REGION F

Regional Water Plan

January 2001

Region F
Water Planning Group

Freese and Nichols, Inc.
LBG-Guyton Associates, Inc.
S-K Engineering, Inc.
Alan Plummer Associates, Inc.
Texas Tech University
Texas Agricultural Experiment Station

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ES.0 EXECUTIVE SUMMARY

ES.1 Introduction

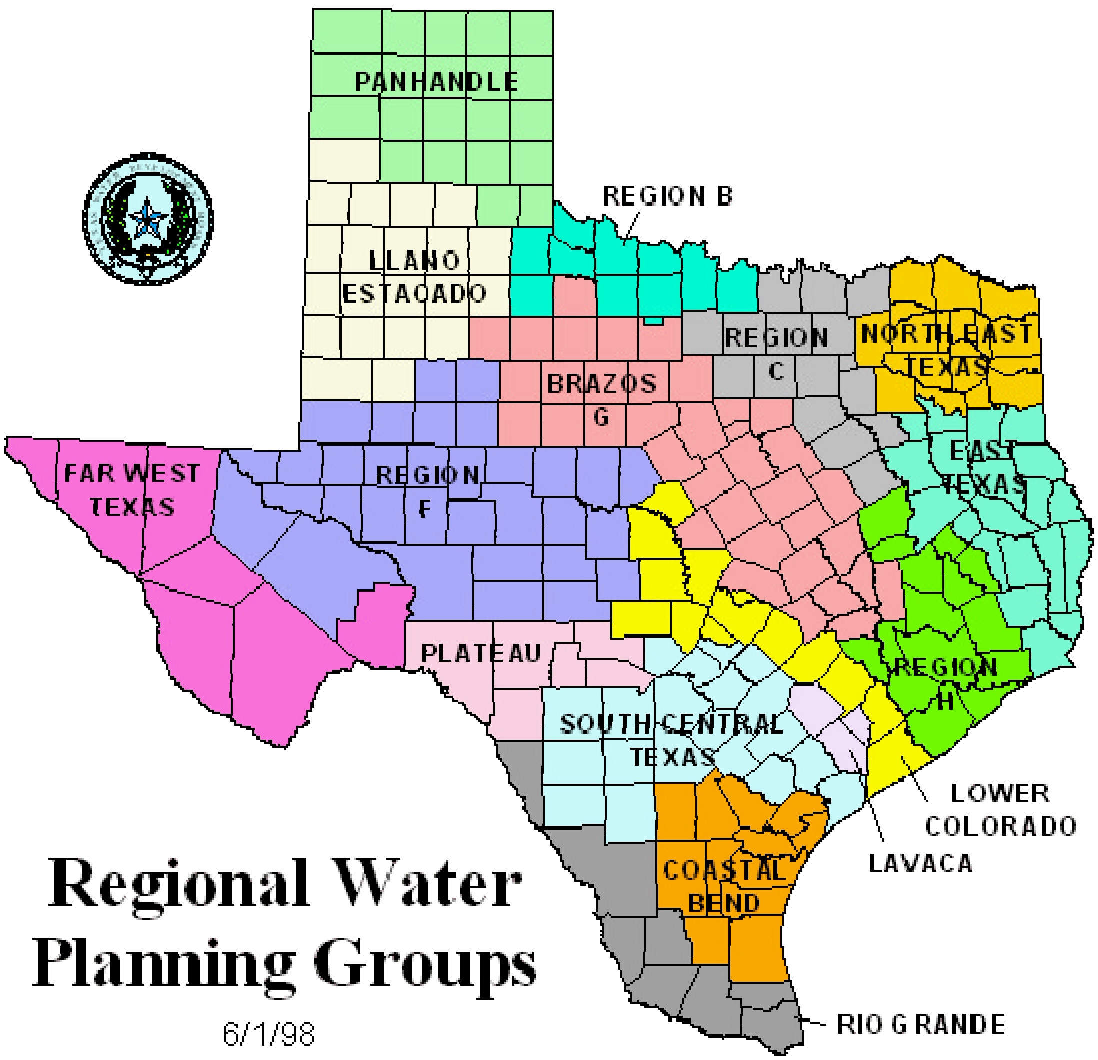
Senate Bill 1 was passed by the 75th Texas Legislature in 1997 to address Texas water issues. This legislation put in place a grass roots planning process to plan for the water needs of the state for the next 50 years. To implement this planning process, the Texas Water Development Board (TWDB) created 16 planning regions across the state. Each regional plan is overseen by a regional water planning group consisting of representatives from 11 different interest groups. Region F, one of the water planning regions, is located in west Texas and covers 32 counties (see Figure ES-1).

