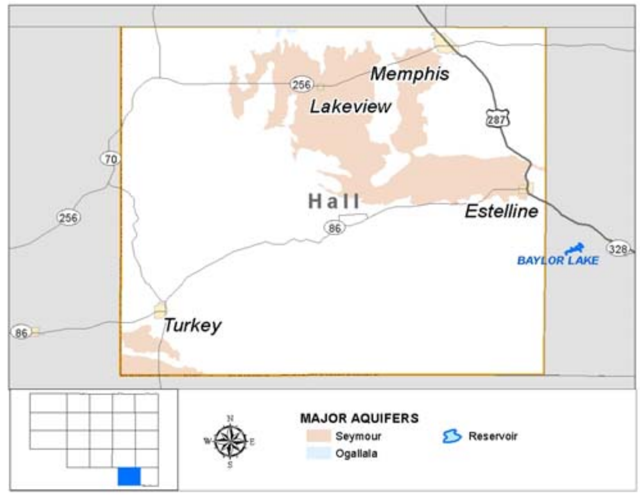
Gray County has a total projected need of nearly 3,000 acre-feet per year. Much of this need can be met through conservation. The municipal needs are planned to be met through conservation and additional groundwater from the Ogallala aquifer. The county's primary source of water, Ogallala aquifer has over 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 Gray County is shown in Table 5D-16.

Table 5D-16: Gray County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
McLean	Ogallala aquifer	No	Municipal conservation, new well in Ogallala
Pampa	Ogallala aquifer and CRMWA system	No	Municipal conservation, new wells in Ogallala, and contracted supplies from CRMWA
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala and reuse	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	Ogallala aquifer	No	None
Steam Electric	Ogallala aquifer	No	None

5D.8 Hall County

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. The largest city in Hall County is Memphis and this city 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.



The only entity with a need in Hall County is the City of Memphis.

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 68 acre-feet by 2050, increasing to approximately 143 acre-feet from 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

Drill Additional Groundwater Well

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 well would be drilled to provide approximately 150 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 2050.

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-17: Recommended Water Strategies for Memphis (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	68	100	133
Recommended Strategies							
Municipal Conservation	$0.5	34	23	14	14	14	14
New Wells	$1.1	0	0	0	150	150	150
Total	**$1.6**	**34**	**23**	**14**	**164**	**164**	**164**

5D.8.2 Hall County – Other (Brice-Lesley, Estelline, Lakeview, Turkey)

A survey returned by the Hall County Judge indicated that two communities, Estelline and Lakeview, as having water quantity and quality concerns. The City of Turkey and Brice-Lesley WSC also are planning to expand their water supplies. The potential strategies for Hall County-Other include.

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well (Brice-Lesley)

- Drill Additional Groundwater Well (Estelline)
- Drill Additional Groundwater Well (Turkey)
- Water Quality Improvements (Lakeview)

Drill Additional Groundwater Well (Brice-Lesley)

This strategy assumes that one new wells will be drilled near Brice-Lesly 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 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 2020.

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 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 $0.3 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 Seymour aquifer and other surrounding water resources. 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 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 $0.1 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 Seymour aquifer and other surrounding water resources. 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.

Drill Additional Groundwater Well (Turkey)

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 $1.3 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.

Advanced Treatment (Nitrate Removal)

This strategy assumes the development of advanced treatment facilities to treat the City of Lakeview'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 0.1 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 2020.

Quantity, Reliability, and Cost

This strategy will produce approximately 75 acre-feet per year. The capital cost is estimated at $1.6 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-18.

Table 5D-18: Recommended Water Strategies for Hall County-Other (Brice-Lesley, Estelline, Lakeview, Turkey) (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need[1]		0	3	1	0	0	0
Recommended Strategies							
Municipal Conservation	$0.7	25	26	26	26	26	26
New Well (Brice-Lesley)	$0.3	50	50	50	50	50	50
New Well (Estelline)	$0.1	50	50	50	50	50	50
New Well (Turkey)	$1.3	100	100	100	100	100	100
Advanced Treatment (Nitrate Removal)	$1.6	75	75	75	75	75	75
Total	**$4.0**	**300**	**301**	**301**	**301**	**301**	**301**

[1]The need is shown for the aggregated water user. Needs for small rural communities may differ.

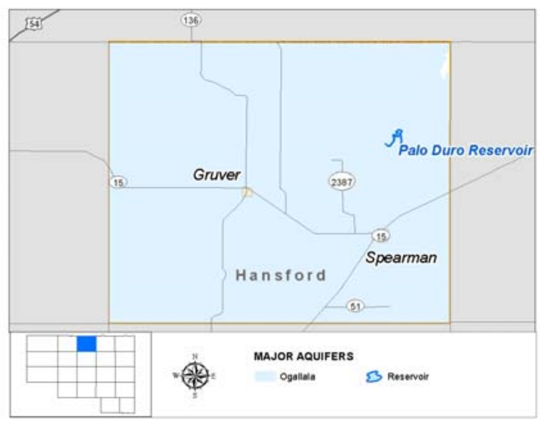
5D.8.3 Hall County Summary

Hall County has a total projected need of less than 100 acre-feet per year. Much of this need can be met through conservation. 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 above what is currently developed it also has known water quality concerns. The recommended water plan for Hall County is shown in Table 5D-19.

Table 5D-19: Hall County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Memphis	Seymour aquifer and Greenbelt reservoir	Yes	Municipal conservation, New well in Ogallala and increase supplies from Greenbelt reservoir
County-Other	Ogallala and Seymour aquifers and Greenbelt reservoir	Yes	Municipal conservation, New wells in the Ogallala (Briscoe, Donley) and Seymour (Hall) and Nitrate Removal
Irrigation	Seymour aquifers and Red River water rights	No	Irrigation conservation
Livestock	Seymour and Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Other aquifer	No	None
Steam Electric	None	-	-

5D.9 Hansford County



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 PDRA, 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 2040. Projected needs for Gruver range from 111 acre-feet in 2040 to 344 acre-feet 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 PDRA, Gruver may be interested in developing a regional transmission system to use water from Palo Duro Reservoir. This strategy is evaluated for PDRA in Chapter 5C. The potential water management strategies for Gruver include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well
- Develop PDRA Transmission System (See Section 5C.6)

Drill Additional Groundwater Wells

This strategy assumes that 2 new wells will be drilled to provide approximately 350 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 2040.

Quantity, Reliability and Cost

The quantity of water from this strategy should be able to produce 350 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 $1.4 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 PDRA Transmission System

The Palo Duro Reservoir transmission project is an alternative 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 $5.6 million associated with their portion of the project. This project is evaluated for the PDRA in Chapter 5C.

Table 5D-20: Recommended Water Strategies for Gruver (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	111	196	272	344
Recommended Strategies							
Municipal Conservation	$1.0	23	25	26	28	30	31
New Wells	$1.4	0	0	350	350	350	350
Total	**$2.4**	**23**	**25**	**376**	**378**	**380**	**381**

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 634 acre-feet per year by 2070. As a member of the PDRA, Spearman may be interested in developing a regional transmission system to use water from Palo Duro Reservoir. This strategy is evaluated for PDRA in Chapter 5C. The potential water management strategies for Spearman include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well
- Develop PDRA Transmission System (See Section 5C.6)

Drill Additional Groundwater Wells

This strategy assumes that 2 new wells will be drilled provide approximately 650 acre-feet per year and are assumed to produce water approximately 554 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 650 acre-feet per year with average well capacities of 620 gpm. Reliability of Ogallala supplies is moderate since availability depends on other water users. For costing purposes, the transmission system includes 1 mile of 14-inch pipeline and a well field pump station. The capital cost for the additional groundwater well is approximately $3.4 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 PDRA Transmission System

The Palo Duro Reservoir transmission project is an alternative 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 $4.8 million associated with their portion of the project. This project is evaluated for the PDRA in Chapter 5C.

Table 5D-21: Recommended Water Strategies for Spearman (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	283	466	634
Recommended Strategies							
Municipal Conservation	$0	24	24	25	25	26	27
New Wells	$3.4	0	0	0	650	650	650
Total	**$3.4**	**24**	**24**	**25**	**675**	**676**	**677**

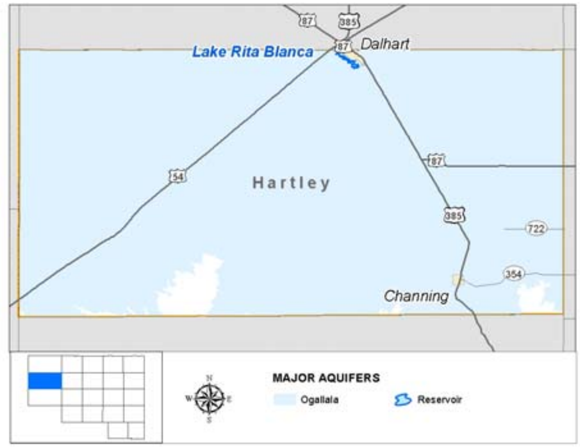
5D.9.3 Hansford County Summary

Hansford County has a total projected need of 900 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 over 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-22.

Table 5D-22: Hansford County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Gruver	Ogallala aquifer	Yes	Municipal conservation, New well in Ogallala
Spearman	Ogallala aquifer	Yes	Municipal conservation, New well in Ogallala
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer, Canadian River	Yes	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.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 total population of approximately 8,800, 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 irrigated agriculture. 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 98,000 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-23. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-23: Recommended Water Strategies for Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		77,305	93,368	98,650	92,699	83,415	74,130
Recommended Strategies							
Irrigation Conservation	$12.7	29,197	52,161	90,476	103,095	113,047	120,509
Total	**$12.7**	**29,197**	**52,161**	**90,476**	**103,095**	**113,047**	**120,509**

5D.10.2 Hartley County Summary

Hartley County has a total projected water need of over 99,000 acre-feet per year. 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 irrigated agriculture can be met through conservation. There is a projected unmet water need for Irrigation of about 48,100 acre-feet in 2020, which decreases to zero by 2050. After 2050, 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 Hartley County is shown in Table 5D-24. The unmet needs are shown in Table 5D-25.

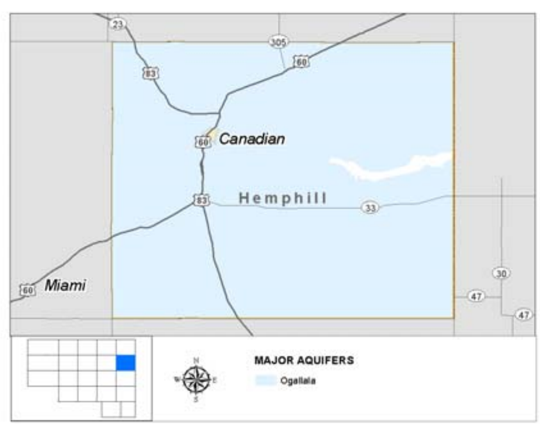
Table 5D-24: Hartley County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Dalhart	Ogallala aquifer	No	Municipal conservation, Additional Ogallala
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer	Yes	Irrigation conservation
Livestock	Ogallala and Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	No	None
Mining	None	-	-
Steam Electric	None	-	-

Table 5D-25: Unmet Water Needs in Hartley County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
Irrigation	(48,108)	(41,207)	(8,174)	0	0	0

5D.11 Hemphill County

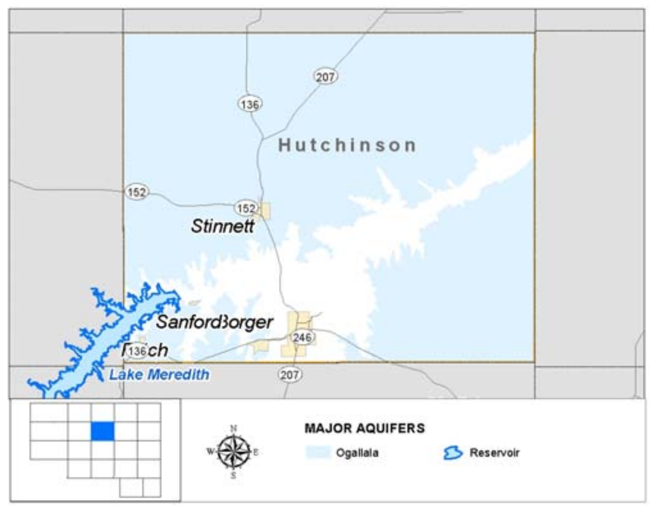


Hemphill County is located along the eastern edge of the PWPA. The City of Canadian, with a population of 3,000 is the largest city in the county. Water users in Hemphill County obtain their current water supplies from the Ogallala aquifer, with a small amount coming from the local supplies for livestock. Current sources of supply 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-26.

Table 5D-26: 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.

The entities in Hutchinson County obtain their water from the Ogallala aquifer and CRMWA. Borger receives water from CRMWA and is also a wholesale 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 2020 and increasing to over 7,000 acre-feet 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 projected to have needs over the planning period.

5D.12.1 Borger

The City of Borger is a wholesale 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 is currently developing 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, additional groundwater 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 2050. Projected needs for Stinnett range from 115 acre-feet in 2050 to 216 acre-feet in 2070. These needs can be met through additional groundwater development to replace reductions in capacities. As a member of the PDRA, Stinnett may be interested in developing a regional transmission system to use water from Palo Duro Reservoir. This strategy is evaluated for PDRA in Chapter 5C. The potential water management strategies for Stinnett include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well
- Develop PDRA Transmission System (See Section 5C.6)

Drill Additional Groundwater Wells

This strategy assumes that one new well will be drilled to provide approximately 225 acre-feet per year. Treatment associated with this strategy is minimal and most likely includes chlorine disinfection. This well is assumed to be approximately 380 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 prior to 2050.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 225 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 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.

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 PDRA Transmission System

The Palo Duro Reservoir transmission project is an alternative 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 $7.5 million associated with their portion of the project. This project is evaluated for the PDRA in Chapter 5C.

The recommended strategies for Stinnett are shown in Table 5D-27.

Table 5D-27: Recommended Water Strategies for Stinnett (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	115	165	216
Recommended Strategies							
Municipal Conservation	$1.2	37	38	37	37	37	37
New Wells	$0.9	0	0	0	225	225	225
Total	**$2.1**	**37**	**38**	**37**	**262**	**262**	**262**

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 2020. Projected needs for TCW Supply range from 75 acre-feet in 2020 to 569 acre-feet 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
- Purchase water from Borger

Drill Additional Groundwater Wells

This strategy assumes that 2 new wells will be drilled to provide approximately 350 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 2 miles of TCW Supply's distribution system. A 12-inch transmission pipeline and pump station are included in this strategy.

Time Intended to Complete

The wells will be completed prior to 2020. 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 575 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.

Table 5D-28: Recommended Water Strategies for TCW Supply (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		75	251	375	466	535	569
Recommended Strategies							
Municipal Conservation	$1.3	58	59	59	59	59	59
New Wells	$3.9	575	575	575	575	575	575
Total	**$5.2**	**633**	**634**	**634**	**634**	**634**	**634**

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 have needs ranging from nearly 860 to 4,416 acre-feet per year beginning in 2030 due to increasing demands and limited supplies from Borger. As Borger develops strategies to meet its demands, the needs for manufacturing in Hutchinson County will be met. The City of Borger is a wholesale water provider. The strategies recommended for Borger are discussed in Section 5C.3.

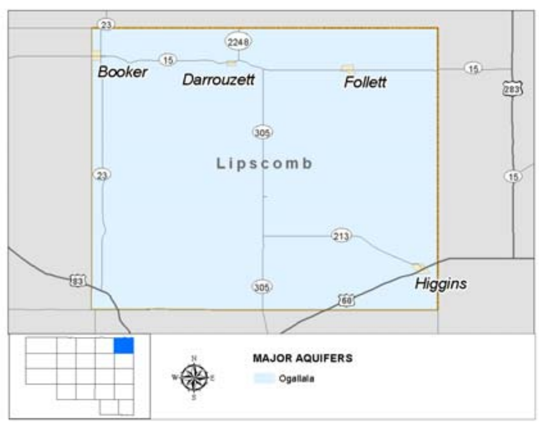
5D.12.5 Hutchinson County Summary

Hutchinson County can fully meet its projected needs through the development of water strategies by the wholesale water providers, Borger and CRMWA, the development of additional groundwater in the Ogallala, and conservation. While irrigation does not 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-29 shows the recommended water plan for Hutchinson County.

Table 5D-29: Hutchinson County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Borger	Ogallala aquifer and CRMWA system	Yes	Municipal conservation, new wells in Ogallala and contractual supplies from CRMWA
Fritch	Ogallala aquifer	No	Municipal conservation
Stinnett	Ogallala aquifer	No	Municipal conservation, new well in Ogallala
TCW Supply Inc.	Ogallala aquifer	No	Municipal conservation, new well in Ogallala
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer and local supply	Yes	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala aquifer and local supply (stock ponds and irrigation)	No	None
Manufacturing	Ogallala aquifer, reuse, CRMWA system	Yes	Purchase from Borger
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

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. It lies on the county border with Ochiltree County and extends into Ochiltree County.

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 wholesale 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 over 550 acre-feet by 2070. The potential water management strategies for Booker include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well

Drill Additional Groundwater Wells

This strategy assumes that 2 new wells will be drilled to provide approximately 700 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 700 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 $1.5 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-30: Recommended Water Strategies for Booker (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need (including sales)		0	0	100	333	456	575
Recommended Strategies							
Municipal Conservation	$0	15	17	18	19	20	21
New Well	$1.5			550	550	550	700
Total	$1.5	**15**	**17**	**568**	**569**	**570**	**721**

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. The recommended strategies for additional supply include purchasing water from Booker.

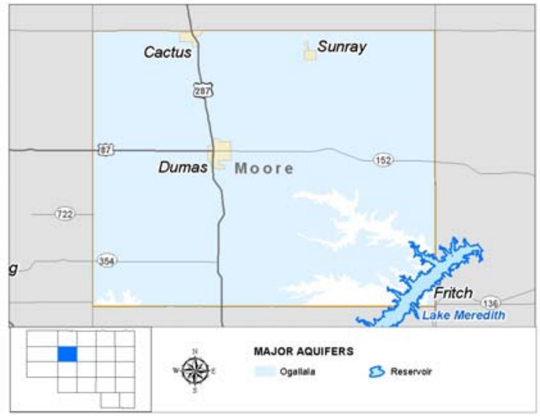
5D.13.3 Lipscomb County Summary

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 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-31 shows the recommended water plan for Lipscomb County.

Table 5D-31: Lipscomb County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Booker	Ogallala aquifer	Yes	Municipal conservation, new wells in Ogallala
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer and Canadian River	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 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 population of over 16,000.

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 PDRA, but they currently do not receive water from PDRA. Due to the competition for water, Moore County is shown to have a need of about 2,600 acre-feet per year in 2020 and increasing to 20,760 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 latter 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 PDRA and a wholesale 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 PDRA. Currently, Dumas obtains its water supply from its own wells in the Ogallala aquifer in 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 over 4,400 acre-feet per year. Dumas has approximately 27,800 acre-feet of undeveloped groundwater rights in Hartley County that will be used to meet its need. To provide the full 4,400 acre-feet by 2070, the city may need to acquire additional water rights. The city intends to fully meet its projected demands with groundwater. As an alternative, 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

- Develop PDRA Transmission System (See Section 5C.6)

Drill Additional Groundwater Wells

This strategy assumes that 9 new wells would be drilled to provide approximately 4,500 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 2020. This project will likely be implemented in phases, with new wells coming on line 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 4,500 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 $12.5 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 PDRA Transmission System

As a member of the PDRA, 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 alternative 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 $45.6 million associated with their portion of the project. This project is fully evaluated in Chapter 5C for PDRA.

