West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan

August 2004

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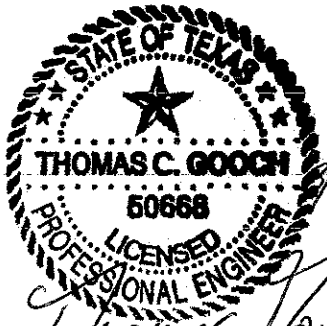

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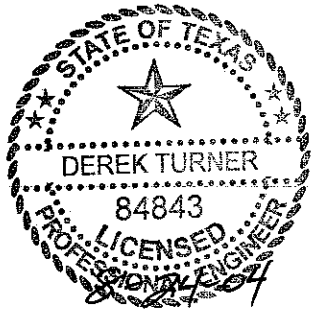

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WEST CENTRAL BRAZOS RIVER BASIN REGIONAL WATER TREATMENTAND DISTRIBUTION FACILITY PLAN

Executive Summary

In the latter part of the last decade West Texas experienced a significant drought, and some areas are still in drought of record conditions. One of the areas hit hard by this drought was the upper part of the Brazos River Basin. Small community lakes went dry, limited groundwater sources were being depleted, and the farming community reported significant losses in earnings. In response to these conditions and the needs of the community, the Brazos River Authority ("Authority") authorized this study with funding assistance from the United States Economic Development Administration (EDA) and the Texas Water Development Board (TWDB). The West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan evaluates the water needs in an 18-county area, assesses the economic impacts of water shortages and identifies a plan to develop and efficiently utilize the water resources in the area.

Much of the study area (shown on Figure ES-1) relies on surface water for its water supply. Groundwater, where available, is often limited in quantity; yet for many rural counties in the northwestern part of the study area, groundwater is the only available water source. Evaluations of available water supply to the study area found that on a regional basis, there are sufficient water supplies to meet municipal demands. As shown on Figure ES-2, the currently available municipal supply is estimated at over 120,000 acre-feet per year over the planning period. Projected municipal demands under drought conditions range from 69,300 acre-feet per year in year 2000 to 77,800 acre-feet per year in 2040, an increase of 8,500 acre-feet per year.

While there appear to be sufficient total water supplies for municipal and manufacturing needs in the study area, seven water users were identified with projected water shortages over the planning period. These users include the cities of Throckmorton, Sweetwater, and Strawn, Shackelford Water Supply Corporation (WSC), Stephens County Rural WSC, West Central Texas Municipal Water District (WCTMWD), and an unincorporated area in northeast Brown County. The total shortage for the study area is estimated at less than 8,700 acre-feet per year, with most of the shortage attributed to the city of Sweetwater (3,781 acre-feet per year) and WCTMWD (3,762 acre-feet per year).

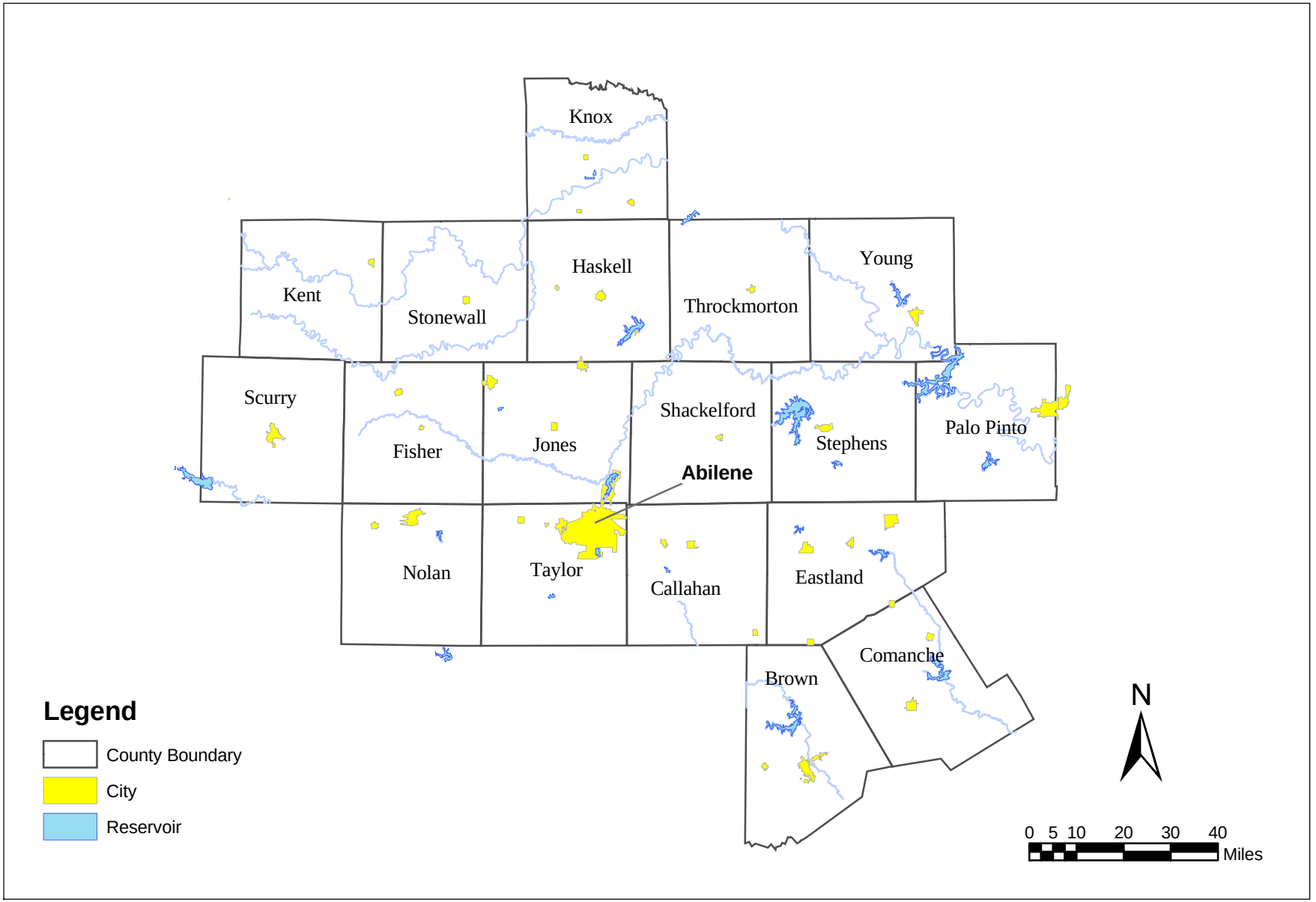
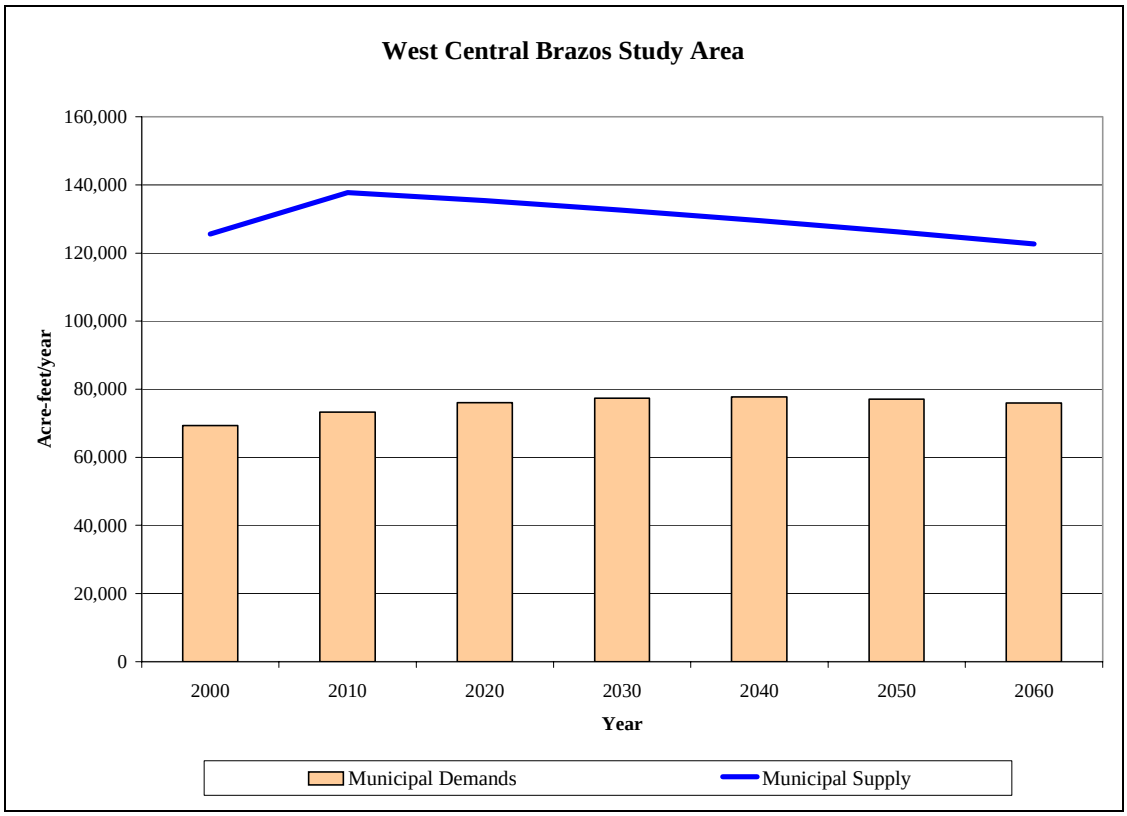


Figure ES-1 West Central Brazos Study Area

Figure ES-2

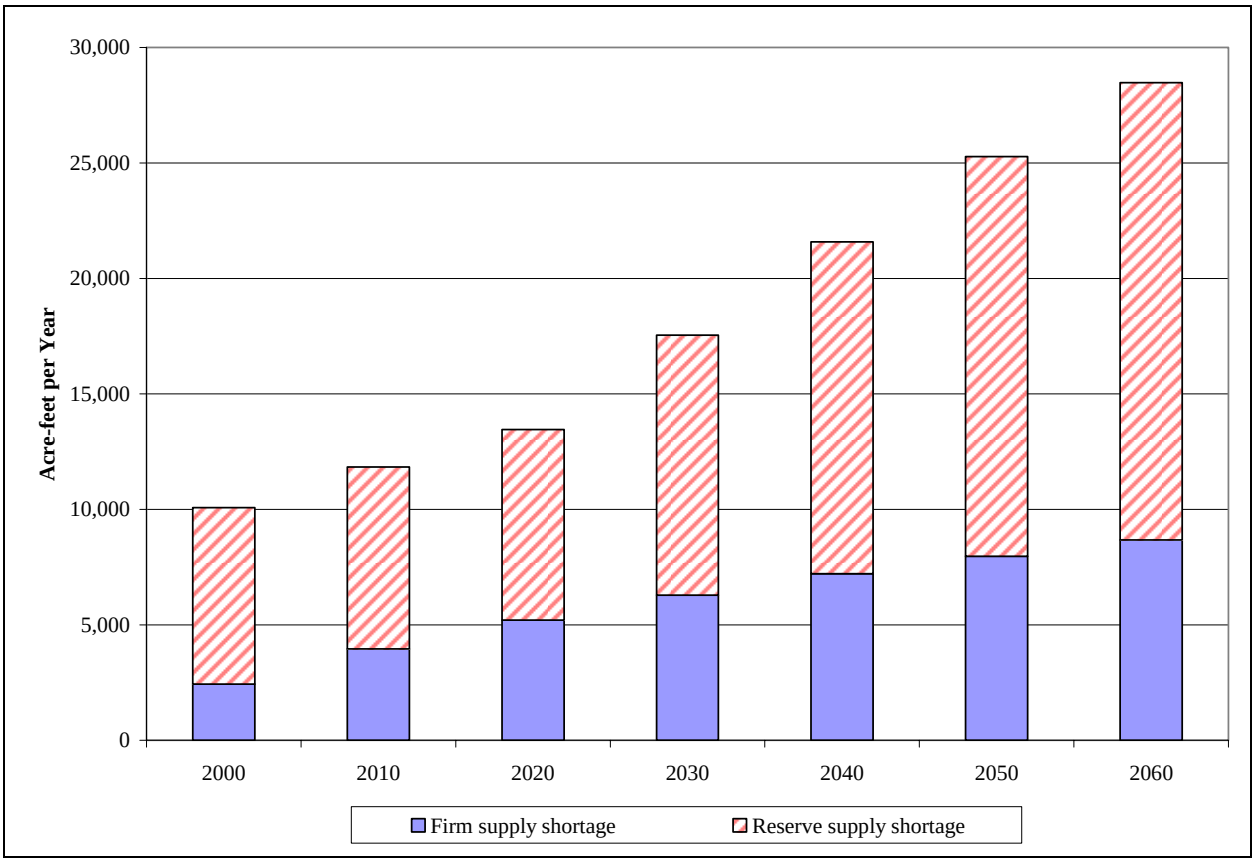
Municipal Supply and Demand in West Central Brazos Study Area



Other entities were identified as having sufficient water to meet the projected demands but limited reserve supplies for higher growth rates and/or more severe drought conditions. To assess the need to develop additional reserve supplies, a safety factor of 1.25 times the projected demands was applied. This assumed that a water provider should have a reserve supply of 25 percent of the projected demands. Using this criterion, six other water providers were identified as needing to develop additional water to maintain a reserve supply. As shown on Figure ES-3, the total estimated shortage in the study area, including the reserve shortage, is 28,500 acre-feet per year in year 2060. The WCTMWD, Brown County WID#1 and the city of Sweetwater each had reserve shortages greater than 5,000 acre-feet per year. Shortages for the other entities ranged from less than 100 acre-feet per year to 2,400 acre-feet per year. Two entities, Rising Star and the city of Lawn, were also identified as having water treatment concerns, and the cities of Anson, Cisco and Gordon were identified with no emergency or back-up supplies. Water supply needs were identified for a total of 19 entities, all of which are listed in Table ES-1.

Figure ES-3

Projected Water Supply Shortages



1. Firm supply shortage is the amount of water needed to meet projected demands.
2. Reserve supply shortage is the amount of water needed to have a reserve supply equal to 25% of the projected demands.
3. These shortages were determined on an individual basis and do not reflect possible surplus supplies of other entities within the study area.

Recognizing the vulnerability of small surface lakes and the uncertainty of groundwater, this study focused on interconnecting existing supply sources and developing new supplies to provide a safe level of supply to water users and increase the reliability of existing sources to promote economic growth in the region. Collectively, over 25 potential water management strategies were evaluated to meet specific needs in the region. In addition, three general strategies (brush control, weather modification and salt water control) were reviewed as potential means to improve water quality and quantity in the region.

Table ES-1
Integrated List of Strategies to Meet Regional Water Needs

Water user	Strategy	Year Needed	Supply Amt (ac-ft/yr)	Cost per 1,000 gal
Throckmorton	*Renew emergency contract with Ft. Belknap*	*2005*	*100*	*Unknown*
	Midway Group regional WTP with supply from Possum Kingdom	*2005*	*193*	*$4.12*
	New pipeline from Lake Stamford	2040	800	$4.54
Sweetwater	*New groundwater well field*	*2005*	*5,100*	*$1.62*
Shackelford WSC	*Midway Group regional WTP with supply from Possum Kingdom*	*2005*	*250*	*$4.12*
	Purchase water from Throckmorton from Lake Stamford supply	2040	200	$4.54
Stephens County RWSC	*Midway Group regional WTP with supply from Possum Kingdom*	*2005*	*400*	*$4.12*
	Purchase water from Throckmorton from Lake Stamford supply	2050	200	$4.54
Strawn	*Purchase water from Eastland County WSD*	*2005*	*200*	*$3.33*
Rising Star	*Install a nitrate treatment system and connection to existing Westbound WSC system*	*2005*	*150*	*$1.86*
WCTMWD	*Agreement with the Authority regarding retention of Possum Kingdom priority inflows*	*2005*	*19,000*	*Unknown*
	Clear Fork Diversions to Hubbard Creek	2040	16,000	$1.44
Lawn	*Purchase water from local provider*	*2005*	*150*	*$5.23*
NE Brown Co.	*Purchase water from Zephyr WSC*	*2005*	*170*	*$5.47*
BCWID #1	*Permit modifications*	*2005*	*8,600*	*Unknown*
ULMWD	New groundwater well field	2010	1,000	$1.43
Breckenridge	Midway Group regional WTP with supply from Possum Kingdom	2040	650	$4.12
Graham	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	2040	550	Unknown
	Purchase Possum Kingdom water and blend with Lake Graham at WTP	2040	360	$3.23
Palo Pinto MWD	Purchase Possum Kingdom water and blend with existing supply	2040	1,000	$1.27
	Turkey Peak Reservoir	After 2040	7,600 (raw) 4,000 (treat)	$1.15 $2.70
Abilene	Increase Hubbard Creek Lake supply with Clear Fork Diversion (existing infrastructure)	2040	12,500	$2.30
	Increase transmission capacity from Hubbard Creek and purchase Possum Kingdom water[1]	After 2040	8,000 (raw) 18,100 (tot)	$4.59 $3.13
NCTMWA	Interconnection with Abilene through Hamlin	NA	700	$3.36
	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	After 2040	3,000	Unknown
Cisco	Back-up supplies from Eastland County WSD	NA	500	NA
Gordon	Back-up supplies from Palo Pinto MWD	NA	100	NA
Anson	Emergency connection to Abilene-Hamlin line	NA	550	NA
West Brazos	Salt water control in Stonewall County	NA	NA	NA
Regional	Weather modification	NA	NA	NA

1. *The projects recommended for implementation in the next two years are shown in red italicized print.*
2. This strategy would use 8,000 af/y from Possum Kingdom plus the 12,500 af/y from the Clear Fork diversion. After treatment there would be a combined 18,100 af/y of treated water. The cost to treat and transport the additional 8,000 ac-ft is $4.59/1,000 gallons. The average cost for the 18,100 ac-ft is $3.13/1,000 gallons.

Hydraulic analyses were conducted for seven water systems to evaluate the potential of moving water between entities using existing and/or modified infrastructure. All scenarios were found to be technically feasible, with two scenarios demonstrating the greatest potential impact to the region:

- Interconnection between Abilene and North Central Texas MWA
- Interconnections among Shackelford WSC, Stephens County Rural WSC and the city of Throckmorton

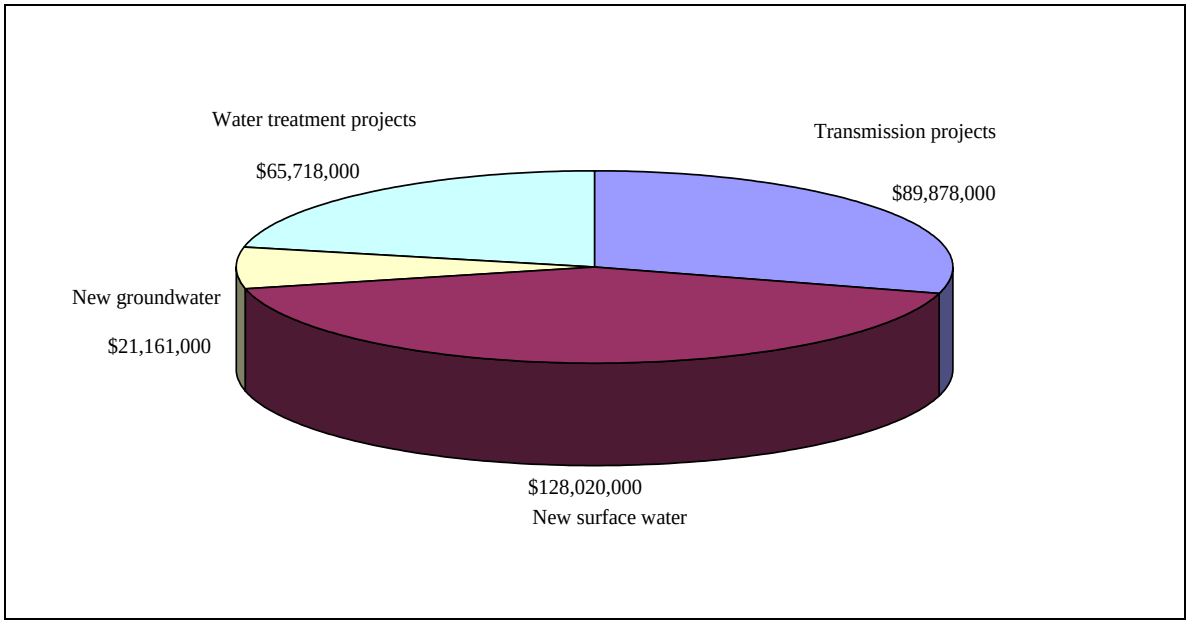
Other scenarios evaluated included the use of the West Central Brazos Water Distribution System (formerly the Kerr-McGee pipeline) and expansions of local water supply corporations or districts.

Table ES-1 lists the strategies that were identified as having the greatest potential to help meet regional needs, including 17 new infrastructure projects. These new infrastructure strategies would provide approximately 43,700 acre-feet per year in new water supplies or transfers of existing supplies with a total capital cost estimated at $305 million. Other strategies would safe guard 31,200 acre-feet per year of surface water supplies through contract agreements and permit modifications. Costs and quantifiable increases in supplies were not assessed for the general strategies. The capital costs by strategy type are shown on Figure ES-4.

Each of the strategies identified to meet a shortage was shown to have positive economic impacts to the region. Other strategies provide additional water supplies that are needed to attract new businesses and development.

Of the identified strategies, eleven were recommended for implementation within the next two years. These eleven strategies are listed on Table ES-1 in red print and have a total capital cost of $34.6 million. These strategies are necessary to meet current demands or water treatment standards. Some of the entities have already initiated discussions or studies for these projects. Others are still in the investigative stage. Strategies with the greatest capital cost are associated with new water supplies (Clear Fork Diversions to Hubbard Creek Lake and Turkey Peak Reservoir) and are not projected to be needed until after year 2040. The other significant capital cost project, a new pipeline from Hubbard Creek Lake to Abilene, is also not needed until after 2040.

Figure ES-4
Capital Costs by Strategy Type



Any of the strategies identified in this plan will require coordination and appropriate agreements with the respective entities. Financial assistance will be needed for most of the strategies identified in this plan and continued support by the Authority, TWDB and EDA is essential for continued growth in the region. Considerable improvements to drought-proofing the West Central Brazos study area can be achieved through interconnections and contract agreements at capital costs of approximately $50 million. To develop substantial quantities of new water supply (20,000 to 30,000 acre-feet per year), significant additional capital improvements would be needed.

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APPENDICES

1.0 Introduction

1.1 Authorization

In September 2002, the Brazos River Authority (the "Authority") authorized Freese and Nichols, Inc. to prepare the West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan. This study is funded by the Authority, United States Economic Development Administration (EDA) and the Texas Water Development Board (TWDB).

1.2 Purpose

The purpose of this study is to identify the water supply needs in an 18-county area, assess economic impacts and constraints associated with the lack of water, and identify a plan to develop and efficiently utilize the water resources in the study area. Where possible, a regional approach is employed with a goal to drought-proof the study area by building a water grid through existing, modified and new facilities as appropriate.

The focus of this study is on public water supply systems and their ability to meet current and projected municipal and manufacturing water demands. Needs for agricultural, livestock, mining and steam electric power water were not specifically addressed unless the water was obtained from a major municipal provider.

This plan is intended to supplement the regional water planning process with data and information that can be used by the entities in the study area and the regional water planning groups.

1.3 Project Scope

The scope of this project includes 12 tasks that outline the necessary data collection, evaluation and public participation needed to complete this study. A brief description of each task is presented below.

Task 1: Data Collection – This task includes collecting data on water resources in the study area, historical and projected population and water demands, and baseline economic data. It also includes a water use and facility survey for water providers to obtain local input and assess local water resource issues. The findings from this task are included in Chapters 2 and 3.

Task 2: Emergency Action Plan - This task is to develop an emergency plan for the study area, laying out the measures that might be taken, triggers that would initiate emergency action, and the possible timing of emergency measures in an attempt to avoid severe economic distress. An

Emergency Action Plan was prepared in June 2003 as a separate document, and it is available from the Authority.

Task 3 – Facility Inventory – This task inventories existing facilities for public water supply systems that provide more than 280 acre-feet per year of supply. A database with Geographic Information System (GIS) interface was developed and will be maintained by the Authority. A summary of the inventory is presented in Chapter 5, and the report along with schematics of local water treatment plants is included in Appendix E.

Task 4 – Hydraulic Analysis – This task assesses the potential to deliver water to other users through existing public water systems. It includes the development of a hydraulic model of each selected system to assess the capacities of the system under current conditions and with modifications. The results of this study are summarized in Chapter 6 and the report is included in Appendix F.

Task 5 – Water Supply Alternatives – This task includes evaluating the reliability of supplies in the study area and developing alternatives for providing additional water supply. The findings of the supply analysis are presented in Chapter 4, and the water supply alternatives are discussed in Chapter 7 and Appendices G, H and I.

Task 6 – Reservoir Site Evaluations – Four potential new reservoir sites were evaluated as part of the water supply alternatives. Descriptions of the sites, estimated supplies and costs are included in Appendices G and H.

Task 7 – Water Supply Projections – This task addresses the specific water needs for the Midway Group, which consists of the cities of Throckmorton and Breckenridge, Shackelford County WSC and Stephens County Rural WSC. As part of this task, population and water demand projections were developed for the Midway Group. The findings of this task are included in Chapter 4 and Appendix D.

Task 8 – Water Treatment – As part of the Midway Group assessment, water treatment options for different water supply alternatives for the Group were evaluated. The findings of this task are included in Appendix G.

Task 9 – Economic Analysis – This task includes economic analyses of water supply alternatives that were identified to meet a supply shortage. It also includes an assessment of potential economic impacts of new reservoir construction. The economic study report is included in Appendix J and summarized in Chapter 8.

Task 10 – Recommendations – This task identifies the water supply strategies that provide the greatest potential impacts to meet regional needs. The findings from the alternative and economic analyses are used to develop an integrated list of strategies that can deliver water to public water supply systems in the study area. Discussions of these strategies and other recommendations are included in Chapters 9 and 10. Financing options for these strategies are discussed in detail in Appendix K.

Task 11 – Public Meetings and Workshops – To promote public participation and enhance communication with local water suppliers, numerous public meetings and workshops were held from September 2002 to the present. Comments received from the public on the draft study report are included in Appendix L.

Task 12 – Report – This task assembles the data and findings of the study into this report. The facility database and associated GIS mapping conducted as part of this study are not included in the report.