This report presents the data and analysis developed as part of the Senate Bill 1 water planning process for Region F. In accordance with the guidelines set forth by TWDB, the regional water plan includes the following tasks:

- Description of the Region
- Development of Population and Water Use Projections
- Evaluation of Current Water Supplies
- Comparison of Supply and Demand
- Identification, Evaluation, and Selection of Water Management Strategies
- Recommendations for Regulatory, Administrative or Legislative Policy Issues, and
- Plan Adoption, Including Public Participation

This document is a comprehensive compilation of information from previous planning reports, on-going planning efforts and new data. The Region F planning group worked together with their consultants, water providers, the public, and other regional water planning groups to fulfill the requirements of Senate Bill 1. This plan is intended to be a tool to identify water issues in the region. It is not intended to legislate or control water. The conclusions and recommendations reported in this plan are based on available data. As more data becomes

Figure ES-1


PANHANDLE
REGION B
LLANO ESTACADO
REGION C
NORTHEAST TEXAS
BRAZOS G
EAST TEXAS
FAR WEST TEXAS
REGION F
PLATEAU
REGION H
SOUTH CENTRAL TEXAS
LOWER COLORADO
LAVACA
COASTAL BEND
Regional Water Planning Groups
6/1/98
RIO GRANDE

available, recommendations may change and new strategies identified. The Senate Bill 1 planning process provides entities the ability to modify the regional water plan as needed. At a minimum, the plan will be updated every five years.

ES.2 Description of Region F

Region F is located in the western part of the state that is generally rural with most of the population concentrated in cities and towns. There are three major metropolitan areas in the region: Midland, Odessa and San Angelo. Ranching, irrigated agriculture, and the oil and gas industry have historically dominated the regional economy and culture.

Most of Region F is located in the upper portion of the Colorado and Rio Grande Basins, with a small portion lying in the Brazos Basin. There are six major rivers and 17 water supply reservoirs that characterize the regional surface water hydrology. In addition, eleven aquifers lie within the region. Of these, six aquifers (Edwards-Trinity, Cenozoic Pecos Alluvium, Ogallala, Dockum, Hickory and Lipan Aquifers) provide a significant amount of water in the region. Twelve ground water conservation districts within Region F provide management of these ground water resources.

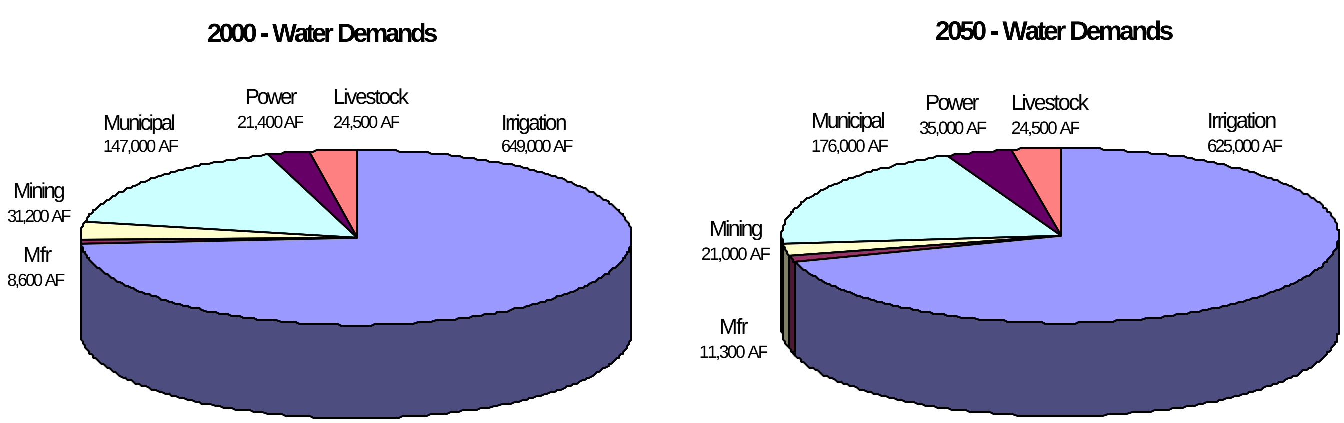
There are three entities that provide regional wholesale water service in Region F: the Colorado River Municipal Water District (CRMWD), Brown County Water Improvement District Number One (BCWID) and the Upper Colorado River Authority (UCRA). Cities and water supply corporations generally provide retail water supply to local customers.