Table 5D-32: Recommended Water Strategies for Dumas (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		290	1,021	1,785	2,679	3,550	4,437
Recommended Strategies							
Municipal Conservation	$0	133	152	171	190	210	231
New Wells	$12.5	2,000	2,000	2,000	4,500	4,500	4,500
Total	**$12.5**	**2,133**	**2,152**	**2,171**	**4,690**	**4,710**	**4,731**

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 PDRA. The projected needs for Sunray are 232 acre-feet per year in 2030 and increasing to 847 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 PDRA 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
- Develop PDRA Transmission System (See Section 5C.6)

Drill Additional Groundwater Wells

To fully meet its needs Sunray will need to develop additional supply totaling approximately 850 acre-feet of water per year. Presently, Sunray owns 764 acre-feet 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 three 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 on line 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 850 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 well is approximately $3.5 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 PDRA Transmission System

As a member of the PDRA, Sunray is interested in developing a regional transmission system to use water from Palo Duro Reservoir. The Palo Duro Reservoir transmission project is an alternative 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 $9.4 million associated with their portion of the project.

Table 5D-33: Recommended Water Strategies for Sunray (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	232	501	633	752	847
Recommended Strategies							
Municipal Conservation	$1.8	37	42	46	52	57	63
New Wells	$3.5	0	850	850	850	850	850
Total	**$5.3**	**37**	**892**	**896**	**902**	**907**	**913**

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 less than 500 people. Moore County-Other is shown to have a small need beginning in 2050. The maximum amount of the needs is 30 acre-feet per year. Some water is provided to County-Other users from the City of Cactus. The majority of Moore County-Other supply is from unincorporated rural wells in the Ogallala aquifer. There is a projected increase in demands in Moore County, which is expected to be provided by the local cities and municipal conservation. The additional demand for County-Other provided by the cities is addressed with each city.

Table 5D-34: Recommended Water Strategies for Moore County-Other (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	13	21	30
Recommended Strategies							
Municipal Conservation	$0	14	15	17	19	21	23
Sales from Cactus		58	76	93	112	128	145
Total	**$0**	72	91	110	131	149	168

5D.14.5 Moore County Manufacturing

The manufacturing needs in Moore County range from 1,877 to 7,746 acre-feet per year over the planning period. 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 wholesale 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

Drill Additional Groundwater Wells

This strategy assumes that 15 new wells will be drilled near the location of need. 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 4,000 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. The capital cost for the additional groundwater well is approximately $11.2 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. 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-35: Recommended Water Strategies for Moore County-Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		1,877	2,346	2,754	4,445	6,147	7,746
Recommended Strategies							
Purchase from Cactus	$0	1,877	2,346	2,754	3,102	3,439	3,790
New Wells	$11.2	0	0	0	4,000	4,000	4,000
Total	**$11.2**	**1,877**	**2,346**	**2,754**	**7,102**	**7,439**	**7,790**

5D.14.6 Moore County Irrigation

The irrigation needs in Moore County range from about 3,900 to nearly 6,200 acre-feet per year over the planning period. These needs can be fully met through conservation. A summary of the projected water needs and strategies for Moore County is shown in Table 5D-36. The irrigation conservation strategy is discussed in Section 5B.2.

Table 5D-36: Recommended Water Strategies for Moore County Irrigation (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		0	0	0	0	3,882	6,171
Recommended Strategies							
Irrigation Conservation	$5.3	13,308	24,120	41,895	47,571	52,037	55,406
Total	**$5.3**	**13,308**	**24,120**	**41,895**	**47,571**	**52,037**	**55,406**

5D.14.7 Moore County Summary

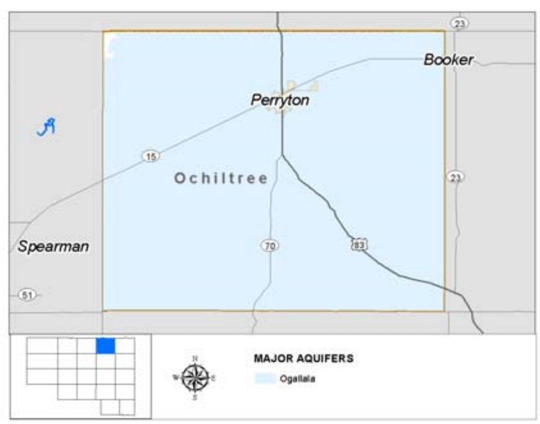
The preferred source of water for Moore County is the Ogallala aquifer. This source is heavily used by current users, such that by 2070, the undeveloped supply in the entire county is estimated at 1,100 acre-feet per year. This is not enough water to fully meet the county's projected needs. Conservation provides a means to balance the water supplies among users. Irrigation conservation can save over 50,000 acre-feet pear year of Ogallala water by 2060 in Moore County. Some of this water savings would become available to other users. Collectively, the municipal water users are expected to develop approximately

11,000 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-37.

Table 5D-37: Moore County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Cactus	Ogallala aquifer	Yes	New wells in Ogallala, Municipal conservation
Dumas	Ogallala aquifer	Yes	New wells in Ogallala, Municipal conservation
Sunray	Ogallala aquifer	Yes	New wells in Ogallala, Municipal conservation
County-Other	Ogallala aquifer	Yes	Supplies from Cactus, Municipal conservation
Irrigation	Ogallala and Dockum aquifers, Canadian River and reuse	Yes	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer	Yes	Purchase from Cactus, New wells in Ogallala
Mining	Ogallala aquifer	No	None
Steam Electric	Ogallala aquifer	No	None

5D.15 Ochiltree County



Ochiltree County is located on the Texas-Oklahoma border in the northern part of the PWPA. The largest city is Perryton, with a population over 9,500. The primary source of water in Ochiltree County is the Ogallala aquifer. Only about one-fourth of the available supply in the county has been developed. There is sufficient water to meet the county's projected water needs. The City of Perryton is shown to have a need starting in 2020 due to declining production of its well field.

5D.15.1 Perryton

The City of Perryton currently obtains its water from the Ogallala aquifer in Ochiltree County. The city is showing a need of nearly 2,800 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. The city 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

Drill Additional Groundwater Wells

This strategy assumes that 8 new wells would be drilled to provide approximately 2,800 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 two miles of Perryton's existing infrastructure. The strategy includes a 2-mile 18-inch pipeline to transport the water to the city.

Time Intended to Complete

Some of the additional wells will be completed by 2020. This project will likely be implemented in phases, with new wells coming on-line 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 2,800 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 $10.6 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 are 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-38: Recommended Water Strategies for Perryton (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		478	963	1,438	1,877	2,341	2,786
Recommended Strategies							
Municipal Conservation	$0	85	90	96	103	111	119
New Wells	$10.6	1,400	1,400	1,400	2,800	2,800	2,800
Total	**$10.6**	**1,485**	**1,490**	**1,496**	**2,903**	**2,911**	**2,919**

5D.15.2 Ochiltree County Summary

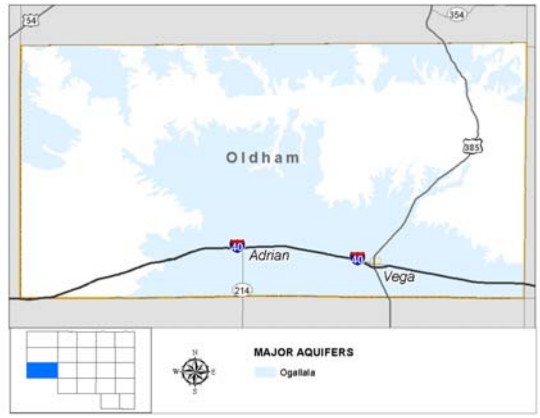
Ochiltree County has plenty of undeveloped water in the Ogallala aquifer. The needs identified for the City of Perryton are associated with expected declines in production of existing wells and increases in demands. With further development of water from the Ogallala aquifer, Ochiltree County can fully 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-39 shows the recommended water plan for Ochiltree County.

Table 5D-39: Ochiltree County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Perryton	Ogallala aquifer	Yes	Municipal, conservation, New wells in Ogallala aquifer
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
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. Oldham is a rural county, with demands totaling about 6,200 acre-feet per year. 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 population of less than 1,000.



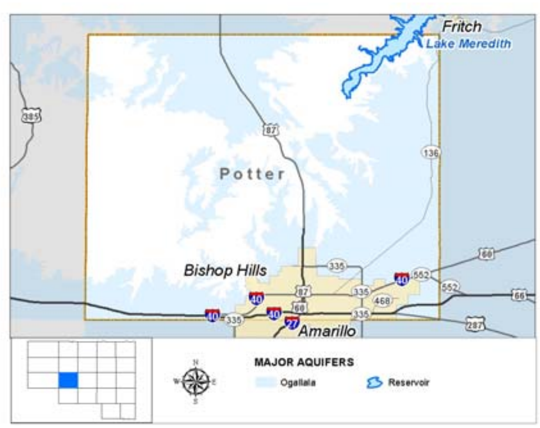
Most of the water supply in Oldham County is obtained from the Ogallala and Dockum aquifers. The county has sufficient supplies to meet the projected demands through the planning period. Conservation is recommended for the City of Vega and irrigation use. Water saved through these measures can be used for future needs. Conservation measures are discussed in Chapter 5B. Table 5D-40 shows the recommended water plan for Oldham County.

Table 5D-40: Oldham County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Vega	Ogallala aquifer	No	Municipal conservation
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	-	-

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 total population over 200,000, of which slightly more than half is located in Potter County. The remaining population is in Randall 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. 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 and livestock use.

Potter County is found to have a projected need of over 39,000 acre-feet per year, of which is mostly associated with the City of Amarillo. County-Other and 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 wholesale 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 Potters County well field, expanding the 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.17.2 Potter County – Other

The demands for Potter County-Other increase by about 1,700 acre-feet per year by 2070. The projected needs are approximately 680 acre-feet per year in 2020, increasing to over 2,500 acre-feet per year by 2070 for the Red and Canadian basins combined. Small water supply corporations supply a portion of these demands. The majority of Potter County-Other supply is from unincorporated rural wells in the Ogallala aquifer. It is anticipated that this pattern will continue over the planning period, and it is assumed that as demands increase, additional rural municipal wells will be installed. However, there is not sufficient undeveloped groundwater supplies to meet all of the projected need for County-Other and other users. It is assumed that additional wells will be developed in the Dockum and Ogallala aquifers for a total supply of 1,600 acre-feet per year. This results in an unmet need of about 500 acre-feet per year, after conservation. If Amarillo is willing, Amarillo could sell water to Potter County-Other. This has not been confirmed with the city.

The potential water management strategies for Potter County-Other include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Well in Ogallala aquifer
- Drill Additional Groundwater Well in Dockum aquifer

Drill Additional Groundwater Wells in Ogallala aquifer

This strategy assumes that 15 new wells will be drilled near the location of need. Since County-Other 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. Treatment such as chlorine disinfection is required for municipal use.

Time Intended to Complete

This strategy will be in place by 2020. Wells will be drilled as needed.

Quantity, Reliability and Cost

The quantity of water from this strategy should be able to produce 900 acre-feet per year with average well capacities of 70 gpm. Water is assumed to be produced from approximately 240 feet below the ground surface. Reliability of Ogallala supplies is low to moderate since there is limited supplies and competition for the water. The capital cost for the additional groundwater well is approximately $4.

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. The supply amount assumed for this strategy respects the MAG limits and should not impact other strategies. To prolong the life of this water resource, water conservation is also recommended.

Impact on Agriculture and Natural Resources

There is little agricultural use in Potter County. Therefore, no significant impact on agricultural or natural resources is expected from this strategy.

Other Relevant Factors

There are no other identified relevant factors.

Drill Additional Groundwater Wells in Dockum aquifer

This strategy assumes that 12 new wells will be drilled near the location of need. Since County-Other 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. Treatment such as chlorine disinfection is required for municipal use.

Time Intended to Complete

This strategy will be in place by 2020. Wells will be drilled as needed.

Quantity, Reliability and Cost

The quantity of water from these strategies should be able to produce 700 acre-feet per year with average well capacities of 70 gpm. Water is assumed to be produced from approximately 250 feet below the ground surface. Reliability of Dockum supplies is low to moderate since there is limited supplies and competition for the water. The capital cost for the additional groundwater well is approximately $3.3 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 Dockum will continue to deplete the storage in the aquifer. The supply amount assumed for this strategy respects the MAG limits and should not impact other strategies.

Impact on Agriculture and Natural Resources

There is little agricultural use in Potter County. Therefore, no significant impact on agricultural or natural resources is expected from this strategy.

Other Relevant Factors

There are no other identified relevant factors.

Table 5D-41: Recommended Water Strategies for Potter County-Other (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		683	956	1,262	1,583	1,953	2,548
Recommended Strategies							
Municipal Conservation	$13.4	266	291	318	347	379	413
New Wells (Dockum)	$3.3	700	700	700	700	700	700
New Wells (Ogallala)	$4	900	900	900	900	900	900
Total	**$20.7**	**1,866**	**1,891**	**1,918**	**1,947**	**1,979**	**2,013**

5D.17.3 Potter County Manufacturing

The current supplies for manufacturing in Potter County include self-supplied Ogallala 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 manufacturing are 2,000 acre-feet in 2020 and, increasing to 9,600 acre-feet in 2070. Of these needs, Amarillo is expected to meet up to 6,360 acre-feet per year in 2070 through existing contracts. The remaining shortage would be met with new strategies. Potentially feasible strategies for manufacturing are limited due to the availability of local groundwater and competition for these supplies. There is some Ogallala water available in early decades but none after 2050. Considering these limitations the potential water management strategies for Potter County Manufacturing include:

- Purchase additional water from Amarillo
- Purchase direct reuse water from Amarillo

Purchase Additional Water from Amarillo

With the development of new strategies, Amarillo has supplies in excess of its needs. To help meet the projected water shortages for Potter County Manufacturing, Amarillo could provide additional water to this user. For planning purposes, it is assumed that Amarillo provide up to 2,000 acre-feet per year of additional supply beginning in 2020. The reliability would be moderate to high, depending upon the reliability of Amarillo's new strategies. It is assumed that no additional cost would incur for planning purposes. The conditions of the water purchase would be between the city and customer. There are no additional impacts associated with this purchase agreement. Potential impacts of the source strategies are discussed for the City of Amarillo's strategies in Section 5C.2.

Purchase Direct Reuse Water from Amarillo

Currently, the City of Amarillo sells all of its wastewater effluent to Xcel Energy for cooling purposes. The contract with Xcel limits the city's ability to use this water for other purposes. This strategy assumes that an agreement with Xcel Energy is reached to provide direct reuse to manufacturers in Potter County. The strategy includes plant improvements at Amarillo's wastewater plant, advanced treatment of the reuse water by reverse osmosis, and a 10-mile 18-inch pipeline to transport the reuse water to the end users. Currently, there are no specific users identified for this water.

Time Intended to Complete

This strategy will be in place by 2050.

Quantity, Reliability and Cost

The quantity of water from reuse should be able to produce 5,700 acre-feet per year (5 MGD). Reliability of reuse supplies is high, assuming agreements can be reached for the quantity. The capital cost for the direct reuse is approximately $57.7 million.

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 expected to be less than projected in Chapter 2. Also, there is an alternate strategy for Amarillo to develop direct reuse for its own use. This strategy, if implemented, could impact the supplies available to Potter County manufacturing, but this impact cannot be assessed at this time due to the uncertainty of the future steam electric power needs.

Impact on Agriculture and Natural Resources

There is little agricultural use in Potter County. Therefore, no significant impact on agricultural or natural resources is expected from this strategy.

Other Relevant Factors

This strategy would require extensive coordination with the TCEQ to obtain the necessary permits for use and discharge. It also would require a modification to the agreement with Xcel Energy for purchase of Amarillo’s wastewater.

Table 5D-42: Recommended Water Strategies for Potter County Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		2,099	3,611	5,239	6,714	8,130	9,633
Recommended Strategies							
Purchase from Amarillo (existing contracts)	$0	642	1,749	3,008	4,192	5,236	6,360
Purchase from Amarillo (additional supply)	$0	2,000	2,000	2,500	3,000	3,000	3,500
Total	**$0**	**2,642**	**3,749**	**5,508**	**7,192**	**8,236**	**9,860**
Alternate Strategy							
Purchase reuse water from Amarillo	$57.7	0	0	5,700	5,700	5,700	5,700

5D.17.4 Potter County Summary

Potter County has a projected need of over 38,500 acre-feet 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-43. Table 5D-44 shows a small unmet need to Potter County-Other in 2070.

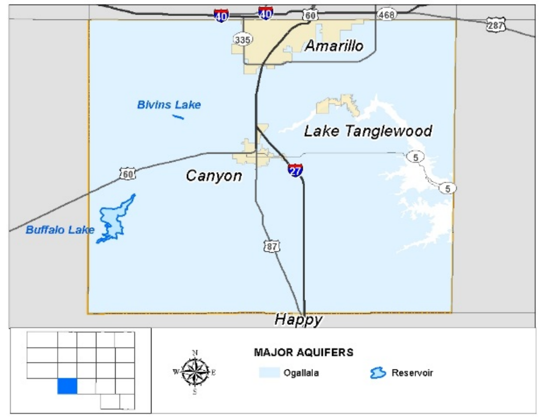
Table 5D-43: Potter County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Amarillo	CRMWA system Ogallala aquifer	Yes	Potter, Roberts and Carson Counties well fields, Municipal conservation, and contracted supplies from CRMWA
County-Other	Ogallala and Dockum aquifers	Yes	New wells in Ogallala and Dockum, Municipal conservation
Irrigation	Ogallala aquifer, local supply and reuse	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala and Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer & CRMWA system	Yes	Purchase from Amarillo
Mining	Ogallala aquifer	No	None
Steam Electric	Ogallala aquifer, CRMWA system and reuse	No	None

Table 5D-44: Unmet Water Needs in Potter County (ac-ft/yr)

Water User Group	2020	2030	2040	2050	2060	2070
County-other	0	0)	0	0	0	(535)

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 210,000 people reside in Randall County. The remaining portion of the population live in Potter County. Other towns in Randall County include Canyon and Lake Tanglewood. A small portion 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, 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, Lake Tanglewood, County-Other and Manufacturing.

5D.18.1 Amarillo

The City of Amarillo is a water user group and a wholesale 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 2020 with a projected need of 4,313 acre-feet per year by 2070. The potential water management strategies for Canyon include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Wells in Randall County

Drill Additional Groundwater Wells in Randall County

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. However, there is insufficient supplies from the Dockum based on the MAG values to fully meet the city's projected needs. As a result the city would also need to utilize water from the Ogallala aquifer. For the purposes of this plan, it is estimated that 9 wells will be drilled in the Dockum and Ogallala aquifers by 2070 to provide an estimated 4,300 acre-feet of additional water supply. 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 one phase by 2020. However, the city may choose to drill the wells in phases.

Quantity, Reliability, and Cost

The quantity of water from this strategy is 4,300 acre-feet 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 $11.6 million with a unit cost of water at $425 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-45: Recommended Water Strategies for Canyon (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		1,009	1,589	2,176	2,770	3,779	4,313
Recommended Strategies							
Municipal Conservation		127	142	156	171	187	203
Purchase from Amarillo		94	239	384	507	0	0
New Wells	$11.6	1,400	2,100	2,800	2,800	3,800	4,300
Total	**$11.6**	1,621	2,481	3,340	3,478	3,987	4,503

5D.18.3 Lake Tanglewood

The City of Lake Tanglewood currently obtains its water supply from the Ogallala aquifer in Randall County. The City has a need of 172 acre-feet in 2020, reaching its peak need of 284 acre-feet by 2070. This need is due to declining supplies from their current well field. Potentially feasible water management strategies include:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Wells

Drill Additional Groundwater Well

The City is need of additional water supplies. For planning purposes, this strategy consists of two new 150 gpm wells and associated collection piping. Additionally, a 3 mile 8-inch transmission line and small pump station were included. These wells would produce water from approximately 150 feet below the surface. Minimal treatment such as chlorine disinfection will be required.

Time Intended to Complete

This project is assumed to be online by 2020 for planning purposes. The city may choose drill the wells in phases if necessary.