2.0 Area Description

The West Central Brazos project area consists of 18 counties in the upper Brazos River Basin as shown on Figure 2.1. Portions of Scurry, Nolan, Taylor, Callahan, and most of Brown counties also lie in the Colorado River Basin, and portions of Knox and Young counties lie in the Red River Basin. Most of the counties within the study area are located in the Brazos G Water Planning Region. Scurry and Brown Counties are located in Region F and the city of Olney in Young County is in Region B.

2.1 Population of Study Area

This area of the state is predominantly rural and is not projected to grow much over the 50-year planning horizon. The largest city is Abilene with a population of nearly 116,000. Four other cities have current populations between ten and twenty thousand: Brownwood, Mineral Wells, Snyder and Sweetwater. The historical populations by counties are shown on Table 2.1**.**

The total population of the 18-county region was 339,442 in 2000. The Texas Water Development Board (TWDB) projects the population to increase to 362,148 by 2060 [(1)1]. This represents an average 0.11 percent annual growth rate for the area, which is about half of the growth rate in the previous fifty years. Palo Pinto County has the highest projected growth in the study area with most of the growth occurring closest to the Dallas-Fort Worth metroplex in the city of Mineral Wells. Brown, Scurry and Taylor Counties also show increased growth. The remaining counties show little to no growth. As part of this study, new population and water demand estimates were developed for the members of the Midway Group, which include Stephens County Rural Water Supply Corporation, Shackelford County Water Supply Corporation, city of Throckmorton and the city of Breckenridge. Each of these entities projected higher growth for their service areas than reported by the TWDB. This is due in part to increases in week-end residents and the projected conversion from seasonal to permanent residents. The TWDB-projected populations and the revised populations by county are presented in Tables 2.2 and 2.3, respectively**.** The historical and projected population for the study area is shown on Figure 2.2. Comparisons of the approved TWDB populations, revised populations, and the Brazos G Regional Water Plan projections by county [(2)] are included in Appendix A.

[1] Superscripted numbers in parenthesis correspond to references that are listed at the end of this report.

Figure 2.1

Table 2.1

Historical Population by Decade

County Name	1950	1960	1970	1980	1990	2000
Brown	28,607	24,728	25,877	33,057	34,371	37,674
Callahan	9,087	7,929	8,205	10,992	11,859	12,905
Comanche	15,516	11,865	11,898	12,617	13,381	14,026
Eastland	23,942	19,526	18,092	19,480	18,488	18,297
Fisher	11,023	7,865	6,344	5,891	4,842	4,344
Haskell	13,736	11,174	8,512	7,725	6,820	6,093
Jones	22,147	19,299	16,106	17,268	16,490	20,785
Kent	2,249	1,727	1,434	1,145	1,010	859
Knox	10,082	7,857	5,972	5,329	4,837	4,253
Nolan	19,808	18,963	16,220	17,359	16,594	15,802
Palo Pinto	17,154	20,516	28,962	24,062	25,055	27,026
Scurry	22,779	20,369	15,760	18,192	18,634	16,361
Shackelford	5,001	3,990	3,323	3,915	3,316	3,302
Stephens	10,597	8,885	8,414	9,926	9,010	9,674
Stonewall	3,679	3,017	2,397	2,406	2,013	1,693
Taylor	63,370	101,078	97,853	110,932	119,655	126,555
Throckmorton	3,618	2,767	2,205	2,053	1,880	1,850
Young	16,810	17,254	15,400	19,083	18,126	17,943
TOTAL	**299,205**	**308,809**	**292,974**	**321,432**	**326,381**	**339,442**

Table 2.2

TWDB Projected Population by Decade

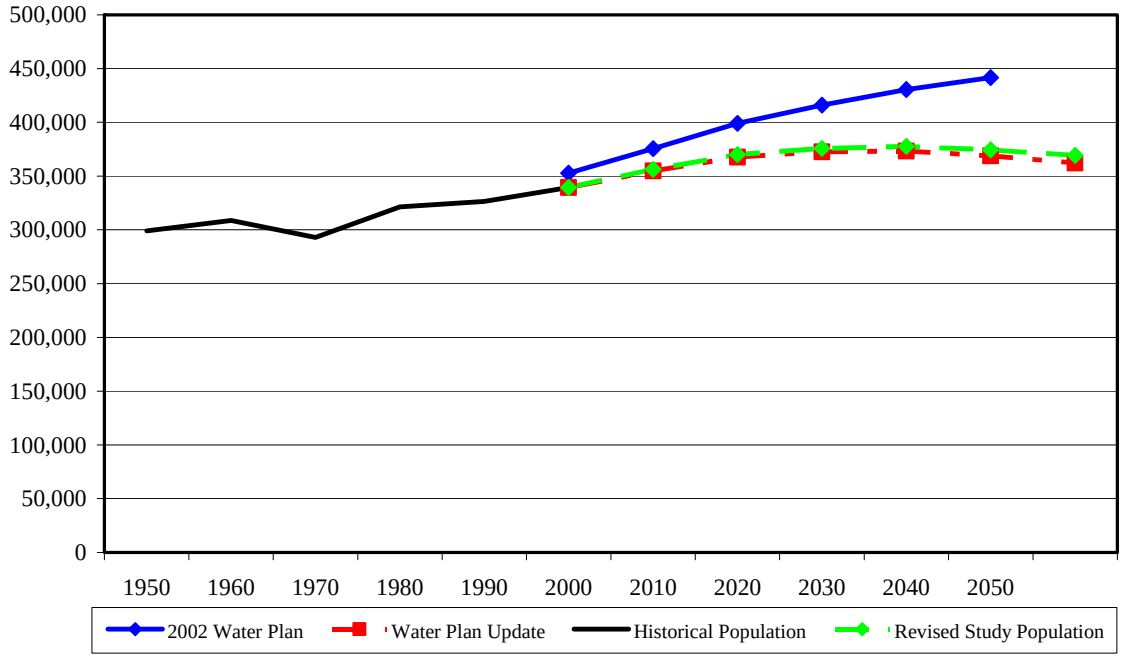
County Name	2000	2010	2020	2030	2040	2050	2060
Brown	37,674	39,324	40,602	40,959	40,959	40,959	40,959
Callahan	12,905	12,829	12,980	12,750	12,492	12,206	11,968
Comanche	14,026	14,273	14,721	14,860	14,816	14,503	14,045
Eastland	18,297	18,336	18,382	18,061	17,566	16,989	16,226
Fisher	4,344	4,264	4,259	4,097	3,972	3,910	3,717
Haskell	6,093	5,860	5,741	5,580	5,496	5,345	5,089
Jones	20,785	21,211	21,729	21,695	21,366	20,738	19,933
Kent	859	840	821	733	602	535	472
Knox	4,253	4,197	4,305	4,310	4,321	4,316	4,272
Nolan	15,802	16,550	17,177	17,464	17,412	16,747	15,954
Palo Pinto	27,026	28,895	31,147	33,048	34,897	37,074	39,589
Scurry	16,361	16,998	17,602	17,923	18,092	18,203	18,203
Shackelford	3,302	3,456	3,638	3,603	3,406	2,997	2,516
Stephens	9,674	9,873	10,030	10,102	10,005	9,624	9,321
Stonewall	1,693	1,687	1,634	1,555	1,455	1,365	1,279
Taylor	126,555	136,370	142,645	145,634	146,529	143,772	139,309
Throckmorton	1,850	1,851	1,793	1,713	1,584	1,483	1,407
Young	17,943	18,116	18,513	18,541	18,328	18,059	17,889
TOTAL	**339,442**	**354,930**	**367,719**	**372,628**	**373,298**	**368,825**	**362,148**

Table 2.3
Revised Projected Population for the West Central Brazos Area

County Name	2000	2010	2020	2030	2040	2050	2060
Brown	37,674	39,324	40,602	40,959	40,959	40,959	40,959
Callahan	12,905	12,829	12,980	12,750	12,492	12,206	11,968
Comanche	14,026	14,273	14,721	14,860	14,816	14,503	14,045
Eastland	18,297	18,341	18,391	18,072	17,581	17,007	16,247
Fisher	4,344	4,264	4,259	4,097	3,972	3,910	3,717
Haskell	6,093	5,860	5,741	5,580	5,496	5,345	5,089
Jones	20,785	21,211	21,729	21,695	21,366	20,738	19,933
Kent	859	840	821	733	602	535	472
Knox	4,253	4,197	4,305	4,310	4,321	4,316	4,272
Nolan	15,802	16,550	17,177	17,464	17,412	16,747	15,954
Palo Pinto	27,026	28,900	31,156	33,059	34,911	37,091	39,609
Scurry	16,361	16,998	17,602	17,923	18,092	18,203	18,203
Shackelford	3,302	3,610	3,965	4,230	4,443	4,581	4,736
Stephens	9,674	10,841	11,725	12,225	12,646	12,908	13,285
Stonewall	1,693	1,687	1,634	1,555	1,455	1,365	1,279
Taylor	126,555	136,370	142,645	145,634	146,529	143,772	139,309
Throckmorton	1,850	1,962	2,043	2,110	2,163	2,243	2,352
Young	17,943	18,121	18,522	18,552	18,342	18,076	17,909
TOTAL	**339,442**	**356,177**	**370,018**	**375,808**	**377,598**	**374,504**	**369,338**

Figure 2.2

West Central Brazos Area - Population Comparison
2002 State Water Plan vs. Projections for Water Plan Update



2.2 Water Supplies

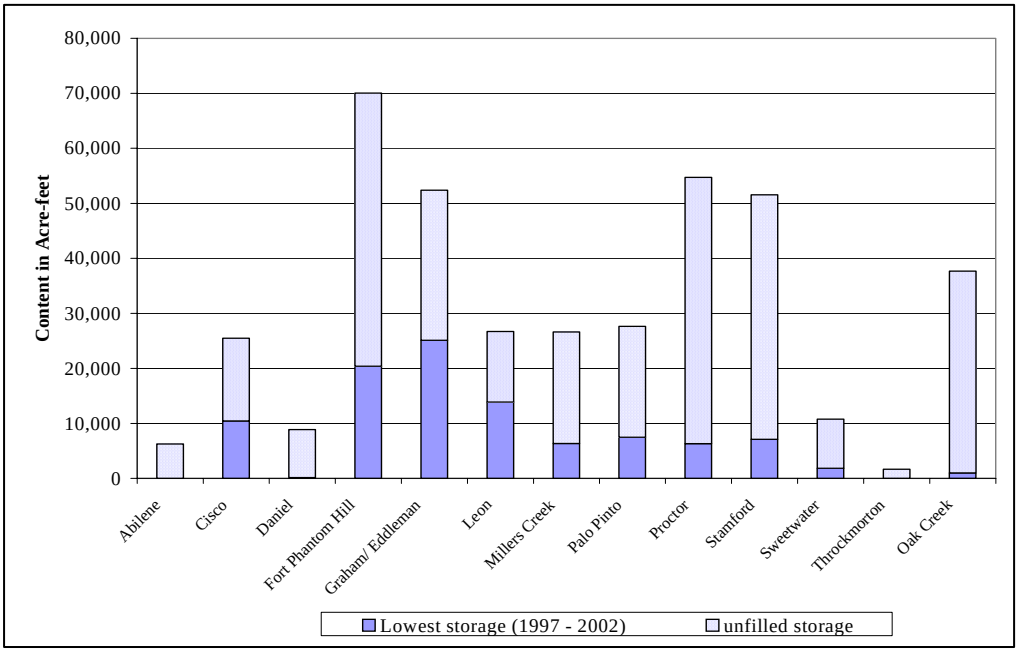
Much of the available water supply in the West Central Brazos Study area is surface water from local reservoirs and streams. There are limited groundwater supplies from the Seymour and other local aquifers. Some water from outside the region is provided to retail providers. This includes supplies from the Colorado River Municipal Water District (CRMWD) (O.H. Ivie and J.B Thomas), Wichita Falls (Lake Kickapoo), Oak Creek, and Lake Coleman.

2.2.1 Surface water

Many of the surface water supplies have recently recovered from the significant drought in the late 1990s through 2002. For some reservoirs this drought was the worst drought on record (Lake Proctor)[22]. Other reservoirs are still in drought conditions (Lake Daniel, Sweetwater, Oak Creek, and CRMWD reservoirs)[23]. An indication of the severity of this drought is shown on Figures 2.3 and 2.4, which show the lowest content recorded between 1997 and 2002 of selected reservoirs in the study area. A summary of pertinent data for area reservoirs is presented in Table 2.4. Reservoirs outside the study that are or could be used by suppliers within the West Central Brazos area are listed in Table 2.5.

Figure 2.3

Historical Low Content between 1997 and 2002 for Small Reservoirs
(Less than 100,000 acre-feet of capacity)



Note: The minimum storage content for Lakes Abilene, Daniel and Throckmorton were less than 150 acre-feet.

Figure 2.4

Historical Low Content between 1997 and 2002 for Large Reservoirs (Greater than 100,000 acre-feet of capacity)

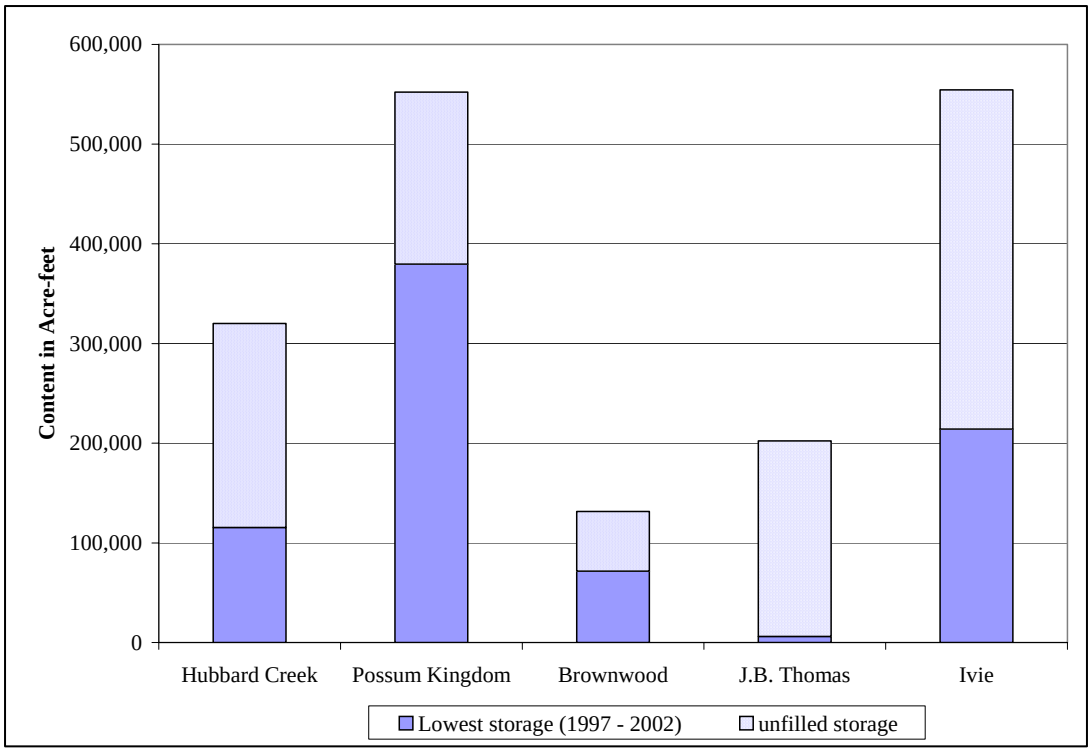


Table 2.4

Surface Water Reservoirs within the West Central Brazos Study Area [3]

Reservoir	County	Conservation Capacity[1] (Acre-Feet)	Current Uses	Owner	Permitted Diversion (Ac-Ft/Yr)
Abilene	Taylor	11,868	Municipal	City of Abilene	1,675
Baird	Callahan	2,070	Municipal	City of Baird	550
Brownwood	Brown	131,429	Municipal, Industrial, Irrigation	Brown County WID #1	29,712
Cisco	Eastland	45,000 (26,000)	Municipal	City of Cisco	2,027
Clyde	Callahan	5,748	Municipal	City of Clyde	1,000
Daniel	Stephens	11,400	Municipal	City of Breckenridge	2,100
Fort Phantom Hill	Jones	73,960 (70,036)	Municipal, Industrial, Steam Electric	City of Abilene	30,690
Graham/ Eddleman	Young	52,386 (52,750)	Municipal	City of Graham	20,000
Hubbard Creek	Stephens	320,000 (324,983)	Municipal, Industrial, Mining, Irrigation	West Central Texas MWD	56,000
Kirby	Taylor	8,500	Irrigation	City of Abilene	5,000[2]
Leon	Eastland	28,000	Municipal, Industrial	Eastland Co. WSD	6,300
McCarty	Shackelford	2,600	Municipal	City of Albany	600
Millers Creek	Baylor	30,696	Municipal, Industrial, Mining	North Central Texas MWD	5,000
Palo Pinto	Palo Pinto	44,124 (27,650)	Municipal, Steam Electric	Palo Pinto MWD No. 1	18,500
Possum Kingdom	Palo Pinto	724,739 (570,243)	Municipal, Manufacturing, Mining, Steam Electric, Irrigation, Hydropower	Brazos River Authority	230,750
Proctor	Comanche	59,400 (55,715)	Municipal, Manufacturing, Irrigation	USACE Brazos River Authority (wtr rt)	19,658
Stamford	Haskell	60,000	Municipal, Industrial, Steam Electric	City of Stamford	10,000
Sweetwater	Nolan	10,000	Municipal, Industrial	City of Sweetwater	3,740
J.B. Thomas	Scurry	204,000	Municipal, Industrial	CRMWD	30,050
Throckmorton	Throckmorton	1,675	Municipal	City of Throckmorton	600
Trammel	Nolan	2,500	Municipal	City of Sweetwater	2,000
Tucker	Palo Pinto	1,200	Municipal	City of Strawn	160

1. Permitted capacity is shown. Values in parenthesis are the conservation storage estimates from the latest sedimentation surveys.
2. Permitted amount for Lake Kirby includes 3,765 acre-feet per year for municipal use. The city of Abilene currently only uses water from Lake Kirby for irrigation.

Table 2.5

Surface Water Reservoirs outside the West Central Brazos Study Area that Are Used or Potentially Could Be Used within the Study Area [(3)]

Reservoir	County	Conservation Capacity[1] (Acre-Feet)	Current Uses	Owner	Permitted Diversion (Ac-Ft/Yr)
Coleman	Coleman	40,000	Municipal, Industrial	City of Coleman	9,000
Olney/Cooper	Archer	6,165	Municipal	City of Olney	1,260
Kickapoo	Archer	106,000	Municipal	Wichita Falls	40,000
Oak Creek	Coke	30,000	Municipal, Industrial	City of Sweetwater	10,000
O.H. Ivie	Concho	554,340	Municipal, Industrial	CRMWD	43,264
Alan Henry	Garza, Kent	115,937	Municipal, Recreation	City of Lubbock	29,900

1. Permitted capacity is shown.

2.2.2 Groundwater

Three TWDB-designated major aquifers are present in portions of the 18-county area: the Trinity, Edwards-Trinity, and the Seymour. (See Figure 2.5.) Two TWDB-designated minor aquifers, the Dockum and Blaine, are also present in a portion of the study area. Other undesignated minor aquifers in the region may provide very small quantities of water mostly through domestic and stock wells.

Groundwater is the major source of water supply for Kent, Fisher, Nolan, and Stonewall counties in the western portion of the study area, and is the only source of municipal supply in Kent County. Several cities have begun to look for groundwater resources to supplement existing surface water supplies. A brief description of the aquifers in the West Central Brazos study area is presented below.

Trinity and Edwards-Trinity

The Edwards and Trinity aquifers consist of Cretaceous age sediments of carbonate sand and limestone found in the southern portion of the 18-county area. In the southwest portion of the 18-county area Edwards limestone is sometimes found as caps over the underlying Trinity Sand. Because the Edwards portion of the Edwards-Trinity aquifer is not present in the study area, these two aquifers will be referred to as the Trinity in this report.

Figure 2.5

In the 18-county area, the well yields from the Trinity typically range from less than 50 gallons per minute (gpm) to over 250 gpm. The water quality is generally good and is acceptable for most municipal and industrial purposes. In some locations, brine contamination from oil field activities has caused elevated total dissolved solids. Elevated nitrate concentrations are also a concern in some areas. Some other potential concerns are elevated bacteria and nutrients, especially in the proximity to the recharge zone. The Brazos G Regional Water Plan [(2)] estimates that the total availability or sustainable yield of the Trinity aquifer is relatively low, ranging from 0.5 to 2.0 percent of annual rainfall that occurs over the outcrop areas of the aquifer. The higher percentage is applied to those areas with more productive formation in the west.

Seymour

The Seymour aquifer is comprised of numerous isolated alluvial pockets in mostly the northwestern portion of the 18-county area and is comprised of Quaternary deposits of unconsolidated conglomerates, gravels, sands, and silty clays. The thickness is typically less than 100 feet with saturated thickness averaging about 50 feet. Well yields range from 1 to 1,800 gpm and average about 200 gpm. Water quality is variable with total-dissolved solids content ranging from 300 to 3,000 mg/l. Elevated nitrate concentrations are concerns for municipal supplies. The water chemistry generally varies locally due to the shallow nature of this formation and local land use practices. The Brazos G report estimates the total availability or sustainable yield of the Seymour aquifer at about 8 percent of annual rainfall or about 2 inches per year over the outcrop areas. However, in many of the areas groundwater is currently being produced at higher rates than the estimated sustainable yields, especially in Knox and Haskell Counties.

Dockum

The Dockum Group was deposited as fluvial and deltaic sediments during the Triassic Age and generally consists of sands, silts, shales, and to a lesser extent gravels. The primary water-bearing zone in the Dockum Group is commonly referred to as the Santa Rosa and ranges in thickness up to 700 feet. In the 18-county area, the Dockum is mostly in Scurry and Nolan counties. The Dockum supplies mostly irrigation and domestic use but also provides some

municipal water in those two counties. Well yields range from less than 100 to 400 gpm and average around 200 gpm. Water quality is variable with total dissolved solids often ranging from 500 to 600 mg/l. The Brazos G report estimates the total availability or sustainable yield of the Dockum as a relatively low percentage of the rainfall that occurs over the outcrop areas of the aquifer.

Blaine Aquifer

The Blaine Formation is composed of shale, sandstone, and beds of gypsum, halite, and anhydrite of Permian age. The Blaine Formation can be up to 1,200 feet thick in the region. However, the saturated thickness is often very thin. Most of the groundwater produced from the Blaine is used for irrigation purposes because the water quality is very poor. Yields from wells completed into the Blaine aquifer can be as high as 1,000 gpm, but are generally very small. Total dissolved solids range from less than 1,000 to greater than 10,000 mg/L. Fresh water can be found in the topographically higher areas where the Blaine crops out, and recharge from precipitation or possibly from overlying alluvium occurs. The Brazos G report estimates the total availability or sustainable yield of the Blaine aquifer as a relatively low percentage of rainfall that occurs over the outcrop areas of the aquifer and equal to about 1 inch per year.

2.3 Water Quality

The quality of the water sources in the West Central Brazos region is a concern for some users. The locations of groundwater in the region is scattered and quality can vary with source and location. Elevated levels of nitrates and dissolved solids are common in the Seymour and Trinity aquifers, and high concentrations of bacteria and nutrients have been found in the outcrop area of the Trinity aquifer. Salt seeps and springs located in the upper portions of the Brazos basin contribute to the chloride and dissolved solids concentrations in Possum Kingdom Lake. Elevated chlorides and dissolved solids are also a concern for some reservoirs in the Upper Colorado Basin. Other quality issues include suspended solids in Lake Fort Phantom Hill, elevated sulfate levels at Lake Stamford, and elevated total organic carbon in Millers Creek Lake.

Generally the water quality for the other reservoirs in the study area is good. Historical concentrations for chlorides and dissolved solids for available reservoirs are summarized in Table 2.6 [(4)].

Table 2.6

Summary of Water Quality Indicator Parameters[1]

Reservoir	Chlorides			Total Dissolved Solids		
	Maximum	Minimum	Median	Maximum	Minimum	Median
Brownwood	172	40	62	626	238	296
Cisco	38	22	27	302	202	226
Ft. Phantom Hill	142	80	109	551	130	460
Graham	223	124	165	576	386	509
Hubbard Creek	745	139	279	1,490	234	700
Ivie	550	129	425	2,440	534	1,245
Leon	127	46	71	790	224	317
Palo Pinto	129	26	54	394	188	268
Possum Kingdom[2]	1,542	232	1,087	2,179	1,293	1,803
Proctor[2]	248	22	82	592	283	360
Stamford	648	146	293	2,250	584	1,195
J.B. Thomas[3]	184	96	140	756	446	601

1. Data was obtained from the TCEQ website for available water quality from 1993 to the present [(4)].
2. Authority provided data for available sampling results from 1997 to June 2002.
3. Only two sampling results were available for J.B. Thomas.

2.4 Water Suppliers

Most of the municipal water is provided through city, water supply corporations, water districts and other retail providers. There are seven primary wholesale water providers within the study area. These include the city of Abilene, Palo Pinto County MWD #1, Upper Leon River MWD, Brown County WID #1, Eastland County WSD, West Central Texas MWD, and North Central Texas MWA. All but one of these providers supply treated water to municipal customers. West Central Texas MWD provides only raw water from Hubbard Creek Lake. Brown County WID#1, Palo Pinto County MWD #1, and Upper Leon River MWD provide both raw and treated water.

The major retail providers include the cities of Abilene, Mineral Wells and Sweetwater. Abilene provides most of the municipal water in Taylor and Jones Counties. The city of Mineral Wells provides water to suppliers in Palo Pinto County and Parker County, which is outside of

the study area. Sweetwater supplies communities in Nolan and Fisher Counties. A schematic of the water supply sources, wholesale providers and recipients is shown on Figure 2.6. The service boundaries as designated by certificates of convenience and necessity (CCNs) are shown on Figure 2.7.

2.5 Historical Water Use

Texas Water Development Board (TWDB) collects data on historical municipal water use and other use. Information was available to the regional water planning groups for water use through 1997 [(5)]. More current data was recently released by the TWDB, but these data do not include municipal sales and other data pertinent to this study. Therefore, the 1997 historical water use data was used as the basis for individual city use, and is included for comparisons to the recent 2001 water uses reported by county [(6)]. Year 1997 was also a dry year with typically higher water use. However, the reported irrigation use in 2001 was 37 percent higher than reported in 1997. This is mainly attributed to higher irrigation water use in Comanche and Knox Counties.

In 2001, the counties in the West Central Texas study area had a reported total water use of 246,615 acre-feet. The largest historical water use is for irrigated agriculture at 143,855 acre-feet per year, followed by municipal use at 63,755 acre-feet per year. Manufacturing water use is the historically lowest water use category. Summaries of the historical municipal water use by county for years 1990, 1997 and 2001 are shown in Table 2.7. The 2001 water use for non-municipal purposes is presented in Table 2.8, and the total 2001 water use by type is shown in Figure 2.8. The 1997 use for selected cities within the study area is shown in Table 2.9.