ES.3 Projected Population and Water Demand

As of 1998, Region F accounts for approximately 3 percent of Texas's population. The three metropolitan areas (Midland, Odessa, and San Angelo) comprise nearly half of the region's population. The cities of Brownwood and Big Spring also have populations greater than 20,000. The total population in the region in year 2000 is estimated at 638,000, and is expected to increase over the 50-year planning period to nearly 922,000. This represents a total increase of 44 percent in the region's population, or an average growth rate of 0.74 percent per year. Most of the increase is projected to occur in the metropolitan areas and surrounding communities.

As growth occurs in the region, the water demands will increase. The total water demand in Region F is projected to increase from 881,500 acre-feet per year in 2000 to 900,200 acre-feet per year by 2050. The largest water user is irrigated agriculture, which accounts for nearly 75 percent of the total demand. Municipal is the next largest water user, with manufacturing, mining, steam electric power generation and livestock collectively accounting for only 10 percent of the water demands. Over the planning period, irrigation and mining demands are expected to decrease, while municipal, manufacturing and steam electric demands are projected to increase. Livestock demands are projected to remain the same through 2050. Some of the reduction in demands for irrigation is attributed to the assumed implementation of water conserving irrigation technologies, and the reduction in mining use is primarily due to the decline of the oil and gas industry in the region. The increases for the other categories are related to growth and the deregulation of the power industry. It is expected that these increases will occur in the more populous counties and to a lesser extent in the rural areas. A comparison of water demands for years 2000 and 2050 is shown on Figure ES-2.

Figure ES-2 Region F Water Demands



ES.4 Evaluation of Current Supplies

The current water supply in Region F consists of ground water, surface water from reservoirs, local supplies and wastewater reuse. Ground water is the largest source of water in the region, accounting for 66 percent of the total currently available supply. Reservoirs, which provide most of the municipal supplies, account for 21 percent of the supply. Local supplies, which include river diversions, stock tanks and small reservoirs, and wastewater reuse account for the remainder of the region's water supply.

Ground water use in the region is generally from four major aquifers and seven minor aquifers. The available supply for each aquifer is based on the quantity of water in storage, the potential for recharge to the aquifer, and water quality limitations. In several counties, some of the aquifers are currently being used at rates that cannot be sustained over a long period of time. The two most critical aquifers are the Edwards-Trinity in Glasscock County and the Ogallala in Midland County. As a result, the annual available ground water supply was limited to a quantity that is sustainable over the planning period.

Of the 17 major reservoirs in the region, the largest surface water sources include the CRMWD system (Lake Ivie, Lake J.B. Thomas and Lake Spence) and Lake Brownwood. Much of the municipal supply is provided by these reservoirs, as well as supply for other demands. Other reservoirs in the region are significant sources of water for municipal, industrial, steam electric, and irrigation demands. Colorado City/Champion Creek, Oak Creek and Lake Nasworthy provide water for steam electric power, and Twin Buttes and Red Bluff Reservoir are used for irrigation demands.

Based on firm yield analyses of the region's reservoirs and operational constraints for steam electric plants, the total available supply is estimated at 243,600 acre-feet per year in year 2000. Due to reductions in capacities from sedimentation, the reservoir supply is expected to decrease to 235,100 acre-feet per year by 2050.

Local supplies include river diversions, stock tanks for livestock, and small local surface water supplies. These sources account for approximately 6,000 acre-feet per year of supply. Wastewater reuse is another water source that is used widely in the region for municipal irrigation and irrigated agriculture. A small amount of reuse is used for industrial demands.

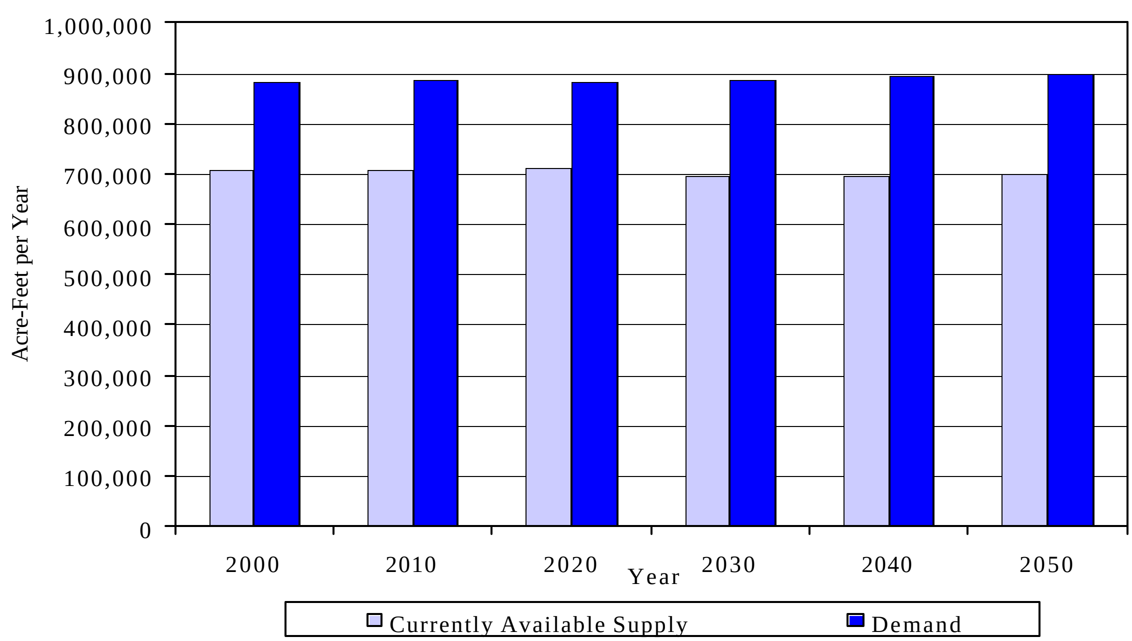
The total amount of current reuse in Region F is estimated at 24,000 acre-feet per year in 2000, increasing to 34,000 acre-feet per year by 2050.