Quantity, Reliability, and Cost

The quantity of supply available from this strategy is 300 acre-feet. The reliability of this supply is considered moderate due to competition from other water users. The capital cost for the additional groundwater and associated infrastructure is $3.0 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

The increased demands on the Ogallala aquifer will continue to deplete the available storage. This strategy respects the MAG limits for the Ogallala aquifer in Randall County and is not expected to have any impacts other management strategies. However, there may be competition for water among users in Randall County.

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-46: Recommended Water Strategies for Lake Tanglewood (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		172	200	225	248	266	284
Recommended Strategies							
Municipal Conservation	$0.5	25	24	24	24	24	24
New Wells	$3.0	300	300	300	300	300	300
Total	**$3.5**	**325**	**324**	**324**	**324**	**324**	**324**

5D.18.4 Randall County - Other

The demands in Randall County for county-other municipal supply are expected to increase significantly from approximately 640 acre-feet per year to 2,600 acre-feet per year. The current supply to Randall County-Other is primarily the Ogallala aquifer. A small amount of supply comes from the Dockum aquifer, and a small quantity of water is provided from the City of Amarillo to the Palo Duro Canyon State park for municipal use. Groundwater is limited in parts of the county, with some residential wells in northeast Randall County experiencing significant reductions in production. To meet the projected growth in demands, the potentially feasible water management strategies for Randall County-Other are:

- Municipal Conservation (see Section 5B.1)
- Drill Additional Groundwater Wells

Drill Additional Groundwater Wells

To meet these projected needs, groundwater wells will likely need to be expanded and/or improved to access deeper water. This groundwater recommended strategy assumes that additional water rights are already owned by the individuals and includes the development of 8 new wells. The 8 new wells would be drilled to provide approximately 2,800 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 2020. Individuals will likely develop wells on an as needed basis, but the strategy costs and supplies are developed in one phase for planning purposes.

Quantity, Reliability and Cost

The quantity of water from these strategies should be sufficient. Reliability of Ogallala supplies is moderate since availability depends on other water users. The capital cost for additional groundwater wells is approximately $5.3 million.

Environmental Issues

No significant environmental impact is expected for the recommended strategies.

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 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

None identified.

Table 5D-47: Recommended Water Strategies for Randall County-Other (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		637	978	1,339	1,731	2,172	2,638
Recommended Strategies							
Municipal Conservation	$0	143	158	173	189	207	225
Amarillo sales	$0	2	6	10	13	15	17
New Wells	$5.3	500	1,000	1,200	2,600	2,600	2,800
Total	**$5.3**	**645**	**1,164**	**1,383**	**2,802**	**2,822**	**3,042**

5D.18.5 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 about 40 to 620 acre-feet per year beginning in 2020 due to increasing demands and limited supplies from Amarillo. Through existing contracts, Amarillo is expected to provide about half of this need. To meet the remaining 300 acre-feet per year need, the potentially feasible water management strategies considered for Randall County Manufacturing include:

- Drill Additional Groundwater Wells

Drill Additional Groundwater Wells

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 four new wells. The two new wells would be drilled to provide approximately 300 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 $746,000.

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 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

None identified.

Table 5D-48: Recommended Water Strategies for Randall County Manufacturing (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		41	169	295	401	508	619
Recommended Strategies							
Purchase from Amarillo		52	131	211	279	324	367
New Wells	$0.75		300	300	300	300	300
Total	**$0.75**	**352**	**421**	**511**	**579**	**624**	**667**

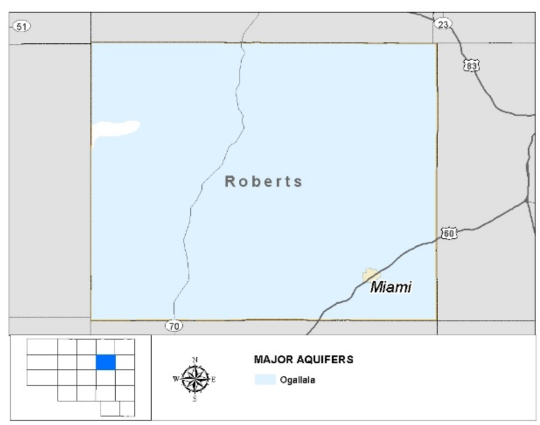
5D.18.6 Randall County Summary

Randall County has a projected need of over 28,000 acre-feet 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-49.

Table 5D-49: Randall County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Amarillo	Ogallala aquifer and CRMWA system	Yes	Potter Phase II, Carson and Roberts Counties well fields, Municipal conservation
Canyon	Ogallala aquifer and CRMWA system	Yes	New wells in Ogallala, Municipal conservation
Lake Tanglewood	Ogallala aquifer	No	New wells in Ogallala
County-Other	Ogallala & Dockum aquifers and CRMWA system	Yes	New wells in Ogallala, Conservation, Sales from Amarillo
Irrigation	Ogallala aquifer, Red River and reuse	No	Irrigation conservation
Livestock	Ogallala & Dockum aquifers and local supply (stock ponds)	No	None
Manufacturing	Ogallala aquifer & CRMWA system	Yes	New wells in Ogallala, Purchase from Amarillo
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.19 Roberts County



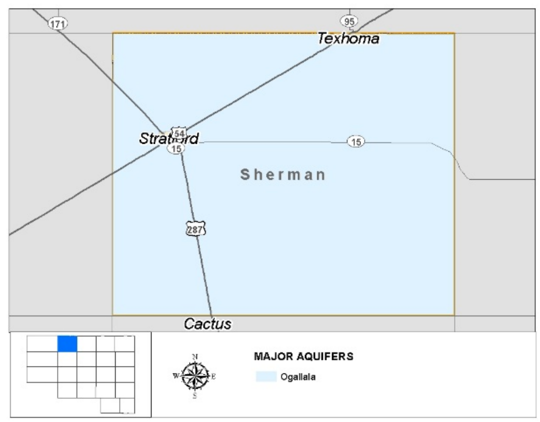
Roberts County is located in the northeastern portion of the PWPA. The population of Roberts County is about 1,000 people of which, 600 live in Miami. Nearly all of its water supply is derived from the Ogallala aquifer. Small amounts of surface water are used from the Canadian Run-of-River for irrigation 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 Robert's 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. Additional information on CRMWA and their strategies can be found in Section 5C.1.1. Roberts County has ample supply to support all current and future projected demands. The only strategy recommended for Roberts County is irrigation conservation.

Table 5D-50: Roberts County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Miami	Ogallala aquifer	No	Municipal conservation
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer and reuse	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala aquifer and local supply (stock ponds)	No	None
Manufacturing	None	-	-
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 total population of approximately 2,200, which accounts for about two thirds of the County's total population.

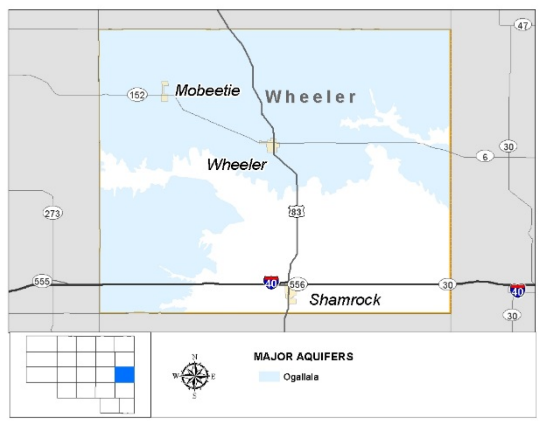
Sherman County is one of the larger irrigation water users in the region. The primary source of water in the county is the Ogallala aquifer. Smaller quantities of local Canadian Run-of-River and local livestock supply are also used in the county.

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. However, there are no projected needs over the planning period. Irrigation conservation is recommended as a way to preserve water for future use. A summary of the water plan for Sherman County is shown in Table 5D-51.

Table 5D-51: Sherman County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Stratford	Ogallala aquifer	No	Municipal conservation
County-Other	Ogallala aquifer	No	None
Irrigation	Ogallala aquifer & local supply	No	Irrigation conservation
Livestock	Ogallala aquifer and local supply (irrigation and stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifer	No	None
Steam Electric	None	-	-

5D.21 Wheeler County



Wheeler County is located on the eastern edge of the PWPA. 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 is the largest city in Wheeler County with a population of nearly 2,000 people. Shamrock shows no needs over the planning period. The next largest city is Wheeler, with a population of about 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 2020 and reaching a peak need of 483 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 Wells

Drill Additional Groundwater Well

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 2 new wells and associated well field piping will be necessary to meet the City's water needs. These 2 new wells will provide approximately 500 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 2020. 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 500 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 $2.8 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-52: Recommended Water Strategies for Wheeler (ac-ft/yr)

	Capital Cost ($ Millions)	2020	2030	2040	2050	2060	2070
Need		184	249	308	365	412	453
Recommended Strategies							
Municipal Conservation	$0	15	15	16	16	17	18
New Wells	$2.8	500	500	500	500	500	500
Total	**$2.8**	**515**	**515**	**516**	**516**	**517**	**518**

5D.21.2 Wheeler County Summary

Wheeler County has a total projected water need of 453 acre-feet per year, 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-53: Wheeler County Water Management Plan

Water User Group	Current Supplies	Need	Proposed Water Management Strategies
Shamrock	Ogallala aquifer	No	Municipal conservation
Wheeler	Ogallala aquifer	Yes	Municipal conservation, New wells in Ogallala aquifer
County-Other	Ogallala, Blaine, Seymour and Other aquifers	No	None
Irrigation	Ogallala, Blaine, Seymour, Other aquifers and reuse	No	Irrigation conservation, Precipitation enhancement
Livestock	Ogallala, Blaine, Seymour, Other aquifers and local supply (stock ponds)	No	None
Manufacturing	None	-	-
Mining	Ogallala aquifers	No	None
Steam Electric	None	-	-

Attachment 5-1

Water Management Strategies Considered and Evaluated

Region A - List of Potentially Feasible Water Management Strategies

Sponsor	**WMS**
Multiple Entities	Municipal Conservation
Multiple Entities	Irrigation Conservation
Claude	New Groundwater (Ogallala)
Panhandle	New Groundwater (Ogallala)
Wellington	New Groundwater (Seymour)
Wellington	Expanded Use (RO Treatment)
Dalhart	New Groundwater (Ogallala)
Texline	New Groundwater (Ogallala)
McLean	New Groundwater (Ogallala)
Pampa	New Groundwater (Ogallala)
Pampa	Purchase from CRMWA
Memphis	New Groundwater (Ogallala)
County-Other (Hall)	New Groundwater- Brice-Lesly (Ogallala)
County-Other (Hall)	New Groundwater-Estelline (Seymour)
County-Other (Hall)	Expanded Use-Lakeview (RO Treatment)
Gruver	New Groundwater (Ogallala)
Gruver	Develop PDRA Transmission System
Spearman	New Groundwater (Ogallala)
Spearman	Develop PDRA Transmission System
Stinett	New Groundwater (Ogallala)
Stinett	Develop PDRA Transmission System
TCW	New Groundwater (Ogallala)
Manufacturing (Hutchinson)	Purchase from Borger
Booker	New Groundwater (Ogallala)
Manufacturing (Lipscomb)	Purchase from Booker
Dumas	New Groundwater (Ogallala)
Dumas	Develop PDRA Transmission System
Sunray	New Groundwater (Ogallala)
Sunray	Develop PDRA Transmission System
County-Other (Moore)	New Groundwater (Ogallala)
Manufacturing (Moore)	Purchase from Cactus
Perryton	New Groundwater (Ogallala)
County-Other (Potter)	New Groundwater (Ogallala)
County-Other (Potter)	New Groundwater (Ogallala)
County-Other (Potter)	New Groundwater (Dockum)
Manufacturing (Potter)	Direct Reuse from Amarillo
Manufacturing (Potter)	Purchase from Amarillo
Canyon	New Groundwater (Ogallala, Dockum)
Lake Tanglewood	New Groundwater (Ogallala)

County-Other (Randall)	New Groundwater (Ogallala)
Manufacturing (Randall)	New Groundwater (Ogallala)
Wheeler	New Groundwater (Ogallala)
Amarillo	Purchase from CRMWA
Amarillo	Potter Co. Well Field
Amarillo	Carson Co. Well Field
Amarillo	Roberts Co. Well Field
Amarillo	Reuse
Borger	Purchase from CRMWA
Borger	New Groundwater (Ogallala)
Cactus	New Groundwater (Ogallala)
Cactus	Develop PDRA Transmission System
Canadian River Municipal Water Authority	Replacement Wells
Canadian River Municipal Water Authority	Roberts Co. Well Field
Canadian River Municipal Water Authority	Conjunctive Use with Lake Meredith
Canadian River Municipal Water Authority	Brush Control
Palo Duro River Authority	Develop PDRA Transmission System
Greenbelt MIWA	Donley Co. Well Field

Attachment 5-1: Water Management Strategies Considered and Evaluated

County	Identified WUG Need		WMSs Required To be Considered																	
	WUG	Maximum Need 2020-2070 (ac-ft/yr)	Conservation	Drought Management	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	Emergency transfer of water	Brush Control	Precipitation Enhancement	Desalination	Aquifer Storage and Recovery	Cancellation of Water Rights	Interbasin Transfers
Armstrong	Claude	110	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Carson	Panhandle	582	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Collingsworth	Wellington	595	●	○	○	○	○	○	○	●	○	●	○	○	○	○	○	○	○	○
Dallam, Hartley	Dalhart	2,807	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Dallam	Texline	161	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Dallam	Dallam County Irrigation	94,226	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Gray	McLean	182	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Gray	Pampa	3,806	●	○	○	○	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Hall	Memphis	133	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Hall	Hall County - Other	3	●	○	○	○	○	○	○	●	○	●	○	○	○	○	○	○	○	○
Hansford	Gruver	344	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Hansford	Spearman	634	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Hartley	Hartley County Irrigation	98,650	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Hutchinson	Stinnett	216	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Hutchinson	TCW Supply	569	●	○	○	○	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Hutchinson	Hutchinson County Manufacturing	4,416	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Lipscomb, Ochiltree	Booker	451	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Lipscomb	Lipscomb County Manufacturing	124	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Moore	Dumas	4,437	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Moore	Sunray	847	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Moore	Moore County - Other	30	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Moore	Moore County Manufacturing	7,746	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Moore	Moore County Irrigation	6,171	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

	Identified WUG Need		WMSs Required To be Considered																	
County	WUG	Maximum Need 2020-2070 (ac-ft/yr)	Conservation	Drought Management	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	Emergency transfer of water	Brush Control	Precipitation Enhancement	Desalination	Aquifer Storage and Recovery	Cancellation of Water Rights	Interbasin Transfers
Ochiltree	Perryton	2,786	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Potter	Potter County - Other	2,548	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Potter	Potter County Manufacturing	9,633	○	○	●	○	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Randall	Canyon	4,313	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Randall	Lake Tanglewood	284	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Randall	Randall County - Other	2,638	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Randall	Randall County Manufacturing	619	○	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
Wheeler	Wheeler	453	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○
	Wholesale Water Providers:																			
Potter, Randall	Amarillo	55,926	●	○	●	○	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Hutchinson	Borger	6,438	●	○	○	○	●	○	○	●	○	○	○	○	○	○	○	○	○	○
Moore	Cactus	5,465	●	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Multiple	CRMWA	80,936	●	○	○	○	○	●	○	●	○	○	○	○	●	○	○	●	○	○
Multiple	Greenbelt MIWA	0	●	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○

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 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 applicable strategies will have a low impact on 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.

Entity	County Used	Basin Used	Strategy	Quantity (Ac-Ft/Yr)	Maximum Need	Percentage of Max Need Met	Quantity Score	Reliability	Anunal Cost ($/Ac-Ft)	Cost Score	Impacts of Strategy on:				Overall Score (5-40)
											Environmental Factors	Agricultural Resources/ Rural Areas	Other Natural Resources	Key Water Quality Parameters	
Claude	Armstrong	Red	Conservation	29	110	26%	2	3	$714	4	5	5	5	5	29
			New Groundwater (Ogallala)	400	110	363%	5	3	$790	4	4	4	4	4	28
Panhandle	Carson	Red	Conservation	48	582	8%	1	3	$795	4	5	5	5	5	28
			New Groundwater (Ogallala)	600	582	103%	5	5	$621	4	4	4	4	4	30
Wellington	Collingsworth	Red	Conservation	50	595	8%	1	3	$806	4	5	5	5	5	28
			New Groundwater (Seymour)	180	595	30%	2	2	$1,485	3	4	4	3	4	22
			Nitrate Removal (RO Treatment)	500	595	84%	4	2	$1,029	3	4	4	3	3	23
Dalhart	Dallam	Canadian	Conservation	113	2,807	4%	1	3	$364	5	5	5	5	5	29
			New Groundwater (Ogallala)	2,700	2,807	96%	4	3	$213	5	4	4	4	4	28
Texline	Dallam	Canadian	Conservation	28	161	17%	1	3	$656	4	5	5	5	5	28
			New Groundwater (Ogallala)	150	161	93%	4	5	$778	4	4	4	4	4	29
Irrigation	Dallam	Canadian	Conservation	140,612	94,226	149%	5	3	$17	5	5	5	5	5	33
McLean	Gray	Red	Conservation	27	182	15%	1	3	$897	4	5	5	5	5	28
			New Groundwater (Ogallala)	200	182	110%	5	5	$446	5	4	4	4	4	31
Pampa	Gray	Canadian	Conservation	240	3,806	6%	1	3	$619	4	5	5	5	5	28
			New Groundwater (Ogallala)	2,000	3,806	53%	3	5	$490	5	4	4	4	4	29
Memphis	Hall	Red	Conservation	34	133	25%	2	3	$964	4	5	5	5	5	29
			New Groundwater (Ogallala)	150	133	113%	5	3	$848	4	4	4	4	4	28
County-Other	Hall	Red	Conservation	26	50	52%	3	3	$744	4	5	5	5	5	30
			New Groundwater - Turkey (Ogallala)	100	50	200%	5	3	$1,380	3	4	4	5	5	29
			New Groundwater- Brice-Lesley (Ogallala)	50	50	100%	4	3	$688	4	4	4	3	4	26
			New Groundwater-Estelline (Seymour)	50	50	100%	4	3	$360	5	4	4	3	4	27
			Nitrate Removal (Lakeview)	75	50	150%	5	3	$3,345	1	4	4	3	3	23
Gruver	Hansford	Canadian	Conservation	31	344	9%	1	3	$943	4	5	5	5	5	28
			New Groundwater (Ogallala)	350	344	102%	5	3	$450	5	4	4	4	4	29
			Develop PDRA Transmission System	271	344	79%	4	1	$4,866	1	4	4	3	3	20
Spearman	Hansford	Canadian	Conservation	27	634	4%	1	3	$615	4	5	5	5	5	28
			New Groundwater (Ogallala)	650	634	103%	5	3	$636	4	4	4	4	4	28
			Develop PDRA Transmission System	116	634	18%	1	1	$1,708	3	4	4	3	3	19
Irrigation	Hansford	Canadian	Conservation	37,260	0	N/A	5	3	$17	5	5	5	5	5	33
Irrigation	Hartley	Canadian	Conservation	120,509	98,650	122%	5	3	$17	5	5	5	5	5	33
Canadian	Hemphill	Canadian	Conservation	93	0	N/A	5	3	$681	4	5	5	5	5	32
Stinnett	Hutchinson	Canadian	Conservation	37	216	17%	1	3	$827	4	5	5	5	5	28
			New Groundwater (Ogallala)	225	216	104%	5	3	$477	5	4	4	4	4	29
			Develop PDRA Transmission System	116	216	54%	3	1	$6,407	1	3	4	3	3	18
TCW	Hutchinson	Canadian	Conservation	59	569	10%	1	3	$570	4	5	5	5	5	28
			New Groundwater (Ogallala)	575	569	101%	5	3	$736	4	4	4	4	4	28
Irrigation	Hutchinson	Canadian	Conservation	10,281	0	N/A	5	3	$17	5	5	5	5	5	33
Booker	Lipscomb	Canadian	Conservation	21	575	4%	1	3	$597	4	5	5	5	5	28
			New Groundwater (Ogallala)	700	575	122%	5	5	$270	5	4	4	4	4	31
Dumas	Moore	Canadian	Conservation	231	4,437	5%	1	3	$629	4	5	5	5	5	28
			New Groundwater (Ogallala)	4,500	4,437	101%	5	2	$332	5	4	4	4	4	28
			Develop PDRA Transmission System	1,356	4,437	31%	2	1	$3,620	1	3	4	3	3	17