Overall the municipal use in 2001 is about the same as used in 1990. Year 1997 was generally a higher municipal use year with most of the increase associated with the city of Abilene in Jones and Taylor counties. Several counties show a decline in municipal water use. This is partly due to decreased population and advanced conservation efforts in some communities because of the drought conditions.

The available data on the historical water use from local reservoirs are presented in Table 2.10. This information was obtained from the sources listed in the table.

Figure 2.6 Water Supply Schematic

Figure 2.7 CCN Map

Table 2.7

Historical Municipal Water Use by County

County	Historical Use (acre-feet)		
	1990[1]	**1997[1]**	**2001[2]**
Brown	6,338	5,859	6,231
Callahan	1,579	1,666	1,785
Comanche	1,773	1,813	1,774
Eastland	3,066	2,617	2,852
Fisher	725	843	592
Haskell	825	931	864
Jones	2,726	4,097	2,851
Kent	188	166	500
Knox	813	761	747
Nolan	4,002	4,237	4,161
Palo Pinto	4,165	4,292	4,430
Scurry	3,185	3,915	3,087
Shackelford	788	814	696
Stephens	1,822	1,426	1,118
Stonewall	356	298	280
Taylor	27,373	29,403	26,811
Throckmorton	289	289	274
Young	3,050	3,474	4,702
TOTAL	**63,063**	**66,901**	**63,755**

1. Historical use is the amount reported to the TWDB and summarized in the TWDB database files provided to the regional water planning groups (histsum.xls) [(5)].
2. Historical use reported to the TWDB, available on the TWDB website [(6)].

Table 2.8

Historical (2001) Non-Municipal Water Use by County

County	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
Brown	416	2,427	0	7,326	1,387	11,556
Callahan	0	81	0	934	1,033	2,048
Comanche	23	80	0	45,433	3,946	49,482
Eastland	37	79	0	14,756	1,080	15,952
Fisher	159	468	0	2,734	589	3,950
Haskell	0	101	397	30,160	481	31,139
Jones	1	290	0	4,068	899	5,258
Kent	0	685	0	0	442	1,127
Knox	0	26	0	28,017	1,047	29,090
Nolan	537	277	0	3,055	438	4,307
Palo Pinto	26	2	2,650	1,222	844	4,744
Scurry	6	2,606	0	2,120	525	5,257
Shackelford	0	523	0	244	729	1,496
Stephens	8	7,312	0	467	502	8,289
Stonewall	0	14	0	1,854	469	2,337
Taylor	852	242	6	399	1,169	2,668
Throckmorton	0	40	0	0	772	812
Young	33	159	2,098	66	992	3,348
TOTAL (Ac-Ft)	**2,098**	**15,412**	**5,151**	**142,855**	**17,344**	**182,860**

1. Data obtained from TWDB website, 2003 [6].

Figure 2.8

West Central Brazos Study Area Water Use in 2001

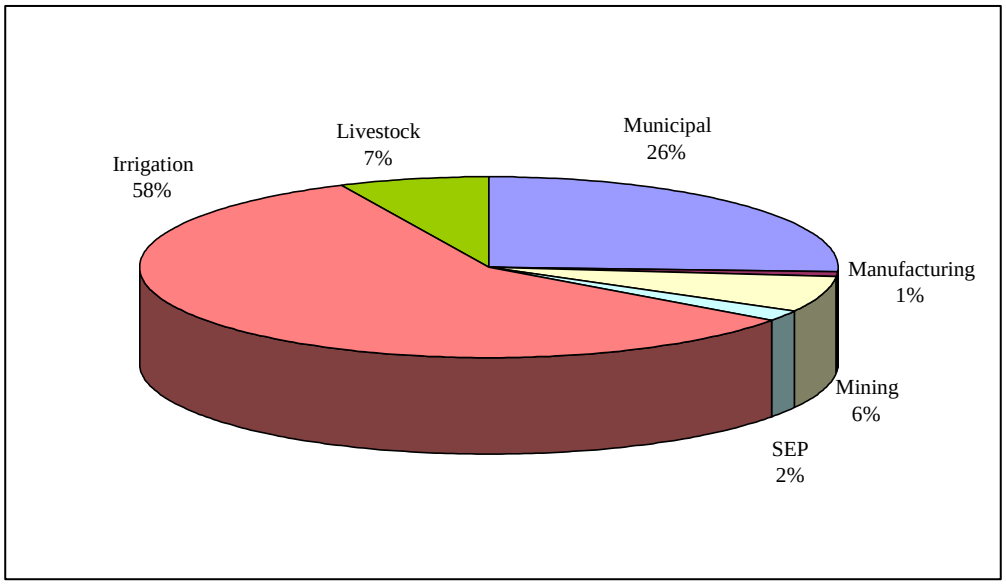


Table 2.9

Historical (1997) Municipal Water Use for Selected Cities in West Central Brazos Study Area

City Name	County	Self-supplied (Ac-Ft)	Purchased (Ac-Ft)	Total Water Use (Ac-Ft)	% Ground water	Mun Sales (Ac-Ft)	Ind Sales (Ac-Ft)	Power Sales (Ac-Ft)	Raw Sales (Ac-Ft)	Net Mun Use (Ac-Ft)	Pop	Per capita Use (gpcd)	Source(s)
Brownwood	Brown		3,916	3,916		211	470			3,235	19,353	149	Lake Brownwood
Early	Brown		803	803		294	5			504	2,615	172	Lake Brownwood
Comanche	Comanche		635	635		12	8			615	4,605	119	Lake Proctor
Cisco	Eastland	726		726		118				608	4,134	131	Lake Cisco
Eastland	Eastland		885	885		260				625	3,712	150	Lake Leon
Ranger	Eastland		579	579		189				390	2,798	124	Lake Leon
Haskell	Haskell		592	592		37				555	3,103	160	Lake Millers Creek)
Anson	Jones		757	757		221				536	2,612	183	Hubbard Creek Lake
Stamford	Jones	2,202		2,202		765			448	1,437	3,280	391	Lake Stamford
Sweetwater	Nolan	5,383		5,383		1,014	546	405	735	3,418	11,779	259	Oak Ck Res, Lake Sweetwater, groundwater
Mineral Wells	Palo Pinto		3,756	3,756		981	22			2,753	15,294	161	Lake Palo Pinto
Snyder	Scurry		3,648	3,648	23	534				3,114	11,932	233	CRMWD- JB Thomas & Groundwater
Albany	Shackelford	312	519	831		281				550	2,002	245	Lk McCarthy; Lk Hubbard Creek
Brecken-ridge	Stephens	1,149	143	1,292		355	6			931	5,805	143	Lk Daniel; Lk Hubbard Creek
Abilene	Taylor	31,353	107	31,460	1	2,184	1,031		325	28,245	117,077	215	Ft Phantom Hill, Lk Abilene, Lk Kirby, Groundwater, Hubbard Crk

1. Data obtained from TWDB database files (citysum.xls), 1998[(5)]. This is self reported data by the respective entity to the TWDB.

2. Reported historical use is for 1997, which was a dry year. For several cities the 1997 water use was substantially less than in previous years. Cities with lower than normal usage include Brownwood, Eastland, Ranger, and Breckenridge.

Table 2.10

Historical Usage by Reservoir
(in Acre-feet per year)

Reservoir	Permitted Diversion	Year						Data Source
		1997	1998	1999	2000	2001		
Proctor	19,658							
Irrigation		3,844	5,356	7,315	5,701	5,717		Data provided by Authority. File: PK_Proctor WU.xls
Upper Leon MWD		3,441	3,613	3,727	3,790	3,085		Data provided by the Authority. File: PK_Proctor WU.xls
Possum Kingdom	230,750	13,007	6,755	7,109	17,020	7,218		Data provided by TCEQ (adjusted for hydropower use)
Hubbard Creek	56,000	2,433	12,019	27,535	27,843	15,437		Data provided by TCEQ
Abilene		107	8,904	21,043	21,204	12,242		Data provided by Abilene, file: City of Abilene waterUsage Data.xls
Anson		757	NA	NA	NA	NA		Data obtained from TWDB records: file: Histmun.xls
Breckenridge		143	157	627	1,431	902		Data provided by Breckenridge
Albany		522	768	902	967	862		Data provided by Albany
Ft Phantom Hill	30,690	22,493	19,161	1,533	2,289	10,649		Data provided by Abilene, file: City of Abilene waterUsage Data.xls
Abilene	1,675	1,334	1,233	359	17	0		Data provided by Abilene, file: City of Abilene waterUsage Data.xls
Cisco	2,027	726	914	1,047	896	1,050		Data provided by City of Cisco (1999-2001). TCEQ data for 1997-98.
Leon	6,300	1,464	1,543	1,857	1,768	1,583		Data provided by Eastland Co. WSD
Graham	20,000	2,545	2,868	5,802	4,658	3,344		Data provided by TCEQ

Note: Data obtained from the TCEQ is self reported data from the respective entity.

Table 2.10 (continued)

Reservoir	Permitted Diversion	Year						Data Source
		1997	1998	1999	2000	2001		
Palo Pinto	18,500	2,735	4,278	6,597	4,616	4,531		Data provided by TCEQ.
Municipal use		2,126	4,278	4,752	4,616	4,531		Data provided by TCEQ
Industrial use		609	NA	1,845	NA	NA		Data provided by TCEQ.
Brownwood	29,712	8,151	12,553	11,639	14,295	11,961		Data provided by BCWID #1, Infrastructure assessment study, April 2002. TCEQ data for 2001.
Miller's Creek	5,000	1,375	1,580	1,508	1,523	NA		Data provided by TCEQ.
Oak Creek	10,000	5,302	4,760	3,670	4,309	1,071		Data provided by TCEQ.
Sweetwater	3,740	89	224	150	221	198		Data provided by TCEQ.
Stamford	10,000	2,358	2,325	1,820	1,777	1,293		Data provided by TCEQ.
Lake Tucker	160	139	187	186	168	164		Data provided by TCEQ
Lakes Olney/ Cooper	1,260	697	758	556	146	666		Data provided by TCEQ. No diversions reported in January – June, 2000.
J.B. Thomas	30,050	5,027	NA	6,731	13,560	7,034		Data provided by TCEQ
Lake Daniel	2,100	1,149	1,267	783	0	208		Data provided by Breckenridge

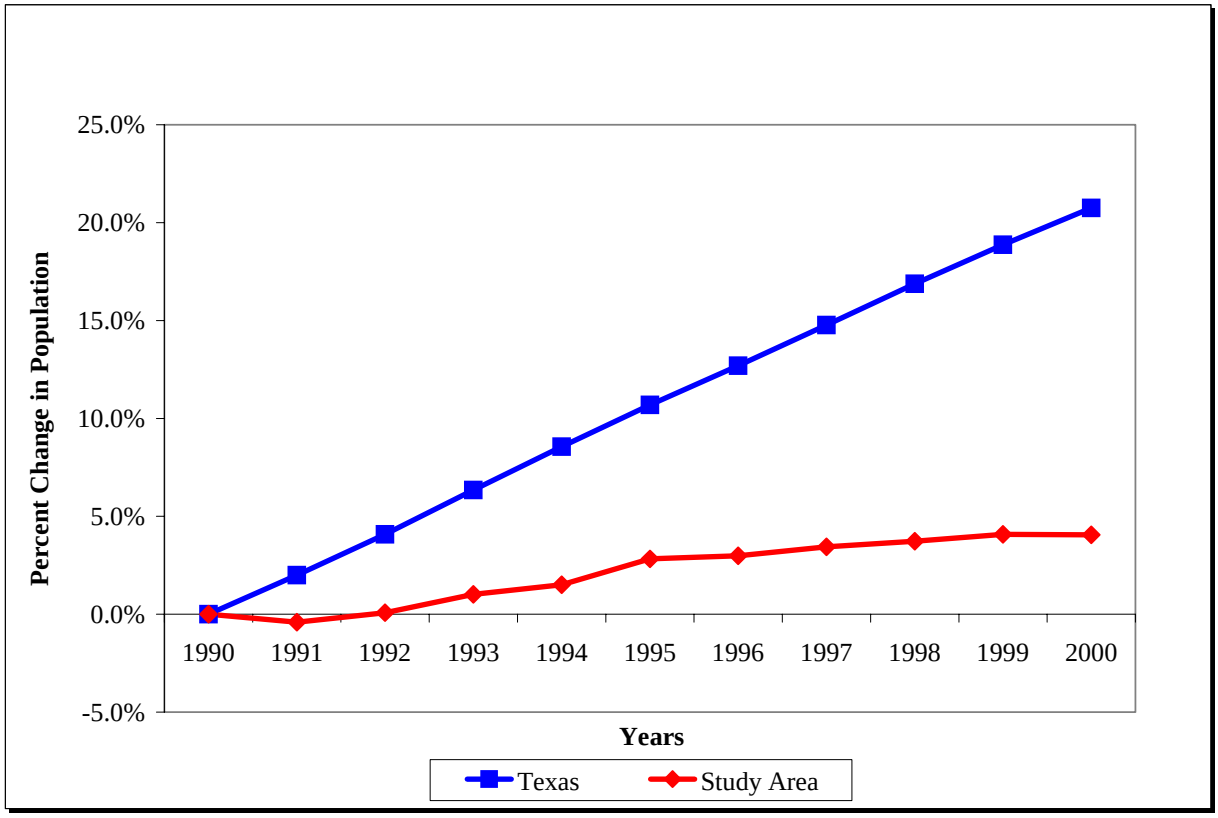
Note: Data obtained from the TCEQ is self reported data from the respective entity.

2.6 Economic Baseline Summary

As previously discussed, the West Central Brazos study area is predominantly rural in nature with only a few large cities. As with many rural communities, the population tends to grow more slowly than urban areas. Figure 2.9 shows that over the past decade the rate of growth in the West Central Brazos study area has lagged behind the average growth in the state. While Texas has seen a cumulative growth of 20.8 percent, the West Central Brazos study area has grown only 4.1 percent. (See Section 2.1 for population changes by county).

Figure 2.9

Cumulative Percent Change in Population Growth for Texas and the West Central Brazos Study Area



The region was hit hard by the drought in the mid-1990s, which impacted much of the ranching and farming industry in the area. Over the past decade, farm earnings decreased significantly, with losses in some years. In year 2000 farm earnings accounted for less than 1 percent of the total personal income in the region. However, employment in the farming community has remained steady and has actually increased over the decade. Much of the revenues received in the study area come from non-agricultural industries. Non-agricultural industry earnings increased by 20 percent over the past decade (based on year 2000 dollars), and large increases were seen in construction, manufacturing and in the finance and real estate industries. Non-farm employment increased for all industries, with the exception of mining where the number of employees significantly decreased. The greatest increases in employment were seen in the construction and manufacturing sectors. Earnings generated from non-agricultural industries in year 2000 provided 62 percent of the personal income in the region with the remainder of income coming from dividends, interest, rent, transfer payments or from outside the study area. A comparison of the cumulative percent change in non-agricultural earnings to the state is shown on Figure 2.10. Some of the difference in growth in the latter part of the decade between the WCB study area and state average can be partly attributed to the rapid growth in the high-tech industry in other areas of the state. A summary of the baseline economic data for the study area is presented in Table 2.11. This table shows the total earnings and income in the 18-county area. Specific data by county will be used as appropriate for the economic analyses discussed in Chapter 8.

Figure 2.10

Cumulative Percent Change in Non-Agricultural Earnings for Texas and the West Central Brazos Study Area

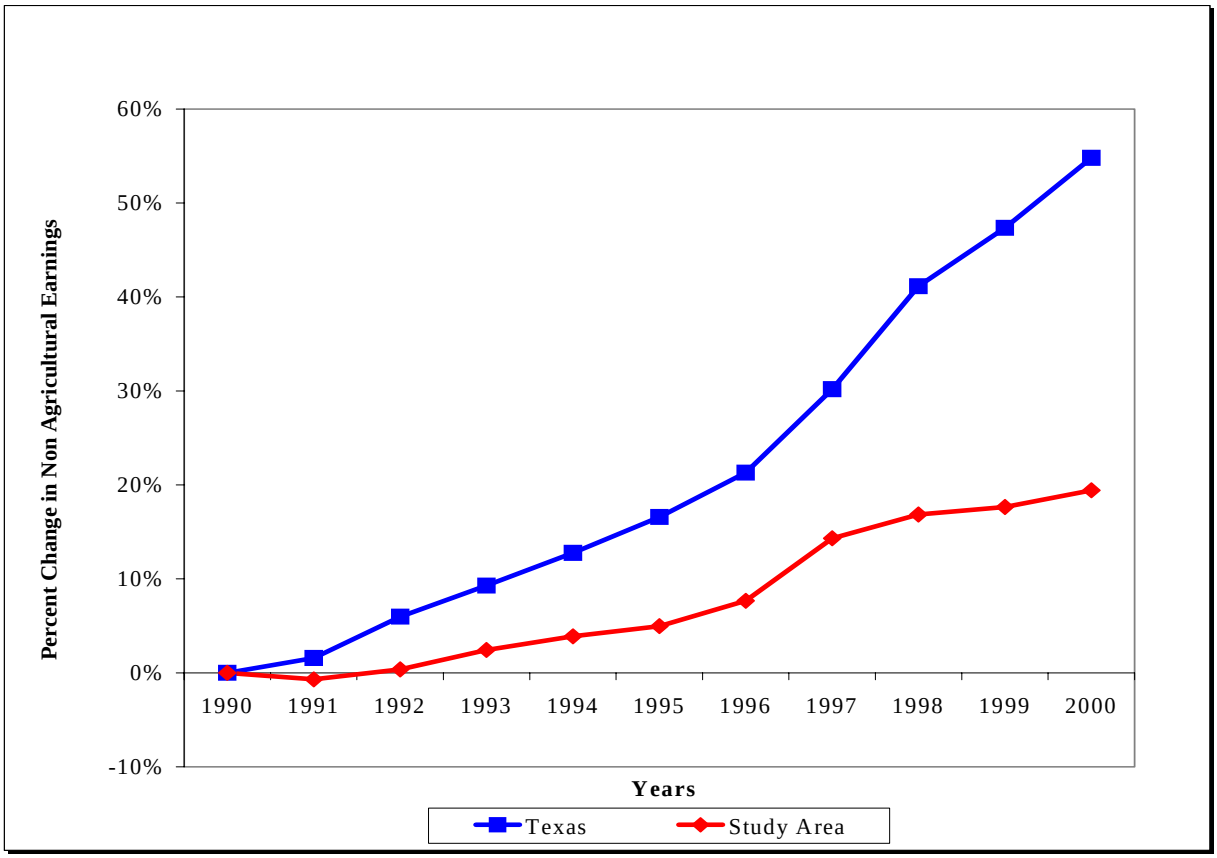


Table 2.11

Summary of Earnings and Income in the West Central Brazos Study Area

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Farm Earnings (1,000 $)	$165,640	$70,666	$145,373	$123,351	$88,005	$54,769	-$968	$67,266	$20,180	$115,276	$35,287
Non-Agricultural Earnings (1,000 $)	$2,891,451	$2,991,817	$3,114,570	$3,274,338	$3,408,342	$3,541,818	$3,742,673	$4,082,841	$4,253,464	$4,381,525	$4,611,033
Personal Income (1,000 $)	$4,852,017	$4,964,484	$5,253,168	$5,457,895	$5,599,740	$5,889,835	$6,163,706	$6,716,873	$6,975,828	$7,174,257	$7,471,117
Per Capita Income ($)	$14,899	$15,308	$16,118	$16,591	$16,940	$17,584	$18,372	$19,931	$20,641	$21,154	$22,033
Unemployment (%)	5.80%	5.80%	6.70%	6.20%	5.80%	5.40%	5.20%	4.70%	4.40%	4.30%	3.80%
Earnings and Income Inflated to Year 2000 $											
Farm Earnings (1,000 $)	$218,275	$89,368	$178,492	$147,041	$102,248	$61,900	-$1,063	$72,221	$21,325	$119,195	$35,287
Non-Agricultural Earnings (1,000 $)	$3,810,260	$3,783,608	$3,824,124	$3,903,194	$3,959,975	$4,002,971	$4,110,765	$4,383,567	$4,494,840	$4,530,497	$4,611,033
Per Capita Income ($)	$19,634	$19,359	$19,790	$19,777	$19,682	$19,874	$20,179	$21,399	$21,812	$21,873	$22,033

3.0 Water User Surveys

A total of 107 surveys were mailed to wholesale and retail water providers in the study area. The water supply and distribution system surveys requested information on historical water sales, purchases, treatment and distribution system facilities, planned improvements and other concerns. A complete list of the survey recipients and copies of the blank surveys are provided in Appendix B.

A total of 46 surveys were returned, including all seven wholesale providers. Follow-up meetings were held with each wholesale provider and the cities of Mineral Wells and Sweetwater. The most recent TWDB population projections, current water contracts, water rates, future plans and water supply concerns were discussed. Some respondents acknowledged the projected decline in population and attributed much of this decrease to water supply constraints. The Stephens County Rural WSC and the cities of Abilene, Albany and Cisco disagreed with the projections, predicting an increase in service population. The city of Mineral Wells disagrees with the population distribution between Parker and Palo Pinto Counties, and believes there will be higher growth in Palo Pinto County.

Many of the water suppliers in the region have recently completed system improvements or have future plans for improvements. A list of the rural development projects within the study area is included in Appendix C. Other future plans reported in the surveys include:

- Rhineland WSC plans to add a groundwater well and blend with purchased water from North Central Texas MWA.
- City of Roscoe is considering drilling a new groundwater well that is low in nitrates. Current water supply is groundwater from the Dockum Aquifer.
- Rising Star (Eastland County) is considering installing a reverse osmosis system to treat groundwater with elevated nitrates.
- The communities of Graham, Graham East WSC and Fort Belknap WSC are working together to develop water supplies from Possum Kingdom reservoir.

Other studies and projects that are being pursued in the study area, but were identified after the completion of the water user surveys include:

- Joint water supply study with the city of Abilene and West Central Texas MWD on the feasibility of the Cedar Ridge Reservoir site and other water supply options.

- Negotiations between the Eastland County WSD and the 3P Water Group, which represents Santo WSC, Sturdivant-Progress WSC, cities of Strawn and Gordon, and possibly the North Rural WSC. The 3P Water Group is requesting approximately 850 acre-feet per year of water from Lake Leon to be treated at the Eastland County WSD's water treatment plant.

Water rates within the study area vary considerably, depending on infrastructure requirements and availability of supply. Retail water rates for 10,000 gallons of treated water range from less than $20 for residential customers of Abilene MWS to a high of $115 from Comanche County WSC. Of the water rates reported in the surveys, the median rate for 10,000 gallons of treated water is $58. Costs for raw water from the wholesale providers were reported at $0.22 and $0.47 per 1,000 gallons, which do not include buy-in costs. The BCWID #1 includes a buy-in rate for new customers for capital improvements. The buy-in rate is set for 20 years and is added to the water rate. Raw water rates for West Central Texas MWD were not provided because they are contingent upon transmission costs and vary with customer.

Several respondents noted that water consumption has decreased due to the drought, but will increase when sufficient supplies become available. There are concerns that the lack of water will limit growth. Other entities, such as Abilene, are marketing low water use industries and feel that long-range planning is the key to continued growth. Some water suppliers are greatly increasing their service areas and are looking for additional water to meet the growing needs. Fort Belknap WSC is completing a five-year expansion program, increasing the number of connections from 1,000 to 1,850 beginning in 2003. Based on requests for service and the increase of meters, Stephens County Rural WSC is expected to grow at 4 percent per year and Shackelford WSC is projected to increase by 60 percent over the next forty years.

To help meet water demands, three potential new reservoir sites were identified: Throckmorton County, Turkey Peak reservoir site in Palo Pinto County, and Breckenridge site in Throckmorton County. Other suggestions included:

- Divert portion of Lake Creek or Mexican Creek flows to Millers Creek Lake,
- Construct a pipeline between Haskell and Stamford to interconnect Millers Creek with Lake Stamford,
- Consider Aquifer Storage and Recovery (ASR) in the Seymour Aquifer, which would involve placing available surface water in the ground for future use
- Supplement existing surface water with new groundwater
- Utilize water from Possum Kingdom Lake, and

- Implement reuse programs.

The cities of Abilene and Aspermont currently use treated wastewater effluent for irrigation. Mineral Wells is considering a reuse program.

Follow-up meetings with the major providers identified several other concerns and observations regarding water planning in the study area. These include:

- The city of Abilene expressed concerns that the city may not be able to get the full 15,000 acre-feet per year contracted from Ivie Reservoir due to the drought. Abilene is considering alternate back-up supplies, possibly Possum Kingdom Lake.
- Local control and the price of water are likely to be key considerations in development of a regional water supply system. The entities within the study area appear to be receptive to regional cooperation.
- State and federal grants available to small water suppliers to meet crisis needs can be counterproductive. They encourage small systems to seek financial assistance during a crisis rather than generating revenues to address problems in a timely way. For the same reason, the grants can work against long-range planning and regionalization.
- Many entities envision the Authority as instrumental in coordinating regional projects. They acknowledge the Authority's role in utilizing the West Central Brazos Water Distribution System (formerly the Kerr McGee pipeline) and future water from Possum Kingdom Lake.
- The rural WSCs have very low per capita water use, and TCEQ's delivery rate requirements (0.6 gpm per person) require distribution lines to be oversized and pose several problems. Some entities have successfully modified the minimum flows for rural systems to 0.4 gpm per person.
- There are limitations in the distribution lines of rural systems, including both capacity and network, which limits service to new growth. The Rural Development Agency will provide funding to WSCs for current conditions, but will not provide funding for future growth.

4.0 Supply and Demand Analyses

4.1 Water Demands

Water demands were developed for most of the municipal entities within the West Central Brazos study area using TWDB-approved population projections [(1)] and available historical per capita data [(5)]. These demands represent dry year water needs, which are typically higher than during normal and high rainfall years. To best estimate dry year demands, the highest per capita water use reported over the last ten years was generally selected as the base per capita use. Detailed projections were developed for members of the Midway Group using revised population projections based on planned and expected expansions of service. The projected municipal water demands by county in the study area are shown in Table 4.1. Some municipal water is provided to users outside the study area, and the projected demands for these users by county are shown in Table 4.2. The projected demands generally do not include reductions for water conservation. This was because many of the entities in the region are rural, have low per capita water use, and reductions in use due to conservation may not be realized.

Demands were also developed for the major water providers in the study area, and included retail and wholesale municipal customers, manufacturing demands, and steam electric power demands. All demands on the water provider were considered including water demands to entities outside the study area. County irrigation demands were not included unless there were contracts with a water provider. Both manufacturing and power demands were estimated from the draft projections developed for the 2006 regional water plans [(1)].

