Task 3
Water Supply Analysis

3.1 Evaluation of Adequacy of Current Water Supplies

This chapter of the regional water plan presents an evaluation of current groundwater and surface water supplies available to the Panhandle region for use during a repeat of the drought of record. An analysis of supplies versus demands for all water user groups was conducted to determine shortages or adequacy of supplies. The sources described in this narrative are quantified throughout this report and in the attached Appendix D & V.

Groundwater sources which are identified in this chapter include two major and three minor aquifers. These include the Ogallala, Seymour, Blaine, Dockum, and Rita Blanca aquifers. The Whitehorse was not included in the analysis during this round of planning due to the lack of data specifically tied to this aquifer. SB2 and TWDB guidelines require that Groundwater Availability Models (GAMs) are to be used to determine available groundwater supplies, unless more site specific information is available. The GAM program, whose development was overseen by the TWDB, has completed several groundwater models for major aquifers in Texas including both the northern and southern Ogallala aquifer models. In addition, GAM results were included for the Seymour and Blaine aquifers. The Dockum Aquifer GAM is not yet complete and availabilities calculated for the Dockum are based on data reported in published reports.

Developing a GAM involves gathering much information about the aquifer of interest, including rate of recharge, pumping rates, physical boundaries of the aquifer, geology, and historical water levels. This information is used as inputs into a mathematical computer model that can show the changes in water levels of the aquifer over time as a result of climate and pumping changes.

The volume of water available from the Ogallala, Seymour and Blaine aquifers was determined using the GAMs. Available supplies of water from the Dockum were determined using estimates of saturated thickness, specific yield, and recharge rates from historical studies and published reports. In Carson, Dallam, Hartley, Hutchinson, Moore, Roberts, and Sherman counties, the Ogallala GAM model could not supply the demands which were input as requested pumpage for some decades. This was due in part to the spatial locations of the demands rather than the total water availability within the county. To address these spatial limitations, the available water supplies to water user groups were reduced to reflect the GAM results. The total availability of groundwater from the Ogallala is limited to 1.25% of the water in storage as reported by the Ogallala GAM.

In the previous round of planning, the PWPG selected a 50/50 methodology for groundwater availability. The policy simply stated that the group wanted to have 50% of the 1998 saturated thickness of the aquifer left in 50 years. After deliberation and extensive discussion on the proper implementation and quantification of such a policy, the planning group proposed a revised methodology for the current round of planning. The current management policy for the PWPA is not more than an annual 1.25% withdrawal of current saturated thickness of the aquifer with a 5-year recalculation of the saturated thickness remaining. All water availabilities from groundwater stated in this plan do not exceed this 1.25% policy.

Available surface water supplies were determined using TCEQ-approved Water Availability Models (WAMs). WAMs have now been completed for each of the river basins in Texas. Because the WAMs were developed for the purpose of reviewing and granting new surface water rights permits, the assumptions in the WAMs are based upon the legal interpretation of water rights and sometimes do not accurately reflect current hydrologic operation. WAM Run 3, which is the version required for planning, assumes full permitted diversions by all water rights and no return flows unless return flows are specifically included in the water right. Availabilities for each water right are analyzed in priority date order, with water rights with the earliest permit date diverting first. Run 3 also does not include agreements or operations that are not reflected in the water rights permits and does not account for reductions in reservoir storage capacities due to sediment accumulation. For planning purposes, adjustments were made to the WAMs to better reflect current and future surface water conditions in the region. Further discussion of these adjustments can be found in the Surface Water Supplies section of this chapter. Surface water supplies identified in the regional water plan include three reservoirs designated for drinking water supply. The three major reservoirs that were identified as significant sources of surface water in the PWPA are Lake Meredith, Palo Duro Reservoir, and Greenbelt Reservoir.

Ten smaller reservoirs are discussed with respect to their use as potential future surface water supplies. These reservoirs are currently used for limited water supply, recreation, flood control, soil erosion control, and wildlife habitat. These include Lake McClellan, Buffalo Lake, Lake Tanglewood, Rita Blanca Lake, Lake Marvin, Baylor Lake, Lake Childress, Lake Fryer, Club Lake, and Bivens Lake. Because yield studies are not routinely performed on smaller reservoirs designated for uses other than drinking water supply, no firm yield information is available for these reservoirs.

As required by TWDB rules [§357.5(k)(1)F], county judges in each of the 21 counties were contacted to determine if any of the county commissioner's courts had water availability requirements. No specific requirements were identified within the PWPA.

3.1.1 Groundwater Supplies
Two major aquifers, the Ogallala and Seymour (Figure 3-1), and three minor aquifers, the Blaine, Dockum, and Rita Blanca (Figure 3-2) supply the majority of all water uses in the PWPA. The Ogallala aquifer supplies the predominant share of groundwater, with additional supplies obtained from the remaining aquifers.
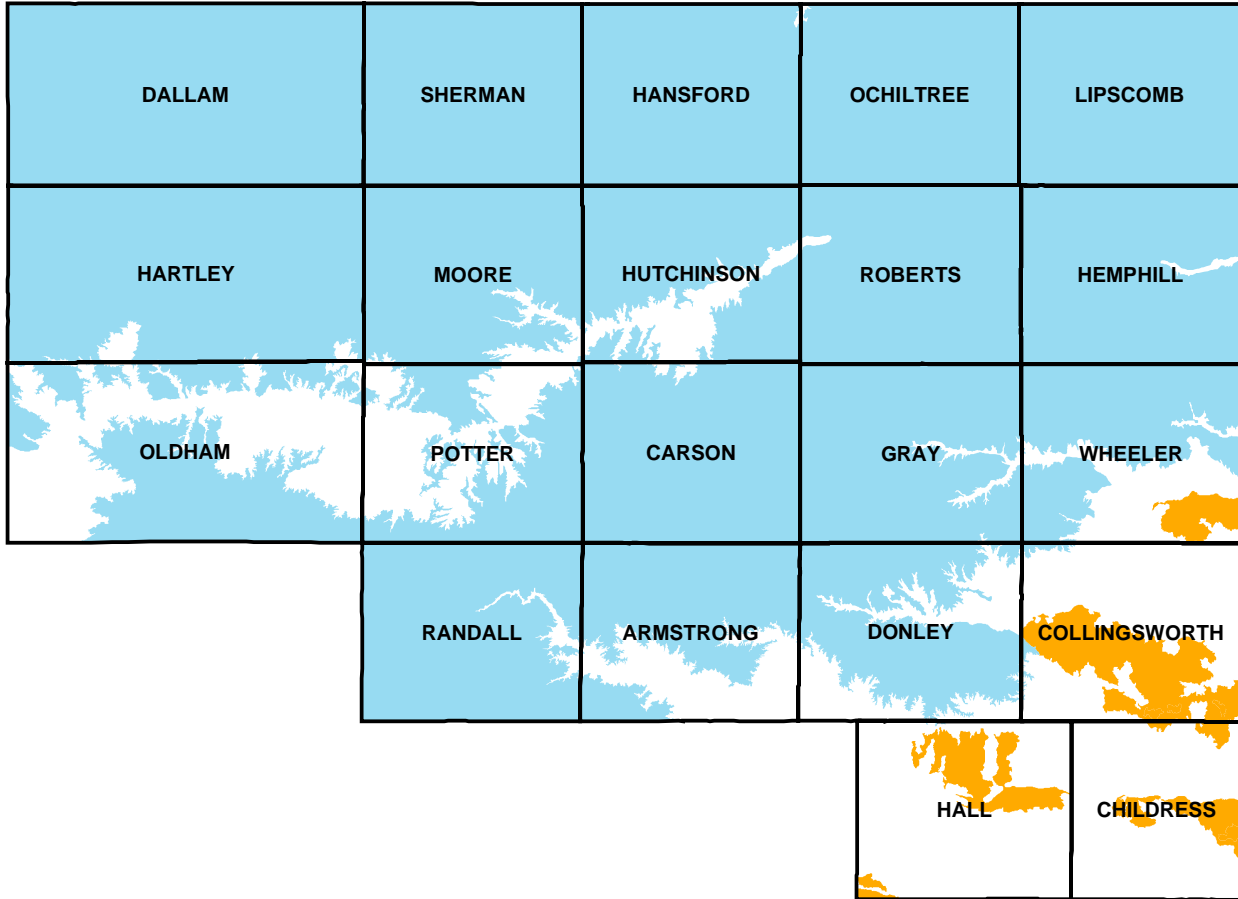
Figure 3-1: Major Aquifers in the Panhandle Water Planning Area
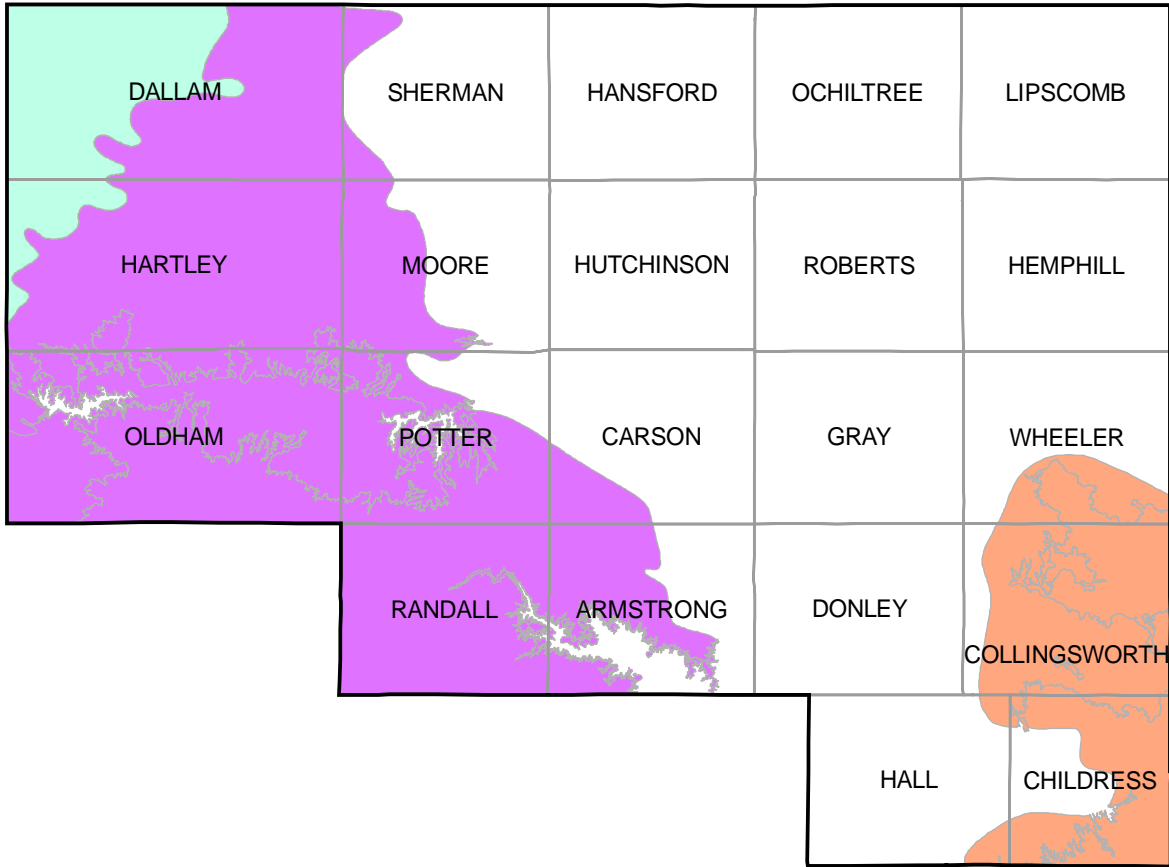
Figure 3-2: Minor Aquifers in the Panhandle Water Planning Area