Attachment 5-2
Strategy Evaluation Matrix

Entity	County Used	Basin Used	Strategy	Quantity (Ac-Ft/Yr)	Maximum Need	Percentage of Max Need Met	Quantity Score	Reliability	Anunal Cost ($/Ac-Ft)	Cost Score	Impacts of Strategy on: Environmental Factors	Agricultural Resources/ Rural Areas	Other Natural Resources	Key Water Quality Parameters	Overall Score (5-40)
Sunray	Moore	Canadian	Conservation	63	847	7%	1	3	$886	4	5	5	5	5	28
			New Groundwater (Ogallala)	850	847	100%	5	2	$474	5	4	4	4	4	28
			Develop PDRA Transmission System	271	847	32%	2	1	$3,712	1	3	4	3	3	17
County-Other	Moore	Canadian	Conservation	23	30	77%	4	3	$786	4	5	5	5	5	31
Manufacturing	Moore	Canadian	New Groundwater (Ogallala)	4,000	3,956	101%	5	2	$332	5	4	4	4	4	28
Irrigation	Moore	Canadian	Conservation	55,406	6,171	898%	5	3	$17	5	5	5	5	5	33
Perryton	Ochiltree	Canadian	Conservation	119	2,786	4%	1	3	$370	5	5	5	5	5	29
			New Groundwater (Ogallala)	2,800	2,786	100%	5	5	$425	5	4	4	4	4	31
County-Other	Potter	Red	Conservation	265	1,212	22%	1	3	$552	4	5	5	5	5	28
			New Groundwater (Ogallala)	576	1,212	48%	2	2	$488	5	4	4	4	4	25
County-Other	Potter	Canadian	Conservation	149	1,336	11%	1	3	$311	5	5	5	5	5	29
			New Groundwater (Ogallala)	324	1,336	24%	1	2	$488	5	4	4	4	4	24
County-Other	Potter	Canadian	New Groundwater (Dockum)	700	1,336	52%	3	2	$527	4	4	4	3	4	24
Manufacturing	Potter	Canadian	Direct Reuse from Amarillo	5,700	3,273	174%	5	4	$1,312	3	3	4	2	4	25
			Purchase from Amarillo	3,500	3,273	107%	5	5	N/A	1	4	4	4	4	27
Canyon	Randall	Red	Conservation	203	4,313	5%	1	3	$647	4	5	5	5	5	28
			New Groundwater (Ogallala, Dockum)	4,300	4,313	100%	4	3	$425	5	4	4	3	4	27
Lake Tanglewood	Randall	Red	Conservation	25	284	9%	1	3	$636	4	5	5	5	5	28
			New Groundwater (Ogallala)	300	284	105%	5	3	$1,035	3	4	4	4	4	27
County-Other	Randall	Red	Conservation	413	2,638	16%	1	3	$495	5	5	5	5	5	29
			New Groundwater (Ogallala)	2,800	2,638	106%	5	3	$248	5	4	4	4	4	29
Manufacturing	Randall	Red	New Groundwater (Ogallala)	300	252	119%	5	3	$301	5	4	4	4	4	29
Wheeler	Wheeler	Red	Conservation	18	453	4%	1	3	$618	4	5	5	5	5	28
			New Groundwater (Ogallala)	500	453	110%	5	5	$625	4	4	4	4	4	30
Wholesale Water Providers:															
Amarillo	Potter and Randall	Red and Canadian	Conservation	2,762	55,926	5%	1	3	$254	5	5	5	5	5	29
			Purchase from CRMWA	33,271	55,926	59%	3	5	N/A	1	5	4	4	4	26
			Potter Co. Well Field	6,000	55,926	11%	1	3	$941	4	3	4	3	4	22
			Carson Co. Well Field	11,200	55,926	20%	1	3	$441	5	3	4	4	4	24
			Roberts Co. Well Field	11,200	55,926	20%	1	5	$1,538	3	3	4	4	4	24
			Reuse	6,100	55,926	11%	1	5	$1,368	3	3	4	2	3	21
Borger	Hutchinson	Canadian	Conservation	107	6,438	2%	1	3	$416	5	5	5	5	5	29
			Purchase from CRMWA	4,700	6,438	73%	3	5	N/A	1	5	4	4	4	26
			New Groundwater (Ogallala)	6,000	6,438	93%	4	5	$577	4	4	4	4	4	29
Cactus	Moore	Canadian	Conservation	55	5,465	1%	1	3	$487	5	5	5	5	5	29
			New Groundwater (Ogallala)	5,500	5,465	101%	5	2	$422	5	4	4	4	4	28
			Develop PDRA Transmission System	1,744	5,465	32%	2	1	$4,057	1	3	4	3	3	17
CRMWA			Replacement Wells	28,000	80,936	35%	2	5	$177	5	4	4	4	4	28
			Roberts Co. Well Field	48,000	80,936	59%	3	5	$676	4	3	4	4	4	27
			Conjunctive Use with Lake Meredith	16,400	80,936	20%	1	3	$451	5	4	4	3	5	25
Palo Duro River Authority			Develop PDRA Transmission System	3,875	5,465	71%	3	1	$3,810	1	3	4	3	3	18
Greenbelt MIWA			Donley Co. Well Field	2,000	0	N/A	5	3	$629	4	3	4	4	4	27

1. Maximum Need for water users is the need after contractual obligations are met from wholesale water providers. The need shown for the WWP is the calculated need shown in Subchapter 5C.

Entity	County	Basin	Strategy	Environmental Factors															Agricultural Impacts		
				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	Temporary	Permanent	Score
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
			New Groundwater (Ogallala)	8	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	0	0	4
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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	0	0	4
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 Groundwater (Seymour)	14	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	0	0	4
			Expanded Use (RO Treatment)	5	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	3	4	0	0	4
Dalhart	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 Groundwater (Ogallala)	3	N/A	4	Low	3	Low	3	11	3	Low	3	N/A	5	4	4	0	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 Groundwater (Ogallala)	1	N/A	4	Low	3	Low	3	11	3	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
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 Groundwater (Ogallala)	1	N/A	4	Low	3	Low	3	11	3	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 Groundwater (Ogallala)	11	N/A	4	Low	3	Low	3	11	3	Low	3	N/A	5	4	4	0	0	4
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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	4	4	0	0	4
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
			New Groundwater- Turkey (Ogallala)	10	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	5	4	0	0	4
			New Groundwater- Brice-Lesly (Ogallala)	1	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	4	4	0	0	4
			New Groundwater-Estelline (Seymour)	1	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	4	4	0	0	4
			Expanded Use-Lakeview (RO Treatment)	5	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	3	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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	0	0	4
			Develop PDRA Transmission System	48	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	3	4	5	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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	0	0	4
			Develop PDRA Transmission System	23	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	3	4	2	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
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
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 Groundwater (Ogallala)	1	N/A	4	Low	3	Low	3	11	3	Low	3	N/A	5	4	4	0	0	4
			Develop PDRA Transmission System	122	N/A	3	Low	3	Medium	2	11	3	Low	3	N/A	5	3	3	0	0	4
TCW	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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	11	3	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	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 Groundwater (Ogallala)	2	N/A	4	Low	3	Low	3	11	3	Low	3	N/A	5	4	4	0	0	4
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 Groundwater (Ogallala)	9	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	1	0	4
			Develop PDRA Transmission System	140	N/A	3	Low	3	Medium	2	12	3	Low	3	N/A	5	3	3	14	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 Groundwater (Ogallala)	3	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	0	0	4
			Develop PDRA Transmission System	150	N/A	3	Low	3	Medium	2	12	3	Low	3	N/A	5	3	3	15	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
Manufacturing	Moore	Canadian	New Groundwater (Ogallala)	4	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	4	2	4
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
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 Groundwater (Ogallala)	8	N/A	4	Low	3	Low	3	10	4	Low	3	N/A	5	4	4	1	0	4
County-Other	Potter	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 Groundwater (Ogallala)	15	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	0	0	4

Entity	County	Basin	Strategy	Environmental Factors															Agricultural Impacts		
				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	Temporary	Permanent	Score
County-Other	Potter	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 Groundwater (Ogallala)	15	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	0	0	4
County-Other	Potter	Canadian	New Groundwater (Dockum)	12	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	0	0	4
Manufacturing	Potter	Canadian	Direct Reuse from Amarillo	206	N/A	3	Low	3	Medium	2	12	3	Low	3	N/A	5	4	3	0	0	4
			Purchase from Amarillo	0	N/A	5	Medium	2	None	4	N/A	5	N/A	5	N/A	5	4	4	0	0	4
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 Groundwater (Ogallala, Dockum)	9	N/A	4	Low	3	Low	3	13	3	Low	3	N/A	5	4	4	0	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
			New Groundwater (Ogallala)	9	N/A	4	Low	3	Low	3	13	3	Low	3	N/A	5	4	4	0	0	4
County-Other	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 Groundwater (Ogallala)	8	N/A	4	Low	3	Low	3	13	3	Low	3	N/A	5	4	4	0	0	4
Manufacturing	Randall	Red	New Groundwater (Ogallala)	4	N/A	4	Low	3	Low	3	13	3	Low	3	N/A	5	4	4	0	0	4
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 Groundwater (Ogallala)	7	N/A	4	Low	3	Low	3	9	4	Low	3	N/A	5	4	4	0	0	4
Wholesale Water Providers:																					
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
			Purchase from CRMWA	0	N/A	5	None	4	None	4	N/A	5	N/A	5	N/A	5	4	5	0	0	4
			Potter Co. Well Field	285	N/A	3	Low	3	Medium	2	Varies	3	Low	3	N/A	5	4	3	0	0	4
			Carson Co. Well Field	71	N/A	3	Low	3	Low	3	Varies	3	Low	3	N/A	5	4	3	7	0	4
			Roberts Co. Well Field	502	N/A	3	Low	3	Medium	2	Varies	3	Low	3	N/A	5	4	3	0	0	4
			Reuse	175	N/A	3	Medium	2	Medium	2	Varies	3	Low	3	N/A	5	3	3	0	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
			Purchase from CRMWA	0	N/A	5	None	4	None	4	N/A	5	N/A	5	N/A	5	4	5	0	0	4
			New Groundwater (Ogallala)	37	N/A	4	Low	3	Low	3	11	3	Low	3	N/A	5	4	4	4	0	4
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 Groundwater (Ogallala)	15	N/A	4	Low	3	Low	3	12	3	Low	3	N/A	5	4	4	0	0	4
			Develop PDRA Transmission System	171	N/A	3	Low	3	Medium	2	12	3	Low	3	N/A	5	3	3	0	0	4
CRMWA			Replacement Wells	15	N/A	4	Low	3	Low	3	Varies	3	Low	3	N/A	5	4	4	0	0	4
			Roberts Co. Well Field	433	N/A	3	Low	3	Medium	2	Varies	3	Low	3	N/A	5	4	3	0	0	4
			Conjunctive Use with Lake Meredith	1,421	N/A	2	Positive	5	Medium	2	N/A	5	Low	3	N/A	5	5	4	0	0	4
Palo Duro River Authority			Develop PDRA Transmission System	249	N/A	3	Low	3	Medium	2	Varies	3	Low	3	N/A	5	3	3	25	0	4
Greenbelt MIWA			Donley Co. Well Field	94	N/A	3	Low	3	Low	3	Varies	3	Low	3	N/A	5	4	3	0	0	4

Chapter 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 2016 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 also shall 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 2016 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 F.

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 is 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 delivered water 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 Use of Groundwater	Brush Control	Conjunctive Use	Advanced Treatment	Precipitation Enhancement
Total dissolved solids (TDS)	+	+ / -	+ / -		+ / -	+	-	
Alkalinity	+					+		
Hardness	+					+		
Dissolved Oxygen (DO)	+	+ / -	+ / -		+ / -	+		
Nitrogen	+	+ / -	+ / -		+ / -	+	-	
Phosphorus	+	+ / -	+ / -		+ / -	+		
Radionuclides				-				
Metals [2]		+	- [2]	- [2]			- [2]	

[1] 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.
+ Positive Impact
- Negative Impact

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 through conservation may improve water quality.

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 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 in the immediate vicinity of the discharge in the receiving stream. Total loading to the stream (i.e. the amount of dissolved material in the waste stream) should not change significantly.

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.

6.1.3 Voluntary Transfers

Voluntary transfers generally involve the sale of water from one provider to another. In the PWPA, these transfers are expected to be primarily groundwater sources. The surface water sources in the region are fully utilized. Additional use of surface water is discussed under Conjunctive Use in Section 6.1.6.

Voluntary transfers of groundwater sources will have minimal impacts on water quality parameters assuming there is no relative change in the amount of groundwater pumped. Impacts on key water quality parameters for large increases in groundwater pumpage to meet contractual sales are discussed in Section 6.1.4 (New and/or Expanded Use of Groundwater Resources).

Pending the location and use of the water under voluntary transfers, changes in locations of return flows (if applicable) could impact flows in receiving streams. Such impacts would be site specific and could be positive or negative, pending the changes.

Generally, these impacts are relative to the quantities of water that are diverted or redistributed. Small quantities are likely to have minimal to no impacts, while large quantities may have measured impacts.

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 one strategy proposes to use water from the Ogallala aquifer which has low to moderate levels of TDS. The City of Wellington is the only entity with additional groundwater development in the Seymour aquifer. Naturally occurring salt seeps and high TDS waters are common in Collingsworth County 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 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 a recommended strategy for CRMWA. This strategy would conjunctively use surface water from Lake Meredith and groundwater from the Ogallala aquifer. It would allow CRMWA the ability to operate Lake Meredith in a manner that minimizes impacts to key water quality parameters in the lake 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 strategy that treats surface water or groundwater to drinking water standards and then pumps this water into an aquifer for storage. The water is 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 strategy, may allow a reservoir operator to minimize impacts to key water quality parameters while still providing users with sufficient supplies from stored groundwater. ASR is expected to have minimal impacts on key water quality parameters of water in the aquifer because the treated water being pumped into the aquifer will be of equal or great quality than the supply already in the aquifer. This strategy is recommended for CRMWA.

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.

6.1.9 Precipitation Enhancement

Precipitation enhancement is considered as part of the irrigation conservation strategies. These operations are already in progress, so there are no expected changes in water quality associated with this strategy.

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 voluntary transfer 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. The methodology for assessing the available supply of water rights for this regional water plan protects the existing supplies of all current and future 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 G, 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 model. 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. Under these assumptions, the TWDB's findings can be summarized as follows:

- It is estimated that not meeting the identified water needs would result in an annually combined lost income impact of approximately $219 million in 2020, increasing to $3.3 billion in 2070

- In 2020, the region would lose approximately 3,100 jobs, and by 2070 job losses would increase to approximately 52,300.

This study was conducted for each water use type (economic sectors) and was designed to be consistent across the water planning different 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, for many counties in the PWPA one of the economic drivers for other sectors (municipal and manufacturing) is the agricultural sector. There is concern that the socioeconomic study conducted for the PWPA does not consider these important interconnections with impacts to irrigated agriculture (i.e., forward linkage). An example of forward linkage is 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 backward linkages, including indirect effects and induced effects, such as changes in local spending among employees of the affected industries.

As required by statute, the socioeconomic 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 severe drought. 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 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 for included in those agreements where those amounts were known. In some cases there were insufficient supplies to meet existing contracts. In those cases, water 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 96 percent of the current water used in the region is from the Ogallala aquifer. Of the recommended strategies, 75 percent of the new water supply is associated with conservation in 2070 with irrigation conservation accounting for 74 percent. The remaining 25 percent is from additional development of the PWPA water resources.

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 do 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, as adopted by the GMAs, were honored for both currently developed supplies and potential future strategies. For the Ogallala aquifer the DFCs were considered both geographically and in time for irrigation and municipal water users.

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. Descriptions of the major strategies and the ways in which they minimize threats include the following:

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 123,011 acre-feet of water annually by 2020, reducing impacts on both groundwater and surface water resources. By 2070, the recommended conservation strategies savings total 488,140 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 500,000 acre-feet per year when including the plumbing code savings.

6.5.2 Wastewater Reuse

This strategy 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 Voluntary Transfers

Under this strategy, surface and ground water rights holders with surplus water supplies will provide water to areas with current or projected needs. This strategy is proposed for customers of wholesale water providers and expanded sales to manufacturing water users that are already purchasing from a water provider. As proposed, this strategy will only use water that is available on a sustainable basis and will not significantly impact key water quality parameters.

6.5.4 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 the 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.

6.5.5 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.

6.5.6 Conjunctive Use

Conjunctive use supports the management of surface water and groundwater sources to provide water necessary for beneficial use while protecting the individual water resource during periods of drought.

6.5.7 Aquifer Storage and Recovery

Aquifer Storage and Recovery represents an important operational solution for managing supplies and minimizing evaporation. CRMWA is planning to use ASR to store surplus supplies to be used during periods of high demands. This will provide operational flexibility by fully using the capacity in the pipeline from Roberts County. 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.

6.5.8 Advanced Treatment

The City of Wellington has a recommended long-term strategies for nitrate removal. Advanced treatment represents a potential additional source of water that could be used to augment existing freshwater sources.

6.5.9 Precipitation Enhancement

This strategy will support the water supplies in the Region by increasing stream flows and reducing irrigation demands due to increased rainfall.

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 2012 Census of Agriculture, the PWPA has approximately 1,774,000 acres of land in 2,276 farms. Approximately 71 percent of the harvested cropland occurred in seven counties (Carson, Dallam, Hansford, Hartley, Moore, Ochiltree, and Sherman). The 2012 Census saw a reduction of acreage in production and number of farms. 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 15 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 over 50 percent of the counties 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 are two counties in the PWPA that have 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. In Potter County, there is a considerable expected growth in County-Other that cannot be met through the development of local groundwater supplies. The City of Amarillo has limited means to serve unincorporated County-Other. It is expected that with the growth of this water user group, the municipal developments will incorporate into a city or town, at which time the City of Amarillo could serve them. 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 2016 Panhandle Water Plan collectively demonstrate compliance with these regulations. Appendix F presents a summary of the major components of the plan and references the regulations. The content of the 2016 Plan has been evaluated against this regulatory matrix.

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 were 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 industrial water needs in the PWPA. The plan assumes that this resource will be fully utilized to meet the growing demands of the power industry in the region.

The proposed conservation measures for the PWPA will continue to protect and conserve the State's resources for future water use.

Chapter 7 Drought Response Information, Activities, and Recommendations

7.1 Drought Conditions and Drought of Records

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.

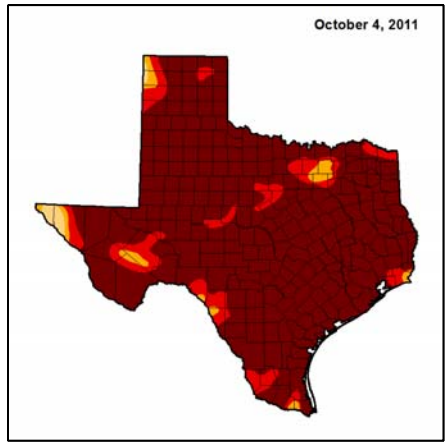
These definitions are not mutually exclusive, and provide valuable insight into the complexity of droughts and their impacts. They also help to identify factors to be considered in the development of appropriate and effective drought preparation and contingency measures.

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.



Drought Monitor, October 2011

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 but there still are areas in the PWPA that have severe drought conditions.

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 1950's. 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 located in the Canadian River Basin, are at less than 10 percent full as of October 2014. Greenbelt Reservoir, located in the Red River Basin, is approximately 15 percent full.

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 drought of records for the reservoirs in the PWPA are shown in Table 7-1.