For most counties, the demands are expected to generally stay about the same through the planning period. Palo Pinto and Stephens Counties have the greatest percentage increase due to expected growth for the Mineral Wells area and the service area for Stephens County Rural WSC, respectively. This trend was also observed for the larger water providers in the area, where increases in demands occurred due to expanded service areas and growth in larger cities. A summary of the water demands for these providers and the Midway Group is shown in Table 4.3.

Table 4.1

Projected Municipal Demands by County - West Central Brazos Study Area

	Projected Municipal Demands (acre-feet per year)						
County Name	**2000[1]**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Brown	6,888	7,189	7,422	7,487	7,487	7,487	7,487
Callahan	1,744	1,735	1,755	1,726	1,691	1,655	1,625
Comanche	1,825	1,858	1,916	1,934	1,928	1,887	1,828
Eastland	2,978	2,984	2,992	2,940	2,859	2,765	2,642
Fisher	738	727	725	700	682	673	643
Haskell	994	959	942	918	904	881	843
Jones	4,192	4,279	4,383	4,374	4,309	4,183	4,019
Kent	181	177	172	154	126	112	98
Knox	750	740	759	759	761	760	754
Nolan	4,076	4,269	4,430	4,506	4,491	4,319	4,115
Palo Pinto	4,735	5,031	5,386	5,688	5,980	6,322	6,721
Scurry	3,648	3,788	3,920	3,989	4,027	4,051	4,051
Shackelford	934	1,011	1,100	1,155	1,188	1,190	1,192
Stephens	1,670	1,851	2,032	2,185	2,301	2,429	2,563
Stonewall	334	333	323	308	287	270	252
Taylor	28,909	31,152	32,587	33,271	33,474	32,844	31,824
Throckmorton	383	412	441	466	492	523	557
Young	3,518	3,554	3,633	3,639	3,596	3,543	3,511
Total	**68,497**	**72,050**	**74,919**	**76,201**	**76,585**	**75,896**	**74,728**

1. These demands represent projected dry year demands and do not necessarily reflect actual historical usage in year 2000.

Table 4.2

Projected Municipal Demands by County – Outside the Study Area[1]

	Projected Municipal Demands (acre-feet per year)						
County Name	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Coleman	379	375	376	376	376	376	376
Mills	6	6	7	7	8	7	7
Parker	422	776	776	776	776	776	776
Runnels	15	18	32	42	53	62	73
Total	**822**	**1,175**	**1,191**	**1,201**	**1,213**	**1,221**	**1,232**

1. These demands represent projected dry year demands on water providers in the West Central Brazos Study area by users that are located outside the study area. The demands for year 2000 do not necessarily reflect actual historical usage in year 2000.

Table 4.3

Water Demands for Water Providers

Water Provider	Projected Demands (acre-feet/year)						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Abilene	34,121	36,931	38,265	39,185	39,632	39,258	38,567
Brown County WID #1[1]	17,186	19,338	20,230	19,773	19,848	19,919	19,987
Eastland County WSC	1,777	1,814	1,862	1,883	1,889	1,869	1,837
Graham	5,344	4,958	4,578	4,878	5,207	5,604	6,114
NCTMWA	1,696	1,661	1,659	1,630	1,606	1,577	1,532
Palo Pinto MWD	6,533	7,270	7,492	8,032	8,555	9,181	9,926
Stamford[2]	2,330	1,729	1,667	1,719	1,767	1,815	1,869
Sweetwater[3]	5,940	6,477	7,332	7,840	8,336	8,761	9,251
Upper Leon MWD[4]	3,416	5,170	5,323	5,447	5,561	5,755	5,890
WCTMWD[5]	23,646	23,980	24,256	24,448	24,564	24,651	24,724
Midway Group							
Breckenridge[6]	1,655	1,862	1,989	2,098	2,163	2,241	2,333
Throckmorton	236	278	288	298	310	322	338
Shackelford Co. WSC	223	310	341	370	401	430	452
Stephens Co. RWSC	299	417	517	585	655	735	808

1. Demands are based on TWDB population projections. BCWID #1 expects higher growth in Brown County and greater demands for manufacturing water [(9)]. Using BCWID # 1 projections, the projected water demand for BCWID # 1 in 2060 is 28,475 acre-feet per year.
2. The decrease in the city of Stamford's demands in 2010 is because Stamford will no longer provide raw water to the city of Hamlin. Hamlin will receive water from Albany, which will be treated in Abilene and transported through a new 14-inch pipeline.
3. The demands for Sweetwater include steam electric power demands on Oak Creek reservoir. This power plant is currently moth-balled.
4. The increase in demands for Upper Leon MWD beginning in 2010 is attributed to a contract with Stephenville.
5. The demands for WCTMWD include contractual demands for Abilene and projected demands for the other three member cities: Albany, Anson and Breckenridge. It also includes projected demands for these three member cities' customers.
6. The city of Breckenridge has a contract with Stephens County RWSC for 12 million gallons per month. The demands for Breckenridge include Stephens County RWSC demands up to the maximum contract amount. Actual total supply to Stephens County RWSC from Breckenridge is less due to higher monthly demands in summer months.

4.2 Water Supplies

Surface and groundwater supplies were evaluated for each of the larger water providers. The Water Availability Model (WAM) of the Brazos River Basin, in conjunction with a separate

reservoir operation model, was used to estimate surface water supplies. Groundwater supplies were estimated from current well field configurations and capacities.

The Brazos WAM was developed under the direction of the Texas Commission on Environmental Quality (TCEQ) to assess the availability of water within the basin for the purposes of water right permitting. The model uses the state's prior appropriation system, which is based on the water right priority date, to determine availabilities. The scenario the state uses for permitting and designated for regional water planning is the full authorization simulation. "Full authorization" assumes the user diverts the maximum amount of water authorized in the permit, returns any flows specified in the permit to the stream and stores the maximum allowable amount of water in a permitted reservoir or other facility. This assumption does not account for reductions in reservoir capacity due to sediment accumulation.

The TCEQ permitting scenario (Run 3) assumes full utilization of water rights that are diverted in priority date order, and no return flows (unless specified in a permit). For priority order analyses, the water right with the earliest priority date (most senior right) is allowed to divert water up to its full permit amount. After the most senior right diverts all water available under its permit or what is available in the stream, the right with the next earliest priority date is allowed to divert water. This process continues until all water rights have the opportunity to divert water. The total amount of water availability to each water right is determined on a monthly basis. The WAM also has an option to determine availabilities on a "natural order" basis. Under natural order, water is diverted sequentially from the most upstream water right to the most downstream right. While natural order analyses are not consistent with the state appropriation doctrine, they provide an estimate of potential water availabilities if agreements are obtained from downstream senior water rights holders.

The WAM for the Brazos River Basin was developed by HDR, Inc., in 2001 [(10)]. Hydrologic data was developed over the period of record from 1940 to 1997. The TCEQ published an update to the model in September 2002, incorporating new or changed water rights through September 25, 2002 [(11)]. This updated model was used in this study to determine the inflows to reservoirs within the West Central Brazos study area.

Reservoir firm yields were evaluated under both priority order and natural order simulations. The inflows to each reservoir were determined from the Brazos WAM Run 3, using the permitted capacities of the reservoirs in the basin. These inflows were then inputted into a

separate reservoir operation model developed by Freese and Nichols, Inc. using the respective reservoir's year 2000 area-capacity. This analysis was repeated using projected year 2060 area-capacity data to assess projected yields. The reservoir capacity data for West Central Brazos reservoirs are summarized in Table 4.4.

Table 4.4

Summary of Reservoir Capacity Data

	Storage Capacity (acre-feet)		
Reservoir	**Permitted**	**2000**	**2060**
Abilene	11,868	5,079	3,794
Cisco	45,000	25,683	25,433
Daniel	11,400	9,060	7,956
Phantom Hill	73,960	69,389	63,050
Graham	52,386	45,059	36,564
Hubbard Creek	320,000	324,484	314,068
Kirby	8,500	5,843	3,027
Leon	28,000	26,105	24,545
Millers Creek	30,696	26,988	17,605
Palo Pinto Lake	44,124	26,405	21,427
Possum Kingdom[1]	724,739	540,809	372,731
Lake Proctor	59,400	54,838	47,257
Lake Stamford	60,000	51,511	47,287
Sweetwater	10,000	10,371	9,061

1. The Authority has contracted for a hydrographic survey of Possum Kingdom Lake. When this survey is completed, the sedimentation rate and projected future storage capacity will be re-evaluated.

Due to continuing drought conditions and low reservoir contents, the hydrologic data were extended from 1997 through 2002 for seven reservoirs (Fort Phantom Hill, Lake Proctor, Lake Daniel, Palo Pinto Lake, Hubbard Creek, Lake Stamford and Millers Creek Lake). Under natural order analyses, Lakes Proctor, Daniel, Millers Creek and Palo Pinto entered new critical periods after 1998. Due to the complexity of the operation of Fort Phantom Hill it was unclear from the extended analysis if this lake has also entered into a new critical period. Only Lake Proctor has fully recovered from the drought. The other three reservoirs are still in drought conditions. Recent studies by HDR, Inc. for the Brazos G indicate that the severity of the on-going drought continues to impact the available supplies for these reservoirs. A summary of the reservoir yields developed under this study is presented in Table 4.5.

The available water supplies to the major water providers were assessed using the firm yields identified under WAM analysis, existing contract agreements and capacities of groundwater systems. The supplies were compared to the projected demands for these entities, which are shown graphically in Appendix D. The available supplies reported in the Brazos G water plan [(2)] are also included in these graphs. For some providers there are considerable differences in the supply amounts. These differences are attributed to different assumptions in the analyses, the most significant of which is the application of prior appropriations in the WAM analyses.

Table 4.5

Summary of Reservoir Firm Yield Analyses
(Values reported in acre-feet per year)

Reservoir	Priority Date	Permitted Diversion	WAM Reservoir Yields (Run 3)			
			Priority Order		Natural Order	
			2000	2060	2000	2060
Abilene	01/23/18	1,675	2,800	2,500	3,000	2,500
Brownwood	09/29/25	29,712	39,700	38,400	39,750	37,200
Cisco	04/16/20	2,027	1,300	1,300	1,300	1,300
Daniel	04/26/46	2,100	1,160	800	1,160	770
Fort Phantom Hill	03/05/37	30,690	17,300	16,500	19,800	18,800
Graham/ Eddleman	11/21/27 11/15/54	20,000	7,100	6,300	7,800	7,300
Hubbard Creek	05/28/57	56,000	22,000	21,000	43,300	42,300
J.B. Thomas[1]	08/05/46	30,000	0	0	13,200	13,100
Leon	5/17/31 3/21/52 3/25/86	6,300	5,500	5,100	5,600	5,300
Millers Creek	10/01/58	5,000	3,600	1,700	7,200	4,700
O.H. Ivie[1]	02/21/78	113,000	136,900	123,300	97,500	83,500
Oak Creek	04/27/49	10,000	5	0	3,900	3,400
Olney/Cooper	02/26/53	1,260	800	800	800	800
Palo Pinto	7/3/62 9/08/64	18,500	12,900	10,900	12,850	11,400
Possum Kingdom	04/06/38	230,750	280,800	209,200	289,700	219,900
Proctor	12/16/63	19,658	14,600	12,300	14,800	12,500
Stamford	06/08/49	10,000	6,600	5,800	10,900	10,000
Sweetwater	10/17/27	3,740	1,420	1,330	1,440	1,400

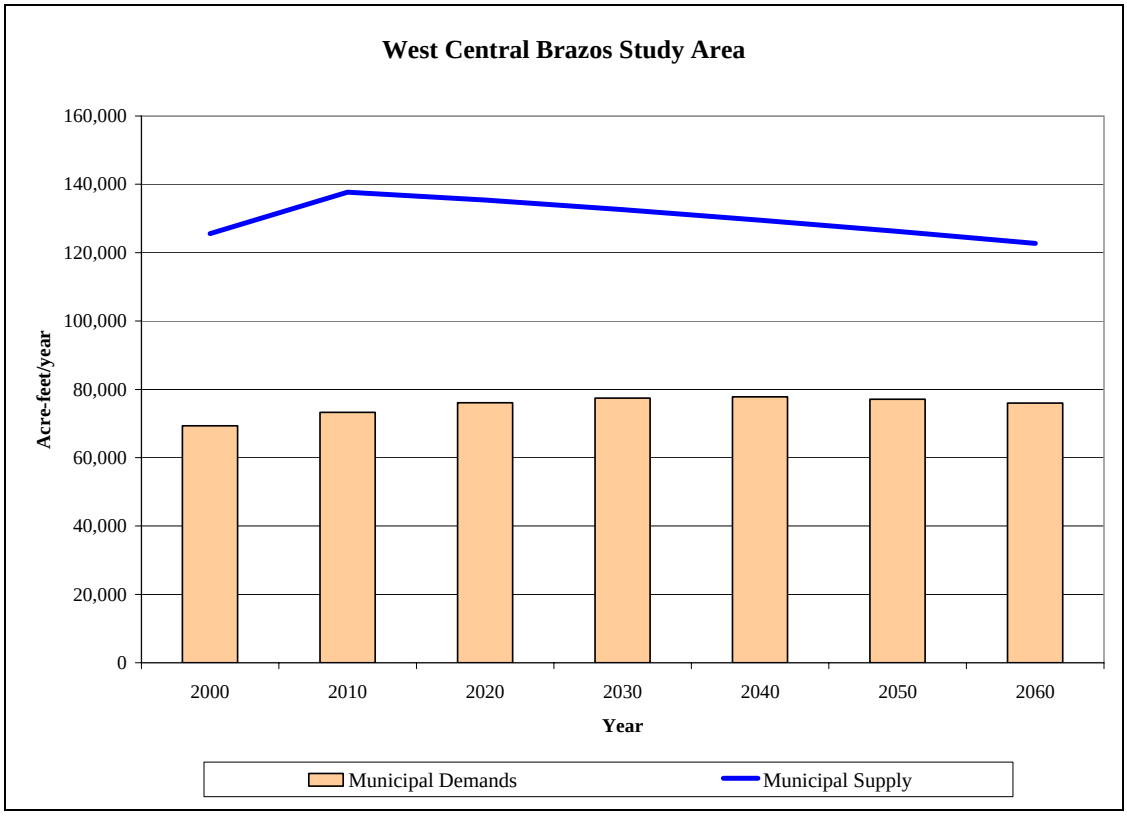
1. The reservoirs in the CRMWD system (J.B. Thomas and O.H. Ivie) are operated as a system with Spence Reservoir and groundwater supplies.

4.3 Water Supply and Demand Comparison

The supply and demand comparison focused on the needs for municipal and manufacturing water. The larger providers of municipal water were evaluated individually and all water demands for these providers were considered. The city of Snyder is a member city of the Colorado River Municipal Water District (CRMWD) and located in Scurry County. The CRMWD intends to meet the needs of its member cities through existing supplies or newly developed supplies. It was assumed that Snyder's needs would be met by supplies from CRMWD and no specific supply/demand analysis was conducted for Snyder.

On a regional basis, there are sufficient water supplies to meet the municipal demands in the West Central Brazos study area. A comparison of the projected regional demands to supplies is shown on Figure 4.1. The increase in supply in 2010 is due to the contract between CRMWD and Abilene for water from Lake Ivie.

Figure 4.1
Comparison of Municipal Supply and Projected Demands



While there is available supply on a regional basis, some entities were shown to have projected shortages. The comparison of supply and demands for the water providers is presented in Table 4.6. Based on this comparison, seven water users were identified with shortages at some time over the planning period. These users and the respective shortages are summarized in Table 4.7. Municipal users in northeast Brown County were identified with shortages due to limitations of the groundwater supplies. These shortages, which were identified in the Region F regional water plan [(12)] and estimated to range from 135 to 581 acre-feet per year, are also shown on Table 4.7. A current study by Jacob and Martin for expansion of local water supply service to this area shows a need of 170 acre-feet per year. This difference is most likely due to expansions of existing systems since the Region F report was prepared and differences in the projected growth of the area.

Further review of the supply and demand analysis found that several entities were shown to have sufficient supplies to meet the projected demands, but had limited reserve supplies for additional growth or more severe drought conditions. Most entities do not operate their systems on a firm yield basis, which assumes during drought that all the water in a reservoir is diverted. However, safe supply may be defined differently by each provider. For reservoir operators, "safe supply" may be a fraction of the firm yield or the "safe yield" of a reservoir (which means the minimum reservoir content equals a one year supply). Others may define safe supply based on a safety factor of their existing demands. For planning purposes, this study assumed that an entity would plan to have reserve supplies equal to 25 percent of the projected demands (above the projected demands). This analysis was conducted only for the major water providers, and a safety factor of 1.25 was applied to the demands of each provider. With these assumptions six additional water providers were identified with shortages of reserve supplies. In addition, two providers were identified with shortages due to water quality concerns (cities of Lawn and Rising Star). The total shortages, including reserve supply shortages, are presented in Table 4.8.

Table 4.6

Supply and Demand Comparison for Water Providers in the West Central Brazos Study Area

	Projected Demands (Ac-ft/yr)							Available Supply (Ac-ft/yr)							Projected Water Needs (Ac-ft/yr)						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Abilene	34,121	36,931	38,265	39,185	39,632	39,258	38,567	36,112	50,913	50,714	50,515	50,316	50,117	49,916	1,991	13,982	12,449	11,330	10,684	10,859	11,350
Brown County WID #1	17,186	19,338	20,230	19,773	19,848	19,919	19,987	29,712	29,712	29,712	29,712	29,712	29,712	29,712	12,526	10,375	9,482	9,939	9,864	9,793	9,725
Eastland County WSC	1,777	1,814	1,862	1,883	1,889	1,869	1,837	5,530	5,462	5,394	5,326	5,258	5,190	5,119	3,753	3,648	3,532	3,443	3,369	3,321	3,282
Graham	5,344	4,958	4,578	4,878	5,207	5,604	6,114	7,050	6,965	6,880	6,795	6,710	6,625	6,538	1,706	2,007	2,302	1,917	1,503	1,021	424
NCTMWA	1,696	1,661	1,659	1,630	1,606	1,577	1,532	3,643	3,324	3,005	2,686	2,367	2,048	1,729	1,947	1,663	1,346	1,056	761	471	197
Palo Pinto MWD	6,533	7,270	7,492	8,032	8,555	9,181	9,926	12,898	12,566	12,234	11,902	11,570	11,238	10,906	6,365	5,296	4,742	3,870	3,015	2,057	980
Stamford	2,330	1,729	1,667	1,719	1,767	1,815	1,869	4,325	4,325	4,325	4,325	4,325	4,325	4,325	1,995	2,596	2,658	2,606	2,558	2,510	2,456
Sweetwater	4,847	5,162	5,450	5,640	5,748	5,700	5,613	4,324	3,909	3,494	3,079	2,664	2,249	1,832	-523	-1,253	-1,956	-2,561	-3,084	-3,451	-3,781
Upper Leon MWD	3,416	5,170	5,323	5,447	5,561	5,755	5,890	6,437	6,437	6,437	6,437	6,437	6,437	6,437	3,021	1,267	1,114	990	876	682	547
WCTMWD	23,646	23,980	24,256	24,448	24,564	24,651	24,724	22,014	21,839	21,664	21,489	21,314	21,139	20,962	-1,632	-2,141	-2,592	-2,959	-3,250	-3,512	-3,762
Midway Group																					
Breckenridge	1,655	1,862	1,989	2,098	2,163	2,241	2,333	3,461	3,378	3,294	3,211	3,128	3,044	2,961	1,806	1,516	1,305	1,113	965	803	628
Throckmorton	236	278	288	298	310	322	338	100	0	0	0	0	0	0	-136	-278	-288	-298	-310	-322	-338
Shackelford Co. WSC	223	310	341	370	401	430	452	230	230	230	230	230	230	230	7	-80	-111	-140	-171	-200	-222
Stephens Co. RWSC	299	417	517	585	655	735	808	295	380	438	442	442	442	442	-4	-37	-79	-143	-213	-293	-366

Notes:

1. Projected demands represent all demands on the water provider, which includes sales to wholesale customers, industrial demands and steam electric power demands.
2. Available supply is based on WAM Run 3 analyses for reservoirs and existing contracts. For Stamford, the supply represents the safe yield of Lake Stamford with the California Creek diversion. (ref. F&N)
3. Details of the supply and demand projections are included in Appendix D.

Table 4.7

Summary of Projected Shortages for Water Providers
(Values reported in acre-feet per year)

Water Provider	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Throckmorton[1]	-136	-278	-288	-298	-310	-322	-338
Shackelford Co. WSC		-80	-111	-140	-171	-200	-222
Stephens Co. RWSC	-4	-37	-79	-143	-213	-293	-366
Sweetwater	-523	-1,253	-1,956	-2,561	-3,084	-3,451	-3,781
Strawn		-2	-9	-15	-21	-28	-36
Northeast Brown County[2]	-135	-321	-447	-570	-581	-525	NA
WCTMWD[3]	-1,632	-2,141	-2,592	-2,959	-3,250	-3,512	-3,762

1. This analysis assumes that the reliable yield of Lake Throckmorton is zero.
2. The projected shortages for northeast Brown County are from the Region F regional water plan [(12)]. The hydraulic analysis discussed in Chapter 6 evaluated providing 170 acre-feet per year to customers in northeast Brown County.
3. These shortages are based on firm yield analysis, actual demands for Albany, Anson and Breckenridge, and contracted amounts for the city of Abilene. Comparisons of contractual obligations to firm yield (priority order) shows that current contract amounts exceed the year 2000 firm yield of Hubbard Creek Lake by 5,260 acre-feet per year. However, the WCTMWD operates on a safe yield basis. Using WAM Run 3 safe yield of 17,000 acre-feet per year, the current contracts exceed the year 2000 safe yield by 10,260 acre-feet per year.

Table 4.8

Summary of Projected Reserve Shortages for Water Providers for Planning Purposes
(Values reported in acre-feet per year)

Water Provider	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Throckmorton	-195	-348	-360	-373	-387	-403	-422
Shackelford Co. WSC	-49	-158	-196	-233	-271	-308	-335
Stephens Co. RWSC	-79	-141	-208	-289	-377	-477	-568
WCTMWD	-7,544	-8,136	-8,656	-9,071	-9,391	-9,675	-9,943
Sweetwater	-1,734	-2,544	-3,318	-3,971	-4,521	-4,876	-5,185
Strawn	-35	-43	-51	-59	-66	-75	-85
Northeast Brown County[1]	-170	-170	-170	-170	-170	-170	-170
Rising Star[2]	-150	-150	-150	-150	-150	-150	-150
Lawn[2]	-125	-125	-125	-125	-125	-125	-125
ULMWD	0	-25	-217	-372	-514	-757	-925
Abilene	0	0	0	-777	-2,129	-2,455	-2,384
BCWID #1	0	0	0	-1,962	-3,479	-5,423	-5,882
Graham	0	0	0	0	0	-380	-1,105
Palo Pinto MWD	0	0	0	0	0	0	-1,007
NCTMWA	0	0	0	0	0	0	-186
Total Reserve Shortage	**-10,080**	**-11,838**	**-13,452**	**-17,550**	**-21,581**	**-25,272**	**-28,472**

1. This analysis assumes a shortage of 170 acre-feet per year based on demands for expansions of Zephyr WSC. Shortages projected in the Region F water plan for northeast Brown County ranged from 134 to 581 acre-feet per year (see Table 4.7).
2. This provider was identified with a shortage due to water quality concerns for its existing supplies. The need includes a reserve supply of 25% above the projected demands.

5.0 Water Treatment Plant Facility Inventory

5.1 Water Treatment Plant and Storage Inventory

Each water treatment plant in the service area with greater than 0.5 mgd capacity was inventoried and an assessment was made of potential facility improvements. A total of 25 treatment plants were inventoried. Visits were made to each of the treatment plants to gain information about the plant, including current operating capacities, the flow of water through the system, previous upgrades and expansions, planned improvements, and possible problems the plant might have meeting future treatment requirements. Detailed descriptions of each plant, evaluations and corresponding schematic flow diagrams are included in Appendix E. A summary of the facility inventory is presented in Table 5.1.

A separate inventory was compiled of the existing ground storage and elevated storage for each system in the study area. Data was obtained from representatives of the water system or through the Texas Commission on Environmental Quality (TCEQ) web site for public water systems [(7)]. The available storage was compared to the minimum TCEQ requirements based on the current number of customers. Tables 5.2 and 5.3 list the findings of the study. None of the systems in the study were found to be out of compliance with TCEQ's minimum requirements although some of the systems meet requirements through additional pumping capacity and pressure storage in lieu of elevated storage. It was also found that throughout the study area there was a surplus storage capacity of 56.79 million gallons, but this surplus is confined to the larger communities.