ES.5 Comparison of Current Supplies and Demands

On a regional basis, the water demands in Region F exceed the currently available supplies throughout the planning period. As shown on Figure ES-3, there is a regional shortage of approximately 170,000 acre-feet per year in 2000, increasing to 200,000 acre-feet per year by 2050. Most of these needs are attributed to large irrigation demands that cannot be met during drought conditions with available ground water sources. Other needs are due to limitations of contractual agreements, infrastructure, water quality and growth.

The quality of water from the Hickory Aquifer is a regional concern. The Hickory Aquifer, a major water supply source in the southeastern part of the region, contains naturally occurring radionuclides that exceed current drinking water standards. It is anticipated that the regulatory agencies will begin enforcement of the radionuclide criteria. As a result, this water source is assumed to be unavailable as the sole source of municipal water supply beginning in 2010. The loss of the Hickory Aquifer and limitations on ground water availability in heavily irrigated counties significantly contribute to the projected water shortages in the region.

Figure ES-3 Comparison of Supply and Demands



ES.6 Water Management Strategies

Management strategies were developed for approximately 40 water user groups that have projected water needs over the planning period. There are ten counties with identified irrigation needs that collectively total over 200,000 acre-feet per year. The counties with the largest irrigation needs are Glasscock, Midland, Reagan, Reeves, and Tom Green. The major municipal needs include the cities of Midland and San Angelo and municipalities that rely on the Hickory Aquifer. In addition, power needs were identified for four counties, mining needs in six counties and manufacturing needs in five counties. For many of these water user groups there are supplies in the region that could be further developed to meet their needs. For the cities of Midland and San Angelo, potential water management strategies have long been identified, only the infrastructure has not been developed. Both these cities own ground water rights that they plan to develop to meet their long-term water needs. However, most of the municipal users of the Hickory Aquifer had no readily identified alternative sources of water. Therefore, six different water management strategies were evaluated for the Hickory users. Of these, four alternatives were retained as recommended strategies:

- Alternative H-1: Brady Creek Reservoir Water Treatment Plant
- Alternative H-3: Lake Ivie Water Treatment Plant
- Alternative H-4: New Ellenburger Well Field, and
- Alternative H-6: New Hickory Well Field (in area with low radionuclides)

The supply from a combination of two or more of these recommended strategies will meet the needs of the water user groups that depend on the Hickory Aquifer. In order for multiple strategies to be successful, it will require the cooperative effort of the different entities. Most likely additional infrastructure will be required to distribute the supply within the area of identified need.

Irrigation also had no readily available water management strategy to meet the projected needs. For most counties with irrigation needs, there were no available supplies that could be further developed for irrigation use. Therefore, the approach to irrigation needs was to employ advanced water conservation irrigation technologies to reduce irrigation demands. These technologies include converting from furrow irrigation to sprinkler or drip irrigation, as appropriate by water source and crop. With an assumed 100 percent adoption of these technologies by 2020, the region could realize between a 40 and 50 percent reduction of irrigation needs between 2020 and 2050. For Andrews and Upton Counties, this management strategy will completely meet all projected irrigation needs. However, after full utilization of advanced irrigation technologies and available wastewater reuse, there still are significant irrigation needs for Glasscock, Midland and Reeves Counties.

In addition to water management strategies identified for specific needs, there are several general water strategies that were identified to increase water supplies within the region or improve the reliability of existing supplies. These strategies include:

- Water conservation and drought response
- Brush control
- Weather modification
- Wastewater reuse
- Recharge enhancement, and
- Desalination and chloride control

Over thirty entities have submitted drought contingency plans to the regional planning group. Other entities either have plans or are in the process of preparing drought contingency plans. The implementation of such plans along with integral water conservation efforts will preserve existing water resources in the region.