Table 7-1: Drought of Records 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.

Drought of record conditions for run of the river supplies are typically evaluated based on minimum annual stream flows. Figure 7-1 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.

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 7-2 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 of these years occur during extreme drought.

Annual Streamflow
Figure 7-1

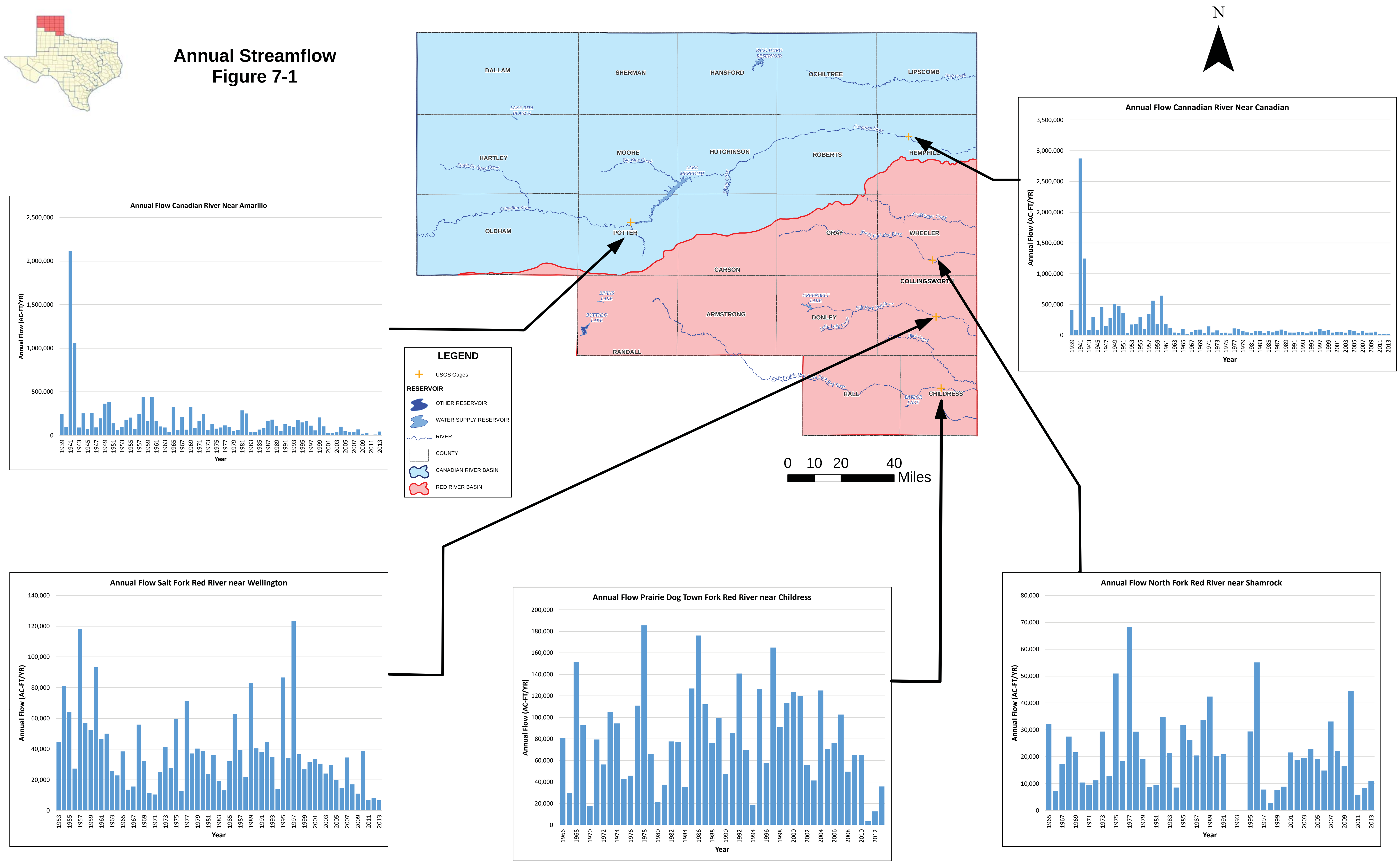


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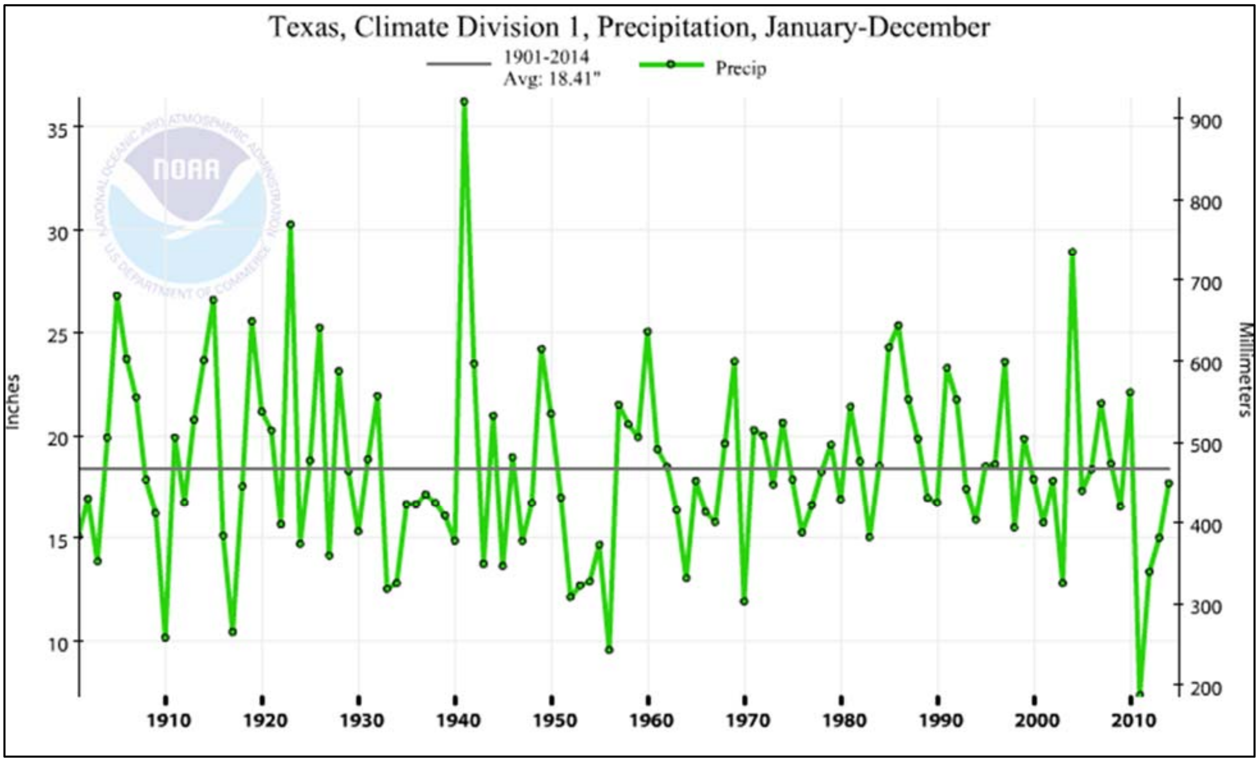
Figure 7-2: Historical Annual Precipitation for the High Plains of Texas

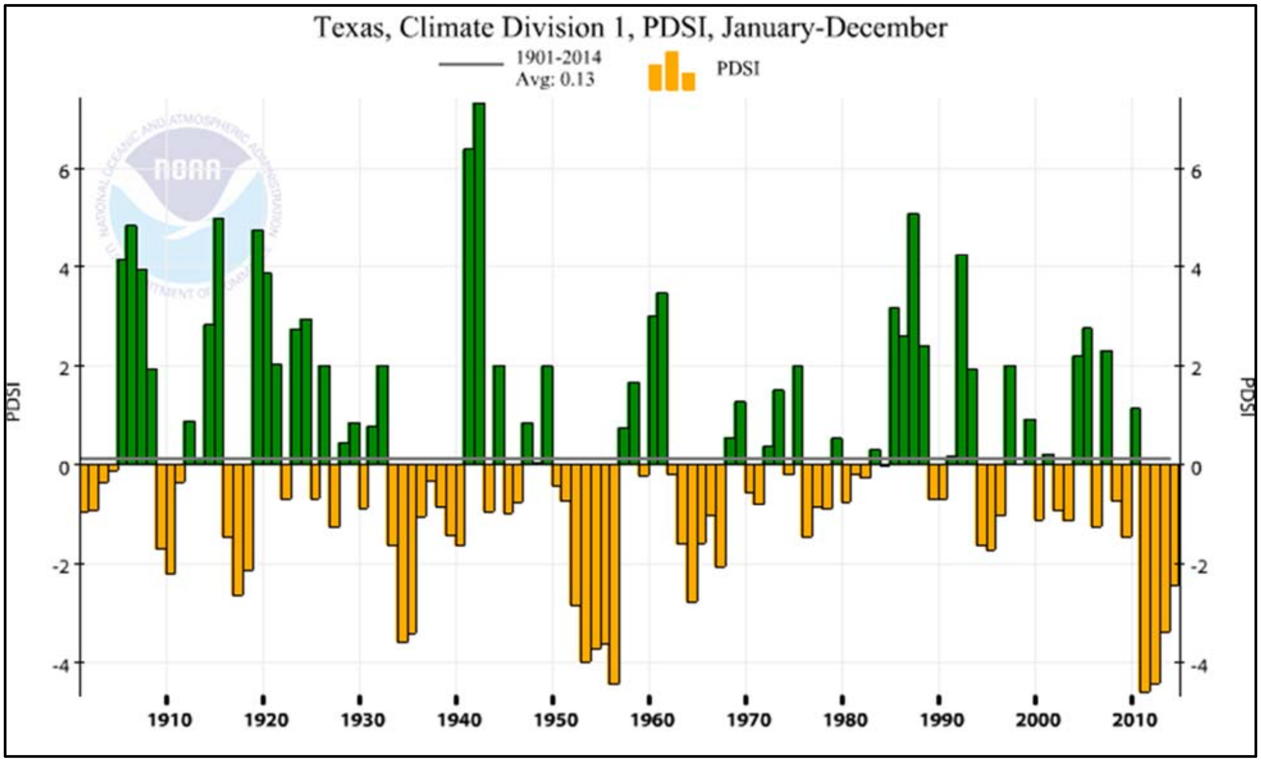


Source: NOAA website (http://www.ncdc.noaa.gov/cag/time-series/us)

Looking at the Palmer Drought Severity Indices over the same time period, Figure 7-3 clearly shows the drought impacts during the 1950s and again since 2011. The Palmer Drought Severity Indices (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 7-3: 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

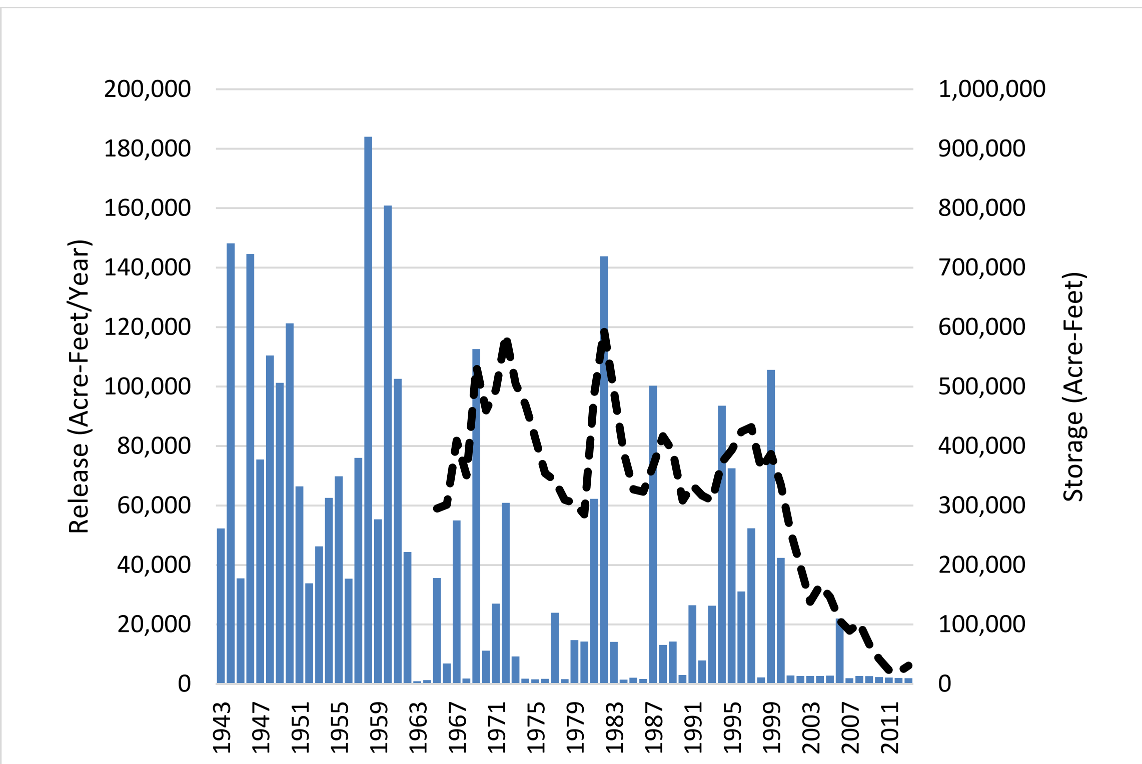
Drought is a major threat to surface water supplies in the PWPA and groundwater supplies that rely heavily on recharge (such as the Seymour aquifer). The Ogallala aquifer, which provides the majority of water supplies in the PWPA, is less impacted by reduced recharge associated with meteorological droughts. The Ogallala aquifer is greatly impacted by agricultural droughts because the demands on the water source can increase significantly. Over time the 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 7-4 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 7-4: 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. TCEQ now also requires all retail public water suppliers serving less than 3,300 connections to prepare and adopt drought contingency plans by no later than May 1, 2009. All drought contingency plans 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, 2014.

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 Drought Contingency Plans and readiness to implement the Drought Contingency Plans as necessary. These drought plans include specific water savings goals and measure 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.

Drought contingency plans 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 (set 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 as a percentage of total supply or total delivery capacity. 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 WWPs' Drought Plans.

Eight drought contingency plans were submitted to the PWPG during this round of planning. Eight 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 one user based trigger actions on well levels, five based actions on storage reservoir levels and seven 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 drought contingency plans submitted to the PWPG.

Table 7-2: Type of Trigger Condition for Entities with Drought Contingency Plans

Entity	Type of Trigger Condition	
	Demand	Supply
Amarillo	X	X
Borger	X	X
Canyon		X
CRMWA		X
Dalhart	X	
Dumas	X	
Greenbelt	X	X
Higgins	X	X
Palo Duro RA		X
Pampa		X
Perryton	X	
Red River Authority		X
Shamrock	X	
Turkey		X
Wellington	X	
White Deer	X	

As of November 1, 2014, there are 14 entities that have initiated their drought contingency plan. Of these entities, all but the City of Wellington and Falcon Water Utility in Randall County receive water supplies from the Greenbelt MIWA. There are also three entities that are currently implementing voluntary drought measures in anticipation of the drought continuing. These entities are the Cities of Claude, Canyon and Dumas.

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 of the groundwater users have expanded groundwater production or are planning to develop additional groundwater in response to the current 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 Panhandle Region Planning Area (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

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 15 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., and Sanford (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.

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
Borger	Sanford
	Stinnett
	WRB Refining

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.

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.

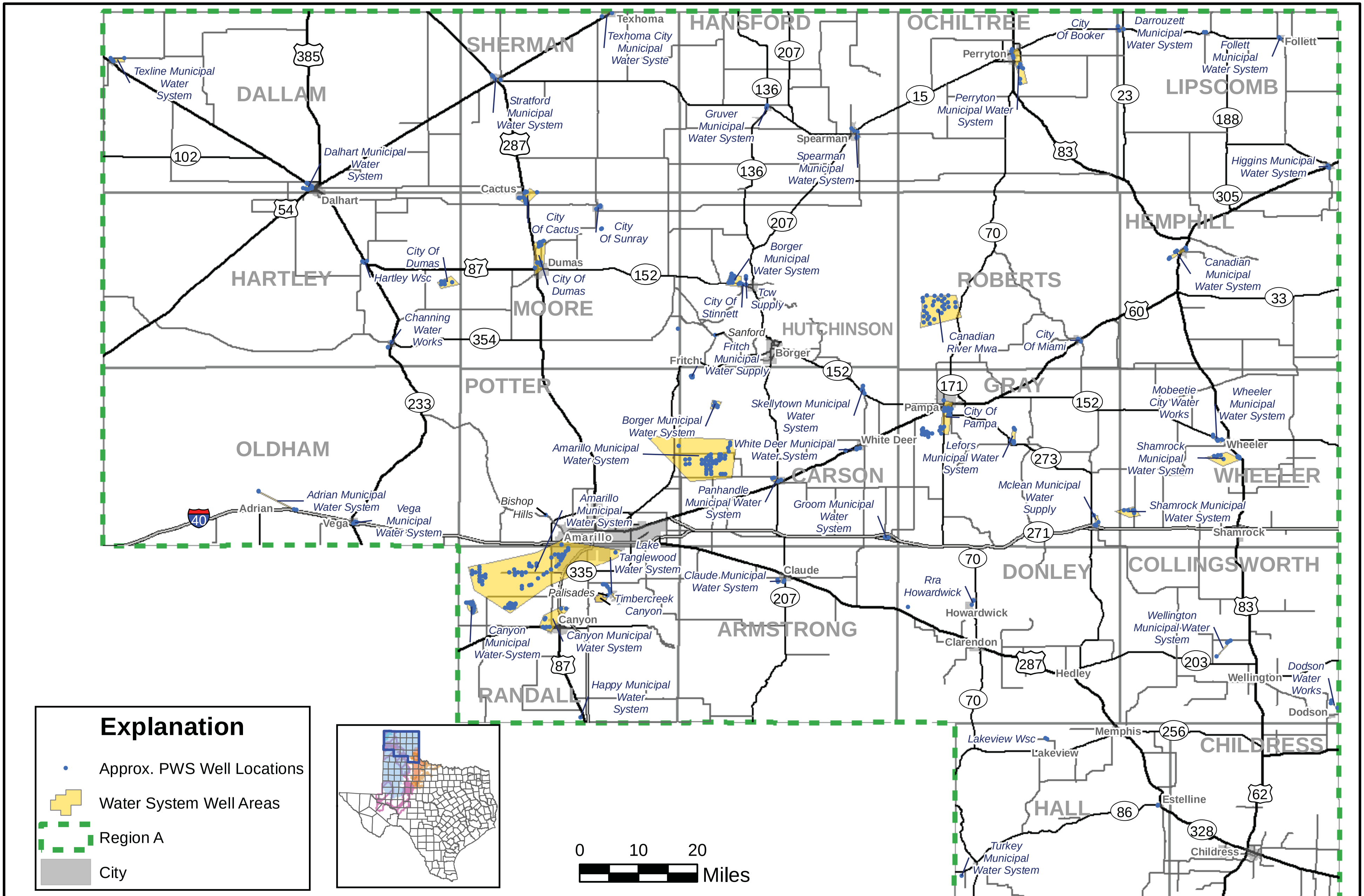
This section provides potential solutions that should act as a guide for municipal water users that are most vulnerable in the event of a loss of supply. This review was limited and did not require technical analyses or evaluations following in accordance with 31 TAC §357.34.

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 7-5 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.



Region A - Panhandle Regional Water Planning Area

Water Supply Systems

FN JOB NO	
FILE	RegA_systems
DATE	April, 2015
SCALE	
DESIGNED	JJR
DRAFTED	LAS

FIGURE 7 - 5

Table 7-5: Emergency Responses to Local Drought Conditions in the PWPA.