For this round of planning, the PWPA provided an updated and recalibrated version of the Ogallala GAM to the state. This effort focused on providing more representative aquifer bottom elevations and refined recharge inputs. The TWDB then took the revisions and ran the GAM to determine groundwater from the Ogallala aquifer for each county in the region for the planning period. The total projected water in storage in the Ogallala is shown in Table 3-1. Figure 3-3 shows the 2000 comparison of the available supply from the Ogallala aquifer and Figure 3-4 shows the change of availability of supplies over the planning period. GAMs for the Seymour and Blaine aquifers were completed in early 2005 and are included in this analysis. The availability of water from the remaining aquifers was determined using estimates of saturated thickness, specific yield, and recharge rates. In cases where these data were not available, historical reports of pumpage and local well level data were used.

A description of the aquifers with regard to their location, geologic and hydrogeologic characteristics, historical yields, chemical quality, and available supply is provided below.

3.1.2 Major Aquifers
3.1.2.1 Ogallala Aquifer
The Ogallala aquifer is present in all counties in the PWPA except for Childress 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).

Table 3-1: Total Water in Storage in the Ogallala Aquifer (GAM 2005 Results in AF)

County	2000	2010	2020	2030	2040	2050	2060
Armstrong	4,051,267	3,946,527	3,841,987	3,762,122	3,660,019	3,594,351	3,516,472
Carson	15,280,781	14,159,377	13,081,706	12,044,288	11,076,423	9,990,939	9,189,765
Collingsworth	85,870	85,792	85,703	85,608	85,514	85,420	85,329
Dallam	17,604,513	14,622,921	12,134,853	10,126,050	8,591,459	7,549,367	6,779,683
Donley	6,249,296	6,071,878	5,906,044	5,754,021	5,622,240	5,514,375	5,424,345
Gray	13,648,169	13,287,191	12,937,973	12,604,708	12,297,143	12,022,161	11,774,680
Hansford	21,693,703	20,385,024	19,092,753	17,850,094	16,716,209	15,729,410	14,852,445
Hartley	24,925,026	22,140,753	19,612,912	17,620,595	16,366,457	15,570,650	15,033,727
Hemphill	15,638,152	15,587,716	15,537,912	15,492,137	15,450,805	15,413,991	15,381,202
Hutchinson	11,112,029	10,275,488	9,463,673	8,736,497	8,113,675	7,629,968	7,245,126
Lipscomb	18,640,279	18,526,166	18,413,261	18,305,998	18,210,229	18,128,137	18,055,287
Moore	10,662,411	8,866,273	7,116,002	5,572,033	4,394,052	3,551,754	2,928,227
Ochiltree	19,795,557	18,847,872	17,955,425	17,118,070	16,368,979	15,724,576	15,156,476
Oldham	2,521,470	2,464,330	2,431,378	2,410,964	2,354,849	2,369,351	2,359,118
Potter	3,045,673	2,857,232	2,716,565	2,602,259	2,417,728	2,396,881	2,304,503
Randall	6,258,380	5,846,443	5,475,627	5,318,727	4,932,887	5,326,169	5,355,003
Roberts	27,494,610	26,805,037	26,098,600	25,455,105	25,011,760	24,689,458	24,396,671
Sherman	19,498,315	16,814,464	14,188,402	11,708,499	9,545,592	7,794,612	6,390,606
Wheeler	7,485,439	7,423,165	7,367,619	7,325,079	7,288,085	7,257,973	7,232,521
TOTAL	**245,690,940**	**229,013,649**	**213,458,395**	**199,892,854**	**188,504,105**	**180,339,543**	**173,461,186**

The PWPG is tasked to plan for water supplies to meet the future water shortages of the Panhandle and has selected a management policy to assure such conditions. The initial 50/50 policy goal to have 50% of saturated thickness remaining in 50 years has been translated for implementation to mean not greater than a 1.25% of annual saturated thickness as an available supply. Aquifer volumes presented in Table 3-1 are used to determine the 1.25% of supply available on a county basis. Table 3-2 shows the availability of supply for the PWPA during the planning period.

Table 3-2: Available Water Supply from the Ogallala
(1.25% Available Supplies in Storage in AFY)