Table 5.1

Summary of West Central Brazos Water Treatment Plant Facility Inventory

Entity	Treatment Facility	Treatment Capacity (MGD)	Pump Capacity (MGD)	Storage Capacity (MG)	Water Source	Meets Current Regulations?	Meets Future Regulations? [1]	Planned Improve-ments?
City of Abilene	Abilene Water Treatment Plant (WTP) (currently not in operation)	1.8	3	0.6	Lake Abilene	Yes	Likely problems meeting Total Organic Carbon (TOC) and turbidity requirements	Study underway
	Grimes WTP	23.5	30	6.0	Lake Fort Phantom Hill/ Hubbard Creek Lake	Yes	Likely problems meeting TOC and turbidity requirements	Study underway
	Northeast WTP	21.3	29	10.0	Lake Fort Phantom Hill/Hubbard Creek Lake	Yes	Likely problems meeting TOC and turbidity requirements	Study underway
	Hargesheimer WTP	8	12	5.0	Lake Ivie	Yes		Study underway
City of Albany	Albany WTP	1.7	5	0.3	Lake McCarty/ Hubbard Creek Lake	Yes	Likely problems meeting drinking water standards, disinfection by-product rules	Yes
City of Anson	Anson WTP	2	1.7	0.3	West Central Texas Municipal Water District	Yes	Likely problems meeting disinfection by-product rules, turbidity requirements	Yes
City of Baird	Baird WTP	0.455	0.8064	0.046	Baird Lake	Yes	Likely problems meeting disinfection by-product rules	
Brown County Water Improvement District	West WTP	10.6		2.0	Lake Brownwood			
	East WTP	8	12	2.0	Lake Brownwood	Improvements-sedimentation basins needed		Yes

1. Evaluation of turbidity compliance is based on expected future regulations.

Table 5.1 (continued)

Entity	Treatment Facility	Treatment Capacity (MGD)	Pump Capacity (MGD)	Storage Capacity (MG)	Water Source	Meets Current Regulations?	Meets Future Regulations? [1]	Planned Improve-ments?
City of Breckenridge	Breckenridge WTP	3.4	6.2	1.02	Hubbard Creek Lake and Lake Daniel			
City of Cisco	Cisco WTP	2.1	3.89	0.3	Lake Cisco	Needs improvements to filter backwash system	Likely problems meeting disinfection by-product and turbidity requirements	
City of Clyde	Clyde WTP	2.0	3.456	0.6	Lake Clyde		Likely problems meeting turbidity requirements	
City of Early	Early WTP	2.0	4.0	0.5	Lake Brownwood	Yes- operating very near capacity	Problems meeting disinfection by-product rules	Yes
Eastland County Water Supply District	Eastland County WTP	6.0	6.84	0.315	Lake Leon		Yes	Yes
City of Gordon	Lake Gordon WTP	0.8	0.72	0.335	Lake C.B. Long, Lake Gordon, Lake Thurber	No	Likely problems meeting turbidity requirements	Yes
City of Graham	Graham WTP	6.1	7.5	1.0	Lake Eddleman			
City of Mineral Wells	Mineral Wells Hill Top WTP	8.0	29.578	3.5	Lake Palo Pinto			
North Central Texas Municipal Water Authority	North Central Texas WTP	4.0	6.05	0.403	Millers Creek Lake		Problems meeting disinfection by-product rules	Yes
City of Olney	Olney WTP	1.86	3.89	0.336	Lakes Olney and Cooper/ Lake Kickapoo		Problems meeting disinfection by-product rules	Yes

1. Evaluation of turbidity compliance is based on expected future regulations.

Table 5.1 (continued)

Entity	Treatment Facility	Treatment Capacity (MGD)	Pump Capacity (MGD)	Storage Capacity (gallons)	Water Source	Meets Current Regulations?	Meets Future Regulations? [1]	Planned Improve-ments?
City of Snyder	Snyder WTP	5.0	11.5	2.3	Lake J.B. Thomas, Lake E.V. Spence, Lake Ivie	Yes	Yes	No
City of Stamford	Stamford WTP	2.6	2.736	0.6	Lake Stamford	Yes	Problems meeting disinfection by-product rules and turbidity requirements	
City of Strawn	Strawn WTP	0.576	1.296	0.6	Lake Tucker	Yes	Problems meeting turbidity requirements	Yes
City of Sweetwater	Sweetwater WTP (under construction)				Groundwater		Yes	
City of Throckmorton	Throckmorton WTP	0.70	1.8	0.087	Lake Throckmorton		Problems meeting by-product regulations and turbidity requirements	Yes
Upper Leon Municipal Water District		7.2	13.61	1.05	Lake Proctor	Yes	Yes	Yes

1. Evaluation of turbidity compliance is based on expected future regulations.

Table 5.2

Storage Inventory for Municipalities in the West Central Brazos Study Area

City	Current # of Customers	Ground Storage	Stand Pipe		Elevated Storage	Required Storage		Deficient?		Surplus Storage
			Ground	Elevated		Total	Elevated	Total	Elevated	
		MG	MG	MG	MG	MG	MG	Yes/No	Yes/No	MG
City of Abilene	37,294	23.100			5.750	7.459	3.729	no	no	21.391
City of Albany	1,073	1.250			0.250	0.215	0.107	no	no	1.285
City of Anson	1,150	0.330			0.250	0.230	0.115	no	no	0.350
City of Aspermont	576	1.580			0.100	0.115	0.058	no	no	1.565
City of Baird	845				0.630	0.169	0.085	no	no	0.461
City of Bangs	830	0.420			0.200	0.166	0.083	no	no	0.454
City of Benjamin	155	0.380			0.050	0.031	0.016	no	no	0.399
City of Breckenridge	2,645	1.000			0.650	0.529	0.265	no	no	1.121
City of Brownwood	7,400	2.500			3.200	1.480	0.740	no	no	4.220
City of Cisco	1,675	0.500			0.500	0.335	0.168	no	no	0.665
City of Clyde	1,480	0.600			0.250	0.296	0.148	no	no	0.554
City of Comanche	1,930	1.000			0.500	0.386	0.193	no	no	1.114
City of Cross Plains	580	0.215			0.100	0.116	0.058	no	no	0.199
City of De Leon	1,066	0.160			0.125	0.213	0.107	no	no	0.072
City of Early	950	0.250			0.500	0.190	0.095	no	no	0.560
City of Eastland	1,731	1.575	0.817	0.204		0.346	0.173	no	*	2.250
City of Gorman	550	0.100			0.075	0.110	0.055	no	no	0.065
City of Graford	275	0.300			0.050	0.055	0.028	no	no	0.295
City of Graham	4,150				1.500	0.830	0.415	no	no	0.670
City of Hamlin	1,250				0.250	0.250	0.125	no	no	0.000
City of Haskell	1,716	0.450			0.750	0.343	0.172	no	no	0.857
City of Jayton	300	0.100			0.050	0.060	0.030	no	no	0.090
City of Knox City	609		0.043	0.024	0.040	0.122	0.061	*	*	-0.015
City of Merkel	1,200	0.050			0.500	0.240	0.120	no	no	0.310
City of Mineral Wells	6,220	1.500			2.550	1.244	0.622	no	no	2.806
City of Munday	648	0.109			0.050	0.130	0.065	no	yes	0.029
City of Newcastle	264	0.050			0.076	0.053	0.026	no	no	0.073
City of Olney	1,730	0.855			0.350	0.346	0.173	no	no	0.859
City of Ranger	1,011	0.000			0.500	0.202	0.101	no	no	0.298
City of Rising Star	325	0.100			0.075	0.065	0.033	no	no	0.110
City of Roby	436	0.490				0.087	0.044	no	yes	0.403
City of Roscoe	546	0.180	0.12	0.09	0.050	0.109	0.055	no	yes	0.331

Table 5.2 (continued)

City	Current # of Customers	Ground Storage	Stand Pipe		Elevated Storage	Required Storage		Deficient?		Surplus Storage
			Ground	Elevated		Total	Elevated	Total	Elevated	
		MG	MG	MG	MG	MG	MG	Yes/No	Yes/No	MG
City of Rotan	930	1.000			0.200	0.186	0.093	no	no	1.014
City of Rule	341	0.200			0.050	0.068	0.034	no	no	0.182
City of Snyder	6,061	3.050			1.200	1.212	0.606	no	no	3.038
City of Stamford	1,872				0.600	0.374	0.187	no	no	0.226
City of Strawn	230	0.067			0.152	0.046	0.023	no	no	0.173
City of Sweetwater	4,787	0.700	0.292	0.084	0.750	0.957	0.479	no	no	0.869
City of Throckmorton	537	0.272			0.104	0.107	0.054	no	no	0.269
City of Tye	541				0.150	0.108	0.054	no	no	0.042
TOTALS	**97,909**	**44.43**	**1.27**	**0.40**	**23.13**	**19.58**	**9.79**			**49.65**

*Utilizes supplier's storage to meet requirements.

Table 5.3

Storage Inventory of Rural Water Systems

Water System	Current # of Customers	Ground Storage	Stand Pipe		Elevated Storage	Required Storage		Deficient?		Surplus
			Ground	Elevated		Total	Elevated	Total	Elevated	Storage
		MG	MG	MG	MG	MG	MG	Yes/No	Yes/No	MG
Bitter Creek WSC	598	0.036			0.236	0.120	0.060	no	no	0.152
Brookesmith SUD	2,530	2.250			0.750	0.506	0.253	no	no	2.494
Brown County WID 1					2.000	n/a	n/a	n/a	n/a	n/a
Callahan County WSC	762	0.048	0.12	0.03		0.152	0.076	no	**	0.046
Coleman County WSC	2,085	0.485			0.520	0.417	0.209	no	no	0.588
Comanche County WSC	190	0.120				0.038	0.019	no	**	0.082
Eastland County WSD						n/a	n/a	n/a	n/a	n/a
Eula WSC	914	0.242	0.279	0.068		0.183	0.091	no	**	0.406
Fort Belknap WSC	1,747	0.360			0.200	0.349	0.175	no	no	0.211
Hawley WSC	690	0.470			0.080	0.138	0.069	no	no	0.412
North Central Texas MWD		2.215				n/a	n/a	n/a	n/a	n/a
North Rural WSC	903	0.252			0.200	0.181	0.090	no	no	0.271
Palo Pinto County MWD 1		0.040			0.050	n/a	n/a	n/a	n/a	n/a
Possum Kingdom WSC		0.786	0.467	0.0943		0.000	0.000	no	no	1.347
Potosi WSC	1,271	0.200			0.250	0.254	0.127	no	no	0.196
Shackelford WSC	960	0.362			0.100	0.192	0.096	no	**	0.270
Steamboat Mountain WSC	1,158	0.275			0.120	0.232	0.116	no	no	0.163
Stephens County Rural WSC (& Woodson)	1,205	0.322	0.054	0.036	0.100	0.241	0.121	no	**	0.271
Taylor County FWSD 1 Tuscola	375	0.150			0.075	0.075	0.038	no	no	0.150
Upper Leon River MWD		1.980				n/a	n/a	n/a	n/a	n/a
West Central Texas MWD		16.000				n/a	n/a	n/a	n/a	n/a
Westbound WSC	566	0.040			0.100	0.113	0.057	no	no	0.027
Zephyr WSC	1,123	0.276				0.225	0.112	no	**	0.051
TOTALS	**17,077**	**26.91**	**0.92**	**0.23**	**4.78**	**3.42**	**1.71**			**7.14**

*Utilizes supplier's storage to meet requirements.

** Utilizes pump capacity in lieu of elevated storage

5.2 Unaccounted water

Unaccounted water is the difference between the amount of water obtained at the water source and the amount of water sold to customers. This difference is often attributed to under metered sales and to losses associated with water treatment, conveyance, maintenance (flushing of water lines), firewater, water main breaks, and other system losses. For municipalities, unaccounted water is typically between 5 and 15 percent of the total water used. Rural water systems often have higher loss percentages due to the lengthy distribution system with relatively few customers. Systems with loss percentages greater than 15 percent for cities and 25 percent for rural systems could potentially benefit from a leak detection and repair program to reduce losses. This depends on the total amount of water loss and the length of the system.

Estimates of unaccounted water for users within the West Central Brazos study area were obtained from the TWDB [8] and responses to the water user surveys. Data was available for 54 water suppliers in the region. Of these suppliers, most reported water losses were less than 20 percent of total water obtained. Six suppliers reported losses greater than 25 percent and are listed in Table 5.4. Most of the suppliers with higher loss rates have relatively low total water usage. The cities of Mineral Wells and Albany reported loss rates between 20 and 25 percent, with average yearly losses of 946 acre-feet and 223 acre-feet, respectively. Brookesmith SUD has very high water losses that are attributed to an aging, undersized system. The SUD has initiated a leak detection and repair program, and is actively replacing pipeline within its system. A comparison of the number of suppliers by loss rates is shown on Figure 5.1.

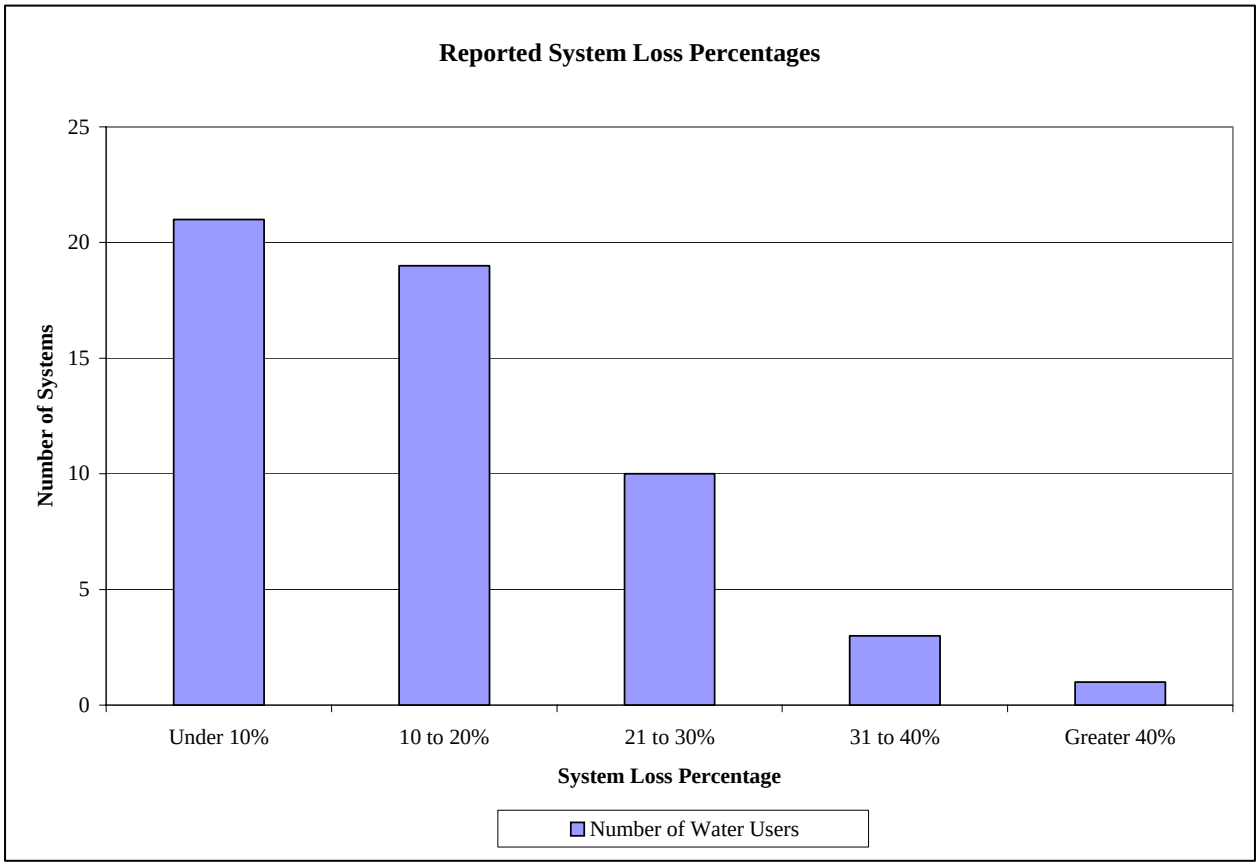
Table 5.4

Users with Unaccounted Water Greater than 25 Percent of Total Use

Water Supplier	Unaccounted Water[1] (Acre-feet/year)	Loss Percentage Range
City of Roscoe	54	26 to 30%
City of Moran	7	26 to 30%
Sylvester-McCaulley WSC	23	31 to 40%
City of Haskell	219	31 to 40%
Gilliland-Truscott Water Supply	32	31 to 40%
Brookesmith SUD	920	Greater than 40%

1. Average amount of unaccounted water for years of available data

Figure 5.1
Unaccounted Water



6.0 Hydraulic Analysis

Moving water between entities within the study area is a potentially viable strategy to meet water shortages and increase the reliability of supplies during drought. There is extensive infrastructure already developed within the West Central Brazos area that is used to transport water to local cities and water supply corporations. In addition, the Authority recently purchased the West Central Brazos Water Distribution System (formerly the Kerr-McGee pipeline), which could move water west from Possum Kingdom Lake to Stephens and Shackelford counties and south to Eastland County. Several of these systems could potentially be used to transport additional supplies to entities that have projected shortages or unreliable supplies due to water quality. Hydraulic studies of selected systems were conducted to provide information necessary to develop such water management strategies and promote regional approaches to water supply issues.

The approach to the hydraulic study was to identify systems that could move adequate quantities of water between entities with the least amount of upgrade and greatest impact on the region. Seven systems were selected for analysis, some with multiple end users. These systems are listed in Table 6.1, along with the potential recipients, and are shown on Figure 6.1. Recipients were identified based on projected water quantity shortages, water quality issues or treatment concerns. Each transmission system was modeled using Haestad Methods WaterCad v. 6.0 software. Generally, the analyses used peak supply flow conditions for wholesale supplies and peak hourly and peak day (supply flow) conditions for direct service by retail suppliers. Alternate demand alternatives were also investigated.

Details of the hydraulic analyses performed for each of these systems are included in the Hydraulic Study Report in Appendix F. The report provides a description of the transmission systems, available current supply and capacities, and identifies upgrades that are needed to meet regulations and provide supply necessary to make the strategy feasible.

The study found that several systems could move adequate amounts of water to the identified users with minimal improvements or upgrades. Most scenarios analyzed required upgrading existing infrastructure and new infrastructure. Some were found to be impracticable due to system constraints and/or high costs. While many of the system interconnections studied provide increased reliabilities of water supplies, implementing these interconnections will

depend on cost, agreements between entities and other factors specific to each system. A summary of the findings follows.

Table 6.1

Hydraulic Systems Analyzed

System Name	Water Source	Potential Recipients
West Central Brazos Water Distribution System (WCBWDS) (formerly Kerr-McGee Pipeline)	Possum Kingdom Lake	Shackelford County WSC Stephens Co. Rural WSC Breckenridge Upper Leon MWD Cisco Eastland County WSD WCTMWD Abilene
Abilene-Hamlin-Stamford	Hubbard Creek Lake Lake Fort Phantom Hill Lake Stamford	NCTMWA Anson
Eastland County WSD	Lake Leon	Cisco Strawn Gorman
Westbound WSC	City of Cisco (Lake Cisco) City of Eastland (Lake Leon) Groundwater	Rising Star Cross Plains
Shackelford Co. WSC Stephens Co. Rural WSC	City of Albany (Hubbard Creek and Lake McCarty) City of Breckenridge (Lake Daniel and Hubbard Creek) Possum Kingdom Lake	Throckmorton Paint Creek WSC
Steamboat WSC	City of Abilene	Lawn
Zephyr WSC	BCWID #1 (Lake Brownwood)	Northeast Brown County

6.1 Summary of Hydraulic Analysis

Abilene to North Central Texas MWA

The hydraulic study evaluated the feasibility of increasing water supplies for a significant portion of the West Central Brazos study area by connecting Abilene to the North Central Texas MWA supply lines. This system involves moving water from Abilene to Hamlin to Stamford to NCTMWA via Haskell. A 14-inch pipeline from Abilene to Hamlin is already under design and

there is an existing 12-inch pipeline from Hamlin to Stamford. A new pipeline between Haskell and Stamford would interconnect three regional water providers, which could potentially benefit 20 entities over a four county area. This interconnection has been discussed in the past and has support from the communities. The hydraulic study confirmed the feasibility of this interconnection. The study found that approximately 2 mgd could be transported from Abilene to Hamlin through the currently proposed pipeline, and 1.2 mgd could be transported from Hamlin to Stamford. With a new 14-inch pipeline from Stamford to Haskell, 2 mgd could be moved to NCTMWA's system. For this scenario, treated water would be obtained from the cities of Abilene and Stamford. If water were transported in reverse from Haskell to Hamlin, the sources would be NCTMWA and/or the city of Stamford. A reverse scenario may be utilized if Hubbard Creek Lake, which is the source of water for Hamlin, was in drought.

As an alternative to this scenario, the city of Anson could connect to the Hamlin line and receive water from Abilene. The city of Anson currently takes raw water from Hubbard Creek Lake. This is the city's only source of water, and there are few alternative sources for emergency measures. The quality of groundwater in the area is poor and advanced treatment such as reverse osmosis would be necessary to utilize any significant quantity. The proximity of the Hamlin line to Anson provides the city with an economical alternative. To provide Anson's full demand a portion of the Abilene-Hamlin pipeline would need to be upgraded from 14 to 18 inches, and a new pipeline to Anson would be needed. Smaller quantities could be provided with no upgrades, but it would reduce the amount of water that could be moved from Abilene to Stamford.

Steamboat Mountain Water Supply Corporation

The city of Lawn is currently seeking a new treated water supply in lieu of extensive improvements to its existing water treatment plant. To provide water directly from Abilene, a new 13-mile pipeline from Abilene to Lawn would be needed. Steamboat Mountain WSC has water lines and pressure facilities that run from Abilene to near the city of Lawn. The hydraulic study evaluated this system and identified upgrades needed to convey additional water from Abilene for Lawn. To provide 250 gpm to Lawn, about 10.5 miles of new water lines would be needed, as well as an in-line pump station and elevated storage tank. The difference in the amount of improvements needed for a direct pipeline versus transmission through Steamboat

Mountain WSC is small. Both are feasible options, and the deciding factor will most likely be the difference in water purchase costs.

Westbound Water Supply Corporation

Westbound WSC has been awarded a grant by USDA Rural Development to make extensive improvements to its water distribution system. These improvements will be installed in close proximity to the cities of Cross Plains and Rising Star. Only relatively minor improvements would be necessary to provide both entities with an alternate water supply. The city of Cross Plains' current water supply appears to be adequate and the improvements that Westbound WSC is making would provide 0.14 mgd to Cross Plains without any upgrades. The city of Rising Star's water supply has elevated levels of nitrates, which will require treatment or blending with a higher quality source. Upgrades to Westbound WSC's system are necessary to provide Rising Star with sufficient supply to meet all of their demands (200 gpm). A small amount of water (40 gpm) could be provided with no upgrades, but this amount probably would not be sufficient for blending to meet water quality standards. However, it could provide back-up and emergency supplies.

Eastland County Water Supply District

Eastland County WSD currently provides service to entities in Eastland County through the cities of Eastland and Ranger. Its only water source is Lake Leon, which has shown to be reliable during recent droughts. A potential additional source of water for the District is Possum Kingdom Lake through the West Central Brazos Water Distribution System (WCBWDS). The south leg of the existing WCBWDS pipeline ends in northern Eastland County near Ranger. This 24-inch pipeline provides raw water for the North Ridge Corporation (an oil and gas production company). Eastland County WSD has requested water from the Authority through this line and could treat the water and transport it to several entities within the area through its existing facilities. Potential recipients include the cities of Cisco, Gorman and Strawn. Alternatively, Eastland County WSD could supply these entities with treated water from Lake Leon.

Three different analyses of the Eastland County WDS system was conducted to provide supply to: 1) Cisco through the city of Eastland, 2) Gorman directly from the treatment plant, and

3) Strawn through the Ranger supply line. The modeling assumed that all water supplies would be obtained from the District's treatment plant located near Lake Leon. For the city of Cisco, the Eastland County WSD system would be capable of providing 1.4 mgd without modifications. A new 14-inch pipeline would be required to interconnect the city of Eastland with Cisco. No additional head pressure would be required from the District's water treatment plant.

The analysis for city of Gorman found that 19 miles of new water line would be needed to interconnect with the District's water treatment plant. The city currently takes water from the ULMWD and appears to have a sufficient supply. The anticipated cost for these improvements for supplemental supply would be high, and does not appear to be a feasible option for Gorman.

The city of Strawn is located northeast of the city of Ranger and currently obtains water from Lake Tucker, a small local lake. The reliability of this supply is unknown, but based on the performance of similar lakes in the area it is probably low. To provide water from Eastland County WSD, the District's system was modeled to supply Strawn with 200 gpm. Approximately 13 miles of new 6-inch water line would be needed from the Ranger supply line on the south side of Interstate 20 to Strawn. A pressure reducing valve would be required due to the elevation of Ranger Hill to the east of the connection point. No other modifications to the District's system would be necessary.

Shackelford WSC and Stephens County Rural WSC

The Midway Group, which includes the cities of Breckenridge and Throckmorton, Shackelford County WSC, and Stephens County Rural WSC, has been attempting to secure additional water sources for some time. These entities have made requests of the Authority for water supplies from Possum Kingdom Lake using WCBWDS. Shackelford WSC and Stephens County Rural WSC systems are between the WCBWDS pipeline and the City of Throckmorton. Both systems also have applied for funding through Rural Development to finance extensive system improvements. These improvements could be upgraded to provide a 200 gpm supply to the city of Throckmorton, which is only a portion of its current peak needs. The city recently was restricted to this amount due to severe drought. In light of the recent water shortage in Throckmorton and the uncertainty of the city's contract with Graham, this potential source may be necessary even though it would not provide all of the city's needs. The proposed system upgrades could also allow water to be transported to the Haskell/Throckmorton county line for a

possible interconnection with Paint Creek WSC. The Paint Creek WSC could use this supply to serve the southeastern portion of its system or approximately 50 customers. The improvements necessary to provide this amount of water would not be extensive. In all, the proposed scenario would interconnect at least nine systems including: Albany, Breckenridge, Ft. Belknap WSC, Graham, Paint Creek WSC, Stamford, Stephens County Rural WSC, Shackelford WSC and Throckmorton.

West Central Brazos Water Distribution System

The West Central Brazos Water Distribution System (WCBWDS) is a relatively unused system that could potentially provide raw water to a large portion of the study area. The Authority has received requests from numerous area water suppliers, including the Midway Group, interested in purchasing raw water from Possum Kingdom Lake that could be conveyed through the WCBWDS facilities. With only pump station improvements and some additional pipeline capacity, the facilities have enough capacity to serve the existing customers and the Midway Group's current needs. With the addition of a booster station and a 27-inch parallel pipeline, the facilities could serve the additional requests of West Central Texas MWD, Eastland County WSD, the city of Graham, and the city of Albany. Extensive improvements would be necessary to provide the requested supply to the city of Abilene, although facilities are in place from the WCBWDS intake all the way to Abilene. Without considering Abilene, the WCBWDS pipeline could provide water to 20 or more entities. Including Abilene and its customers, approximately 38 entities could benefit by using the WCBWDS.

Zephyr Water Supply Corporation

A portion of northeast Brown County relies exclusively on groundwater. Previous studies indicated that the reliability of this source for long-term supplies is low. There is sufficient surface water from Lake Brownwood to meet the needs in this area, but using it would require expanding the facilities of local water supply corporations. The Zephyr WSC, which has service within seven miles of the area, is a potential water supplier to northeast Brown County. The WSC has recently completed plans for water system improvements through a grant by USDA Rural Development. The proposed improvements with some additional expansion could serve approximately 140 customers in the area. Based on the hydraulic analyses, approximately

26.3 miles of new water lines, ranging in sizes from 2 inches to 6 inches, would be needed to serve this area. A new pump station would also be necessary.

6.2 Conclusion and Recommendations

Each of the systems analyzed appears to be a technically feasible project. Only the Eastland County WSD to Gorman scenario does not appear to be economically feasible at this time. These analyses provided valuable data that were used to develop strategies to meet the region's water needs. The selection of a project for further consideration in this study was dependent upon the water needs of the recipient and the potential to generate the greatest impacts to the region. The evaluations of water management strategies are presented in Chapter 7.

While these projects are technically feasible, there are other factors that can affect their implementation. For many of the identified recipients, the cost to implement the project compared to the level of need will be an important consideration. The likelihood of other sources becoming available at less cost compared to those proposed must also be considered.