Entity											Implementation Requirements		
Water User Group Name	County	2010 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	1,345	496	▪					▪	▪			
	Ochiltree	9	7	▪					▪	▪			
Cactus	Moore	3,000	985	▪	▪	▪			▪	▪			
Canadian	Hemphill	2,340	786	▪					▪				
Claude	Armstrong	1,369	358	▪	▪	▪			▪	▪			
Fritch	Hutchinson	2,300	437	▪					▪	▪		CRMWA	
	Moore	34	2	▪					▪				
Groom	Carson	595	179	▪					▪	▪			
Gruver	Hansford	1,178	310	▪					▪	▪			
Happy	Randall	100	11	▪	▪	▪			▪				
Lake Tanglewood	Randall	1,174	319	▪	▪	▪			▪	▪		CRMWA	
McLean	Gray	802	205	▪		▪			▪	▪			
Miami	Roberts	633	224	▪					▪	▪			
Panhandle	Carson	2,626	572	▪					▪	▪			
Shamrock	Wheeler	1,963	350	▪		▪			▪	▪			
Spearman	Hansford	3,307	672	▪					▪	▪			
Stinnett	Hutchinson	2,001	446	▪			▪			▪		Phillips; Tri-City Water Company	▪

Entity											Implementation Requirements		
Water User Group Name	County	2010 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	2,365	470	▪					▪	▪			
Sunray	Moore	2,550	504	▪					▪	▪			
TCW Supply Inc.	Hutchinson	2,139	738	▪			▪		▪	▪		Phillips	▪
Texline	Dallam	607	227	▪	▪	▪			▪	▪			
Vega	Oldham	1,017	272	▪	▪	▪			▪				
Wellington	Collingsworth	2,241	525	▪					▪				
Wheeler	Wheeler	1,374	507	▪					▪	▪			
White Deer	Carson	1,076	106	▪					▪	▪	Pump Station & Treatment	Groom	
Dalhart	Dallam	5,518	1,815	▪					▪	▪			
	Hartley	2,754	854	▪					▪	▪			
County-Other[1]													
Skellyton	Carson	619		▪					▪	▪			
Adrian	Oldham	166		▪	▪	▪			▪				
Bishop Hills	Potter	193		▪	▪	▪			▪				
Channing	Hartley	363		▪	▪	▪			▪	▪			
Darrouzett	Lipscomb	350		▪					▪	▪			
Dodson	Collingsworth	109		▪		▪			▪				

Entity											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 7-5 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 in Edwards Aquifer near San Antonio. 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 are 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 reservoir 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. Nine of the 42 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 this option as viable for all 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 Drought Contingency Plan. 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 Drought Contingency Plans 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, 2014 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 Drought Contingency Plan on July 14, 1999 and the same was revised on January 14, 2009. 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 declining since 2000. The triggers and actions for CRMWA are shown in the following table. 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)
Moderate	3 to 5	Above and Cities are to initiate appropriate stage of DCP
Severe	> 5	Above
Critical/ Emergency	> 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 Drought Contingency Plan 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	Voluntary measures to achieve 10% use reduction
Moderate	Water level = 2,634; Demand > 7.5 MGD	20% use reduction; reduce customer storage to 75% capacity; initiate customer's Stage 2 of DCP
Severe	Water level = 2,631; 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; 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 River Authority adopted a conservation plan for Palo Duro Creek 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	Communication, voluntary outdoor water schedule
Moderate	2,864 < Water level < 2,876	10% reduction in deliveries, request mandatory limits in outdoor water use
Severe	Water level < 2,864	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 Ground Water Supply

Both run-of-river and ground water 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 Drought Contingency Plans that are specific to their water supplies. Other water users, such as agricultural or industrial users, may not have Drought Contingency Plans. 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 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 Palmer Drought Index.

Table 7-9: Drought Severity Classification

Category	Description	Possible Impacts	Palmer Drought 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-the-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 Drought Contingency Plan, 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 drought contingency plans were developed for the PWPG and are available on line through the PRPC 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 Recommendations

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 minimized impacts to people and resources. Region A 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.

- Follow the outline template for Chapter 7 provided to the regions by the Texas Water Development Board.

- Evaluate the drought preparedness impacts of unanticipated population growth or industrial growth within the region over the planning horizon.

To meet these recommendations, Region A has developed this chapter to correspond with the sections of the outline template. The planning group has also considered unanticipated population or industrial growth over the planning period in the development of this plan. Furthermore, Region A 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. Lastly, this kind of uncertainty was accounted for in the Region A plan through extensive coordination with local water providers.

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

Source, Source Manager and DCP Triggers

Source	Manager[1]	PWPA User
Lake Meredith	CRMWA	Amarillo
		Borger
		Pampa
		Manufacturing (Hutchison County)
Greenbelt Lake	GMIWA	Childress County-Other
		Childress
		Donley County-Other
		Clarendon
		Hall County-Other
		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)
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)
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)
Dockum Aquifer - Dallam County		Irrigation (Dallam County)
Dockum Aquifer - Hartley County		Livestock (Hartley County)
Dockum Aquifer - Moore County		Irrigation (Moore 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)
		Livestock (Potter County)
Dockum Aquifer - Randall County	Happy	County-Other (Randall County)
		Livestock (Randall County)
Ogallala Aquifer - Armstrong County	Claude	County-Other (Armstrong County)
		Irrigation (Armstrong County)
		Livestock (Armstrong County)
		Mining (Armstrong County)
Ogallala Aquifer - Carson County	Amarillo	County-Other (Carson County)
	Groom	Irrigation (Carson County)
	Panhandle	Livestock (Carson County)
	Skellytown	Manufacturing (Carson County)
	White Deer	Mining (Carson County)
Ogallala Aquifer - Collingsworth County		Irrigation (Collingsworth County)
		Livestock (Collingsworth County)
Ogallala Aquifer - Dallam County	Dalhart	County-Other (Dallam County)
	Texline	Irrigation (Dallam County)
		Livestock (Dallam County)

Source	Manager[1]	PWPA User
Ogallala Aquifer - Donley County		County-Other (Donley County)
		Irrigation (Donley County)
		Livestock (Donley County)
		Mining (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)
		Steam Electric Power (Gray County)
Ogallala Aquifer - Hall County	Memphis	County-Other (Hall 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)
	Dalhart	Irrigation (Hartley County)
		Livestock (Hartley County)
		Manufacturing (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)
	Fritch	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)
		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)
		Steam Electric Power (Moore County)
Ogallala Aquifer - Ochiltree County	Booker	County-Other (Ochiltree County)
	Perryton	Irrigation (Ochiltree County)
		Livestock (Ochiltree County)
		Mining (Ochiltree County)
Ogallala Aquifer - Oldham County	Vega	County-Other (Oldham County)
		Irrigation (Oldham County)
		Livestock (Oldham County)
		Mining (Oldham County)
Ogallala Aquifer - Potter County	Amarillo	County-Other (Potter County)
		Irrigation (Potter County)
		Livestock (Potter County)
		Manufacturing (Potter County)
		Mining (Potter County)

Source	Manager[1]	PWPA User
Ogallala Aquifer - Randall County	Amarillo	County-Other (Randall County)
	Canyon	Irrigation (Randall County)
	Lake Tanglewood	Livestock (Randall County)
		Manufacturing (Randall County)
		Mining (Randall County)
Ogallala Aquifer - Roberts County	CRMWA	Amarillo
	Miami	Borger
		Pampa
		County-Other (Roberts County)
		Irrigation (Roberts County)
		Livestock (Roberts County)
		Mining (Roberts County)
Ogallala Aquifer - Sherman County	Stratford	County-Other (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)
Other Aquifer - Collingsworth County		County-Other (Collingsworth County)
		Livestock (Collingsworth County)
Other Aquifer - Donley County		Livestock (Donley County)
Other Aquifer - Hall County		Livestock (Hall County)
		Mining (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)
		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			Review DCP	Implement appropriate stage of DCP	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

Attachment 7-2: Summary of Drought Contingency Plans 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.
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	
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.
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

Attachment 7-2: Summary of Drought Contingency Plans in PWPA

Water Provider	Water Sources	Stage 1 Trigger	Response	Stage 2 Trigger	Response	Stage 3 Trigger	Response	Stage 4 Trigger	Response
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.
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.
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

Chapter 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.

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.

TPWD has compiled a listing of potential ecologically significant stream segments located in PWPA. These stream segments were selected by TPWD because of the above-listed criteria.

As part of the planning process, fourteen segments were evaluated by the PWPG for potential recommendation as unique stream segments. After careful consideration of the unknown consequences of recommendation, the PWPG makes no recommendations for river and stream segments of unique ecological value. The following stream segments were presented to the planning group for consideration by TPWD:

- 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

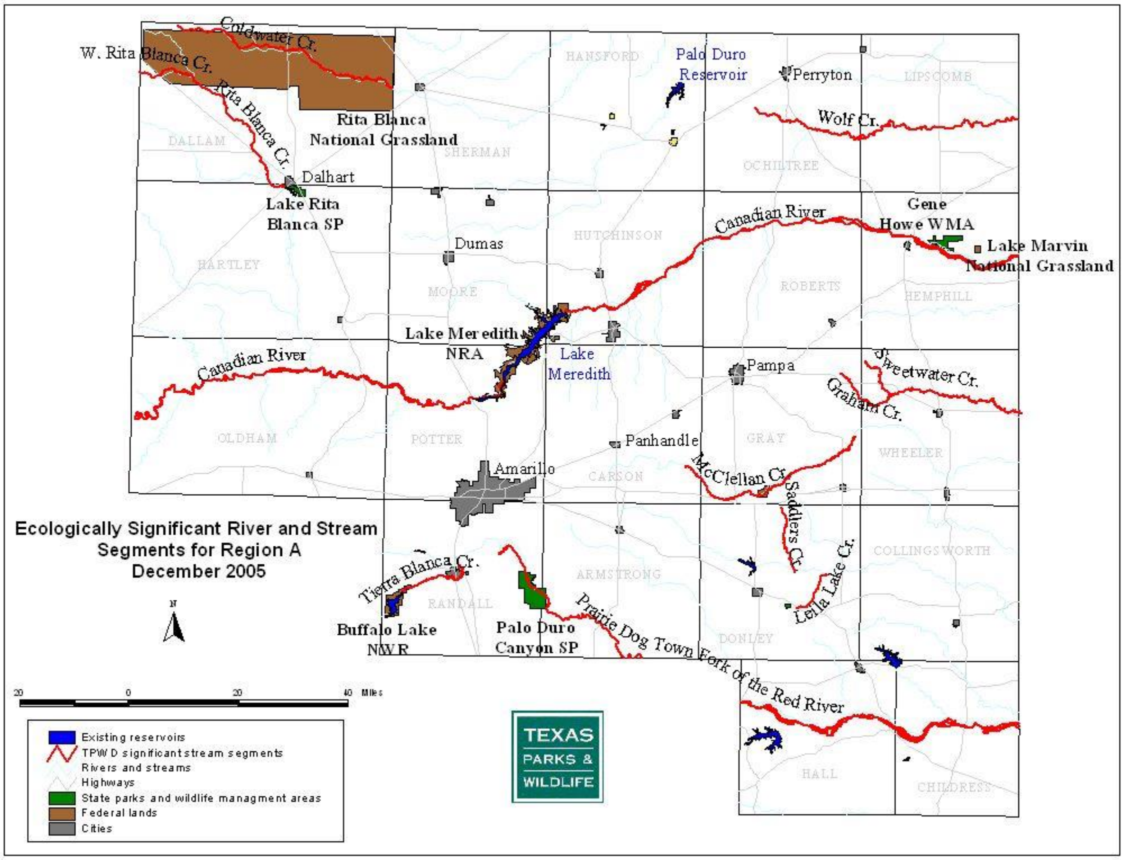
8.2 Sites of Unique Value for the Construction of Reservoirs

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.

Figure 8-1: Ecologically Significant River and Stream Segments in the PWPA



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 2016 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

Consider requiring development of the State Water Plan every 10 years instead of every five years, with sponsorship of special studies between planning cycles. This would allow full updates of the State Water Plan following updated population census. It also may better align the regional water plans with the schedule specified for the GMA process, which is critical to defining the amount of groundwater supplies that are available for regional planning purposes.

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. In order to create an equitable situation with regard to groundwater management, these areas should be included in a local district contained within the regional planning area.

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 utilizing 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 clarity on the ownership of brackish groundwater. Based on current groundwater law it is unclear who has ownership of brackish groundwater. The PWPG would like the legislature to address this issue of ownership to provide greater clarity.

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.

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 those "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 appropriate 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 at least 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.

TWDB should allow groundwater supplies in the regional water plans to exceed the Modeled Available Groundwater (MAG) if the RWPG obtains written permission from a groundwater conservation district to allow a strategy that uses more groundwater than the MAG.

- This approach assumes that the strategy is consistent with the management plan of the GCD, but allows for minor needs to be covered without excessive administrative actions.
- Allows a GCD to apply local knowledge to account for variations in permitting approaches and usage patterns, while honoring the Desired Future Conditions (DFCs) of the aquifer.
- Approach could also be used in areas with no GCDs if the RWPG demonstrates compliance with the DFCs.

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. Recharge rates are near zero for most of the area over the Ogallala aquifer with slopes around playas having the highest rates. 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 a ten year period to the extent that regional lakes are at all-time lows. It is recommended that TCEQ extend the current Water Availability Models for the Canadian and Red River Basins to capture the current drought in the PWPA.

Prioritization of projects in the State and Regional Water Plans should only consider projects with capital costs. Projects without capital costs would likely seek funding from the State.

Chapter 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 2016 Regional Water Plan. In order 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 2016 Regional Water Plan.

The IFR survey and report was sent to entities during the summer of 2015 and the results are incorporated in this chapter. Of the 60 entities surveyed, 9 returned the IFR survey while an additional two entities responded to the PWPG Water Management Strategy Survey. This represents a response rate of approximately 15 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 recently adopted 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 Distress Areas (EDAP)

Both grants and 0% 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 new 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 fund 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 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 wholesale 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;

and 3) 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 July and received until the middle of August. 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	$261,142,000
Booker	$1,560,400
Borger	$29,463,900
Cactus	$18,191,900
Canadian	$2,294,900
Canyon	$11,614,100
Childress	$4,098,000
Claude	$3,612,900
County-Other	$30,442,800
CRMWA[1]	$342,749,050
Dalhart	$4,197,900
Dumas	$12,544,700
Fritch	$1,367,000
Greenbelt MIWA[1]	$12,617,000
Gruver	$2,350,200
Irrigation	$55,637,900
Lake Tanglewood	$3,468,400
Manufacturing	$11,990,800
McLean	$1,459,300
Memphis	$1,653,900
Miami	$373,200
Pampa	$8,618,100
Panhandle	$4,777,600
Perryton	$10,584,100
Shamrock	$1,301,900
Spearman	$3,665,600
Stinnett	$2,120,200
Stratford	$1,489,900

Entity	Total Capital Cost for Recommended Strategies
Sunray	$5,348,400
TCW Supply Inc.	$5,236,900
Texline	$1,520,500
Vega	$608,100
Wellington	$7,803,400
Wheeler	$2,795,600
White Deer	$704,400
PWPA	$869,404,950

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

Ten of the sixty entities surveyed responded. The total funding required by the responding entities was about $288 million dollars, which accounts for about 33 percent of the total costs for recommended strategies in the PWPA. Of the responding entities about 16 percent of the funds will be needed for planning and acquisition. The remaining 84 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 H.

Chapter 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 22 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, their respective interest groups, and their principle county of interest. Table 10-1 also lists the six former members of the PWPG who also participated in the planning process for the 2016 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	Janet Guthrie	City of Canadian/Hemphill County	Hemphill
Counties	Judge Vernon Cook	Retired (Roberts County)	Roberts
Municipalities	Emmett Autrey	City of Amarillo	Potter and Randall
	David Landis	City of Perryton	Ochiltree
Industries	Bill Hallerberg	Retired (Potter County)	Potter
	Jay Weber Sandy Keys Denise Jett (Ret)	ConocoPhillips	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 Grady Skaggs (Ret)	Consultant	Serves entire region
	Tonya Kleuskens Cole Camp (Ret)	Farmer	Potter
Small Businesses	Rusty Gilmore	Water Well Driller	Dallam
Electrical Generating Utilities	Rick Gibson (Ret)	Xcel Energy	Potter (serve entire region)
River Authorities	Jim Derington	Palo Duro RA	Hansford
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
	Kent Satterwhite John Williams (Ret)	Canadian River Municipal Water Authority	Hutchinson and 3 member cities in the region
Water Utilities	Dean Cooke Charles Cooke (Ret)	TCW Supply	Hutchinson
Groundwater Management Areas	Danny Krienke	GMA#1	Ochiltree and 17 other counties
	Amy Crowell	GMA#6	Collingsworth, Childress and Hall
Higher Education	John Sweeten	Texas A&M AgriLife Research and Extension Center at Amarillo	Entire Region

Ret – Retired during the planning cycle.

In addition to the 23 voting members, the PWPG has six key 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:

Table 10-2: Panhandle Water Planning Group Other Key Stakeholders

PWPG Member	Position	Interest Group	Membership
Sarah Backhouse Doug Shaw (former)	Texas Water Development Board (TWDB)	TWDB (Rules)	Non-Voting
Matt Williams	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
Charles Munger	Texas Parks & Wildlife	TPWD (Rules)	Non-Voting
Troy Headings Cleon Namkin (Deceased)	USDA/NRCS	Agriculture	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 excellent throughout the process. Public Participation opportunities were afforded to the region through the following broad categories.

Special Regional Water Planning Presentations – Working primarily through the Panhandle Regional Planning Commission (PRPC), the PWPG provided speakers to interest groups throughout the planning process. PWPG members also provided presentations to various civic organizations throughout the planning process. Presentations were given throughout the region and even into adjoining regional water planning regions.

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 ahead of the scheduled meetings and all presented meeting materials are made available on the site within 5 workings of each meetings' 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.

Public Information Meetings – The PWPG held all meetings in accordance with the open meetings act and encouraged public attendance at the meetings.

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 9, 2011.

Required Public Hearing –The public hearing on the Initially Prepared Water Plan was held at the Texas A&M AgriLife Research and Extension Center in Amarillo on June 22, 2015. Members of the public and PWPG were in attendance. There were no public comments submitted at the meeting.

Panhandle Water Planning Group Meetings – The PWPG conducted numerous public meetings over the past five years as necessary to develop the 2016 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, wholesale water providers and groundwater conservation districts. One survey was sent to all municipal water users, wholesale 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 2011 water strategies, potential emergency interconnections, proposed 2016 water strategies and potential financing options for strategies that are included in the 2016 Plan.

10.4 Panhandle Water Planning Group Functions

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 777 non-reimbursed hours of time. In addition, PWPG members have traveled over 32,000 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 $56,000 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 60 month planning process, the PWPG has conducted 15 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 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 and fourth 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 three 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 10 meetings in the same 60 month 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.

Early in the fourth 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 this one time during the fourth cycle of regional water planning.

The Agriculture Committee met five times in the fourth 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. Middle Agriculture Committee meetings focused on how to prioritize the Agriculture Strategies in the 2011 Regional Plan including potential grouping of strategy suites. The later Agriculture Committee meetings focused on the development of Agriculture Strategies for the 2016 Panhandle Regional Water Plan.

The Executive Committee of the PWPG has served multiple functions though out the fourth planning cycle. The Executive Committee has continued to function in the role of conducting administrative reviews for member nominations 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 fourth 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 and Public Participation activities. Throughout the five year process the Executive Committee met 12 times over the 60 month 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 $73,000 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. The Initially Prepared Plan (IPP) was considered for approval on April 20, 2015.

10.9.1 Public Hearing

The PWPG conducted the required public hearing at 6 PM on June 22, 2015. The hearing was held at the Texas A&M AgriLife Research and Extension Center facility in Amarillo, Texas. All required notifications for the hearing were posted prior to the 30-day cut-off. Over 200 direct mail notices were sent to interested parties, interest groups, agencies, individuals, water rights holders, public utilities, and local officials. 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. Attendance at the hearing totaled over 20 individuals (including 6 PWPG members). Oral comments were received at the hearing and written comments were received through September 23, 2015. No official oral or written comments were given at the hearing.