Brush control was identified as a preferred management strategy to increase ground water recharge and/or stream flows. It is estimated that one acre-foot of water is lost annually for every 10 acres of brush. On-going studies of the North Concho, Middle Concho and Upper Colorado Rivers will provide data necessary to assess the impacts of brush control on local water resources.

Weather modification increases the efficiency of precipitation production in a cloud. Two weather modification programs are in place in Region F. Data has indicated increases of 15 percent or more of rainfall in areas participating in weather modification. Continuation and enhancement of these programs could increase surface runoff to reservoirs, reduce irrigation demands, and increase recharge to ground water sources.

Wastewater reuse is a strategy that is already widely used in Region F for irrigated agriculture, municipal irrigation and fire protection, and manufacturing needs. The benefits of wastewater reuse are that it is a drought-proof water source, the supply increases with growth, and it provides an alternative water source when high quality water is not needed. As new water supplies become more difficult to develop, wastewater reuse will become more attractive for a variety of uses.

Recharge enhancement is the process in which surface water is purposefully directed to areas with permeable soils or fractured rock to increase localized ground water recharge. Information on topography, drainage, soil properties, and the extent and hydraulic properties of the aquifer outcrop is needed to determine favorable recharge sites. Construction of recharge structures in areas with high recharge potential could increase ground water supplies in the region.

The removal of salts from ground and surface water sources has the potential to improve existing water supplies and make new supplies available. Two basic approaches are used in Region F: 1) controlling the amount of salts entering a water resource (chloride control projects), and 2) removing the salts before use (desalination). Recent studies indicate that the existing chloride control projects in the Colorado River basin are controlling approximately 40 percent of the contaminant loading. The continued use of chloride control management practices will improve water quality and provide a more versatile water supply. In addition, desalination can provide a higher quality of water. In 1999 there were more than 100 desalination facilities in Texas, including one in Fort Stockton. As the technologies for desalination become more cost effective, this strategy will be more economically feasible.

ES.6.1 Water Management Strategies Costs

Capital and annual costs were developed for all potentially feasible water management strategies. These costs ranged from a low of $20 per acre-foot for advanced irrigation technologies in several counties to over $1,700 per acre-foot for some municipal strategies. Details of each cost estimate are included in Appendix D of the Initially Prepared Plan. A summary of capital costs and quantities of new supply for different use types in the region is presented in Table ES-1. These costs do not include retail distribution improvements that may be needed as demands increase.

Table ES-1 Water Management Strategies Costs

Water Use Type	Additional Supply (ac-ft/yr)	Estimated Capital Cost
Municipal	70,200	$194,568,000
Irrigation	95,400[1]	$81,047,000
Manufacturing	1,900	$5,839,000
Mining	9,800	$21,193,000
Steam Electric Power	16,400	$24,934,000
Total	***193,700***	***$327,581,000***

1. Most of the additional supply for irrigation is actually a reduction in water demands due to advanced irrigation technologies.

ES.6.2 Recommended Water Management Strategies by County

The recommended strategies for each county in Region F are summarized below. These strategies represent the findings of the supply and demand comparison and community participation, as specified by the Senate Bill 1 process. There may be water users that will need to improve their existing water supplies or develop new supplies over the planning period, but are not specified in the plan due to inclusion with the "county-other" category or changes to their water needs.

- **Andrews County**
  - Improve irrigation practices to maximize benefit of existing supplies.

- **Borden County**
  - Improve irrigation practices to maximize benefit of existing supplies.
  - Manufacturing may need to increase use of existing local supplies by 2040.

- **Brown County**
  - Early may need to purchase treated water from BCWID as customer demands increase above their existing water treatment capacity.
  - BCWID may need to provide treated water to the northern portion of county to supplement ground water supplies.

- **Coke County**
  - Water quality and reliability needs for Robert Lee and Bronte may be addressed by improvements to supply from Lake Spence.

- **Coleman County**
  - There are sufficient water supplies to the needs of the county.

- **Concho County**
  - Portions of Concho County rely on the Hickory Aquifer for municipal supply. These entities will most likely participate in a regional system that will provide water to Concho and McCulloch Counties. This regional system may include Brady Creek Reservoir, Lake Ivie, and/or ground water from the Ellenburger-San Saba Aquifer in San Saba County or the Hickory Aquifer in far southern McCulloch County.
  - For the short-term, Eden will pursue shallow ground water wells to supplement or replace municipal supply from the Hickory.