7.0 Water Management Strategies

While on a regional basis there are sufficient supplies to meet the municipal demands in the study area, some entities were shown to have projected water shortages. Other entities were found to have sufficient supplies to meet the projected demands, but had little reserve supplies for growth or more severe drought conditions. The supply and demand analysis presented in Chapter 4 identified entities with absolute water needs and those with limited reserve supplies. Water management strategies were identified for each of these entities and are discussed in this chapter by type of need: 1) shortage due to limited supply or water quality, and 2) shortage in reserve supply. Additional water management strategies that could provide a higher level of available water in the study area for long-term future growth and development were also identified. Most of the strategies discussed herein utilize existing water sources with new capital improvements to transport and treat water from these sources to the entities with needs.

The supply and demand analysis identified seven water users in the West Central Brazos study area with projected shortages of water sometime over the planning period. These entities include:

- City of Throckmorton
- City of Sweetwater
- Stephens County RWSC
- Shackelford WSC
- City of Strawn
- Rural area in northeast Brown County
- West Central Texas MWD (WCTMWD)

For these entities the water supply shortages are imminent. Each is shown to have shortages beginning by 2010 (see Table 4.7 in Chapter 4). Currently the city of Sweetwater and northeast Brown County rely on overdrafting groundwater to meet its demands, but these sources cannot sustain the pumpage for long-term reliable supply. New or expanded water sources are needed in the near future. The city of Throckmorton is relying on its local lake, which has recovered from the recent drought. However, this lake is unreliable and another severe drought could leave this water source with little to no supply. The supplies for Shackelford WSC and Stephens County RWSC are currently limited by contracts. Shackelford WSC is negotiating new

contracts with the city of Albany and the Authority (for water from Lake Possum Kingdom). Stephens County RWSC has recently negotiated a contract with the Authority for water from Possum Kingdom Lake, but there is no infrastructure in place. The city of Strawn uses Lake Tucker for its water source. This lake is permitted for 160 acre-feet per year. Since 1998, the reported use from this lake has exceeded the permitted diversion. Projected demands for Strawn also exceed the permitted diversion, indicating additional sources are needed for long-term reliable water supply.

The WCTMWD was shown to have significant contractual shortages based on operating policies (safe yield) and current contract amounts. The shortages identified in this study are mainly due to assumptions in the modeling of the water supplies, primarily the adherence to water law that requires the pass through of inflows to senior downstream water rights holders during times of shortage. Supply analyses with holding these inflows show that shortages for existing demands on WCTMWD can most likely be met through agreements with downstream water rights holders.

In addition to these water users, the facility inventory identified two entities with water quality and/or treatment issues. While most water suppliers will need to upgrade and/or replace treatment facilities over the sixty-year planning period, those suppliers with immediate needs were considered for alternative supplies in this study. These entities and the water quality or treatment concern are presented in Table 7.1.

Table 7.1

Water Providers with Water Quality Concerns

Water user	**Quality Concern**	**Treatment Concern**
Rising Star	Nitrates in groundwater supply	
Lawn		TCEQ treatment violation

Six additional water providers were found to have potential shortages of reserve water supply. These shortages were based on an assumed safety factor of 1.25, which means that the provider should have water supplies in excess of 1.25 times the projected demands. This supply amount is referred to in this study as the “safe level” of supply. The “safe level” analysis was conducted only for the major water providers and included all demands on the provider. Some

entities may have operating policies that require different levels of reserve supply. Reserve amounts above the 25 percent estimate were not evaluated in this study.

The cities of Breckenridge, Cisco and Gordon were not identified with a reserve supply shortage, but were found to have some vulnerabilities associated with their local lakes. Current water elevations for Lakes Daniel and Cisco are at or near historical lows, and the reported yields from the WAM model for these lakes were considerably higher than reported in the Brazos G water plan. Lake Gordon, which is the sole source of water for the city of Gordon, is another small local lake that is potentially susceptible to drought. Each of these entities relies on the water supplies from their respective source, yet there is considerable uncertainty of the amount of reliable supply. Due to these uncertainties, these entities were also considered as needing additional supplies. In addition, the city of Anson was identified with no emergency or back-up supplies. The providers with projected reserve or back-up supply shortages include:

Reserve shortages:

- City of Graham
- North Central Texas Municipal Water Authority
- Palo Pinto MWD
- City of Abilene
- Upper Leon MWD
- Brown County WID #1

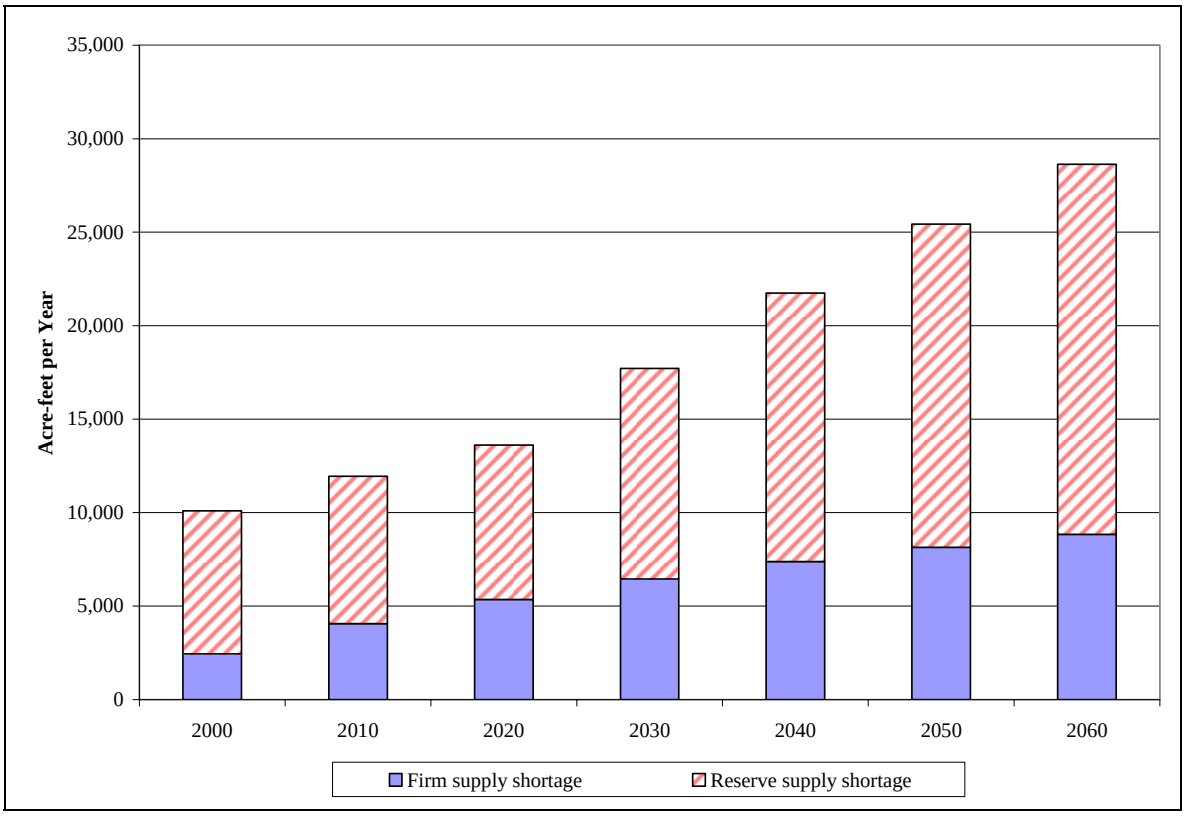
Back-up supply shortages:

- City of Breckenridge
- City of Cisco
- City of Gordon
- City of Anson (emergency supplies)

The total projected shortages for the West Central Brazos study area are shown on Figure 7.1. These shortages include firm supply shortages and reserve supply shortages, and are the basis for water management strategy development.

Figure 7.1

Projected Water Supply Shortages in the West Central Brazos Study Area



Collectively, over 25 potential water management strategies with variations were evaluated to meet the projected needs of specific entities in the study area. These strategies are described in detail in Appendix G and associated cost estimates are included in Appendix H. Generally, the water management strategies fall into five categories:

- Agreements between water suppliers to maximize available yield within the study area,
- Interconnections and movement of existing supplies to meet needs,
- Interconnections and strategies identified for emergency or back-up supplies,
- New supply strategies (surface and groundwater), and
- General projects that provide additional water supply to the region.

Three general strategies were identified: brush control, salt water control and weather modification. These general strategies can improve water quality and usability of existing water sources, and potentially increase water availability within targeted areas. Discussions of the general strategies are included in Appendix I.

Based on the feasibility and costs, specific strategies were identified for further consideration. These strategies are listed in the following tables. Table 7.2 includes strategies to meet identified shortages; Table 7.3 lists the strategies to provide a safe level of supply in the study area (including those needed to meet shortages), and Tables 7.4 and 7.5 identify strategies that could provide additional supplies beyond the safe level. Conservation was not evaluated as a separate strategy, but should be considered prior to the implementation of a recommended strategy. For many entities in the West Central Brazos area per capita water use is relatively low, especially for rural communities, and the realization of water savings from conservation would likely be small. Entities with higher per capita water use could potentially benefit from an aggressive conservation program. Those with reported per capita uses over 250 gallons per person per day include the cities of Sweetwater, Stamford and Albany. Some of the high water use may be attributed to pipe breaks or misreporting of water use data, and further review is needed to assess whether an aggressive conservation program would be successful. Wastewater reuse is another type of conservation strategy that was not specifically reviewed. In the region wastewater reuse has historically been used for irrigation purposes and not for municipal supplies. There are potential opportunities to utilize reuse for municipal irrigation or to potentially augment existing raw water sources. Wastewater reuse may be a viable option for larger cities with significant wastewater discharges.

The identification and recommendation of certain strategies presented in this chapter represents one possible regional approach and does not intend to replace or circumvent local control and direction. The evaluations of the strategies included in Appendices G, J and I provide information that can be used by the entities within the region as they seek to develop reliable water supplies. Implementation of any alternative would require appropriate agreements between the respective entities.

Brief summaries of the strategies that appear to have the greatest potential to help the region meet its projected water needs and promote economic growth follow the respective tables.

7.1 Strategies to Meet Shortages

A list of potential strategies to meet the shortages identified in the supply and demand comparison is presented in Table 7.2.

Table 7.2
Identified Strategies to Meet Shortages

Water user	Strategy	Maximum Shortage[1] (Acre-ft/yr)	Year Shortage Begins	Supply Amt (Acre-ft/yr)	Cost per 1,000 gal
Throckmorton	Renew emergency contract with Ft. Belknap WSC	338	2000	100	Unknown
	Midway Group regional WTP with supply from Possum Kingdom			193	$4.12
	New pipeline from Lake Stamford			340	$5.32
Sweetwater	New groundwater well field	3,781	2000	5,100	$1.62
Rising Star	Install a nitrate treatment system and connection to existing Westbound WSC system	NA	2000	150	$1.86
Lawn	Purchase water from local supplier	100	2000	150	$5.23
NE Brown County	Purchase water from local WSC	170	2000	170	$5.47
Stephens County RWSC	Midway Group regional WTP with supply from Possum Kingdom	366	2000	400	$4.12
WCTMWD	Agreement with the Authority regarding retaining Possum Kingdom priority inflows	3,762[2]	2000	19,000	Unknown
Shackelford WSC	Midway Group regional WTP with supply from Possum Kingdom	222	2010	250	$4.12
Strawn	Purchase water from Eastland County WSD	36	2010	200	$3.33

1. This is the maximum shortage over the 60-year planning period (2000 to 2060).
2. The shortage reported is based on a firm yield analysis. Shortages for WCTMWD are estimated at 10,260 acre-feet in year 2060 using current contract amounts and operational constraints (safe yield operations).

Strategies to Meet an Identified Shortage

Throckmorton – The city of Throckmorton has a projected need of 338 acre-feet per year, which is due to the assumptions that there is no reliable supply from Lake Throckmorton and the city's emergency supply contract with Fort Belknap is not renewed. To meet this need, three strategies were identified. The first is to renew the contract with Fort Belknap at an amount comparable to historical use (this amount could be increased if both parties are amenable). This supply is available only during drought and emergencies. The other strategies include participating with the Midway Group in a regional water treatment plant near Breckenridge that would receive and treat water from Possum Kingdom Lake. The treated water would be transported to Throckmorton through the Shackelford County WSC and Stephens County Rural WSC distribution systems. Improvements to these systems would be needed to meet the demands of the WSCs and Throckmorton. However, due to some limitations of the existing systems, all of Throckmorton's projected needs cannot be met with only these two strategies. To

provide additional supply, raw water from Lake Stamford could be transported to Throckmorton through a new pipeline. The water would be treated at Throckmorton's existing water treatment plant. These strategies could provide sufficient supplies to meet the city's projected needs and provide for some additional growth. If other strategies are developed by others, such as the Cedar Ridge Reservoir in Throckmorton County, the city could consider participating.

Sweetwater – The city of Sweetwater currently uses groundwater from the Dockum aquifer and has water rights in Oak Creek Reservoir and Lake Sweetwater. Both surface water lakes are at record lows and the long-term reliable supply of these sources is uncertain. To meet the city's projected demands, it is proposed that the city develop additional groundwater supplies near its current well fields in western Nolan County. With a projected need of 3,781 acre-feet per year, approximately 50 new wells would be needed at an estimated cost of $ 4 million. This water would be treated at the city's treatment plant. The groundwater source would be operated conjunctively with the city's surface water resources when possible. If the lakes recover soon, the need to develop additional groundwater may be delayed.

Rising Star – Rising Star was shown to have a shortage due to water quality. Nitrates in the city's groundwater wells have exceeded drinking water standards on occasion. The city is considering installing a treatment system to address the nitrates. In addition, to supplement the city's existing supplies and compensate for water that is lost during the treatment process, Rising Star could receive water from the Westbound WSC. A proposed expansion of Westbound WSC's distribution system would be in close proximity to Rising Star, and with minimal improvements the WSC could provide the city with 50 acre-feet per year. The estimated capital costs for the nitrate treatment system and connection to Westbound WSC is $744,000.

Lawn – The city of Lawn also has concerns about its water treatment plant and its ability to adequately treat the water supplies. Potential sources of water include purchasing treated water from local water suppliers. Two alternatives were reviewed. One was a direct pipeline from the city of Abilene's southern connection point to Lawn, and the other was an interconnection through Steamboat WSC. Both alternatives were approximately the same cost and the deciding factors will most likely be the negotiated water purchase cost and other implementation considerations.

Northeast Brown County – A small area in northeast Brown County relies on groundwater from the Trinity aquifer for its water. Groundwater in this area is heavily used and the reliability of this source is uncertain. Previous studies have estimated the need in this area to be nearly 600 acre-feet per year [(12)]. Some of this need has been addressed through expansions of local WSCs. However, there are continued requests for service in this area. The Zephyr WSC, which receives treated water from Lake Brownwood, is expanding its service area boundaries to within seven miles of the area of concern. With some additional expansion, Zephyr WSC could serve approximately 140 customers with an estimated demand of 170 acre-feet per year. The additional capital costs for this expansion are estimated at $2.8 million.

Shackelford County WSC and Stephens County Rural WSC – Both of these WSCs have projected needs totaling nearly 600 acre-feet per year. With additional requests for service, these entities will need new water supplies in the near future. Some of the immediate need identified for Stephens County Rural WSC is associated with monthly contractual limits for supplies from the city of Breckenridge. As monthly demands in non-peak months increase over the planning period, the supply from Breckenridge will increase to the maximum contract amount of 442 acre-feet per year, but additional supplies are still needed. Both Shackelford County WSC and Stephens County Rural WSC have recently contracted with the Authority for water from Possum Kingdom Lake. To utilize this source, the water would be transported via the WCBWDS to an expanded treatment plant at Breckenridge. (Alternatively, a new plant could be constructed to treat this water source.) Some improvements to the WCBWDS line would be needed to meet peak demands of existing customers and the Midway Group. The water would be treated using reverse osmosis or another form of advanced treatment. This strategy could also provide water to the cities of Breckenridge and Throckmorton (discussed above) and a small amount of water (50 acre-feet per year) to Paint Creek WSC, which is located just west of Throckmorton.

Strawn – The city of Strawn shows a small need for additional water beginning in 2040, assuming Lake Tucker can provide 160 acre-feet per year. However, the reliability of this lake is unknown, and based on the performance of similar lakes in the area the reliability is probably low. Also, new treatment standards will require additional improvements to the City's water treatment plant. As an alternative to treating water from Lake Tucker, Strawn could purchase

treated water from Eastland County WSD. Utilizing existing infrastructure, approximately 13 miles of new 6-inch pipeline would be needed from Ranger to Strawn. This source could be used to augment or replace existing supplies. As an alternative, Strawn could participate with a regional project for water from Eastland County WSD. This project would include the cities of Strawn and Gordon, Santo WSC, Sturdivant-Progress WSC, and North Rural WSC. Further discussion of this alternative is included in Section 7.2 and Appendix G.

West Central Texas MWD – The projected need for WCTMWD is largely attributed to the assumptions used in the supply analysis. These assumptions are based upon adherence to water law that requires passing through inflows from upstream reservoirs to downstream senior water rights during drought. To ensure the retention of these inflows, the WCTMWD may want to consider an agreement with the Authority to avoid the necessity of priority pass throughs to Possum Kingdom Lake.

7.2 Strategies to Provide Safe Level of Supply

As evidenced by the recent drought in the West Central Brazos study area, surface water supplies in West Texas can be vulnerable to new and more severe droughts. The long-term reliability of groundwater supplies is also uncertain, especially if groundwater is heavily used due to unreliable surface water supplies. These uncertainties are a driving force in planning for future water supplies where the securing of water is essential to future growth. As previously discussed, a safety factor of 1.25 was used to assess the adequacy of a major water provider's supply to account for some of this uncertainty. Water supply strategies were identified for those providers that did not meet this criterion. The strategies with the greatest potential for implementation are listed in Table 7.3, and brief descriptions of these strategies follow the table. Some strategies were previously discussed in Section 7.2, and only modifications, if applicable, are discussed in this section.

Table 7.3
Identified Strategies to Provide Safe Level of Supply

Water user	Strategy	Reserve Shortage[1] (ac-ft/yr)	Year Shortage Begins	Supply Amt (ac-ft/yr)	Cost per 1,000 gal
Throckmorton	Renew emergency contract with Ft. Belknap	423	2000	100	Unknown
	Midway Group regional WTP with supply from Possum Kingdom			193	$4.12
	New pipeline from Lake Stamford			800	$4.54
Sweetwater	New groundwater well field	5,100	2000	5,100	$1.62
Rising Star	Install a nitrate treatment system and connection to existing Westbound WSC system	150	2000	150	$1.86
Lawn	Purchase water from local supplier	125	2000	150	$5.23
NE Brown County	Purchase water from local WSC	170	2000	170	$5.47
Stephens County RWSC	Midway Group regional WTP with supply from Possum Kingdom	568	2000	400	$4.12
	Purchase water from Throckmorton from Lake Stamford supply			200	$4.54
WCTMWD	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	9,943	2000	19,000	Unknown
	Clear Fork Diversions to Hubbard Creek			16,000	$1.44
Shackelford WSC	Midway Group regional WTP with supply from Possum Kingdom	335	2010	250	$4.12
	Purchase water from Throckmorton from Lake Stamford supply			200	$4.54
Strawn	Purchase water from Eastland County WSD	36	2010	200	$3.33
ULMWD	New groundwater well field	925	2020	1,000	$1.43
Abilene	Increase contract with WCTMWD using supply from Clear Fork Diversion	2,400	2030	12,500	$2.30
BCWID #1	Increase permit to full yield amount and other permit modifications	5,880	2030	8,680	Unknown
Graham	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	1,105	2050	550	Unknown
	Purchase Possum Kingdom water and blend with Lake Graham at WTP			360	$3.23
Palo Pinto MWD	Purchase Possum Kingdom water from the Authority and blend with existing supply	898 (municipal)	2050	1,000	$1.27
NCTMWA	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	186	2060	3,000	Unknown
	Interconnection with Abilene through Hamlin			700	$3.36
Breckenridge	Midway Group regional WTP with supply from Possum Kingdom	NA	NA	650	$4.12
Cisco	Purchase water from Eastland County WSD	NA	NA	500	NA
Gordon	Purchase raw water from Palo Pinto MWD	NA	NA	100	NA
Anson	Emergency connection to Abilene-Hamlin pipeline	NA	NA	550	NA

1. Reserve shortage is the additional supply needed to have water supplies above 1.25 times the projected demands of current customers.

Additional or Changed Strategies to Provide Safe Level of Supply

Midway Group – To provide a safe level of supply to participants of the Midway Group, it is proposed that a greater quantity of water (800 acre-feet per year) be transported from Lake Stamford to Throckmorton. The treatment plant at Throckmorton would be expanded to treat the additional supply. Water could then be sold to water suppliers near Throckmorton, including Shackelford County WSC and Stephens County Rural WSC.

Graham – The city of Graham has sufficient supplies to meet the projected demands, but the reserve supply is low. There are two proposed strategies to provide Graham with a safe level of supply. Similar to the proposed agreement for WCTMWD, the city of Graham may consider entering into an agreement with the Authority to retain Possum Kingdom Lake priority inflows. This agreement would allow Graham to hold inflows that otherwise may be called for under Possum Kingdom's senior water right. The other strategy would utilize water from Possum Kingdom Lake and blend this water with existing supplies at the Graham water treatment plant. The city has a contract with the Authority for water from Possum Kingdom Lake, but no infrastructure. It is proposed that the water be transported through a direct pipeline from Possum Kingdom Lake to the city's water treatment plant. It is assumed that approximately 700 acre-feet per year could be blended and meet secondary treatment standards. Changes in water quality parameters would impact the amount of supply from Possum Kingdom that can be blended.

NCTMWA – The NCTMWA provides water to entities in a three-county area from a single source (Millers Creek Lake). During the last drought, the lake content reached a low of 24 percent of its conservation storage, and NCTMWA began looking for alternate water sources. At that time, a groundwater well was drilled near the NCTMWA water treatment plant for emergency supplies. Groundwater production in this area is good, but the quality can be poor. This can limit the amount of water that can be blended with existing surface water supplies. To provide an adequate safe level of supply to NCTMWA, two strategies were recommended: 1) an interconnection with Abilene through the cities of Hamlin and Stamford, and 2) an agreement with the Authority to retain inflows that otherwise would be passed through to Possum Kingdom Lake. The strategy for a regional interconnection has the potential to provide water over a four-county area, and is described in greater detail in Section 6 and Appendix F. This strategy proposes to utilize existing and planned facilities to move water from Abilene to Stamford. The

only new facilities include a new 14-inch pipeline from Stamford to Haskell and necessary pumping facilities. Once in place, water could be moved from several sources (Abilene's sources, Lake Stamford and Millers Creek Lake) in different directions depending on where the water is needed. An agreement with the Authority would help protect the future yield in Millers Creek Lake. Other strategies that were evaluated for NCTMWA included diversions from Lake Creek to the Miller Creek Lake watershed and further development of local groundwater. The Lake Creek diversion has the potential to supply the NCTMWA with 800 acre-feet per year of raw water provided agreements can be met with downstream water rights holders. Costs for this strategy are similar to the Abilene-Haskell interconnection, and could be considered as an alternate strategy. Use of additional groundwater was not recommended due to water quality concerns. Higher TDS, nitrate and chloride concentrations in NCTMWA supplies could impact existing blending programs of current customers, and ultimately place additional demands on NCTMWA.

Palo Pinto County MWD - Palo Pinto County MWD provides water to Mineral Wells, several small communities and water supply corporations, and an electric generating facility. The sole source of water for Palo Pinto County MWD is Lake Palo Pinto. Presently, the electric power plant on Lake Palo Pinto is not operating. This has reduced the demands on Lake Palo Pinto, but it is uncertain whether the power company will renew its operations at Lake Palo Pinto and if so, at what capacity. With the projected growth in Parker County and demands on Lake Palo Pinto, the District is looking for additional water supplies. Two strategies were identified for Palo Pinto County MWD: 1) releases of water from Possum Kingdom Lake for diversion at Mineral Wells, and 2) expansion of their current facilities with the construction of Turkey Peak Reservoir. Both strategies are feasible and which one is pursued will depend upon the power plant and future growth. As a short-term strategy, water could be released from Possum Kingdom Lake down the Brazos River to a diversion point near Mineral Wells. The water would be transported and blended with water from Lake Palo Pinto at the water treatment plant. This scenario has relatively low costs, but is limited in quantity. For a larger quantity of water, Turkey Peak Reservoir could be pursued. This is discussed under additional supplies for the region. As an alternative to Possum Kingdom Lake releases, several customers of Palo Pinto County MWD are seeking water supplies from Eastland County WSD through the 3P Water Group. These customers include Santos WSC, Sturdivant-Progress WSC and North Rural WSC.

At this time the total amount of supply from this regional project to these suppliers is nearly 700 acre-feet per year, which is not sufficient to meet the total projected reserve shortage of the Palo Pinto County MWD. Also the costs for the 3P Water Group project are higher than other alternatives considered for Palo Pinto MWD. If the 3P Water Group strategy is implemented, it could delay the need for additional supplies for the District.

WCTMWD and Abilene – The city of Abilene provides water to approximately 40 percent of the study area's population. As a major water provider in the region, it is critical that Abilene secure reliable supplies to ensure that its large and small customers have adequate supplies. Abilene's current water sources can meet the projected needs, but there is some uncertainty regarding the long-term reliability of these sources. Lake Ivie and other CRMWD reservoirs are in drought of record conditions and the available supply from these sources will be re-evaluated as the drought progresses and ultimately ends. Reductions in safe yield of the system could impact Abilene's 15,000 acre-feet per year contract for water from Lake Ivie. To provide Abilene with alternative supplies, several options were considered. The strategy that provided the most flexibility in implementation and lower costs for treated water was a yield enhancement project for Hubbard Creek Lake. This strategy would divert peak flows (above 300 cfs) from the Clear Fork of the Brazos River into Hubbard Creek Lake. These diversions could increase the firm yield of Hubbard Creek by 16,000 acre-feet per year, and safe yield by 12,500 acre-feet per year. To divert this water, an agreement with the Authority would be needed for impacts to the yield of Possum Kingdom Lake. Alternatively, WCTMWD could contract with the Authority for an upstream diversion from Possum Kingdom Lake. The additional yield at Hubbard Creek Lake could be transported to Abilene using existing facilities, but peaking capacities would be limited. Peak needs would need to be met with supplies from Fort Phantom Hill and/or Lake Ivie. If the demands on Abilene increase such that additional peaking capacity is needed, an additional pipeline could be constructed. This pipeline would provide the additional capacity to fully utilize the yield in Hubbard Creek Lake and could potentially be used to provide a limited amount of supply from Possum Kingdom Lake. This is a second phase of this strategy and is discussed in Section 7.5 as an option to provide additional supply to the region.