10.9.2 Initially Prepared Plan Adoption

The PWPG conducted a formal Planning Group meeting prior to the Public Hearing on April 20, 2015. Nineteen 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.

10.9.3 Response to Comments

The PWPG received comments on the Initially Prepared Plan from the TWDB and Texas Parks and Wildlife Department (TPWD). The comments from TPWD were not substantive and no changes were made to the Panhandle Water Plan as a result of these comments. The TWDB provided 18 comments that are required by rule to be addressed and seven comments for consideration. These comments are included in Appendix I.

The PWPG carefully considered the comments and proposed responses at the meeting held on November 17, 2015. Formal responses to all comments were made and modifications to the Initially Prepared Plan were incorporated into the final plan. No other comments were received. The comments received and the approved responses are included in Appendix I.

10.9.4 Final Regional Water Plan Adoption

The PWPG adopted the final Regional Water Plan for the PWPA on November 17, 2015, and approved for submission to the TWDB on the same date. The Plan was adopted by a unanimous vote.

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.

Chapter 11 Implementation and Comparison to Previous Regional Water Plan

11.1 Introduction

One of the new requirements for the 2016 Regional Water Plan is the inclusion of a chapter providing a comparison of the current Regional Water Plan to the previous Plan, and a discussion of the differences between the two. This chapter includes a discussion on the major differences between the two Plans and a description of strategies that have been implemented since the publication of the 2011 Plan.

11.2 Differences Between Previous and Current Regional Water Plan

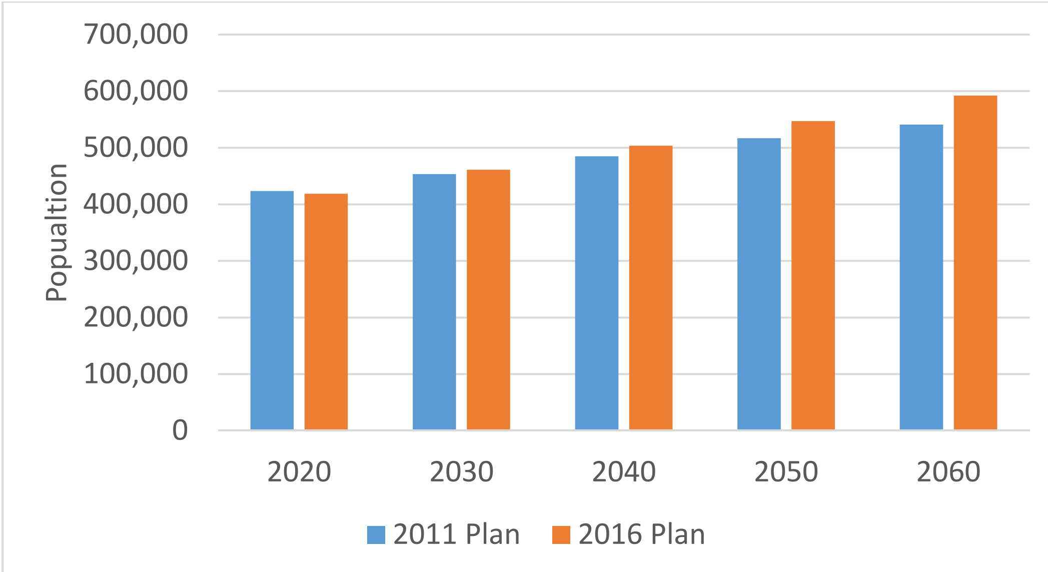
The following sections specifically address changes between the 2011 and 2016 Plan in:

- 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 WWPs, and
- Recommended and alternative water management strategies.

11.2.1 Population Projections

Population projections for the 2016 Plan are based on the 2010 Census and expected growth associated with major metropolitan areas and future oil and gas activities. The 2011 population projections were based on the 2000 Census and were not reflective of recent oil and gas activities. As a result, population projections in the 2016 plan are about the same in 2020 with slightly higher population in the latter decades (Figure 11-1). One of the impacts of changes in population included the change in Water User Groups (WUGS) in the PWPA. Two WUGs in the 2011 Plan are no longer WUGs in the 2016 Plan, Lefors (population < 500) and Hi-Texas Water Company (incorporated into county other). One Wholesale Water Provider (WWP), Mesa Water Inc. is no longer a WWP since their water rights were purchased by the Canadian River Municipal Water Authority (CRMWA).

Figure 11-1: Comparison of PWPA Population



11.2.2 Water Demand Projections

Water demands in the PWPA for the 2016 Plan increased in comparison to the 2011 Plan (Figure 11-2) by approximately 8 to 14 percent. However, a pattern of overall decline continues to be projected throughout the 50 year analysis. Irrigation, manufacturing and municipal water demands are driving these increases (Table 11-1). The 2016 Plan shows lower water demands for mining, livestock and steam electric power.

Figure 11-2: Comparison of PWPA Water Demand

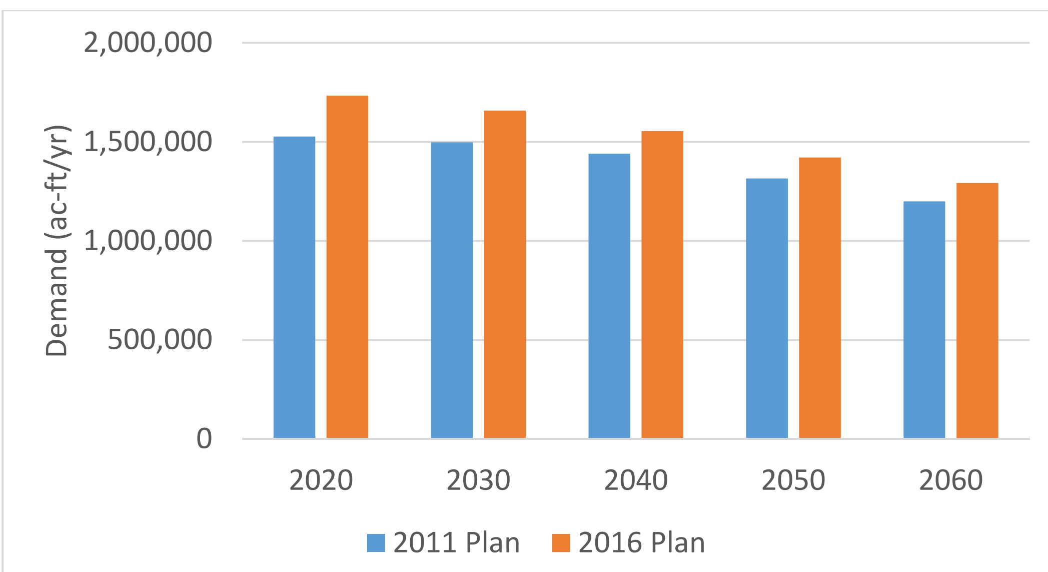


Table 11-1: Changes in Projected Demands from the 2011 Plan to the 2016 Plan by Use Type

Use Type	Changes in Projected Water Demands (ac-ft/yr)				
	2020	2030	2040	2050	2060
Irrigation	202,097	154,866	109,052	99,825	83,814
Livestock	-2,813	-4,062	-4,833	-5,718	-6,718
Manufacturing	2,420	2,591	2,757	2,903	3,112
Mining	-2,735	-3,309	-4,473	-6,030	-6,546
Municipal	7,747	9,603	11,600	14,511	19,620
Steam Electric Power	0	-200	-200	-200	-213
Total	**206,716**	**159,489**	**113,903**	**105,291**	**93,069**

Note: Negative numbers indicate lower demand in the 2016 Plan and positive numbers show higher demand in the 2016 Plan.

Projected demands for irrigation increased the most of all water use types. Table 11-2 identifies changes in irrigation demand by county. The counties with the greatest increases in irrigation demand are Dallam, Hansford, Hartley, and Sherman counties. These counties accounted for greater than 90 percent of the increase in irrigation demand in the 2016 Plan. These four counties are significant agricultural centers accounting for 45 percent of the harvested cropland in the region based on the 2012 Census of Agriculture. Counties in the southwest part of the region show lower irrigation demands than projected in the 2011 Plan.

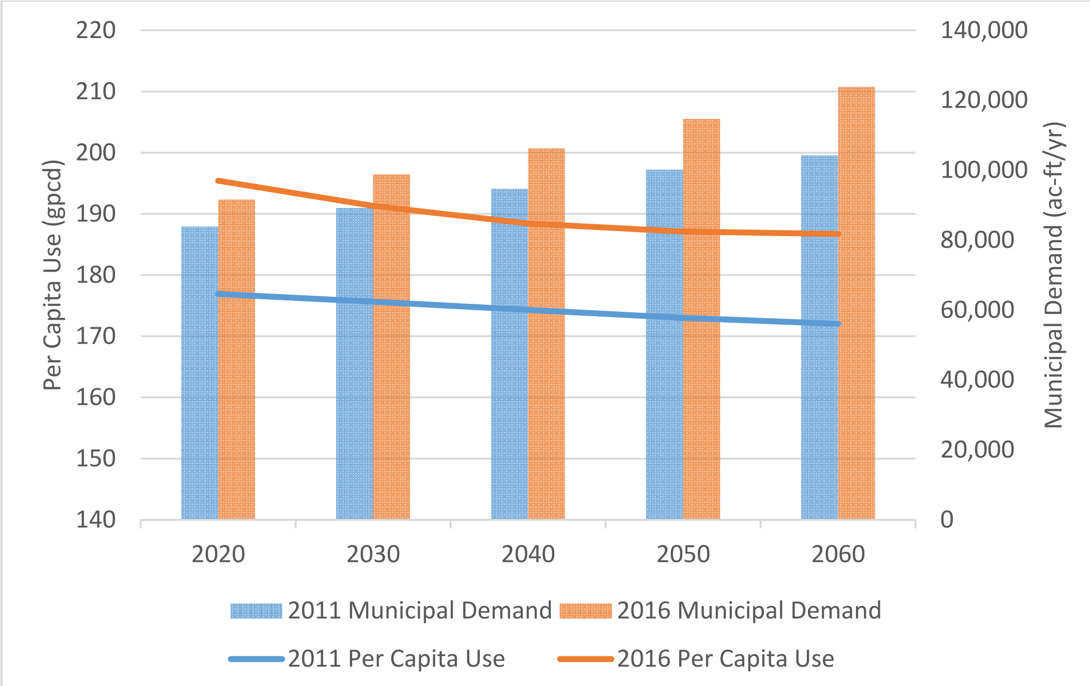
Table 11-2: Changes in Projected Irrigation Demands from the 2011 Plan to the 2016 Plan

County	Change in Projected Irrigation Demand (ac-ft/yr)				
	2020	2030	2040	2050	2060
Armstrong	-494	-554	-597	-531	-465
Carson	6,472	4,856	3,319	6,988	2,582
Childress	1,789	1,676	1,533	1,363	1,192
Collingsworth	-3,964	-3,960	-3,863	-3,434	-3,005
Dallam	86,549	72,882	58,608	52,095	45,584
Donley	-5,596	-5,568	-5,410	-4,809	-4,208
Gray	881	319	-205	-182	-159
Hall	-597	-597	-581	-517	-452
Hansford	19,875	14,975	10,122	8,998	7,873
Hartley	63,717	52,856	41,633	37,007	32,382
Hemphill	202	161	119	106	93
Hutchinson	37	-1,077	-2,073	-1,844	-1,613
Lipscomb	4,463	3,944	3,373	2,999	2,624
Moore	8,027	3,526	-691	-614	-538
Ochiltree	5,404	3,573	1,807	1,606	1,405
Oldham	23	-26	-70	-62	-54
Potter	-2,270	-2,233	-2,143	-1,904	-1,667
Randall	-1,900	-2,135	-2,299	-2,044	-1,788
Roberts	319	143	-24	-21	-19
Sherman	20,445	13,320	7,774	5,763	5,043
Wheeler	-1,285	-1,215	-1,280	-1,138	-996
Total	**202,097**	**154,866**	**109,052**	**99,825**	**83,814**

Note: Negative numbers indicate lower demand in the 2016 Plan and positive numbers show higher demand in the 2016 Plan.

Projected municipal water demand continues to increase with each plan. The 2016 Plan shows additional growth over time with over 19,000 acre-feet per year higher demand in 2060 (Table 11-1). Some of this higher demand is associated with higher per capita water use. Due to the drought in 2011, the starting per capita water use in the PWPA was higher for most municipal water users. As a result the regional average per capita water use in 2020 for the 2016 Water Plan was 195 gallons per person per day. For the 2011 Plan, the regional average was 177 gallons per person per day. The rate of decline over time in per capita water use was about the same (Figure 11-3).

Figure 11-3: Comparison of Projected Per Capita Use and Municipal Demand



11.2.3 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 Plan and continue to be in drought of record conditions. Since the 2011 Plan, the region has experienced record low inflows into area lakes and streams. This has continued to impact the water supplies from these sources. It also impacted the ability to accurately assess the reliable supply from these sources. As a result, alternative approaches to yield analyses were conducted for Lake Meredith and Greenbelt Reservoir. These analyses used extend hydrology and a conditional reliability model approach. This approach provides an estimate of how the reservoir will respond to continuing drought conditions. A similar conditional reliability analysis was conducted for Lake Meredith in the 2006 Water Plan and retained for the 2011 Plan. However, the earlier analysis did not capture the low flows experienced since 2004.

Groundwater modeling assumptions are very different for some aquifers with the development of Desired Future Conditions (DFCs) for use in the 2016 Plans. For the Ogallala aquifer, the DFCs for the 2011 Plan and 2016 Plan are basically the same. The resulting availability differs due to the use of the more recent Northern Ogallala Groundwater Availability Model (GAM) for the development of the Modeled Available Groundwater (MAGs), and the methodology developed by the TWDB to develop the MAG. In the 2011 Plan, water availability in the Ogallala was constrained by the DFC in both time (year) and space (per square mile grid cell). The modeling employed the 2004 Ogallala GAM (Dutton) which had different red bed data. For the 2016 Plan, the time constraint was the 50-year simulation and the spatial constraint was either at a county or multi-county level. This results in different availabilities for the Ogallala both in time and location. In the 2011 plan, the availability for the Seymour and minor aquifers were consistent with the DFCs set for the Ogallala: have 50 percent storage remaining in 50 years. As part of the joint planning process, different DFCs were adopted for these resources.

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. As a result, the availability of supplies were drastically reduced from the 2011 Plan estimates.

For the Seymour aquifer the DFC was set as 50 percent of current volume in storage reaming in 50 years for Pods 1,2 and 3 (Mesquite GCD) in Childress, Collingsworth and Hall Counties. The DFC was set for total decline in water levels to be no more than 1 foot over 50 years for Pods 3 and 4 (Gateway GCD) in Childress County. The impact of these DFCs led to small increases in availability in the 2016 Plan.

For the Blaine aquifer the DFC was 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 these DFCs have led to increases in availability of over 80,000 acre-feet per decade for the Blaine in the 2016 Plan.

11.2.4 Groundwater Availability

Overall groundwater availability is about the same for both the 2011 and 2016 Plans (Figure 11-4). This results primarily from increases of availability in the Ogallala and Blaine aquifers, and reductions in availability from the Dockum aquifer (Table 11-3). Table 11-4 shows the change in availability in the Dockum aquifer between the 2011 Plan and the 2016 Plan.

While the overall availability across the PWPA has increased slightly in the 2016 Plan, the distribution of supplies across the region differ (Figure 11-5). Declines in availability in the counties in the southern portion of the PWPA are mostly attributed to declines in the Dockum aquifer and reduced thickness along the fringes of the Ogallala aquifer. Generally, increases in supplies in the northern portion of the PWPA are a results of increased Ogallala aquifer availability.

Figure 11-4: Comparison of Groundwater Availability from the 2011 and 2016 Plans

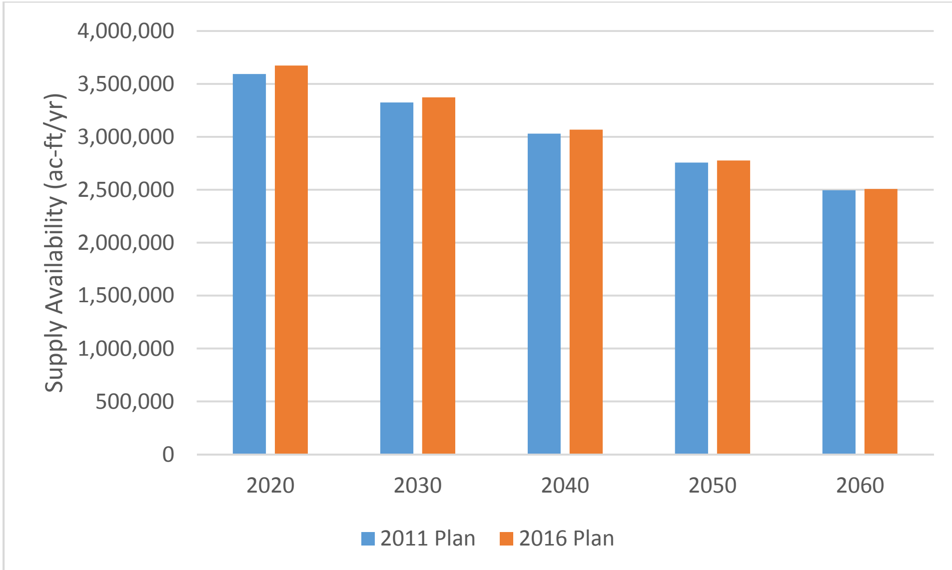
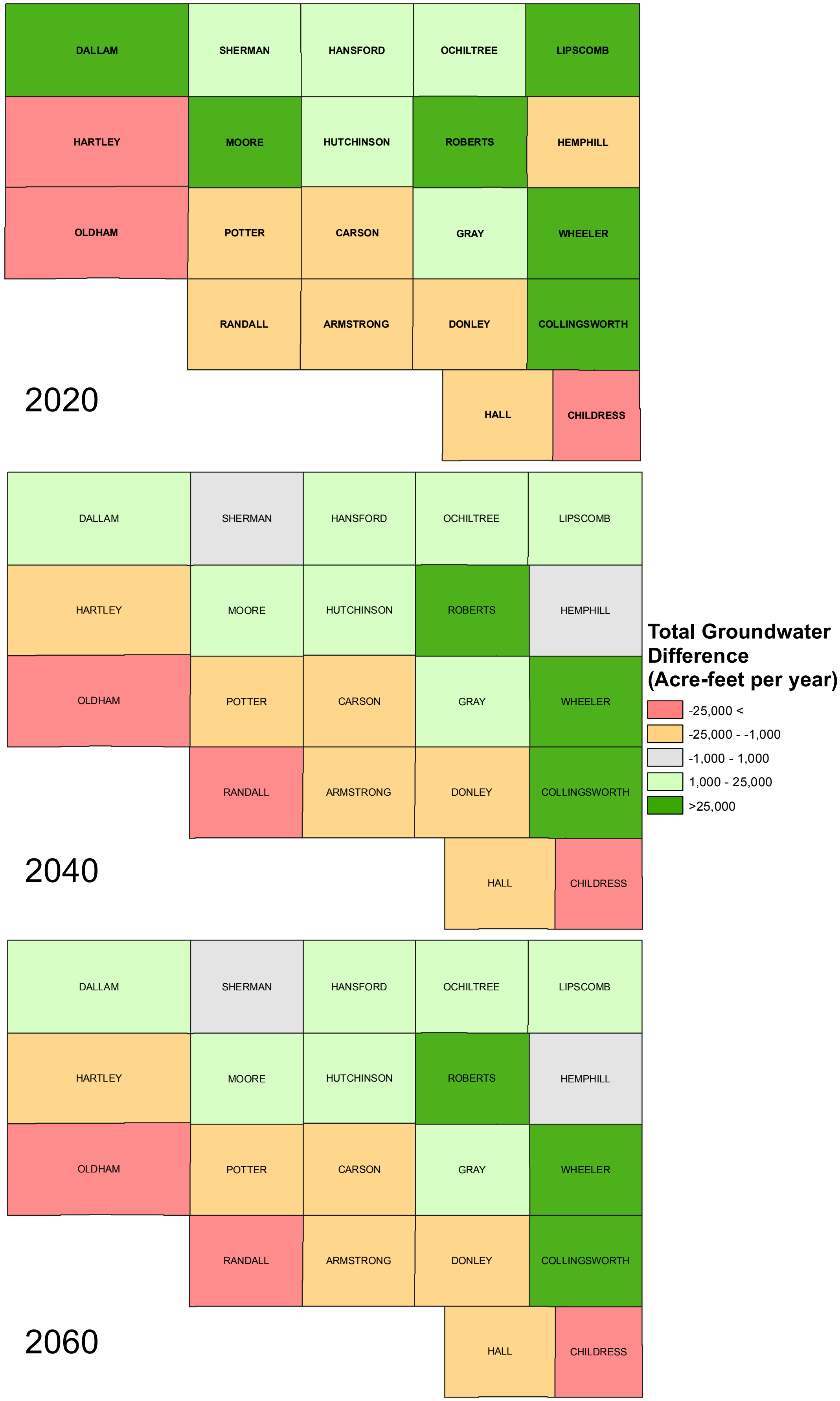