| County	2010	2020	2030	2040	2050	2060
Armstrong	49,332	48,025	47,027	45,750	44,929	43,956
Carson	176,992	163,521	150,554	138,455	124,887	114,872
Collingsworth	1,072	1,071	1,070	1,069	1,068	1,067
Dallam	182,787	151,686	126,576	107,393	94,367	84,746
Donley	75,898	73,826	71,925	70,278	68,930	67,804
Gray	166,090	161,725	157,559	153,714	150,277	147,184
Hansford	254,813	238,659	223,126	208,953	196,618	185,656
Hartley	276,759	245,161	220,257	204,581	194,633	187,922
Hemphill	194,846	194,224	193,652	193,135	192,675	192,265
Hutchinson	128,444	118,296	109,206	101,421	95,375	90,564
Lipscomb	231,577	230,166	228,825	227,628	226,602	225,691
Moore	110,828	88,950	69,650	54,926	44,397	36,603
Ochiltree	235,598	224,443	213,976	204,612	196,557	189,456
Oldham	30,804	30,392	30,137	29,436	29,617	29,489
Potter	35,715	33,957	32,528	30,222	29,961	28,806
Randall	73,081	68,445	66,484	61,661	66,577	66,938
Roberts	315,000	305,000	295,000	285,000	275,000	265,000
Sherman	210,181	177,355	146,356	119,320	97,433	79,883
Wheeler	92,790	92,095	91,563	91,101	90,725	90,407
TOTAL	**2,842,607**	**2,646,997**	**2,475,471**	**2,328,655**	**2,220,628**	**2,128,309**
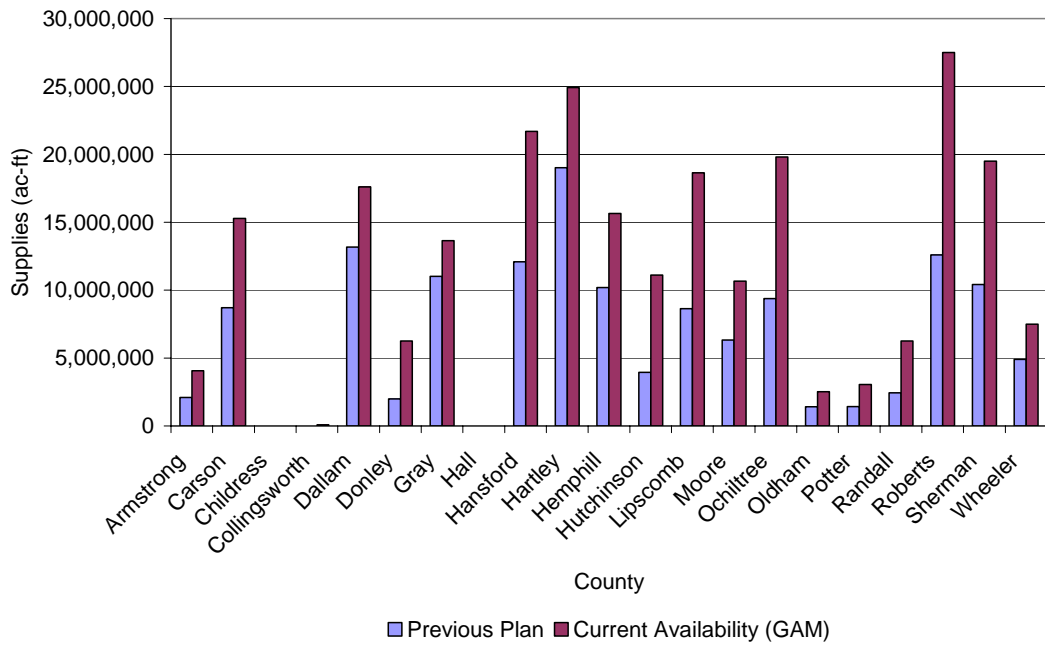
Figure 3-3: Total GAM Supplies from the Ogallala Aquifer
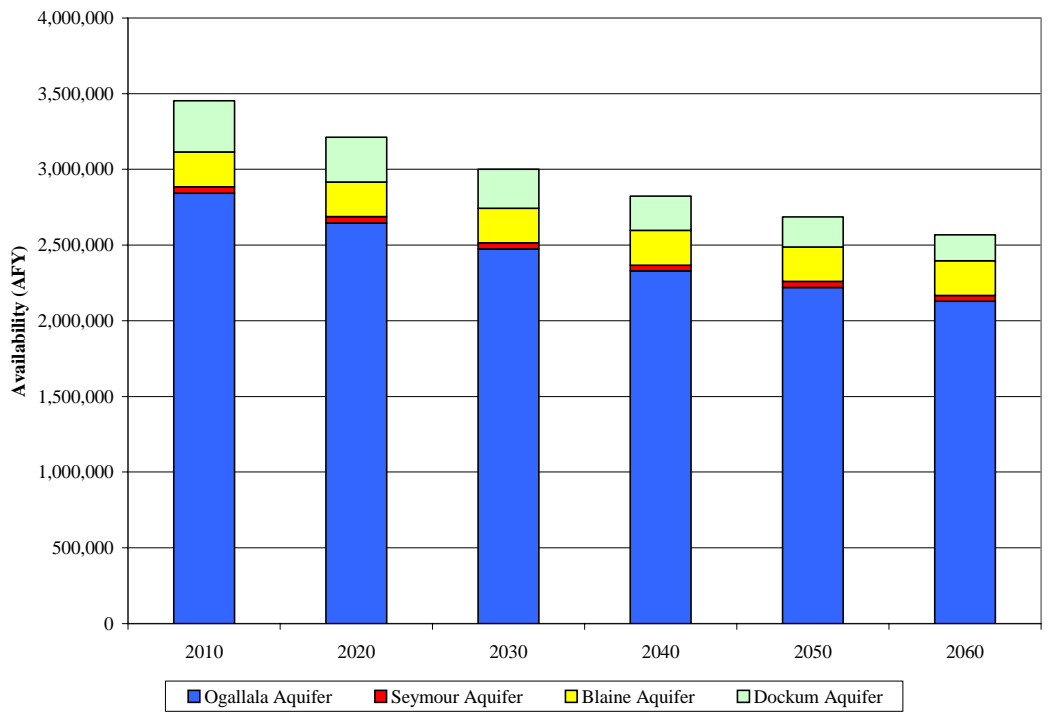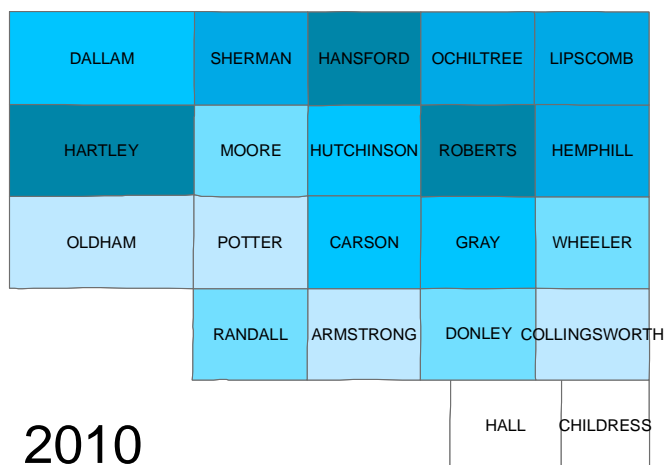

Figure 3-4:   Available Supplies from Groundwater Sources in PWPA

2010

2030

Legend

☐	0 ac-ft
☐	0 - 5,000,000
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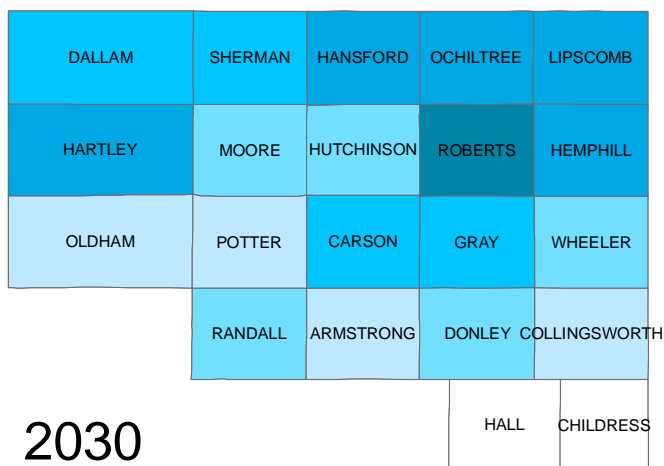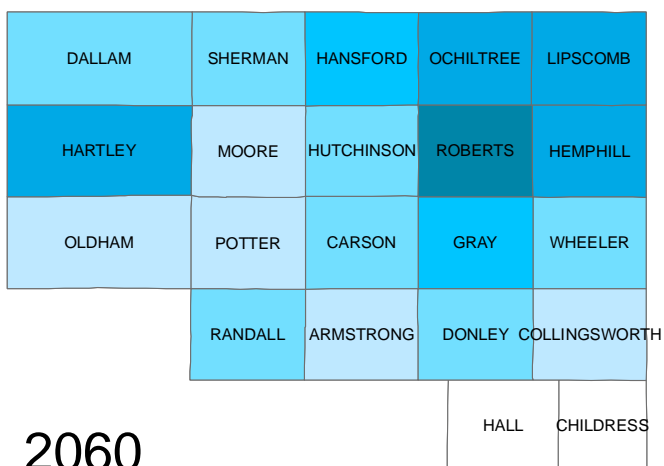
2060

Figure 3-5: Total Volume in Storage in the Ogallala Aquifer (AF)

3.1.2.2 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, Hall, Wheeler, and a very small portion of Donley 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 as a result of direct infiltration of precipitation on the land surface. Surface streams are at a lower elevation than water levels i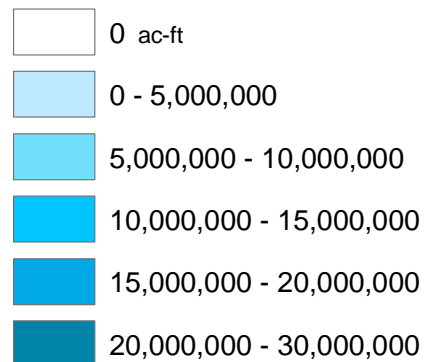n the Seymour aquifer and do not contribute to the recharge. Leakage from underlying aquifers also appears to be insignificant (Duffin, 1992).

Annual effective recharge to the Seymour aquifer in the PWPA is approximately 33,000 acre-feet or five percent of the average annual rainfall that falls on the outcrop area. No significant groundwater level declines have occurred in wells that pump from the Seymour.

As shown on Table 3-3, the Seymour GAM results indicated small declines to increases in storage volumes with the pumpage amounts used for the model. These pumpage amounts in the PWPA ranged from 41,000 acre-feet per year in 2000, decreasing to 26,800 acre-feet per year by 2060. Based on the GAM pumpage and volumes of water remaining in storage, the estimated annual availability from the Seymour aquifer is shown in Table 3-4.

Table 3-3: Total Water in Storage in the Seymour Aquifer (GAM 2005 Results in ac-ft)

County	2000	2010	2020	2030	2040	2050	2060
Childress	130,000	130,000	130,000	140,000	140,000	140,000	140,000
Collingsworth	520,000	480,000	460,000	450,000	450,000	460,000	470,000
Hall	210,000	200,000	180,000	180,000	180,000	190,000	190,000

Source: TWDB 2005

Table 3-4: Available Annual Water Supply from the Seymour Aquifer (in ac-ft)

County	2010	2020	2030	2040	2050	2060
Childress	1,625	1,625	1,750	1,750	1,750	1,750
Collingsworth	19,400	18,900	17,900	17,900	17,900	1,7900
Hall	20,500	20,000	19,000	19,000	19,000	19,000
Wheeler	88	88	88	88	88	88

Source: TWDB 2005

3.1.3 Minor Aquifers

3.1.3.1 Blaine Aquifer

The Blaine Formation 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 occurred in the Blaine aquifer. Declines that have occurred are due to heavy irrigation use and are quickly recharged after seasonal rainfall (TWDB, 1997). As shown in Table 3-6, the annual availability of water from the Blaine aquifer is considered to be the greater than either effective recharge or pumpage rates in the PWPA.