- **Crane County**
  - There are sufficient water supplies to meet the needs of the county.

- **Crockett County**
  - West Texas Utilities will increase the use of its existing well field in Pecos County to meet power demands.

- **Ector County**
  - Mining industry may need to develop ground water supplies from the Dockum and/or Pecos Alluvium to compensate for limited supplies from the Edwards-Trinity. Non-potable water supplies will be used when available for mining needs.

- **Glasscock County**
  - Improve irrigation practices to maximize benefit of existing supplies.

- **Howard County**
  - There are sufficient water supplies to meet the needs of the county.

- **Irion County**
    - There are sufficient water supplies to meet the needs of the county.

- **Kimble County**
    - Cedar processing operations may need to develop ground water supplies from the Edwards-Trinity to supplement existing surface water supplies. Alternatively, wastewater reuse could be expanded to meet demands.
    - Junction will develop ground water supplies from the Edwards-Trinity as supplemental supply to diversions from the South Llano River.

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- **Loving County**
    - There are projected irrigation shortages that cannot be met with identified strategies. Shortages are due to limitations in supplies from Red Bluff Reservoir during drought periods

- **Martin County**
    - Non-potable water from Sulphur Draw chloride control project may be used to meet mining needs in the county.
    - Improve irrigation practices to maximize benefit of existing supplies.

- **Mason County**
    - There are sufficient water supplies to meet the needs of the county.

- **McCulloch County**
    - Portions of McCulloch County rely on the Hickory Aquifer for municipal supply. These entities will most likely participate in a regional system that will provide water to Concho and McCulloch Counties. This regional system may include Brady Creek Reservoir, Lake Ivie, and/or ground water from the Ellenburger-San Saba Aquifer in San Saba County or the Hickory Aquifer in far southern McCulloch County.
    - Brady will construct a surface water treatment plant and begin using Brady Creek Reservoir to reduce reliance on Hickory water.

- **Menard County**
  - The city of Menard may need to develop ground water in the Edwards-Trinity to supplement their surface water supply.

- **Midland County**
  - The city of Midland will develop ground water supplies from the T-Bar Well Field in Winkler County.
  - Manufacturing industries may need to purchase additional water from the city of Midland as demands increase.
  - Improve irrigation practices to maximize benefit of existing supplies.

- **Mitchell County**
  - Unmet steam electric power demands for Mitchell County may be moved to other Counties with excess supplies.

- **Pecos County**
  - There are sufficient water supplies to meet the needs of the county.

- **Reagan County**
  - Improve irrigation practices to maximize benefit of existing supplies
  - Use non-potable water from the Edwards-Trinity to meet mining demands.

- **Reeves County**
  - The cities of Pecos and Balmorhea may need to provide additional supplies to County-Other users through municipal sales.
  - Improve irrigation practices to maximize benefit of existing supplies
  - Use non-potable water from the Pecos Alluvium to meet mining demands.

- **Runnels County**
  - The city of Ballinger may need to purchase raw water from Lake Spence during drought and expand their water treatment plant by 1 MGD.
  - Winters may need to purchase treated water from Ballinger, and the delivery capacity to Winters via North Runnels WSC may be increased.

- **Schleicher County**
  - The city of Eldorado will need to expand their existing well system to increase the reliability of their supplies.

- **Scurry County**
  - There are sufficient water supplies to meet the needs of the county.

- **Sterling County**
  - There are sufficient water supplies to meet the needs of the county.

- **Sutton County**
  - There are sufficient water supplies to meet the needs of the county.

- **Tom Green County**
  - San Angelo will require improvements to increase the capacity of delivery from CRMWD supplies. San Angelo will also develop their McCulloch County well field to provide additional supply.
  - Improve irrigation practices to maximize benefit of existing supplies.
  - Treated effluent from San Angelo may be used to meet increased steam electric demands.

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- **Upton County**
  - Improve irrigation practices to maximize benefit of existing supplies.
  - Utilize excess water savings from improved irrigation practices to help meet mining needs.

- **Ward County**
  - Improve irrigation practices to maximize benefit of existing supplies.
  - Non-potable water from the Pecos Alluvium may be used to meet mining needs.
  - Steam electric demands may be met with ground water from Winkler County.

- **Winkler County**
  - There are sufficient water supplies to meet the needs of the county.

ES.7 Regional Recommendations

The Regional Water Planning Group for Region F identified regulatory, legislative and administrative recommendations for future water planning. These are listed and discussed in Chapter 6 of the Initially Prepared Plan.