Table 11-3: Change in Groundwater Availability from the 2011 Plan to 2016 Plan

Source	Changes in Groundwater Availability (ac-ft/yr)				
	2020	2030	2040	2050	2060
Blaine Aquifer	82,338	82,338	82,338	82,338	81,036
Dockum Aquifer	-250,297	-238,177	-206,277	-178,277	-153,577
Ogallala/Rita Blanca Aquifer	258,094	214,518	173,578	129,299	98,143
Other Aquifer	-11,763	-12,221	-13,724	-15,524	-16,525
Seymour Aquifer	2,075	2,078	2,081	2,081	2,081
Total	**80,447**	**48,536**	**37,996**	**19,917**	**11,158**

Table 11-4: Changes in Dockum Aquifer Supply by County from the 2011 Plan to 2016 Plan

County	Changes in Dockum Aquifer Availability (ac-ft/yr)				
	2020	2030	2040	2050	2060
Armstrong	-18,018	-15,718	-15,718	-11,918	-10,318
Carson	-5,117	-4,417	-4,417	-3,317	-2,917
Dallam	-58,766	-50,866	-50,866	-38,066	-32,766
Hartley	-57,433	-49,833	-49,833	-37,333	-32,233
Moore	-9,805	-7,905	-7,905	-4,805	-3,505
Oldham	-61,428	-54,628	-54,628	-41,828	-36,528
Potter	-4,440	-24,220	-24,220	-18,220	-15,720
Randall	-35,881	-31,181	-31,181	-23,381	-20,181
Sherman	591	591	591	591	591



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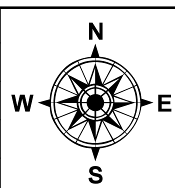


PANHANDLE WATER PLANNING AREA

TOTAL GROUNDWATER DIFFERENCE IN AVAILABILITY

Location Map

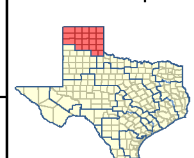


FIGURE 11-5

11.2.5 Surface Water Availability

Surface water availability decreased by approximately 68 percent from the 2011 Plan to the 2016 Plan as shown in Figure 11-6. As of October 2014, the three major reservoirs (Lake Meredith, Greenbelt Reservoir and Palo Duro Reservoir) are in the critical drought period and at less than 13 percent full. Lake Meredith is no longer considered a reliable supply of surface water in the 2016 Plan because of drought and continued low inflows. The available supply from Greenbelt Reservoir is projected to decline by 42 percent in 2060 from the previous plan (Table 11-5).

Figure 11-6: Comparison of Surface Water Availability in the 2011 and 2016 Plans

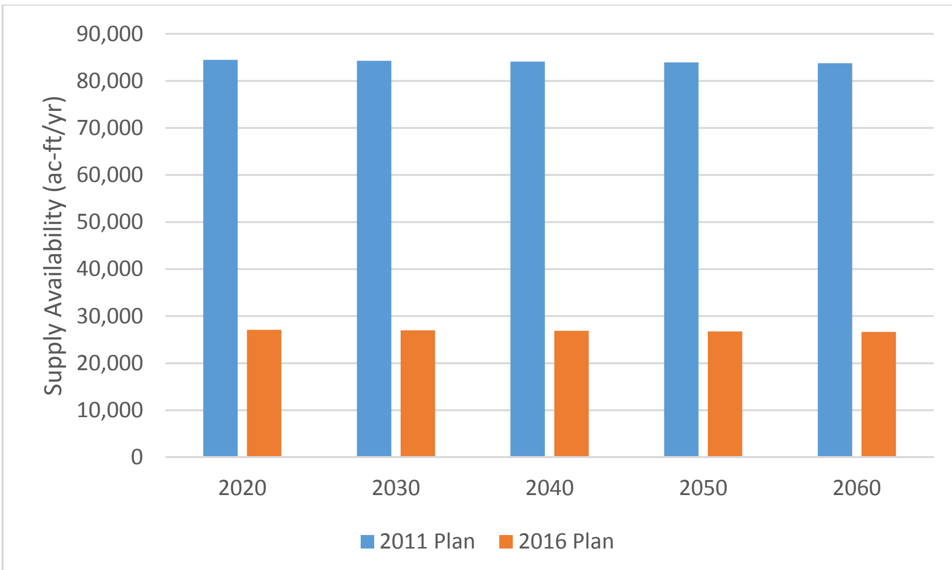


Table 11-5: Projected Change in Surface Water Supply from the 2011 to 2016 Plan in 2060

Supply	2011 Plan	2016 Plan	Percent Change
	(ac-ft/yr)		
Lake Meredith	50,000	0	-100%
Greenbelt Reservoir	6,181	3,578	-42%
Palo Duro Reservoir	3,750	3,750	0%
Local Supplies	21,217	16,783	-21%
Run-of-River	2,598	2,538	-2%

Note: Negative numbers indicate lower supply in the 2016 Plan and positive numbers show higher supply in the 2016 Plan.

11.2.6 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, some sources are no longer used or reduced supplies were available from existing sources. Those sources no longer used include Lake Meredith and Ogallala Aquifer in Collingsworth County (considered non-relevant and not included in GAM Model). Sources with significant reductions in supply include the Dockum aquifer and the Ogallala aquifer in several counties. On the contrary, increasing water demands and drought have caused water users to adopt new supplies, including several that were implemented as strategies from the 2011 Plan. These include the City of Amarillo's Potter County well field (Phase 1), new wells in the Ogallala aquifer for Greenbelt MIWA, additional wells for Borger, Dockum aquifer wells for Canyon and several small direct non-potable reuse projects. Also the allocation of Ogallala aquifer supplies to irrigation and municipalities for the 2016 Plan considered the geographic constraints with a 1-mile buffer. In the 2011 Plan, there was no buffer area used in evaluating the supply allocation. As a result, several large irrigation counties and some municipalities have greater supplies in the 2016 Plan than the 2011 Plan. Table 11-6 shows entities with significant (less than or greater than 50 percent and/or 100 acre-feet) change in supply for the 2016 Plan by the year 2060.

Table 11-6: Entities with Significant Change in Supply (2060) for the 2016 Plan

Higher	Lower
Canadian	Colorado River Municipal Water Authority (CRMWA)
Hutchinson County-Other	Amarillo (CRMWA)
Groom	Armstrong County-Other
Gruver	Hansford County-Other
Dallam County Irrigation	Moore County-Other
Hartley County Irrigation	Ochiltree County-Other
Sherman County Irrigation	Dalhart
Potter County Mining	Potter County Irrigation
Spearman	Lake Tanglewood
	Manufacturing Moore County
	Manufacturing Potter County
	Manufacturing Randall County
	Mclean
	Perryton
	Shamrock
	Stinnett
	Sunray
	TCW Supply Inc
	Vega
	Wheeler

11.2.7 Identified Water Needs

Water Use Type

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 and mining.

Needs

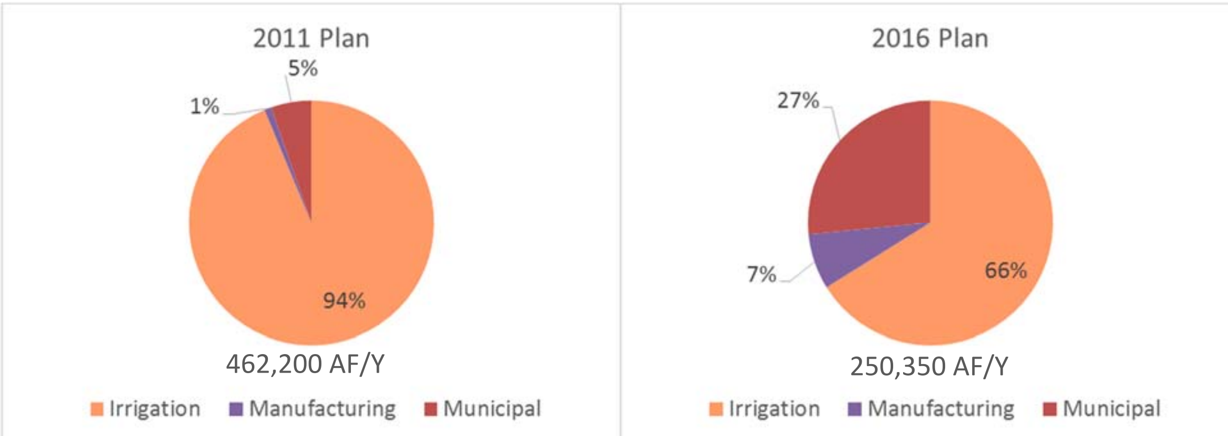
The total needs for the 2016 Plan are considerably less than the 2011 Plan. This is mostly due to the additional supplies for irrigation that were developed in the 2016 Plan. As a result, the distribution of water needs by use type are different with municipal water use having greater needs in the 2016 Plan and irrigation having lower water needs (Figure 11-7).

There are 15 water users shown to have a need in the 2016 Plan, but did not have a need in the 2011 Plan These users include Booker, Claude, Dalhart, Hall County-Other McLean, Pampa, Panhandle, Perryton, Stinnett, TCW Supply, Texline, Wheeler, Wellington and Manufacturing in Lipscomb and Randall Counties. Several users were found to no longer have a need in the 2016 Plan. These are shown in Table 11-7.

Table 11-7: Entities with New Needs or No Need for the 2016 Plan

New Need	No Need
Booker	Irrigation Hansford County
Claude	Irrigation Hutchinson
Dalhart	Irrigation Sherman
Hall County-Other	Moore Steam Electric Power
Manufacturing Lipscomb	
Manufacturing Randall	
Mclean	
Pampa	
Panhandle	
Perryton	
Stinnett	
TCW Supply	
Texline	
Wheeler	
Wellington	

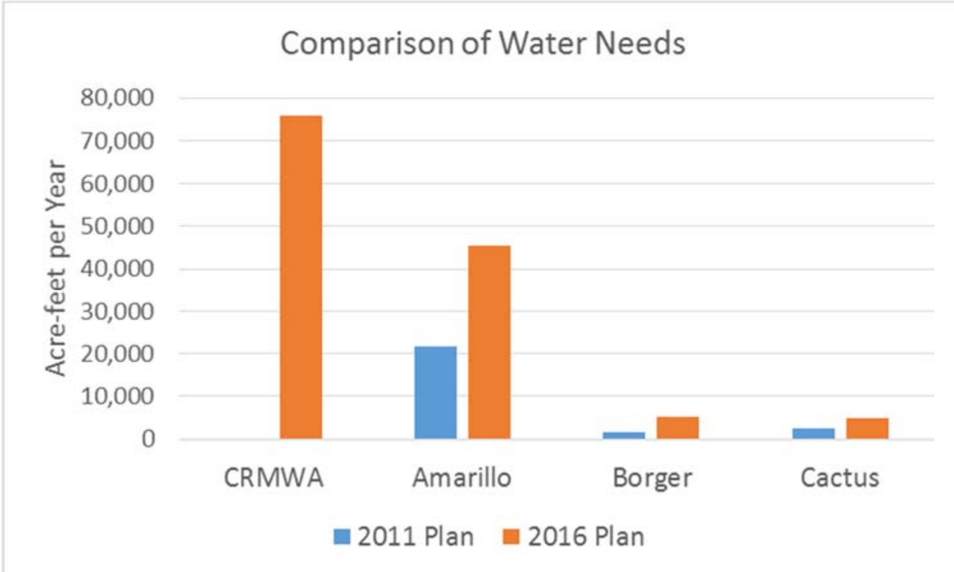
Figure 11-7: 2060 Need by Use Type in the 2011 and 2016 Plans



As shown in the figure above, the municipal water needs in the 2016 Plan represent a much greater percentage of the regional need than developed for the 2011 Plan. The absolute quantities of needs for municipal use are also greater, with the 2060 need for the 2016 Plan being more than 2.7 times the 2060 need in the 2011 Plan. This is mostly attributed to the reduced supplies of Lake Meredith that has historically provided much of the municipal water in the region.

This reduction in available municipal water supplies is evidenced in the increased needs for wholesale water providers: CRMWA, Amarillo, Borger and Cactus. Greenbelt MIWA is shown to be able to meet its projected demands in both plans. Palo Duro RA has no current customers in both plans. Figure 11-8 shows the differences in 2060 water needs by wholesale water provider.

Figure 11-8: Comparison of 2060 Need by Wholesale Water Provider



New Water Management Strategies

Due to changes in water needs, new strategies were developed for the 2016 Water Plan. Also for the 2016 Plan, municipal conservation is a recommended strategy for all cities whether the municipality has a need or not. In the previous plan, conservation was only considered for cities with a need. Table 11-8 lists the 2016 new recommended strategies for water user groups.

Table 11-8: New Recommended Water Management Strategies in the 2016 Plan

Water User Group	New Recommended Water Management Strategy
Claude	Municipal Conservation
Claude	New Groundwater Wells in Ogallala Aquifer
Wellington	Municipal Conservation
Wellington	New Groundwater Wells in Seymour Aquifer
Wellington	Expanded Use (RO Treatment)
Dalhart	Municipal Conservation
Dalhart	New Groundwater Wells in Ogallala Aquifer
McLean	Municipal Conservation
McLean	New Groundwater Wells in Ogallala Aquifer
Hall County-Other	New Groundwater Wells in Seymour Aquifer
Hall County-Other	Expanded Use (RO Treatment)
Stinnett	Municipal Conservation
Stinnett	New Groundwater Wells in Ogallala Aquifer
TCW Supply	Municipal Conservation
TCW Supply	New Groundwater Wells in Ogallala Aquifer
Booker	Municipal Conservation
Booker	New Groundwater Wells in Ogallala Aquifer

Water User Group	New Recommended Water Management Strategy
Lake Tanglewood	Municipal Conservation
Lake Tanglewood	New Groundwater Wells in Ogallala Aquifer
Canyon	New Groundwater Wells in Ogallala Aquifer
Potter County-Other	New Groundwater Wells in Dockum Aquifer
Randall County Manufacturing	New Groundwater Wells in Ogallala Aquifer
Lipscomb County Manufacturing	Purchase from Booker

Table 11-9 lists previous and new recommended water management strategies for the PWPA wholesale water providers. CRMWA and Amarillo have at least one new strategy from the previous plan. There are no changes to the basic recommended strategies for Borger, Cactus and Greenbelt MIWA; however, each of these entities have developed additional groundwater but the WWP is still planning to develop additional supplies. For PDRA the recommended strategy to develop infrastructure to its members is an alternative strategy in the 2016 Plan.

Table 11-9: Wholesale Water Provider Strategies in the 2011 and 2016 Plan

Wholesale Water Providers	2011 Plan	2016 Plan
CRMWA	Acquisition of Water Rights[1]	CRMWA II Transmission from Roberts County
	Replacement Wells in Roberts County Well Field	Replacement Wells in Roberts County Well Field
		Conjunctive Use with Lake Meredith (including brush control and ASR of surface, ground or blended water)
Amarillo	Potter County Well Field (Phase I)[1]	Potter County Well Field (Phase II)
	Roberts County Well Field	Roberts County Well Field
		Carson County Well Field
Borger	New Groundwater (Ogallala)	New Groundwater (Ogallala)
Cactus	New Groundwater (Ogallala)	New Groundwater (Ogallala)
Greenbelt MIWA	Donley County Well Field	Donley County Well Field
Palo Duro River Authority	Develop PDRA Transmission System	Develop PDRA Transmission System[2]

1. Implemented strategy since the 2011 Plan
2. Alternative strategy

New alternative strategies were developed for Amarillo and TCW Supply to potentially meet their projected water needs (Table 11-10). The alternative strategy for Randall County-Other to obtain water from Amarillo in the 2011 Plan was removed.

Table 11-10: New Alternate Water Management Strategies

Entity	New Alternate Strategy
Amarillo	Develop Direct Potable Reuse Supply
Manufacturing Potter County	Purchase reuse water from Amarillo
TCW Supply	Purchase Water from Borger

11.2.8 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.

Municipal Conservation

In the previous plan, only entities with projected needs were considered for municipal conservation. The 2016 Plan recommends conservation measures for all municipalities, regardless if there is a need. Municipal conservation was also considered for County-Other entities with needs. The current plan includes specific conservation Best Management Practices (BMPs) dependent on the population of the city to better identify appropriate conservation measures based on water need and available resources. In the 2011 Plan, conservation savings were estimated on a percent of demand reduction. The 2016 Plan provided more specific BMP savings. Additional information on municipal conservation measures can be found in subchapter 5B.1.

Irrigation Conservation

For the 2016 Plan, a suite of conservation irrigation conservation strategies were identified and the combined savings determined. The recommended irrigation conservation strategies reflect a specific suite of strategies for each county. In the 2011 Plan, all irrigation conservation strategies were evaluated individually and the savings were summed together. This resulted in an over-estimation of conservation savings. This was corrected in the 2016 Plan. Additional information on agricultural water conservation can be found in subchapter 5B.2.

11.2.9 No Longer Considered Water Management Strategies

In addition to new and altered strategies, some strategies included in the 2011 Plan are no longer being considered for the entity for various reasons. These are outlined in Table 11-11.

Table 11-11: Strategies No Longer Considered in the 2016 Plan

Entity	Strategies No Longer Considered in the 2016 Plan
Fritch	New Groundwater Wells in Ogallala Aquifer
Memphis	Purchase from Greenbelt MIWA
Moore County Steam Electric Power	New Groundwater Wells in Ogallala Aquifer

11.3 Implementation of Previously Recommended Water Management Strategies

The following sections discuss the strategies that were recommended in the 2011 Plan, and have been partially or completely implemented since that plan was published. These strategies are included in the 2016 Plan as currently available supply.

11.3.1 Amarillo

Potter County Well Field

In 2011, Amarillo complete the first phase of its Potter County Well Field. The well field included 21 wells and 15 miles of 48” pipeline. This project can supply up to 10 MGD. For planning purposes the estimated supply is over 9,000 acre-feet in 2020, decreasing to 5,600 acre-feet by 2070.

11.3.4 Borger

Ogallala Aquifer

The City of Borger has 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. The city currently has sufficient treatment capacity to treat the annual supply of 2,000 acre-feet. Production wells, pipelines, pumps, and storage facilities have been constructed and the project should be on-line in 2015.

11.3.3 CRMWA

Acquisition of Water Rights

In the 2011 Plan, CRMWA held 263,000 acres of water rights in Roberts County. Since then it has acquired additional rights for a total of 444,833 acres of water rights in Roberts and adjacent counties.

11.4 Conclusion

While there were several significant changes to supplies and demands in the PWPA for the 2016 Plan, the overall recommended strategies remain fairly consistent. Conservation remains a major strategy to meet irrigation and municipal water needs. Groundwater is still the preferred source for new supply development. The region continues to show some unmet water needs for irrigation.