Table 3-5: Total Water in Storage in the Blaine Aquifer (GAM 2005 Results in ac-ft)

County	2000	2010	2020	2030	2040	2050	2060
Childress	4,900,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Collingsworth	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Hall	800,000	800,000	800,000	800,000	800,000	800,000	800,000
Wheeler	2,600,000	2,600,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000

Table 3-6: Available Annual Water Supply from the Blaine Aquifer
(1.25% Available Supplies in Storage in ac-ft)

County	2000	2010	2020	2030	2040	2050	2060
Childress	61,250	62,500	62,500	62,500	62,500	62,500	62,500
Collingsworth	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Hall	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Wheeler	32,500	32,500	31,250	31,250	31,250	31,250	31,250

3.1.3.2 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).

Groundwater availability of the Dockum aquifer is presented in Table 3-7. The availability of water from the Dockum aquifer is estimated to be 1.25% of the total storage estimate plus effective annual recharge (TWDB, 2003).

Table 3-7: Available Annual Water Supply from the Dockum Aquifer
(1.25% Available Supplies in Storage in ac-ft)

County	2010	2020	2030	2040	2050	2060
Armstrong	21,300	18,600	16,300	14,300	12,500	10,900
Carson	6,200	5,400	4,700	4,200	3,600	3,200
Dallam	71,800	62,800	54,900	48,100	42,100	36,800
Hartley	69,700	61,000	53,400	46,700	40,900	35,800
Moore	17,400	15,200	13,300	11,600	10,200	8,900
Oldham	74,000	64,800	56,700	49,600	43,400	38,000
Potter	33,600	29,400	25,800	22,500	19,700	17,300
Randall	43,500	38,000	33,300	29,100	25,500	22,300

Source: TWDB Report 359, 2003

3.1.3.3 <u>Rita Blanca Aquifer</u>

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 the 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 leakage from the Ogallala. No estimates of recoverable storage, saturated thickness, or other water availability parameters for the aquifer were located for the Rita Blanca aquifer. Supplies from the Rita Blanca were modeled in the Ogallala GAM and these supplies are included in Ogallala availability numbers.

According to TWDB data, pumpage from the Rita Blanca averaged about 5,419 acre-feet per year from 1980 to 1997 (Table 3-8). Less than 500 acre-feet per year was pumped by the city of Texline for municipal/industrial supply over this time period. An average of 5,343 acre-feet per year was pumped for irrigation supply and an average of 77 acre-feet per year for municipal uses. All pumpage occurs in Dallam County, and no pumping of the Rita Blanca is reported for Hartley County. Municipal water well levels in the Rita Blanca aquifer have historically remained stable, whereas irrigation well water levels have declined steadily. This indicates that irrigation usage rates are currently mining the Rita Blanca supply. Insufficient data exist to quantify the rate.

**Table 3-8: Average Pumpage and Projected Groundwater Availability
in the Rita Blanca Aquifer for Counties in the PWPA**

County	Average Pumpage 1980-1997* (acre-feet/yr)
Dallam	5,419
Hartley	n/a
Total	5,419

Source: TWDB, 2005

3.2 Surface Water Supplies

Major surface water supplies in the PWPA include Lake Meredith, Palo Duro Reservoir, and Greenbelt Reservoir. The supply available from these reservoirs is determined through the Water Availability Models (WAM) of the Red and Canadian Basins which include evaluations of critical drought, water right diversions, and sedimentation rates. 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 amount of water held for later release for usual purposes such as municipal water supply, power, or irrigation in contrast with storage capacity used for flood control. The following sections contain an evaluation of these reservoirs based on the Red River and Canadian River Water Availability Models and water rights.

As part of the water supply analysis for PWPA, the consultants compared reservoir yields from the Red and Canadian Rivers WAMs to previous work. Some of the yields in both basins were quite different and represent changed conditions. Several procedural problems with the flow naturalization were identified which may explain some of the differences in reservoir yields including:

- Inappropriate application of loss factors

- Inappropriate estimation of missing flow data

- Unjustified adjustments for construction of Lake Meredith

- Use of unadjusted historical flows originating in New Mexico, specifically no adjustments for the construction of major upstream reservoirs

- Selection of inappropriate base for calculation of naturalized or adjusted historical inflow to Lake Meredith, specifically the use of the Canadian gauge in lieu of the Amarillo gauge or derived inflow from historical reservoir changes for the period since 1965

The following list describes the changes made to the TCEQ Canadian River WAM to improve the evaluation surface water supplies for the PWPA:

1 - Extension of the period of record
2- Adjustments for Lake Meredith
3- Adjustment for New Mexico development
4- Channel Loss Correction
5- Changes in the Canadian WAM

The hydrologic period of the model was extended from the period of record of the TCEQ Canadian WAM which was January 1948 through December 1997. The new period is January 1940 through September 2004. The extension allows covering the years before the drought of the 1950's and the recent drought. This extension was made in all primary control points of the Canadian WAM.

Inflows to Lake Meredith were computed with historical data provided by CRMWA. The inflows into Lake Meredith computed by mass balance are generally less than the historical flows at the gage on the Canadian River near Amarillo. The difference is greater after the reservoir was completed than in recent years. The firm yield study of Lake Meredith completed by Lee Wilson and Associates in 1993 acknowledged these losses and suggested that they occurred because of bank and flood plain storage after the initial impoundment. The reductions in the losses over time seem to confirm the theory of bank storage. Once the banks are saturated, lower losses would occur. Bank storage estimates for each month were computed and considered during the recomputation of the naturalized flows Historical diversion by CRMWA were used during the recomputation of naturalized flows. For some months, they are slightly different from the values used in the TCEQ Canadian WAM.

A new control point was created for the gage at the Canadian River near Logan, located a few miles downstream of Ute Reservoir. Historical flows at this gage were adjusted for impoundment, releases, and evaporation losses in the reservoir. This affects the flows entering Texas. Ute reservoir was completed in 1963 with a conservation storage of 110,000 acre-feet. It was then enlarged to 272,770 acre-feet of storage in 1984. Current storage as reported by USGS is 229,710 acre-feet. Plans to provide a firm supply of 24,000 acre-feet per year are being developed by the Eastern New Mexico Rural Water System. This development will reduce the yield of Lake Meredith and should be considered in the Canadian WAM.

Naturalized flows of the TCEQ Canadian WAM assumed a constant loss factor of 30% basin wide. This loss factor was applied to diversion or return flows regardless of the location. The recomputed channel loss factors are listed in Table 3-9.

Table 3-9: Recalculated Channel Losses

From gage	To gage	Loss factor	Source
Canadian River near Logan	Canadian River near Amarillo	5%	Lee Wilson and Associates 1993 Report
Canadian River near Amarillo	Lake Meredith	4%	Historical record analysis
Canadian River near Amarillo	Canadian River near Canadian	38%	Historical record analysis

Other adjustments to the Canadian River WAM include the addition of Ute Reservoir with a diversion of 24,000 acre-feet per year as the most senior right. In addition, minimum storage of Lake Meredith is considered its dead storage of 55,000 acre-feet.

Table 3-10 summarizes the existing yield studies for the three main water supply reservoirs in the PWPA: Lake Meredith, Palo Duro Reservoir, and Greenbelt. According to the existing yield studies for these reservoirs, all of them appear to be currently experiencing their critical drought period.

The firm yield of the three surface water supply reservoirs for the PWPA will very likely be reduced if low flows continue after 2004. However, the firm yield for Palo Duro Reservoir will remain difficult to define using the available hydrologic records in the area.

Table 3-10: Descriptive Information of Water Supply Reservoirs in the PWPA

	Palo Duro Reservoir	Lake Meredith	Greenbelt Reservoir
Owner/Operator	PDRA	National Park Service, BuRec and CRMWA	GM&IWA
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
Date of Impoundment	January 1991	January 1965	December 1966
Sources of Information	PDRA, TWDB, and USGS	CRMWA, TWDB, and USGS	GMIWA, TWDB, and USGS
Conservation Storage (most recent survey)	60,897 acre-feet (1974)	817,970 acre-feet* (1995) (includes sediment storage)	59,110 acre-feet (1965)
Permitted Diversion	10,460 acre-feet/yr	151,200 acre-feet/yr	16,230 acre-feet/yr
Firm Yield	4,000 acre-feet/yr	69,750 acre-feet/yr	8,985 acre-feet/yr

*The Canadian River Compact allows 500,000 acre-feet of conservation storage. Any water stored in excess of 500,000 acre-feet is subject to release at the call of the State of Oklahoma.