ES.8 Areas for Additional Study

Several areas for additional study were identified during the development of this Region F water plan. These include:

- *Ground water*. Additional studies are needed to better assess water quality and quantity issues of ground water for existing users and potential new well fields. These studies shall include new or updated recharge and storage data.
- *Hickory Aquifer*. A task force should be formed for consensus building of affected parties to identify an acceptable regional strategy. As part of this task force, a more in-depth review of the identified strategies should be performed.
- *Desalination*. Additional studies are needed to determine the potential of desalination of regional surface water or ground water for potable water supplies.
- *Irrigated agriculture*. Additional information on irrigated agriculture use is needed.
- *Brush control*. The collection and assessment of data from on-going brush control projects is needed to identify potential areas for future brush control.
- *Data collection and management*. There are several surface water and ground water resources in the region that are not currently monitored or have limited available data. It is recommended that a task force be formed to review regional data needs and management.

- *Population and water use data.* This data should be reviewed and updated based on the 2000 census.

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1.0 DESCRIPTION OF REGION

In 1997, the 75th Texas Legislature passed Senate Bill 1 (SB1), legislation designed to address Texas water issues. With the passage of SB1, the legislature put in place a grass-roots regional planning process to plan for the water needs of all Texans in the next century. To implement this planning process, the Texas Water Development Board has created 16 regional water planning groups across the state and established regulations governing regional planning efforts.

This report is a description of Region F, one of the regions created to implement SB1. Figure 1-1 is a map of Region F, which covers 32 counties in West Texas. The data presented in this regional water plan is a comprehensive compilation of information from previous planning reports, on-going planning efforts and new data. A bibliography is included in Appendix A.

1.1 Introduction to Region F

As Figure 1-1 shows, Region F includes Borden, Scurry, Andrews, Martin, Howard, Mitchell, Loving, Winkler, Ector, Midland, Glasscock, Sterling, Coke, Runnels, Coleman, Brown, Reeves, Ward, Crane, Upton, Reagan, Irion, Tom Green, Concho, McCulloch, Pecos, Crockett, Schleicher, Menard, Sutton, Kimble and Mason Counties. Table 1-1 shows historical populations for these counties from 1900 through 1998 (Dallas Morning News, 1993 and Texas State Data Center, 1999). Figure 1-2 is a plot of the historical population for Region F. During the 1900s, the population of Region F has increased from 81,985 in 1900 to an estimated 590,618 in 1998. Since 1940, the region's population has increased at a compounded rate of 1.3 percent per year.

FIGURE 1-1

Table 1-1
Historical Population of Region F Counties

County	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	1998
Andrews	87	975	350	736	1,277	5,002	13,450	10,372	13,323	14,338	13,976
Borden	776	1,386	965	1,505	1,396	1,106	1,076	888	859	799	758
Brown	16,019	22,935	21,682	26,382	25,924	28,607	24,728	25,877	33,057	34,371	37,051
Coke	3,430	6,412	4,557	5,253	4,590	4,045	3,589	3,087	3,196	3,424	3,367
Coleman	10,077	22,618	18,805	23,669	20,571	15,503	12,458	10,288	10,439	9,710	9,541
Concho	1,427	6,654	5,847	7,645	6,192	5,078	3,672	2,937	2,915	3,044	3,119
Crane	51	331	37	2,221	2,841	3,965	4,699	4,172	4,600	4,652	4,510
Crockett	1,591	1,296	1,500	2,590	2,809	3,981	4,209	3,885	4,608	4,078	4,602
Ector	381	1,178	760	3,958	15,051	42,102	90,995	91,805	115,374	118,934	125,729
Glasscock	286	1,143	555	1,263	1,193	1,089	1,118	1,155	1,304	1,447	1,396
Howard	2,528	8,881	6,962	22,888	20,990	26,722	40,139	37,796	33,142	32,343	32,051
Irion	848	1,283	1,610	2,049	1,963	1,590	1,183	1,070	1,386	1,629	1,739
Kimble	2,503	3,261	3,581	4,119	5,064	4,619	3,943	3,904	4,063	4,122	4,124
Loving	33	249	82	195	285	227	226	164	91	107	114
Martin	332	1,549	1,146	5,785	5,556	5,541	5,068	4,774	4,684	4,956	5,043
Mason	5,573	5,683	4,824	5,511	5,378	4,945	3,780	3,356	3,683	3,423	3,692
McCulloch	3,960	13,405	11,020	13,883	13,208	11,701	8,815	8,571	8,735	8,778	8,751
Menard	2,011	2,707	3,162	4,447	4,521	4,175	2,964	2,646	2,346	2,252	2,336
Midland	1,741	3,464	2,449	8,005	11,721	25,785	67,717	65,433	82,636	106,611	119,647
Mitchell	2,855	8,956	7,527	14,183	12,477	14,357	11,255	9,073	9,088	8,016	9,708
Pecos [c]	2,360	2,071	3,857	7,812	8,185	9,939	11,957	13,748	14,618	14,675	16,003
Reagan [b]		392	377	3,026	1,997	3,127	3,782	3,239	4,135	4,514	4,203
Reeves	1,847	4,392	4,457	6,407	8,006	11,745	17,644	16,526	15,801	15,852	14,478
Runnels	5,379	20,858	17,074	21,821	18,903	16,771	15,016	12,108	11,872	11,294	11,507
Schleicher	515	1,893	1,851	3,166	3,083	2,852	2,791	2,277	2,820	2,990	2,984
Scurry	4,158	10,924	9,003	12,188	11,545	22,779	20,369	15,760	18,192	18,634	18,073
Sterling	1,127	1,493	1,053	1,431	1,404	1,282	1,177	1,056	1,206	1,438	1,364
Sutton	1,727	1,569	1,598	2,807	3,977	3,746	3,738	3,175	5,130	4,135	4,463
Tom Green [b]	6,804	17,882	15,210	36,033	39,302	58,929	64,630	71,047	84,784	98,458	102,775
Upton	48	501	253	5,968	4,297	5,307	6,239	4,697	4,619	4,447	3,749
Ward	1,451	2,389	2,615	4,599	9,575	13,346	14,917	13,019	13,976	13,115	11,801
Winkler	60	442	81	6,784	6,141	10,064	13,652	9,640	9,944	8,626	7,964
Region F Total	**81,985**	**179,172**	**154,850**	**268,329**	**279,422**	**370,027**	**480,996**	**457,545**	**526,626**	**565,212**	**590,618**
% Increase		119%	-14%	73%	4%	32%	30%	-5%	15%	7%	4%