Another alternative that the WCTMWD and Abilene is considering is the Cedar Ridge reservoir in Throckmorton County. The District, in partnership with Abilene, is in the process of a detailed analysis of potential yield and water quality for the proposed reservoir site. The

Brazos G water planning group is also studying this project. As more data and information become available, the findings and recommendations will be refined. More discussion of this alternative is presented in Section 7.4 and Appendix G.

Upper Leon MWD – The Upper Leon MWD currently obtains all of its supply from Lake Proctor. Although existing contracts are projected to be sufficient for the municipal supply through the planning period, groundwater was considered for long-term supply and to help meet other demands on Lake Proctor. Groundwater from the Trinity (Twin Mountains) aquifer in Comanche County could be used in conjunction with existing surface water. The amount of groundwater available for municipal supply depends on available water rights and competing water demands. If water rights can be obtained, the Trinity aquifer has the capability to supply entities with groundwater for extended periods of time, and the close proximity of productive areas of this aquifer to the District make it an attractive potential supply. For this strategy it was assumed that 12 new groundwater wells would be installed within 10 miles of Lake Proctor or a major transmission line. The total capital costs were estimated at $4.2 million.

Brown County WID #1 – Brown County WID#1 appears to have sufficient supplies to meet projected demands, but could improve its reliability through several permit modifications for Lake Brownwood. The District is currently pursuing two modifications - combining use types and eliminating the loss clause in the existing permit. If needed, the District could possibly pursue increasing the permitted diversion amount from Lake Brownwood to the full firm yield of the reservoir.

Breckenridge – To provide additional supply to Breckenridge, the city may choose to participate in the Midway Group regional water treatment plant. The plant would be located at Breckenridge and the city has a request to the Authority for water from Possum Kingdom Lake. This supply would supplement the city's existing supplies from Lake Daniel and Hubbard Creek Lake.

Cisco – The city of Cisco obtains all its water from Lake Cisco. The estimated reliable yield of this lake is 1,300 acre-feet per year, including Battle Creek Diversion, which is sufficient to meet the projected demands for the city. However, Lake Cisco is a single water source for the

city and it has shown some vulnerability to drought recently and during the 1980s. To reduce the risks associated with future drought or other possible catastrophic event, the city of Cisco could purchase treated water from Eastland County WSD for emergency supplies. A strategy for emergency or back-up supplies would provide 1 mgd or an average supply of approximately 500 acre-feet per year. For this strategy, a 10-inch pipeline would be required between the city of Eastland standpipe and the city of Cisco's College Hill Pump Station. The estimated capital costs are $3.6 million with an annual cost of $542,000.

Gordon – The city of Gordon relies solely on Lake Gordon for its water supply. Projected demands for the city are expected to nearly double over the planning period and the city is concerned about the reliability of their water source. To provide back-up supplies to Gordon, two alternatives were considered: 1) participation with the 3P Water Group regional project for treated water from Eastland County WSD, and 2) purchase raw water from Palo Pinto MWD. Both strategies are feasible, but a direct pipeline from Palo Pinto Lake to Gordon has a lower estimated cost. This strategy would include the construction of a 7.5-mile 6-inch raw water pipeline from Palo Pinto Lake to Gordon, along with a lakeside intake structure. Capital costs are estimated at $1.1 million.

Anson – The city of Anson currently receives water from Hubbard Creek Lake through a 14-inch line off of the Abilene/WCTMWD pipeline. Current supplies are sufficient to meet Anson's projected water demands, but there is no back-up or alternate supply for emergencies. Such supplies could be provided through an option to the Abilene – NCTMWA strategy. The Abilene-Hamlin pipeline component of this strategy will pass approximately four miles from Anson. The capacity of this line is 2.0 mgd, of which Anson could take approximately 1.0 mgd from Abilene on an emergency basis. There would be no additional capacity to move water to NCTMWA from Abilene. However, NCTMWA could still receive water from Stamford. This strategy would require a new pipeline from the connection to Anson, which would require coordination with the city of Hamlin. Capital costs are estimated at $887,000.

7.3 Strategies to Provide Additional Supplies

Several strategies were identified that provided supplies above the amount needed to achieve a 1.25 safety factor, but were technically and economically feasible for long-term development. Both of the strategies listed in Table 7.4 would provide water to major municipalities in the region, which could potentially spur additional economic growth.

Table 7.4
Strategies to Provide Additional Supplies

Water user	Strategy	Supply Amt (acre-ft/yr)	Cost per 1,000 gal
Palo Pinto MWD	Turkey Peak Reservoir – raw water	7,600	$1.15
	Turkey Peak Reservoir – treated water	4,000	$2.70
Abilene	Increase transmission capacity from Hubbard Creek Lake and purchase water from Possum Kingdom Lake (includes increased supply with Clear Fork Diversion)	18,100	$3.13

Turkey Peak Reservoir – Turkey Peak Reservoir is a proposed reservoir located immediately downstream of Lake Palo Pinto that would be operated in conjunction with Lake Palo Pinto [(13)]. The proposed reservoir would have a storage capacity of 24,070 acre–feet and inundate approximately 663 acres of land at the normal pool elevation of 867 feet above msl. The spillway would be at the same elevation as Lake Palo Pinto, allowing the reservoirs to act as a single pool. The estimated increase in yield of the Lake Palo Pinto – Turkey Peak Reservoir system is 7,600 acre-feet per year. For this study, it is assumed that 4,000 acre-feet per year of this amount would be used for municipal supply for Palo Pinto County MWD and the city of Mineral Wells. The remainder would most likely be used for steam electric power or other lakeside demands. The capital costs for the reservoir are estimated at $41 million.

The potential for this strategy to be implemented will depend upon the future demands in Palo Pinto County and surrounding area. The current growth trends in Parker and Palo Pinto counties may increase need for this project. Water quality of the reservoir is expected to be good, costs for new water are lower than other alternatives, and the close proximity to a high growth area support consideration of this new source.

Increased Transmission Capacity from Hubbard Creek Lake with Supplies from Possum Kingdom Lake – This strategy would increase the transmission capacity from Hubbard Creek Lake to Abilene to fully utilize the additional yield of the proposed Clear Fork diversion project.

As an option, water could also be transported from Lake Possum Kingdom using the existing WCBWDS to the new pipeline from Hubbard Creek Lake. Some improvements would be needed to the WCBWDS to move the proposed 8,000 acre-feet per year from Possum Kingdom Lake. The water would be transported directly to Abilene's water treatment plants. Expansions of the water treatment facilities would be needed to treat this increased supply. The water from Possum Kingdom Lake could possibly be treated at the new Hargesheimer plant if water from Lake Ivie becomes limited. This proposal provides Abilene with flexibility in using water from different sources and allows staging of new improvements.

7.4 Other Strategies that could Provide Supplies or Improve Water Quality

The evaluation of strategy options for the West Central Brazos study area identified several strategies that were cost comparative and have the potential to improve water availability in the region. These strategies are listed in Table 7.5.

Table 7.5
Other Strategies that could Provide Supplies or Improve Water Quality

Water user	Strategy	Supply Amt (acre-ft/yr)	Cost per 1,000 gal
Abilene	Double Mountain Fork Reservoir	14,000	$3.73
	Direct pipeline from Possum Kingdom Lake with lakeside WTP	14,000	$3.39
	Cedar Ridge Reservoir	14,000	$4.35
Municipal and industrial users in the upper Brazos River Basin	Salt water control above Possum Kingdom Lake	NA	
Regional	Weather modification	NA	

Double Mountain Fork Reservoirs – Two potential dam sites have been studied along the Double Mountain Fork of the Brazos River in Stonewall County for possible water supply to the city of Abilene [14, 15]. Water quality at the proposed sites would be slightly poorer than Possum Kingdom Lake and would require advanced treatment for municipal supply. The estimated yield of the reservoir would range between 34,800 and 43,700 acre-feet per year, depending on the dam site. For this strategy it was assumed that Abilene would contract for 20,000 acre-feet per year of raw water from the reservoir, treat it lakeside, and transport approximately 14,000 acre-

feet per year to the city. The remainder of the water would be used locally in and around Stonewall County. The estimated capital cost for the reservoir is $113 million for the West site and $161 million for the East site. The treatment and transmission capital costs would be slightly less than $100 million. Due to the negative impacts on the yield of Possum Kingdom Lake, this strategy would require an agreement with the Authority to achieve these yield amounts.

Direct Pipeline from Possum Kingdom Lake to Abilene – To provide Abilene with substantial quantities of water from Possum Kingdom Lake, a new pipeline from the lake to Abilene would be needed. Through the WCTMWD, Abilene has requested 20,000 acre-feet per year from the Authority. For this strategy, the water would be treated lakeside and 14,000 acre-feet per year of treated water would be transported to Abilene. The capital costs for the treatment and transmission system are estimated at $128 million.

Cedar Ridge Reservoir – Cedar Ridge Reservoir is a proposed reservoir site on the Clear Fork of the Brazos River in southern Throckmorton County. If constructed, the likely sponsor would be the WCTMWD with the city of Abilene receiving a significant portion of the reservoir's yield. The estimated firm yield of the reservoir is 14,700 acre-feet per year under priority analysis, which is the amount that could be permitted independently of agreements with downstream water rights holders. With agreements with downstream water rights holders, the firm yield of the proposed reservoir would increase to 24,700 acre-feet per year. Advanced water treatment would be needed for municipal supplies from the proposed reservoir due to moderately high total dissolved solids and chlorides. This proposed strategy assumes that Abilene would contract for 20,000 acre-feet per year of raw water from the reservoir, which is nearly the reservoir's entire yield. The water would be treated lakeside, and 14,000 acre-feet per year would be transported to the city. The estimated capital cost for the construction of the reservoir is $123 million, and another $100 million would be needed for the treatment and transmission system. The WCTMWD and the city of Abilene have initiated independent studies of this reservoir site, along with several other potential water sources. If additional data on the water quality of this potential reservoir site indicate advanced treatment would not be needed, the usability for municipal supplies will significantly improve and the recommendations may change.

Salt Water Control above Possum Kingdom Lake – Several studies have been conducted on the benefits of controlling salt water seeps in the upper part of the Brazos River Basin [2, 16, 17]. These studies indicate that with implementation of chloride control, after some period of time, advanced membrane treatment may be reduced such that salt water control may be cost effective. It is likely that implementation of salt water controls in the upper Brazos River Basin will not totally eliminate the need for advanced treatment, but further study should be conducted on the costs and benefits of this strategy.

Weather Modification - In the West Central Brazos study area, there is one on-going weather modification program. This program, sponsored by the West Central Texas Weather Modification Association, performs cloud seeding activities over 4.9 million acres in eight counties: Nolan, Taylor, Callahan, Eastland, Coke, Runnels, Coleman and Comanche. According to Tom Mann of the West Central Texas Council of Governments, this program has increased rainfall by 50 to 73 percent above normal precipitation since its initiation in 2001 [18, 19]. The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Successful rainfall enhancement programs can improve dryland farming, reduce irrigation for irrigated acres, improve forage and potentially increase runoff to local streams and reservoirs. The cost of operating the weather modification program is approximately 10 cents per acre [19].

8.0 Economic Evaluation

Reed, Stowe and Yanke performed an economic analysis to assess the probable impacts to the regional economy that may occur if water needs are not met. These impacts were then compared to the costs of implementing water management strategies identified to meet these needs. The economic analysis was performed only for entities that demonstrated a shortage during the planning period. Economic impacts could not be assessed for strategies identified to meet a safe level of supply. To assess the potential benefits of developing supplies beyond the projected needs of the region, a literature review was conducted regarding the potential impacts of water reservoirs on the local economies. Three case studies were reviewed and are summarized in Section 8.2. The economic report prepared by Reed Stowe and Yanke is included as Appendix J.

8.1 Economic Analysis of Strategies to meet Shortages

As discussed in Chapter 7, seven entities were identified with water supply shortages at some time over the planning period. In addition, two entities were identified with water quality or treatment concerns. The economic analyses evaluated the cost-benefits of recommended strategies for eight of the nine entities. Strategies for northeast Brown County were not evaluated because there is some uncertainty of the amount and extent of the projected water needs for this area.

The results of the economic study found that all recommended strategies showed positive cash flows and economic benefits. If the Midway Group population and demand projections are realized, the regional water treatment plant with infrastructure interconnections receive the largest benefits of the projects analyzed. If the population growth and demands more closely follow the county projections by the State Data Center, the benefits are lower but the project is still economically justifiable.

Large cash flow benefits are also shown for new groundwater development for the city of Sweetwater and a contractual agreement between the WCTMWD and the Authority to hold inflows in Hubbard Creek Lake. For Sweetwater the economic analysis assumed that a large number of people would leave the city if no new water supply were made available. The loss of income and other economic impacts greatly exceeded the project costs. For WCTMWD no

project costs were assessed. The estimated economic benefits for this strategy totaled $1.7 billion, which is attributed to the large number of people affected by this project.

A summary of the economic impact analysis for the project analyses is shown in Table 8.1

Table 8.1

Summary of Economic Impact Analysis

Beneficiary	Total discounted project cash flows [1] (million $)	Cost-Benefit Ratio
Eastland County WSD to the City of Strawn	66.7	15.7
Lake Stamford to City of Throckmorton	70.8	7.2
Abilene to the City of Lawn (direct pipeline from Abilene)	11.0	3.2
Abilene to the City of Lawn (Steamboat Mountain WSC)	10.9	3.08
Westbound WSC to the City of Rising Star (Upgrade WSC System)	27.8	7.9
Westbound WSC to the City of Rising Star (Nitrate treatment)	30.0	17.8
Midway Group Interconnections / Regional WTP	3,285.9[2] 83.4[3]	92.66 3.33
New Groundwater development for the City of Sweetwater	1,273.6	22.32

1. Future cash flows discounted to the year 2009, the assumed year of construction.
2. Based on an average annual forecasted population growth rate of 0.92% as estimated by F&N.
3. Based on an average annual forecasted population growth rate of 0.049% as estimated by TSDC.

8.2 Water Reservoirs Literature Review and Case Studies

To provide information on the potential economic benefits associated with developing additional reservoirs in the West Central Brazos study area, Reed, Stowe & Yanke conducted a literature review and researched the local changes associated with the construction and use of three reservoirs in Texas. The literature review identified two previous studies on the economic impacts of water reservoirs:

- A Study of the Economic Impact of Water Impoundment through the Development of a Comparative-Projection Model [(20)], and
- The Local Economic Effects of Large Dam Reservoirs: U.S. Experience, 1975 – 95 [(21)].

Both papers cited positive economic benefits associated with new reservoirs. Pearson noted positive support to local economies during construction and recreational and land price benefits after construction. The paper by Mostafa focused on how local factors impact the economic benefits of reservoirs. Specifically, the paper addresses the purpose and use of the reservoir and the physical and socioeconomic characteristics of the area. Their findings showed varying impacts depending on the combination of factors for a new reservoir. Some interesting conclusions are:

- Growth is related to existing population. Counties with more people in the nearby vicinity are more likely to experience growth as a result of the reservoir.
- The purpose of the reservoir affects the economic impacts. A reservoir that is primarily for flood control is less likely to have a positive effect on the economy than a reservoir for water supply.
- The larger the water storage, the more positive the effect in areas with limited water supply. If there is other surface water available, the effect is smaller.

Similar findings were shown through the case studies. These studies included three reservoirs built between 1922 and 1965: Lake Weatherford, Lake Mineral Wells, and Lake Pat Mayse. Each of these reservoirs was constructed for water supply and is located in rural counties. For each case study, there was no direct correlation to population growth with reservoir development. Growth rates continued along past trends or declined immediately following the completion of the reservoir. The decline for the city of Mineral Wells was

associated with the closing of a military base. Recent higher growth in Weatherford and Mineral Wells is associated with expanded growth of the Fort Worth metroplex. For Lake Pat Mayse, the acquisition of additional water allowed the city of Paris to provide quality water to both municipal and industrial customers. The city's major wholesale customer is Campbell's Soup, which uses nearly 50 percent of the total water produced by the city. Without this additional water, it is unlikely that Paris could provide sufficient water to meet its customers' needs. This reservoir provided positive economic benefits to the community, but did not simulate higher population growth.

These studies show that a community's economic growth is dependent on many factors, with water as one component. The West Central Brazos study area is predominately rural and new reservoir development may not simulate population growth near the reservoir, but could positively impact economies of the cities that would use the water. As indicated by the literature review, fast growing communities such as Mineral Wells can support the development of additional water supply reservoirs, and this development could potentially spur additional growth. The economic impacts in rural communities are more likely influenced by other factors such as weak inter-industry linkages, poor infrastructure and limited human resources.

9.0 Preferred Alternative

Based on a strict supply and demand comparison analysis, there is a current total need of 2,430 acre-feet per year in the study area, which increases to nearly 8,700 acre-feet per year by 2060. Much of this need is associated with the city of Sweetwater and the WCTMWD. For several entities, the projected shortages are attributed to the unreliability of small local water sources. During the recent drought other water sources also demonstrated some vulnerability, causing many water providers to initiate use restrictions. This uncertainty warrants identifying water strategies that would provide a higher level of supply than needed to only meet the projected demands. This "safe level" of supply would provide some additional water above the projected demands that can be used to promote economic growth in the region. The preferred alternative to provide a safe level of water supply to the West Central Brazos study area is listed in Table 9.1 and includes the following strategies.

- Sales from Possum Kingdom Lake: Midway Group, Graham, Palo Pinto MWD, Abilene (through the Clear Fork diversion project)
- Midway Group Regional Water Treatment Plant
- Pipeline from Lake Stamford to Throckmorton with sales to Shackelford WSC and Stephens County RWSC
- Interconnection between Abilene and NCTMWA with connection to Anson
- Sales from water providers:
  - Local provider to Lawn
  - Eastland County WSD to Strawn and Cisco
  - Palo Pinto MWD to Gordon
  - Westbound WSC to Rising Star
  - Zephyr WSC to Northeast Brown County
- New groundwater
  - City of Sweetwater
  - Upper Leon MWD
- Clear Fork Diversion to Hubbard Creek Lake – WCTMWD and Abilene
- Permit modification for Brown County WID#1
- Agreements with the Authority regarding retention of Possum Kingdom Lake priority inflows: WCTMWD, Graham, and NCTMWA
- Turkey Peak Reservoir
- Water treatment for nitrates – Rising Star
- Salt water Control
- Weather Modification

Table 9.1
Integrated List of Strategies to Meet Regional Water Needs

Water user	Strategy	Year Needed	Supply Amt (ac-ft/yr)	Cost per 1,000 gal
Throckmorton	Renew emergency contract with Ft. Belknap	2005	100	Unknown
	Midway Group regional WTP with supply from Possum Kingdom	2005	193	$4.12
	New pipeline from Lake Stamford	2040	800	$4.54
Sweetwater	New groundwater well field	2005	5,100	$1.62
Shackelford WSC	Midway Group regional WTP with supply from Possum Kingdom	2005	250	$4.12
	Purchase water from Throckmorton from Lake Stamford supply	2040	200	$4.54
Stephens County RWSC	Midway Group regional WTP with supply from Possum Kingdom	2005	400	$4.12
	Purchase water from Throckmorton from Lake Stamford supply	2050	200	$4.54
Strawn	Purchase water from Eastland County WSD	2005	200	$3.33
Rising Star	Install a nitrate treatment system and connection to existing Westbound WSC system	2005	150	$1.86
WCTMWD	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	2005	19,000	Unknown
	Clear Fork Diversions to Hubbard Creek	2040	16,000	$1.44
Lawn	Purchase water from local provider	2005	150	$5.23
NE Brown County	Purchase water from Zephyr WSC	2005	170	$5.47
BCWID #1	Permit modifications	2005	8,600	Unknown
ULMWD	New groundwater well field	2010	1,000	$1.43
Breckenridge	Midway Group regional WTP with supply from Possum Kingdom	2040	650	$4.12
Graham	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	2040	550	Unknown
	Purchase Possum Kingdom water and blend with Lake Graham at WTP	2040	360	$3.23
Palo Pinto MWD	Purchase Possum Kingdom water and blend with existing supply	2040	1,000	$1.27
	Turkey Peak Reservoir	After 2040	7,600 (raw) 4,000 (treat)	$1.15 $2.70
Abilene	Increase Hubbard Creek Lake supply with Clear Fork Diversion (existing infrastructure)	2040	12,500	$2.30
	Increase transmission capacity from Hubbard Creek and purchase Possum Kingdom water[1]	After 2040	8,000 (raw) 18,100 (tot)	$4.59 $3.13
NCTMWA	Interconnection with Abilene through Hamlin	NA	700	$3.36
	Agreement with the Authority regarding retention of Possum Kingdom priority inflows	After 2040	3,000	Unknown
Cisco	Back-up supplies from Eastland County WSD	NA	500	NA
Gordon	Back-up supplies from Palo Pinto MWD	NA	100	NA
Anson	Emergency connection to Abilene-Hamlin line	NA	550	NA
West Brazos	Salt water control in Stonewall County	NA	NA	NA
Regional	Weather modification	NA	NA	NA

1. This strategy would use 8,000 af/y from Possum Kingdom plus the 12,500 af/y from the Clear Fork diversion. After treatment there would be a combined 18,100 af/y of treated water. The cost to treat and transport the additional 8,000 ac-ft is $4.59/1,000 gallons. The average cost for the 18,100 ac-ft is $3.13/1,000 gallons.

These strategies would provide approximately 74,900 acre-feet per year of municipal and industrial supplies to water users in the West Central Brazos study area. Of this amount, 6,600 acre-feet per year is new groundwater supply and 23,600 acre-feet per year is new surface water supply. The remaining amount is associated with transfers of existing supplies to entities with shortages and contract agreements with downstream water rights holders. A schematic of the proposed infrastructure improvements are shown on Figure 9.1.

9.1 Implementation Issues

All of the recommended water strategies will need to be implemented through the respective entities. Many of these strategies will require new contract negotiations, infrastructure improvements, and possibly water rights acquisition. This section presents a brief discussion of implementation issues for different types of strategies.

Interconnection with other water supply systems – Ten strategies involve connections with other water supply systems. Each of these interconnections will require infrastructure improvements that will need to be financed by the benefiting entity or entities. For some entities, this may require issuance of municipal bonds and/or voter approval, which could impact water rates. The proposed interconnections will also require contract negotiations between the buyer and seller. Significant increases in cost of water associated with the infrastructure improvements and water purchase can impede implementation, especially for smaller entities with limited financial resources.

Most of the identified interconnections involve moving water within the respective river basin. If water is moved from one basin to another, it will require an interbasin transfer. For the Northeast Brown County strategy, an interbasin transfer would be required if water is provided from Lake Brownwood to the part of northeast Brown County that is located in the Brazos River basin. However, since this transfer occurs in the same county and the county is partially in the basin of origin, the interbasin transfer would be exempt from many of the requirements. Also, for this alternative most of the identified recipients of the water are located in the Colorado River basin and would not require an interbasin transfer.

Major pipeline projects, such as the Lake Stamford to Throckmorton strategy, will require right-of-way acquisition. If the route crosses private lands, negotiations would need to be reached with the individual landowners. Opposition to the pipeline could impede construction or increase costs if it has to be re-routed.

Figure 9.1

There also may be water quality issues if the recipient uses multiple sources of water. Examples include the Lake Stamford to Throckmorton strategy that proposes to treat Lake Stamford water at Throckmorton. If the water quality is significantly different from Lake Throckmorton, the plant may need improvements to treat water from both sources. Treatability and compatibility testing would be required. Other strategies with multiple water sources include new groundwater for the Upper Leon MWD and NCTMWA, the Midway Group Regional WTP, and the Abilene to NCTMWA interconnection. The Midway Group Regional WTP and the Abilene to NCTMWA strategies would combine treated supplies from different sources, which do not have treatability issues but may elicit taste and odor concerns from customers.

Sale of Possum Kingdom water –Three recommended strategies propose to use water from Possum Kingdom Lake, which has elevated chloride and total dissolved solids. Two of these strategies propose to blend water from Possum Kingdom with an existing source at the water treatment plant. This will require treatability studies and careful monitoring of the blended water to ensure the treated water meets appropriate standards. If there are compatibility issues with the water sources, blending of Possum Kingdom water may not be an option. Customers may object to significant changes in taste and odor of the water supply.

The other strategy, Midway Group Regional WTP, proposes to treat Possum Kingdom water using reverse osmosis (or other comparable method). This will generate a brine reject stream that will require disposal. Options considered include discharge to the Brazos River, deep well injection, oil field flooding, or evaporation ponds. Depending on the disposal option, the cost of disposal and the time needed to obtain necessary permits will vary. For any discharge to state waters, a Texas Pollutant Discharge Elimination Permit would be needed. This permit is issued by the TCEQ and requires demonstration of no to low impacts to the water quality of the receiving stream. Permits for deep well injection are granted by the TCEQ for municipal and manufacturing wastes or by the Railroad Commission for oil and gas operations. The permitting process through TCEQ for deep well injection can be costly and take several years. Options for salt water disposal through the oil and gas industry either by injection or oil field flood are likely to be easier to implement, but these options require willing oil/gas participates with appropriate facilities. The major implementation issue associated with evaporation ponds or drying beds is available space. For small-scale projects, this may be an option, but large scale projects will

generate considerable amounts of brine. There are similar waste disposal issues with the nitrate treatment strategy for Rising Star.

Agreements with the Authority regarding passing priority inflows for Possum Kingdom Lake – It is recommended that three water providers work together with the Authority to establish contractual agreements avoiding the pass through of inflows to Possum Kingdom Lake. Because a priority call by downstream senior water rights has not previously occurred, the necessity for such agreements may not be readily apparent to the water suppliers. A clear understanding of the legal uncertainty of the supply available for their junior water rights will be essential to successful contract negotiations with these providers.

New surface water supplies –Three strategies are proposed to develop new surface water: the Clear Fork diversion into Hubbard Creek Lake, Turkey Peak Reservoir and an increase in the permitted diversion at Lake Brownwood. Each of these strategies will require a water rights permit from the Texas Commission on Environmental Quality (TCEQ). To receive a permit, there must be a demonstration of need, available unpermitted water and an evaluation of potential impacts to downstream water rights holders and the environment. Obtaining a new water rights permit can take several years.

An option for the Clear Fork diversion project is to purchase all diverted water from the Authority, as an upstream diversion from Possum Kingdom Lake. This option will also require a water rights permit for the channel dam and diversion structure.

New groundwater sources - New groundwater sources will need to be developed in accordance with public drinking water requirements. An evaluation of the quality and quantity of groundwater that can be produced from the aquifer must be conducted before it is relied upon to provide water supplies for a public water-supply entity. For the proposed Sweetwater strategy, there are available data to base these estimates. There are some data available from irrigation wells for the ULMWD strategy. The installation of new test wells may be warranted for both strategies. In addition, the rules and regulations of any groundwater conservation districts (GCD) must be followed. This will include the Middle Trinity GCD (Erath and Comanche Counties), the Wes-Tex GCD (Nolan County), and the Lone Wolf GCD (Mitchell County).