3.2.1 Water Rights

According to the TCEQ water rights database there are 104 water rights permit holders in the PWPA representing a total of 185,679 acre-feet/yr. (TCEQ 2004) As shown in Table 3-11, three water rights permits have been assigned to divert more than 1,000 acre-feet/year. These represent a total of 177,690 acre-feet/year, or approximately 95 percent of the total water rights allocated in the PWPA. Table 3-12 summarizes the remaining 101 water rights in the PWPA which are less than 1,000 acre-feet/yr, representing 7,989 acre-feet/year.

Table 3-11: Water Rights in the PWPA Greater Than 1,000 Acre-feet/Year

Water Right Number	Water Right Owner	Authorized Diversion (ac-ft)	Authorized Use	Priority Date	Reservoir	Stream	County
3782	Canadian River Municipal Water Authority	100,000	Municipal/ Domestic	1/30/1956	Lake Meredith	Canadian River	Hutchinson
3782	Canadian River Municipal Water Authority	51,200	Industrial	1/30/1956	Lake Meredith	Canadian River	Hutchinson
3803	Palo Duro River Authority	10,460	Municipal/ Domestic	4/23/1974	Palo Duro Reservoir	Palo Duro Creek	Hansford
5233	Greenbelt Municipal and Industrial River Authority	16,030	Municipal/ Domestic	8/11/1958	Greenbelt Reservoir	Salt Fork Red River	Donley

Table 3-12: Total Water Rights by County in the PWPA Less Than 1,000 Acre-feet/Year

County	Basin Name	Total
Carson	Red	335
Childress	Red	435.5
Collingsworth	Red	1,194
Dallam	Canadian	190
Donley	Red	464
Gray	Canadian	4
Gray	Red	259
Hall	Red	101
Hansford	Canadian	530
Hartley	Canadian	0
Hemphill	Canadian	0
Hemphill	Red	0
Hutchinson	Canadian	646
Lipscomb	Canadian	122
Moore	Canadian	345
Ochiltree	Canadian	0
Oldham	Canadian	30
Potter	Canadian	349
Randall	Red	1,021.5
Roberts	Canadian	640
Sherman	Canadian	275
Wheeler	Red	1,048
Total		**7,989**

3.2.2 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 (CRC). 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)

Four 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). The study by HDR (1987) estimated that the firm yield was about 76,000 acre-feet/yr. and that development of New Mexico projects might further reduce the yield to 66,000 acre-feet/yr. Another yield study in 1993 (Lee Wilson and Associates, 1993) estimated a firm yield of approximately 76,000 acre-feet based on 1991 area-capacity conditions and 1980 sedimentation rates. The yield study showed the reservoir reaching a minimum content of 59,700 acre-feet in May 1981. This content represents the lowest elevation from which the water intake structures can divert water. A TWDB survey of Lake Meredith in 1995 estimated conservation and sediment storage of 817,970 acre-feet (TWDB, 1995). The CRC limits the conservation storage to 500,000 acre-feet. The Freese and Nichols, Inc. study of the Water Availability Model of the Canadian Basin with the hydrology ending in December 2004, shows that the firm yield of Lake Meredith is 69,750 acre-feet per year, assuming full use of Ute Reservoir in New Mexico. Safe yield for Lake Meredith is approximately 63,750 acre-feet per year.

Projections of conservation storage, firm yield, and available supply for Lake Meredith during planning period of 2000 through 2060 are based on the Canadian River WAM. Sedimentation is not anticipated to adversely affect the yield of Lake Meredith during the 50-year planning period. Table 3-13 shows the projected storage, yield, and available supply of Lake Meredith by decade for the planning period.

Table 3-13: Projected Yield and Available Supply of Lake Meredith

	2000	2010	2020	2030	2040	2050	2060
Storage Capacity (acre-feet)	815,989	811,687	807,384	803,082	798,780	794,477	790,175
Conservation Storage * (acre-feet)	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Firm Yield (acre-feet/yr)	69,750	69,750	69,750	69,750	69,750	69,750	69,750
Safe Yield (acre-feet)	63,750	63,750	63,750	63,750	63,750	63,750	63,750

* Limited by provisions of the Canadian River Compact

A large portion of Lake Meredith's inflow (about 90%) originates upstream of the Canadian River gage near Amarillo. The most recent yield study of Lake Meredith was performed in February 1993 (Lee Wilson and Associates, 1993). Total inflows for this study were estimated through a volumetric water balance, subtracting evaporation, diversions, releases and seepage from the observed change in storage. In this analysis, the runoff below the Amarillo gage amounted to about 10% of the total inflow.

Inflow data sources for Lake Meredith have been adequate for previous firm yield studies. The U.S. Geological Survey gage on the Canadian River near Amarillo has supplied important hydrologic records for these computations. The critical period for the reservoir extends beyond the most recent period of analysis. The Amarillo gaging station should continue to serve as the best estimate of the majority of Lake Meredith inflows in future yield studies. Appendices V and W provide more information on the latest hydrology, water availability modeling, and vulnerability assessment of Lake Meredith and Palo Duro.

3.2.3 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. Construction of transmission systems for delivering water to member cities is anticipated to be complete by 2030.

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 (Freese and Nichols, 1974, 1984, 1986) and that the yield is estimated to be 6,543 acre-feet per year. The firm yield with the Canadian River Basin WAM estimated the yield of 4,000 acre-feet year considering a hydrology through September 2004.

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 most 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 4,000 acre-feet in 2000 to 3,875 acre-feet in 2030 and down to 3,750 acre-feet by 2060. Table 3-14 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 3-14: Projected Yield and Available Supply of Palo Duro Reservoir

	2000	2010	2020	2030	2040	2050	2060
Conservation Capacity (acre-feet)	59,702	58,822	57,942	57,062	56,182	55,302	54,422
Firm Yield (acre-feet/yr)	4,000	3,958	3,917	3,875	3,833	3,792	3,750
Available Supply (acre-feet/yr)	--	--	--	--	--	--	

3.2.4 Greenbelt Reservoir

Greenbelt Reservoir is owned and operated by the Greenbelt Municipal and Industrial Water Authority (GM&IWA), 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).

A firm yield analysis of Greenbelt Reservoir was performed using Run 3 of the state-adopted Water Availability Model (WAM) of the Red River Basin. This run assumes full permitted diversions by all water rights and no return flows unless return flows are included specifically in the water right. Results from this analysis show a firm yield of 8,854 acre-ft per year in 2010, 8,592 acre-feet per year in 2030, and 8,200 acre-feet per year in 2060. These findings are summarized in Table 3-15 below.

Table 3-15: Projected Yield and Available Supply of Greenbelt Reservoir

	2000	2010	2020	2030	2040	2050	2060
Conservation Capacity (acre-feet)	52,673	50,651	48,628	46,606	44,584	42,562	40,540
Firm Yield (acre-feet/yr)	8,985	8,854	8,723	8,592	8,461	8,330	8,200
Available Supply (acre-feet/yr)	8,985	8,854	8,723	8,592	8,461	8,330	8,200
Safe Yield (acre-feet/yr)	7,470	7,331	7,192	7,053	6,914	6,775	6,635

The safe yield of the reservoir is estimated to be 7,470 acre-feet/yr (6.66 MGD).

Inflow estimates prior to September 1967 were based on USGS gages near Mangum, Wellington, and Clarendon. Inflows after September 1967 were based on a volumetric balance of the reservoir with USGS surface elevation measurements taken at the dam. Net reservoir evaporation rates were derived from 1-degree quadrangle data published by the TWDB (TWDB, 1967). Reservoir operation studies also included an estimate of historical low-flow releases. Sedimentation rates characteristic of the area were used to estimate a reservoir capacity reduction of 5,770 acre-feet by 1996 (Freese & Nichols, 1997).

Evaluation of Reservoir Yield Studies
The critical period for each of the three reservoirs extends beyond the most recent periods of analyses ending in September 2004. If low flows continue after September 2004, firm yields may be reduced still further. Firm yield analyses based on portions of a critical period rather than the entire critical period may overestimate yields. Values of firm yield already include information through September 2004.

The firm yield estimates using the Water Availability Models consider the latest available evaporation rates computed by TWDB. Most of the previous yield studies for Palo Duro Reservoir and Greenbelt Reservoir used the TWDB's net reservoir evaporation rates available before 1998. Evaporation rates for Lake Meredith for the period after 1965 are determined by on-site measurements. The previous TWDB evaporation data is generally lower than the latest data in the Panhandle Region. Each of the existing yield studies has been completed using estimates of the area-capacity relationships for the planning period 2000-2060 based on the most recent sedimentation surveys. As more recent surveys are conducted, the new area-capacity information should be used to revise the yield estimates. New sedimentation surveys are not available for either Palo Duro or Greenbelt, and the estimates of area-capacity relationships were based on the original surveys before the initial impoundment. The most recent volumetric survey for Lake Meredith was completed in 1995 and considered in the firm yield estimates.

3.2.5 Other Potential Surface Water Sources
Ten 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, Club Lake, and Bivens 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 3-16 summarizes descriptive information about each of the minor reservoirs.

Table 3-16: Descriptive Information of Minor Reservoirs in the PWPA

Reservoir	Stream	River Basin	Use	Water Rights *	Date of Impoundment	Capacity (acre-feet)
Lake McClellan	McClellan Creek	Red	soil conservation, flood control, recreation, promotion of wildlife	U.S. Forest Service (recreational)	1940s	5,005 *
Buffalo Lake	Tierra Blanca Creek	Red	flood control, promotion of wildlife,	n/a	1938	18,150
Lake Tanglewood	Palo Duro Creek	Red	recreation	n/a	1960s	n/a
Rita Blanca Lake	Rita Blanca Creek	Canadian	recreation	Dallam & Hartley Counties (recreational)	1941	12,100
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 acre-feet/yr	1949	9,220
Lake Childress	unnamed tributary to Baylor Creek	Red	n/a	n/a	1923	4,600 (as built)
Lake Fryer	Wolf Creek	Canadian	soil conservation, flood control, recreation,	n/a	1938	n/a
Club Lake	n/a	Red	n/a	n/a	N/a	n/a
Bivens Lake	Palo Duro Creek	Red	ground water recharge	n/a	1926	5,120

Source: Breeding, 1999
               *TCEQ, 2000
               n/a – data are not available

3.2.5.1 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 (TNRCC, 1999). Lake McClellan has a capacity of 5,005 acre-feet (Breeding, 1999).

3.2.5.2 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.

In 1973-1975, a low water dam was built to increase habitat for ducks and geese. In 1978, the low water dam was washed out and the water was released. 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). Buffalo Lake has a water right for storage of 14,363 acre-feet, without a right for diversion.

3.2.5.3 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 for recreational purposes without a right for diversion.

3.2.5.4 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 (TCEQ, 2000). 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.

3.2.5.5 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 (TWDB, 1999).

3.2.5.6 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 (TWDB, 1999), there is currently no infrastructure remaining 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).

3.2.5.7 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, had an original capacity of 4,600 acre-feet; it is 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]. There are no water rights shown for the lake in TCEQ's water rights database (TCEQ, 2000).

3.2.5.8 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).

3.2.5.9 Club Lake

Brookhollow Country Club Lake, a private fishing lake with cabin sites, is six miles northeast of the city of Memphis in Hall County. The reservoir is in the Red River basin. No estimates of lake capacity are available.

3.2.5.10 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).

3.2.5.11 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.

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 4,884 playa lakes are located in the PWPA, covering approximately one percent of the surface area (NRCS, 1999). 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 3-17 shows the estimated acreage and water storage for playa lakes in the PWPA.

Table 3-17: Acreage and Estimated Maximum Storage of Playa Lakes in the PWPA

County	Estimated Area (acres)	Estimated Maximum Storage* (acre-feet)
Armstrong	15,177	45,532
Carson	18,270	54,810
Childress	116	347
Collingsworth	0	0
Dallam	4,125	12,374
Donley	1,903	5,710
Gray	12,907	38,722
Hall	0	0
Hansford	6,981	20,942
Hartley	3,791	11,373
Hemphill	100	299
Hutchinson	3,297	9,890
Lipscomb	234	703
Moore	4,635	13,906
Ochiltree	15,836	47,509
Oldham	4,336	13,009
Potter	3,203	9,609
Randall	16,793	50,378
Roberts	1,368	4,103
Sherman	4,499	13,496
Wheeler	0	0
TOTAL	**117,571**	**352,712**

Source: Fish, et. al., 1997 *Based on average depth of 3 feet

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 may 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.

3.2.6   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 3-18.

Table 3-18 Direct Reuse in the PWPA
-Values in Acre-feet per Year-

County	2010	2020	2030	2040	2050	2060
Carson	14	13	13	13	13	13
Childress	120	117	117	118	120	120
Collingsworth	300	300	300	300	300	300
Dallam	430	421	409	391	379	379
Gray	1,902	1,879	1,615	1,568	1,525	1,525
Hall	7	6	6	6	5	5
Hemphill	13	12	11	10	10	10
Hutchinson	1,332	1,270	1,198	1,112	1,073	1,073
Lipscomb	34	34	34	34	34	34
Moore	547	592	633	664	684	696
Potter	19,381	23,241	24,658	26,262	27,865	31,969
Randall	2,936	2,943	2,956	2,970	2,985	2,995
Roberts	25	23	22	20	18	18
Wheeler	16	15	15	15	14	14
Total	**27,057**	**30,866**	**31,987**	**33,483**	**35,025**	**39,151**

3.2.7 Local Supplies

Local supplies include stock ponds for livestock use and local supplies for mining and irrigation. 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 3-19.

Table 3-19: Summary of Local Supplies in the PWPA
-Values in Acre-feet per Year-

	2010	2020	2030	2040	2050	2060
IRRIGATION LOCAL SUPPLY						
Hansford	150	149	147	146	144	144
Potter	1,686	1,685	1,683	1,682	1,679	1,679
Randall	634	630	627	624	621	621
Sherman	406	405	404	402	400	400
LIVESTOCK LOCAL SUPPLY						
Armstrong	121	121	121	121	121	121
Carson	284	284	284	284	284	284
Childress	300	300	300	300	300	300
Collingsworth	750	750	750	750	750	750
Dallam	741	741	741	741	741	741
Donley	1,225	1,225	1,225	1,225	1,225	1,225
Gray	2,732	2,732	2,732	2,732	2,732	2,732
Hall	301	301	301	301	301	301
Hansford	2,464	2,464	2,464	2,464	2,464	2,464

Table 3-19 (continued)

LIVESTOCK LOCAL SUPPLY						
Hartley	1,702	1,702	1,702	1,702	1,702	1,702
Hemphill	888	888	888	888	888	888
Hutchinson	493	493	493	493	493	493
Lipscomb	657	657	657	657	657	657
Moore	981	981	981	981	981	981
Ochiltree	2,506	2,506	2,506	2,506	2,506	2,506
Oldham	1,249	1,249	1,249	1,249	1,249	1,249
Potter	516	516	516	516	516	516
Randall	516	516	516	516	516	516
Roberts	515	515	515	515	515	515
Sherman	699	699	699	699	699	699
Wheeler	1,561	1,561	1,561	1,561	1,561	1,561
OTHER LOCAL SUPPLY						
Childress	21	21	21	21	21	21
Moore	1,658	1,658	1,658	1,658	1,658	1,658
Total Local Supply	**25,756**	**25,749**	**25,741**	**25,734**	**25,724**	**25,724**

3.2.7   Summary of Available Water Supplies in the PWPA

The currently available water supplies in the PWPA total nearly 3,600,000 acre-feet per year in 2010, decreasing to 2,700,000 acre-feet per year by 2060. Most of this supply is associated with groundwater, specifically 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.

The supplies shown in Table 3-20 represent the amount of supply that is currently developed and potential future supplies that could be developed. These values do not consider infrastructure constraints, contractual agreements, or the economic feasibility of developing these sources. In some counties the available groundwater supplies is significantly greater than the historical use. In other counties, current groundwater use exceeds the available supply based on the 1.25% policy. Consideration of the amount of water that is currently connected and available to water users in the PWPA is discussed in Section 3.3.

Table 3-20: Summary of Water Supplies in the PWPA
-Values in Acre-feet per Year-

Source	2010	2020	2030	2040	2050	2060
Lake Meredith	69,750	69,750	69,750	69,750	69,750	69,750
Greenbelt Lake	8,854	8,723	8,592	8,461	8,330	8,200
Palo Duro Reservoir	3,958	3,917	3,875	3,833	3,792	3,750
Canadian River Run-of-River	296	296	296	296	296	296
Red River Run-of-River	2,168	2,168	2,168	2,168	2,168	2,168
Total Surface Water	**85,026**	**84,854**	**84,681**	**84,508**	**84,336**	**84,164**
Ogallala Aquifer	2,842,607	2,646,997	2,475,470	2,328,655	2,220,628	2,128,308
Seymour Aquifer	41,613	40,613	38,738	38,738	38,738	38,738
Blaine Aquifer	230,000	228,750	228,750	228,750	228,750	228,750
Dockum Aquifer	337,500	295,200	258,400	226,100	197,900	173,200
Other Aquifers	6,098	6,097	6,094	6,091	6,091	6,091
Total Groundwater	**3,457,818**	**3,217,657**	**3,007,452**	**2,828,334**	**2,692,107**	**2,575,087**
Local Supply	25,756	25,749	25,741	25,734	25,724	25,724
Direct Reuse	27,057	30,866	31,987	33,483	35,025	39,151
Total Other Supplies	**52,813**	**56,615**	**57,728**	**59,217**	**60,749**	**64,875**
Total Supply in PWPA	**3,595,657**	**3,359,126**	**3,149,861**	**2,972,059**	**2,837,192**	**2,724,126**

3.3 Water Supply and Demand Summary

This section discusses the comparison of the developed supply in the Panhandle Water Planning Area (PWPA) to the projected demands developed in Chapter 2. Developed supplies are defined as the amount of water available to water user groups considering existing infrastructure, contractual agreements and source availability. This comparison 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 shortage is identified (represented by a negative number). For some users, the available 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 2060.