The rules and regulations vary for each district, but many stipulate some restrictions on groundwater use either through well spacing requirements, production limits, and/or limits on transferring water out of the GCD area. Well spacing and production limits are not likely to be significant implementation issues, however, a transfer permit could potentially impede or delay the implementation of a strategy. Of the strategies considered for this study, there is only one possible out-of-district transfer of groundwater. Mitchell County, which is outside the West Central Brazos study area but only 4 miles from Sweetwater's existing well fields, is a potential source of water for Sweetwater. If the city were to obtain groundwater from Mitchell County, a permit would be required to transfer water out of the county. In granting such a permit, the District must consider several issues, including groundwater availability in the district, alternate supplies for the applicant, amount and proposed use of the transfer, and the impact on the aquifer.

Regional projects – One of the most pressing implementation issues associated with regional projects is participation of the identified beneficiaries. For both the Midway Group Regional WTP strategy and the Lake Stamford to Throckmorton strategy, full participation is critical to having an economically feasible project. At this time, it appears that some of the Midway Group participants are pursuing other alternatives and do not want to commit to a regional system. Shackelford WSC has agreed to participate with Albany in their water treatment plan expansion, and may also participate with Stephens County RWSC in another plant. Stephens County RWSC has applied for funds to construct a 1 mgd treatment plant, which may be expanded to 1.5 mgd pending Shackelford's participation. It is unlikely that both the regional WTP and Lake Stamford pipeline would be pursued at the same time. However, both strategies require improvements and interconnections to the Midway Group's existing distribution systems. Delays of agreements could significantly impact the costs associated with these upgrades.

9.2 Financing Alternatives

For many of the communities identified, the ability to finance the proposed improvements will be a driving factor in implementing these strategies. There are numerous financing mechanisms that may be available to users in the West Central Brazos study area. Some of the more applicable funding options include:

- Market Financing – through General Obligation Bonds, Revenue Bonds, Double-Barreled Bonds, and Certificates of Obligation.
- Financing Programs through the TWDB
    - Drinking Water State Revolving Fund
    - Rural Water Assistance Fund
    - State Participation Program
    - Development Fund II
- U.S. Department of Agriculture Programs
    - Rural Utilities Service Water and Waste Disposal Loans and Grants
- Texas Department of Agriculture Programs
    - Texas Capital Fund Infrastructure Development Program
    - Rural Municipal Finance Program
- Office Rural Community Affairs
    - Community Development Fund
    - Planning and Capacity Building Fund
    - Housing Infrastructure Fund
    - Small Towns Environment Program
- Economic Development Administration Public Works Program
- Brazos River Authority
- Corps of Engineers Programs

Brief descriptions of these financing programs and other potential funding mechanisms are included in Appendix K. The purpose of the funding program, eligible applicants and general restrictions on the use of the funds are also discussed in Appendix K. Additional restrictions may apply and the availability of these funding sources for future long-term projects is unknown. Funding from local, state and federal sources is subject to continued support of the respective sponsor, and changes in the economic climate can impact the availability of funds. Based on current conditions, an assessment of potential applicable funding sources for water strategies identified for the West Central Brazos study area is shown in Table 9.2.

Table 9.2

Summary of Financing Alternatives

Water User	Strategy	Market Financing	TWDB Programs	USDA Programs	TxDA Programs	EDA Programs	ORCA Programs	Authority Programs	COE Programs
Throckmorton	Renew contract with Ft. Belknap								
	Midway Group regional WTP with supply from Possum Kingdom	✓	✓	✓	maybe	✓	✓		
	New pipeline from Lake Stamford	✓	✓	✓	maybe	✓	✓		
Shackelford WSC	Midway Group regional WTP with supply from Possum Kingdom	✓	✓	✓	maybe	✓	✓		
	Purchase water from Throckmorton from Lake Stamford supply	✓	✓	✓		✓	✓		
Stephens County RWSC	Midway Group regional WTP with supply from Possum Kingdom	✓	✓	✓	maybe	✓	✓		
	Purchase water from Throckmorton from Lake Stamford supply	✓	✓	✓		✓	✓		
Breckenridge	Midway Group regional WTP with supply from Possum Kingdom	✓	✓	✓	maybe	✓	✓		
Graham	Agreement with the Authority regarding passing priority inflows to Possum Kingdom								
	Purchase Possum Kingdom water and blend with Lake Graham at WTP	✓	✓	✓	maybe	✓	✓		
Sweetwater	New groundwater well field	✓	✓		maybe	✓	✓		
Strawn	Purchase water from Eastland County WSD	✓	✓	✓	maybe	✓	✓		
Rising Star	Install a nitrate treatment system and connection to existing Westbound WSC system	✓	✓	✓	✓	✓	✓		
Lawn	Purchase water from local provider	✓	✓	✓	maybe	✓	✓		

Table 9.2 (Continued)

Water User		Market Financing	TWDB Programs	USDA Programs	TxDA Programs	EDA Programs	ORCA Programs	Authority Programs	COE Programs
NE Brown County	Purchase water from Zephyr WSC	✓	✓	✓	maybe	✓	✓		
WCTMWD	Agreement with the Authority regarding passing priority inflows to Possum Kingdom								
	Clear Fork Diversions to Hubbard Creek (raw water)	✓	✓	✓		✓	✓		
NCTMWA	Agreement with the Authority regarding passing priority inflows to Possum Kingdom								
	Interconnection with Abilene through Hamlin	✓	✓	✓		✓	✓		
Palo Pinto MWD	Purchase Possum Kingdom water and blend with existing supply	✓	✓		maybe	✓	✓		
	Turkey Peak Reservoir	✓	✓						
Abilene	Increase contract with WCTMWD using supply from Clear Fork Diversion	✓	✓						
ULMWD	New groundwater well field	✓	✓	✓		✓			
BCWID #1	Permit modifications								
Anson	Emergency connection to Abilene-Hamlin pipeline	✓	✓	✓	✓	✓	✓		
Cisco	Connection to Eastland County WSD	✓	✓	✓	maybe	✓	✓		
Gordon	Connection to Palo Pinto Lake	✓	✓	✓	maybe	✓	✓		
Regional	Weather Modification			✓					
Regional	Salt water control			✓					maybe

9.3 Contracts

Transfer of water from one entity to another typically requires contractual agreements. These agreements can vary significantly in content, but most will address the following topics:

- Quantity and type of water (raw or treated) and supply constraints (which could include maximum daily flows, reduction in supplies due to drought or infrastructure constraint, minimum stream flows if water is diverted from a river or stream, or other constraint specific to the contract.)
- Payments and remedies for default
- Responsibilities of the purchaser, including metering and reporting
- Restriction on use of the water, including sales, interbasin transfers, and type of use
- Force majeure and conditions beyond the control of the supplier
- Terms and conditions, such as length of contract, notices, termination, etc.

Some other topics a water supply contract may address include water quality protection, conservation, drought contingency plan requirements, liability protection for the supplier (indemnity/hold harmless clause), and system operation if applicable. Both water quality protection and conservation serve to protect the purchaser and supplier. As new regulations are implemented, it will be the responsibility of both parties to have in place effective non-point source pollution abatement plans and water conservation plans.

9.4 Implementation Plan (Proposed timeline through 2040)

The proposed timeline is based on current and projected demands for the West Central Brazos study area. If there is a significant change in water demands, then adjustments may be needed to this timeline. Other projects that are not specified in this timeline may prove to be feasible at lower costs and should be considered as appropriate to meet the region's needs. Any project recommended for implementation after 2010 should be re-evaluated at a later date in light of conditions at that time and funding opportunities. A summary of projects with estimated capital costs and recommended implementation time is shown on Table 9.3. Cumulative capital cost over time is presented on Figure 9.2, and the distribution of capital costs by project type is presented in Figure 9.3.

Projects that should be initiated within the next two years (2004 – 2005):

- Renew contract between the city of Throckmorton and Fort Belknap WSC
- Midway Group Regional WTP (This could be initiated in phases through smaller treatment plants that could be consolidated at a later time. Shackelford WSC, Stephens County RWSC and Throckmorton should be considered at this time.)
- New groundwater well field for the city of Sweetwater
- Nitrate treatment system for the city of Rising Star
- Supply connection between a local provider and the city of Lawn
- Zephyr WSC expansion into northeast Brown County
- Treated water connection from Eastland County WSD to the city of Strawn
- Agreement between the Authority and WCTMWD regarding passing priority inflows to Possum Kingdom Lake
- Permit modification for Lake Brownwood
- Study on saltwater control in Stonewall County
- Continued operation of weather modification program

Projects that should be implemented by 2010:

- Emergency connection to the city of Anson
- Treated water connection from Eastland County WSD to the city of Cisco
- Back-up raw water connection from Palo Pinto Lake to Gordon
- New groundwater development for ULMWD
- Interconnection between Abilene and NCTMWA (as emergency back-up supply)

Projects that should be implemented by 2020:

- Expansion of Midway Group WTP to include the city of Breckenridge

Projects to be considered between 2030 and 2040:

- New pipeline from Lake Stamford to the city of Throckmorton
- Sales from Throckmorton to WSCs (Shackelford WSC and Stephens County RWSC)
- Possum Kingdom water to the city of Graham
- Agreement between the Authority and Graham regarding passing priority inflows to Possum Kingdom Lake
- Possum Kingdom water to Palo Pinto MWD

- Clear Fork diversion to Hubbard Creek Lake

Projects for consideration after 2040:

- Agreement between the Authority and NCTMWA regarding passing priority inflows to Possum Kingdom Lake
- Turkey Peak Reservoir
- Increase transmission capacity from Hubbard Creek Lake to Abilene and purchase water from Possum Kingdom Lake

Table 9.3

Capital Improvement Projects and Implementation Year

Year to be Implemented	Strategy	Quantity (AF/Y) raw	Quantity (AF/Y) treated	Total Capital Costs
2005	Abilene supply to Lawn through Steamboat Mountain WSC		150	$1,873,737
2005	Expansion of Zephyr WSC into northeast Brown County		170	$2,814,220
2005	New Groundwater for Sweetwater	5,100	5,100	$16,972,419
2005	Nitrate treatment of groundwater for Rising Star with backup connection to Westbound WSC	150	150	$743,585
2005	Regional WTP for Midway Group with sales from Possum Kingdom Lake (implemented in phases – 2005 and 2040)	2,000	1,400	$17,240,991
2005	Supply from Eastland Co. WSD to Strawn	200	200	$1,431,830
2010	Emergency connection to Anson from Abilene to Hamlin line	NA	NA	$886,652
2010	Interconnection between NCTMWA and Abilene through Hamlin & Stamford		700	$5,001,808
2010	Sales from Palo Pinto MWD to Gordon	100	100	$1,102,159
2010	Sales from Eastland County WSD to Cisco		500	$3,580,798
2010	New Groundwater for ULMWD	1,000		$4,188,660
2040	Clear Fork Diversions to Hubbard Creek Reservoir with supply to Abilene	16,000	12,500	$99,115,505
2040	Lake Stamford to Midway Group	800	800	$10,161,780
2040	Sales from Possum Kingdom Lake to Palo Pinto MWD	1,000	1,000	$2,833,608
2040	Supply from Possum Kingdom Lake to Graham with blending at WTP	360	360	$3,801,729
2060	Sales from Possum Kingdom Lake to Abilene with expansion of Hubbard Creek transmission system	8,000	6,000	$73,328,718
2060	Turkey Peak Reservoir (raw water)	7,600	4,000	$59,698,596

Figure 9.2
Cumulative Capital Cost over Time

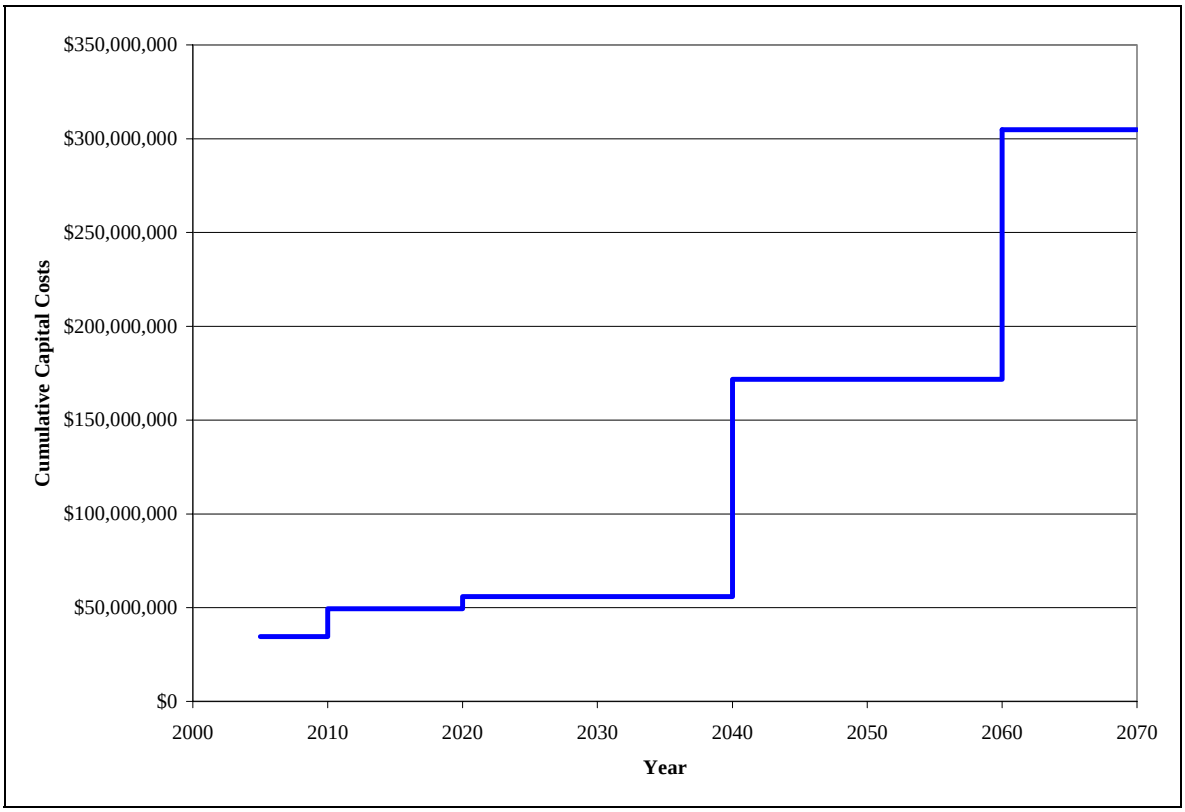
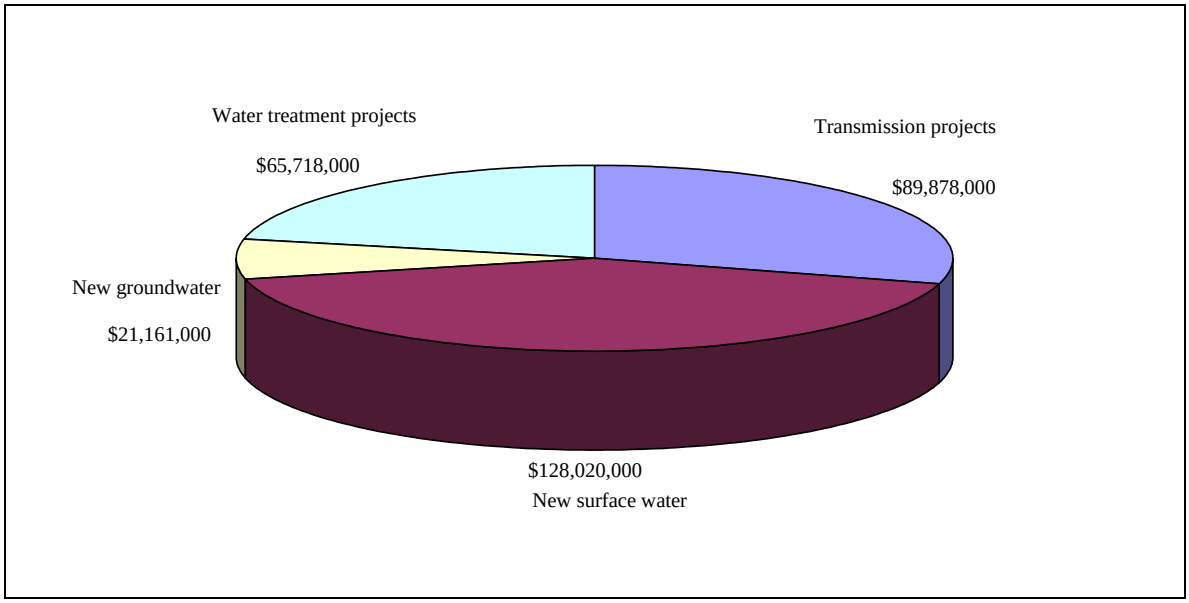


Figure 9.3
Capital Costs by Project Type



10.0 Conclusions and Recommendations

10.1 Conclusions

The West Central Brazos study area has sufficient water supplies to meet regional demands but some areas were shown to have projected shortages. Most of these shortages occur in areas with limited water sources. The northwestern portion of the study area has little developed surface water and the groundwater is isolated with variable quality. There is little to no groundwater in the northeastern part of the study area, and the small local reservoirs tend to be unreliable during drought. The recent drought in the upper Brazos River Basin has demonstrated the vulnerability of surface water supplies in this area. The storage content for many reservoirs dropped significantly over the past five years, with some reservoirs recording all time lows. Four reservoirs entered new critical periods, and three reservoirs – Millers Creek Lake, Lake Daniel, and Palo Pinto Lake- are still in drought of record conditions. Recent studies for the Brazos G indicate that the severity of the on-going drought continues to impact the available supplies for these reservoirs.

The drought hit the farming community in the West Central Brazos study area hard in the latter part of the last decade. While personal income for the region continued to grow, farm earnings declined and reported a loss in 1996. In 2000, farm earnings accounted for less than 1 percent of the total personal income in the area. Non-agricultural industries, such as construction, manufacturing and finance and real estate, grew during the past decade and continue to be strong economic bases.

Several entities are struggling to maintain aging water treatment plants and distribution systems. Approximately two-thirds of the facilities inventoried may have difficulties meeting new treatment standards. There is a desire to use water from Possum Kingdom Lake, but the water would require advanced treatment for municipal and manufacturing use. Economic considerations have delayed utilizing this source.

While these concerns are valid and in some cases substantial, overall there appears to be sufficient water supplies for municipal and manufacturing needs in the study area. The projected growth rates in the study area do not demonstrate significant increases in water demands. The greatest growth is projected to occur in and around the larger cities, such as Abilene and Mineral Wells, and in the eastern part of the study area, which is close to the Fort Worth–Dallas

metroplex. If the growth rates increase in other parts of the study area, the need for water may increase, but water is not the limiting factor for growth. Growth is contingent on many factors, with water being one factor. Other factors include available work force, sufficient power, accessibility to major transit facilities, and other infrastructure and services necessary to support growth. The development of additional water supplies would provide the opportunity for increased growth to the area, but would not guarantee growth.

This study identified seven water users with water shortages over the planning period and identified potential strategies to meet these needs. Each of these strategies was shown to have positive economic impacts to the region and should be considered as a feasible water management strategy by the respective entity. There are also opportunities to interconnect existing water supply systems to increase the reliability of existing sources. The two most promising interconnections are: 1) between the city of Abilene and NCTMWA, using existing and proposed pipelines through the cities of Hamlin and Stamford, and 2) Shackelford WSC, Stephens County RWSC and the city of Throckmorton. These interconnections have the potential to increase water supplies to large portions of the study area that have limited resources. Other interconnections were also shown to be feasible and should be considered for further study.

As the city of Abilene continues to enter into agreements for water supply with smaller communities in the region, the city's need to secure reliable water supplies will increase. Currently, the city obtains water from four separate sources, which provides an increased level of reliability during drought. However, there is some uncertainty about the long-term available supply from these sources. Options for additional supplies include yield enhancement of existing sources, use of water from Possum Kingdom Lake, or the development of new supplies. Each is technically and economically feasible. The pursuit of one or more of these strategies, if any, will depend on projected demands for Abilene and the reliability of their existing sources.

Of the identified new reservoir sites, Turkey Peak Reservoir for the Palo Pinto Municipal Water District appears to have the greatest potential as a new water source. The costs for water are economically feasible and there is a growing demand in Palo Pinto County. Also, previous studies on reservoir construction and growth found that the development of new water supplies is more likely to spur additional growth if they are located near cities. This indicates that the development of Turkey Peak reservoir, which is near the city of Mineral Wells, could further

increase local growth. The need for this water is partially dependent upon the future demands for the power plant located at Lake Palo Pinto. However, if the city and local communities continue to grow at recent rates, the need for additional water may come sooner than projected.

Other alternatives recommended to provide additional water supplies or increase the reliabilities of existing supplies are potentially feasible strategies that should be reviewed for further consideration by the respective entities. These recommendations do not intend to replace local control and direction, and it is recognized that the implementation of any alternative would require local commitments and appropriate agreements between the respective entities. For regional projects, the Authority could act as a facilitator with the other entities. However, the Authority's role will most likely be limited for projects that do not involve the Authority facilities.

In all, seventeen new infrastructure projects were identified to best help drought-proof the study area. These strategies would provide approximately 43,700 acre-feet per year in new water supplies or transfers of existing supplies with a total capital cost estimated at $305 million. Other strategies would safeguard 31,200 acre-feet per year of surface water supplies through contract agreements and permit modifications.

Authority's Role in the Upper Basin

The Authority holds permits for much of the surface water supply in the Brazos River Basin. In the West Brazos Basin, the Authority owns and operates Possum Kingdom Lake and operates Lake Proctor. As a steward of these resources, the Authority is actively working together with local water suppliers to best utilize the available supplies. Regional projects, such as the Regional Water Treatment Plant at Breckenridge, could potentially include the Authority as an operator of the facility. As presently proposed, the regional system would transport water from Possum Kingdom Lake to a facility near Breckenridge via the WCBWDS, treat the water and distribute to users in surrounding counties. The Midway Group was identified as receiving water from this regional plant. Since this strategy was developed, the city of Throckmorton has expressed a desire to not participate in the regional plant and Shackelford WSC has committed to participate in Albany's water treatment plant improvements. The immediate need for this facility appears to be delayed, but it is still a viable alternative to meet the growing needs in this area. It is likely that this strategy would be implemented in phases with Shackelford WSC and Stephens

County RWSC participating in a smaller treatment plant in the near future, and expanding as needed. Other opportunities for use of the WCBWDS are limited as a raw water distribution system for municipal supplies. Due to the water quality of Possum Kingdom Lake it is not desirable to mix this water in other existing reservoirs.

One of the limiting factors for using water from Possum Kingdom Lake for municipal and manufacturing needs is the salt content. Reducing the salts in flows upstream of the reservoir could greatly improve the water quality in Possum Kingdom Lake and other downstream reservoirs. A review of previously proposed studies for salt-water reduction indicates that such projects should be further evaluated for viability. The Authority could act as a facilitator for such studies and possibly subsequent salt-water control projects in the upper basin. If such projects prove to substantially improve the water quality in Possum Kingdom Lake, then the opportunities to sell and use water from Possum Kingdom Lake greatly increase. With higher quality water, the city of Abilene could transport and treat Possum Kingdom water via the WCBWDS and their existing facilities. Without a new pipeline, the capacity of the Abilene system is limited to the extent it could use Possum Kingdom water, but this scenario would allow greater flexibility in using different water sources. The opportunities for the Authority to sell water to smaller communities with conventional treatment systems also increase.

Other potential roles for the Authority include working together with existing customers to implement emergency action plans and providing funding and support to planning and infrastructure projects within the basin. The Authority is actively involved in the regional water planning efforts and is a major sponsor of this study. In these roles as a political subdivision, the Authority can provide political and technical support to foster water supply projects in the region.

<u>EDA's Role in the Region:</u>

The EDA plays an important role in promoting and supporting the economic development in the study area. Through their financing and incentive programs the EDA works together with local governments to solicit new industries that would increase growth and improve the economy for the region. As discussed in Appendix K, the EDA is also a source of funding to support growth.

EDA may provide project funding through the following Investment Programs:

- Public Works Program - Revitalize, expand, and upgrade physical infrastructure to attract new industry.
- Economic Adjustment Program - Assist State and local interests in the design and implementation of strategies to adjust or bring about change to an economy.
- Technical Assistance Program - Collect the information that local public sector and nonprofit officials need in facing difficult challenges in allocating limited resources.

EDA will assist and empower those regions and jurisdictions in the development and implementation of their own economic development and revitalizations strategies based on the data provided in this study. EDA will promote multi-jurisdictional planning efforts, development of institutional capacity, and diversification of involvement and investment.

10.2 Recommendations

This study identified numerous water infrastructure projects and other strategies that would increase the available water to the region and/or improve the reliability of existing water supplies. It is recommended that the strategies identified for immediate needs be considered for implementation by the respective entities. The long-term strategies should be retained for further consideration and included in the regional water planning efforts. Coordination of this plan with the regional and state water plans is necessary to ensure state-supported funding and issuance of state permits if needed. The Authority, EDA and TWDB should continue to provide financial assistance to entities seeking funding to implement these strategies, understanding that this assistance would be within the constraints of existing funding programs.

The region should continue to explore new and different water supply options as they become apparent. Data from regional projects, such as salt water control, brush control and weather modification, should continue to collected and evaluated to demonstrate water supply and economic benefits to the region.

11.0 Public Participation

Public participation is an important component of accurate and viable regional water planning. As part of this study, there were three different public meetings (each held at two locations) and numerous meetings with the larger water suppliers and members of the Midway Group. These meetings were intended to solicit input as the study progressed and receive comments prior to the final report. Each of these meeting was well attended and participants offered valuable input.

The draft report of the West Central Brazos study was presented to water suppliers and the interested public at two public meetings on March 3, 2004. One meeting was held in Abilene and the other was held in Breckenridge. The draft report was available to the public at each meeting and copies were submitted to the Texas Water Development Board (TWDB) at that time. In addition, the report was available to the public on-line through the Authority's website.

Due to public interest, the draft comment period was extended 60 days, giving the public from March 3 to June 1, 2004 to provide comments on the draft report for consideration in the final report. A total of nine water providers and interested public provided written comments on the report. Several others provided verbal comments during the public meetings or by phone. Copies of the letters received from the public are included in Appendix L, and a summary of the comments and responses are presented in Table L-1 in Appendix L.

Review comments from the TWDB were received by the Authority on July 26, 2004 and are also included in Appendix L. Changes to the draft report as a result of the public and TWDB comments are listed in Appendix L.

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