The management policy for the PWPA is a maximum annual 1.25% withdrawal of the recoverable volume of water of the source aquifer, with a 5-year recalculation of the volume remaining. All water availabilities from groundwater aquifers stated in this plan comply with this management policy. All supplies listed as "available" or "availability" in regards to groundwater refer to this policy adjustment to the supply. The implementation of the policy for projections of water user group demand has resulted in several "overdrafts" of the policy that are shown in the analysis with demand as shortages. These shortages are shown primarily for agricultural uses including irrigated agriculture and livestock water. The PWPG has prioritized livestock use over irrigation in areas where shortages where identified. Voluntary transfers of these supplies usually add to the unmet irrigation demand.   In addition, local Groundwater Conservation District rules may be more restrictive in certain areas as permitting requirements

based on geographic extent may limit withdrawals beyond the county-wide 1.25% availability shown in this plan.

3.3.1 Regional Demands

Summarized from Chapter 2, the total demands for the PWPA are projected to decrease from 1,864,748 acre-feet in the year 2010 to 1,780,588 acre-feet per year in 2030 and 1,399,412 acre-feet per year by 2060. The largest water user group demand category is irrigation, which accounted for nearly 90 percent of the total demand in the region in the year 2000, but decreased slightly to 80 percent by year 2060 as municipal demands increased. Municipal is the next largest water user in the PWPA, and livestock is the third largest demand.

3.3.2 Current Supply

The currently developed supply in the PWPA consists mainly of groundwater, 95% 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 over 90 percent of the total supply in year 2010. For cities, the supplies were limited to the developed water rights reported to the PWPA and/or 50% of the well field capacity reported to the TCEQ. For other users, such as local supplies for livestock, the water supplies were limited to historical use as reported to the TWDB.

The total volume of the developed supply for the PWPA in year 2010 was approximately 1,894,000 acre-feet per year and projected to decrease to 1,521,000 by the year 2030 and ultimately to 1,131,000 acre-feet per year in 2060. These supply volumes are shown in Table 3-21.

Table 3-21: Developed Water Supplies to Water User Groups in PWPA
-Values in Acre-feet per Year-

Source	2010	2020	2030	2040	2050	2060
Meredith[1]	30,305	30,305	30,305	30,304	30,305	30,305
Palo Duro[2]	0	0	0	0	0	0
Greenbelt[1]	2,564	2,582	2,587	2,575	2,559	2,489
Run-of-the-River	2,464	2,464	2,464	2,464	2,464	2,464
Total surface water	**35,333**	**35,351**	**35,356**	**35,343**	**35,328**	**35,258**
Ogallala	1,715,250	1,551,180	1,341,189	1,164,337	1,033,574	948,141
Blaine	19,740	19,740	19,740	19,740	19,740	19,740
Seymour	41,271	40,271	38,271	38,271	38,271	38,271
Dockum	24,420	24,420	23,620	21,920	20,520	19,220
Other Aquifers (Rita Blanca, Other)	6,095	6,095	6,092	6,090	6,090	6,090
Total groundwater	**1,806,776**	**1,641,706**	**1,428,912**	**1,250,358**	**1,118,195**	**1,031,462**
Local Supplies	25,756	25,749	25,741	25,734	25,724	25,724
Reuse	26,067	29,934	31,116	32,687	34,255	38,407
Total Supply	**1,893,932**	**1,732,740**	**1,521,125**	**1,344,122**	**1,213,502**	**1,130,851**

1. Quantity of water available is for PWPA users only. Supplies from these sources are also used in other regions.
2. There is no currently available supply from Palo Duro Reservoir because there is no infrastructure.

Table 3-21 is the total available supplies available for use within the PWPA. CRMWA provides drinking water to eight other member cities in the Llano Estacado RWPA and slightly over 30,000 acre-feet per year are allocated from Lake Meredith to water users group in PWPA. CRMWA also supplies water from their Roberts County well field to member cities in the Llano Estacado RWPA.

3.4 Comparison of Demand to Currently Available Supplies

Considering only developed and connected supplies for the Panhandle, on a regional basis the available supply exceeds the demands by only 29,200 acre-feet per year in the year 2010, and is less than the projected demands by nearly 259,500 acre feet per year in 2030, and 268,500 acre feet per year in 2060. This is shown graphically on Figure 3-6.
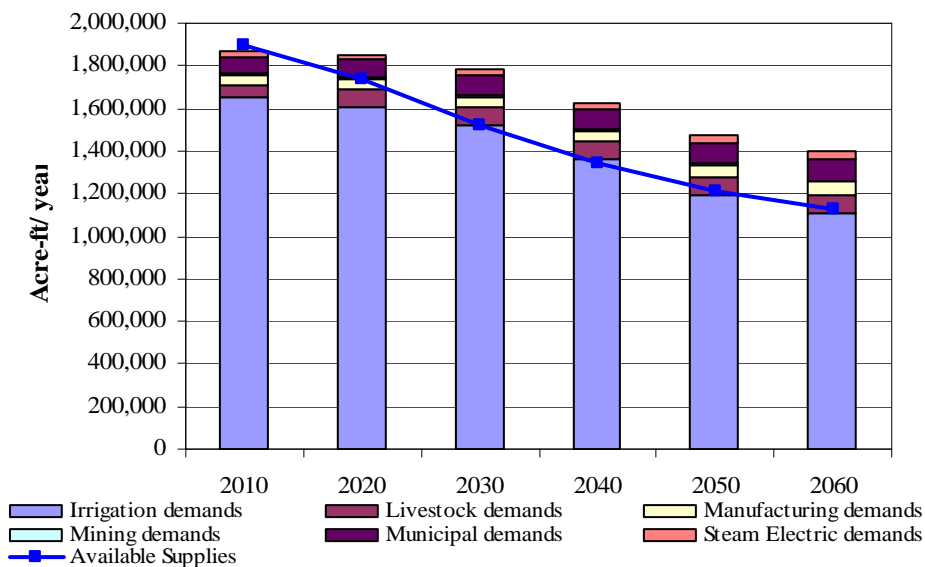

Figure 3-6: PWPA Supplies and Demands (ac-ft/yr)

On a county-basis, there are seven counties with shortages over the planning period. These include Dallam, Hartley, Hutchinson, Moore, Potter, Randall and Sherman. Table 3-22 presents current available supply versus demand by county. Figure 3-7 shows the spatial distribution of shortages in the region for years 2010, 2030 and 2060. Typically the counties with the largest shortages are those with large irrigation demands. The shortages by category and county for years 2000, 2030 and 2060 are summarized in Tables 3-23, 3-24 and 3-25, respectively. Based on this analysis, there are significant irrigation shortages over the 50-year planning period. The municipal shortages shown are typically attributed to growth, allocation limitations in developed water rights, or infrastructure limitations. A brief discussion of these shortages is presented in the following section.
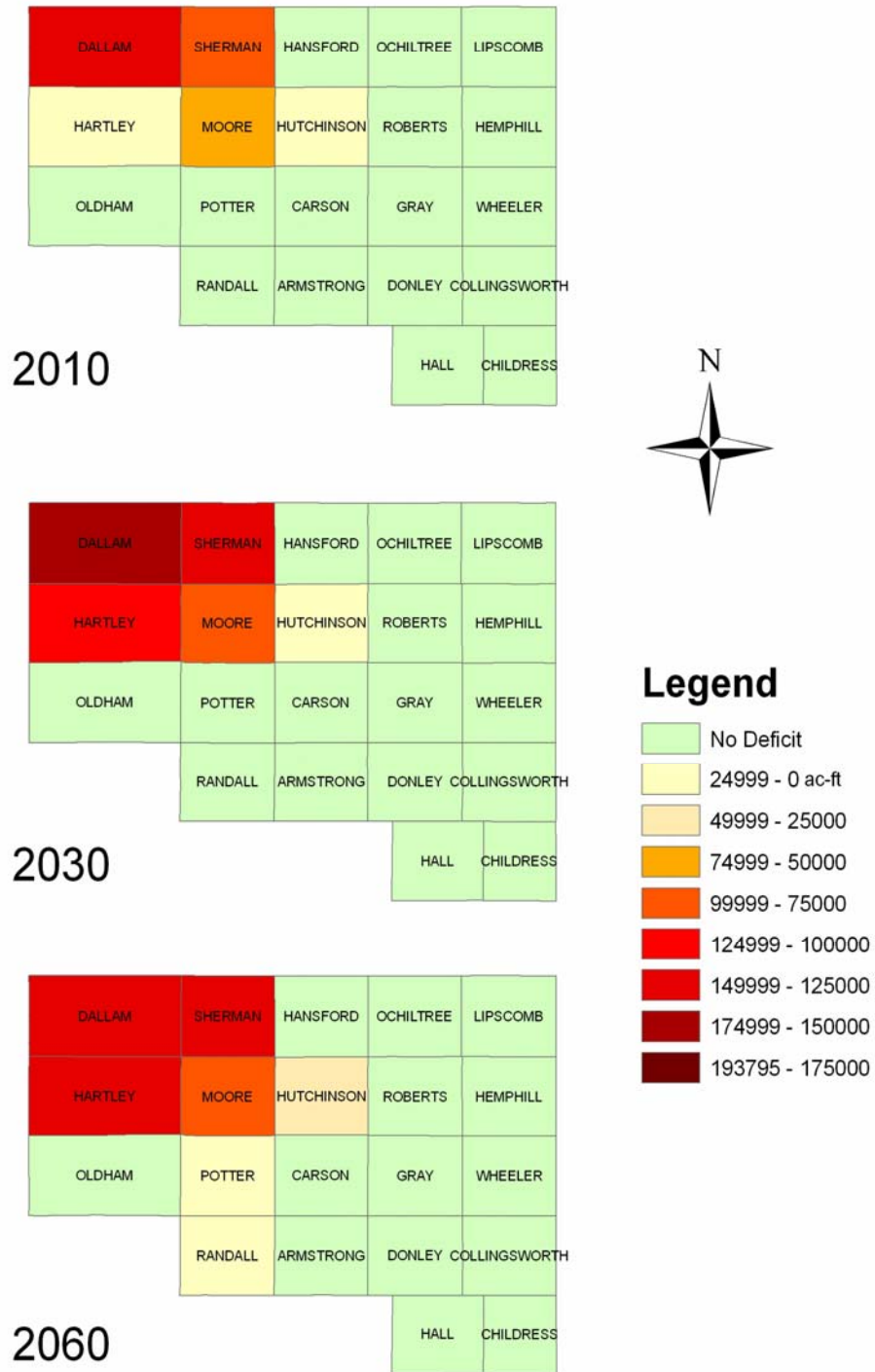
Figure 3-7: Shortages in Region A for Planning Period 2010-2060

Table 3-22: Comparison of Supply and Demand by County

County	Basin	Year 2010		Year 2030		Year 2060	
		Currently Available Supply	Demand	Currently Available Supply	Demand	Currently Available Supply	Demand
Armstrong	Red	17,260	11,276	17,302	10,544	17,759	7,974
Carson	Canadian	42,845	32,088	42,646	29,753	42,605	21,936
	Red	88,110	67,189	74,836	62,406	57,041	45,907
Childress	Red	12,497	12,008	12,545	11,346	12,513	8,755
Collingsworth	Red	32,991	26,249	31,489	24,384	31,486	17,929
Dallam	Canadian	196,097	326,461	139,881	308,970	98,030	229,497
Donley	Red	37,003	22,373	32,703	20,894	23,110	15,744
Gray	Canadian	22,767	13,776	21,934	13,473	21,268	11,461
	Red	33,115	23,544	31,062	22,480	27,277	17,836
Hall	Red	21,741	21,379	20,240	19,864	20,239	14,648
Hansford	Canadian	257,448	141,563	225,759	132,111	188,164	98,670
Hartley	Canadian	273,439	290,085	165,780	271,889	58,655	200,477
Hemphill	Canadian	5,895	2,339	6,028	2,415	6,205	2,417
	Red	7,306	3,567	7,062	3,443	6,805	3,216
Hutchinson	Canadian	83,160	90,623	65,188	89,423	32,557	77,928
Lipscomb	Canadian	35,550	16,093	37,987	15,133	40,923	11,448
Moore	Canadian	128,115	194,568	86,016	184,657	48,706	142,629
Ochiltree	Canadian	141,649	108,494	134,238	101,404	119,739	76,067
Oldham	Canadian	25,106	4,118	24,057	4,214	22,462	3,992
	Red	4,434	3,834	4,347	3,585	4,324	2696
Potter	Canadian	56,668	43,215	53,344	50,295	53,155	61,471
	Red	24,020	20,511	22,224	23,227	18,200	26,880
Randall	Canadian	369	334	349	321	313	300
	Red	86,036	56,119	70,610	59,511	56,642	65,215
Roberts	Canadian	25,256	20,417	22,575	18,931	16,763	13,904
	Red	4,059	2,705	3,595	2,500	2,643	1,814
Sherman	Canadian	211,318	299,079	147,490	283,100	81,013	210,178
Wheeler	Red	19,678	10,741	19,838	10,315	22,254	8,423
TOTAL		**1,893,932**	**1,864,748**	**1,521,125**	**1,780,588**	**1,130,851**	**1,399,412**

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

Insert Table 3-23: Year 2010 Shortages by County and Category
Found in Final Report folder/ Table3-23to3-25_updated.xls

Insert Table 3-24: Year 2030 Shortages by County and Category

Insert Table 3-25: Year 2060 Shortages by County and Category

3.5 Identified Shortages for the PWPA

A shortage occurs when currently available supplies are not sufficient to meet projected demands. In the PWPA there are 30 water user groups (accounting for basin and county designations) with identified shortages during the planning period. Of these, there are 7 cities and several county other water users that are projected to experience a water shortage before 2060. The largest shortages are attributed to high irrigation use and limited groundwater resources in Dallam, Hartley, Moore, and Sherman Counties.

Total shortages for all water user groups are projected to be 310,554 acre feet per year in 2010, increasing to 542,805 acre feet per year in 2030 and 575,637 acre-feet per year by the year 2060. Of this amount, irrigation represents more than 90% in the 2010 projections and 85% of the total shortage of 2060 with nearly 486,365 acre-feet per year. The shortages attributed to the other water use categories total approximately 89,300 acre-feet per year in 2060.

A summary of when the individual water user group shortages begin by county and demand type is presented in Table 3-26. To account for the level of accuracy of the data, a shortage is defined as a demand greater than the current supply by more than or equal to 10 acre-feet.

Table 3-26: Decade Shortage Begins by County and Category

County	Irrigation	Municipal	Manufacturing	Mining	Steam Electric Power	Livestock
Armstrong	-	-	-	-	-	-
Carson	-	-	-	-	-	-
Childress	-	-	-	-	-	-
Collingsworth	-	-	-	-	-	-
Dallam	2010	2010	-	-	-	2010
Donley	-	-	-	-	-	-
Gray	-	-	-	-	-	-
Hall	-	-	-	-	-	-
Hansford	-	-	-	-	-	-
Hartley	2010	2010	-	-	-	2010
Hemphill	-	-	-	-	-	-
Hutchinson	2010	-	2010	-	-	-
Lipscomb	-	-	-	-	-	-
Moore	2010	2010	2010	-	2010	2010
Ochiltree	-	-	-	-	-	-
Oldham	-	-	-	-	-	-
Potter	-	2020	2040	-	-	-
Randall	-	2030	-	-	-	-
Roberts	-	-	-	-	-	-
Sherman	2010	2010	-	-	-	2010
Wheeler	-	-	-	-	-	-

3.5.1 Irrigation

Irrigation shortages are identified for Dallam, Hartley, Hutchinson, Moore, and Sherman counties. All these counties rely heavily on the Ogallala for irrigation supplies. Shortages are observed in Dallam, Hartley, Hutchinson, Moore, and Sherman Counties starting in 2010. Shortages for Hartley and Hutchinson counties are partially attributed to high agricultural use that is confined to only a portion of the county.

3.5.2 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. This includes Gruver and Perryton. At this time, these cities do not show a shortage during the present planning period. Other cities do not appear to have sufficient water rights through the planning period. A list of the municipalities indicating a shortage is presented in Table 3-27. All but two of these cities rely exclusively on groundwater.

Table 3-27: Municipalities with Identified Shortage

City	Surface Water Supply	Groundwater Supply	Year Shortage Begins
Amarillo	X	X	2030
Cactus[1]	-	X	2010
Canyon	X	X	2050
Dalhart	-	X	2010
Dumas[1]	-	X	2010
Stratford	-	X	2010
Sunray[1]	-	X	2010

[1.] A member city of PDRA, but there is no current infrastructure to transmit water from Palo Duro reservoir.

3.5.3 Manufacturing

There are three counties with manufacturing shortages identified in PWPA. Most manufacturing interests buy water from retail providers or develop their own groundwater supplies. For Moore County, these shortages are the result of limited groundwater supplies and competition for the Ogallala aquifer for other shortages. In Hutchinson County, the shortage is attributed to developed infrastructure and significant increases in the projected demands, while in Potter County the shortage is associated with shortages identified with Amarillo.

3.5.4 Mining

Mining is a relatively small demand in the PWPA, and there are no supply shortages.

3.5.5 Steam Electric Power

There is only one steam electric power shortage identified in the PWPA. A shortage of less than 100 acre-feet per year is projected in Moore County beginning in 2010; by 2060 this shortage is projected to be approximately 160 acre-feet per year. All of these shortages are expected to be met by increasing the supply coming from reuse.

3.5.6 Livestock

Livestock shortages in the PWPA are due in part to the competition for Ogallala water in those counties with high use and partly due to significant increases in demands. As previously discussed, the livestock water supply from the Ogallala in Dallam, Hartley, Moore and Sherman counties is limited because of competition for other shortages. Within the PWPA, priority has been given to livestock uses over irrigated agriculture and shortages for livestock water users is made up by voluntary transfers from irrigated agriculture in the county of shortage.

3.6 Conclusions

On a water user group basis, the total demands exceed the total available supply starting in 2010, in large part being attributed to the 1.25% policy limitation on the supply. Most of the shortages are attributed to large irrigation demands that cannot be met with available groundwater sources. Other shortages are due to limitations of contractual agreements, infrastructure, and/or growth. There are supplies in the region that are not fully utilized, such as Palo Duro Reservoir, which could possibly be used for some of the identified shortages. The Ogallala in several counties could be further developed. However, often the needed infrastructure is not developed or the potential source is not located near a water supply shortage. Further review of the region's existing supplies and other options and strategies to meet shortages is explored in more detail in Chapter 4 and the impacts of these strategies on water quality is discussed in Chapter 5.