Notes:
a. Population data through 1990 are from the *Texas Almanac* (Dallas Morning News, 1993). Data from 1998 are from the Texas State Data Center.
b. Reagan County was formed from part of Tom Green County in 1903
c. Terrell County was formed from part of Pecos County in 1905.

Figure 1-2
Historical Population of Region F

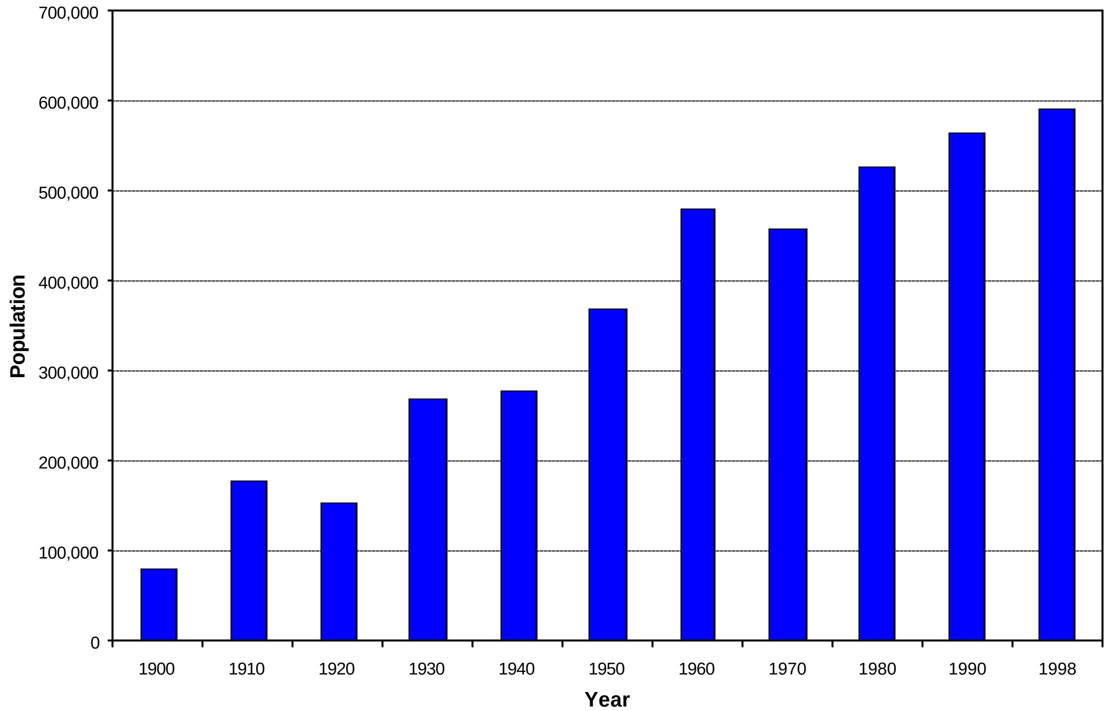
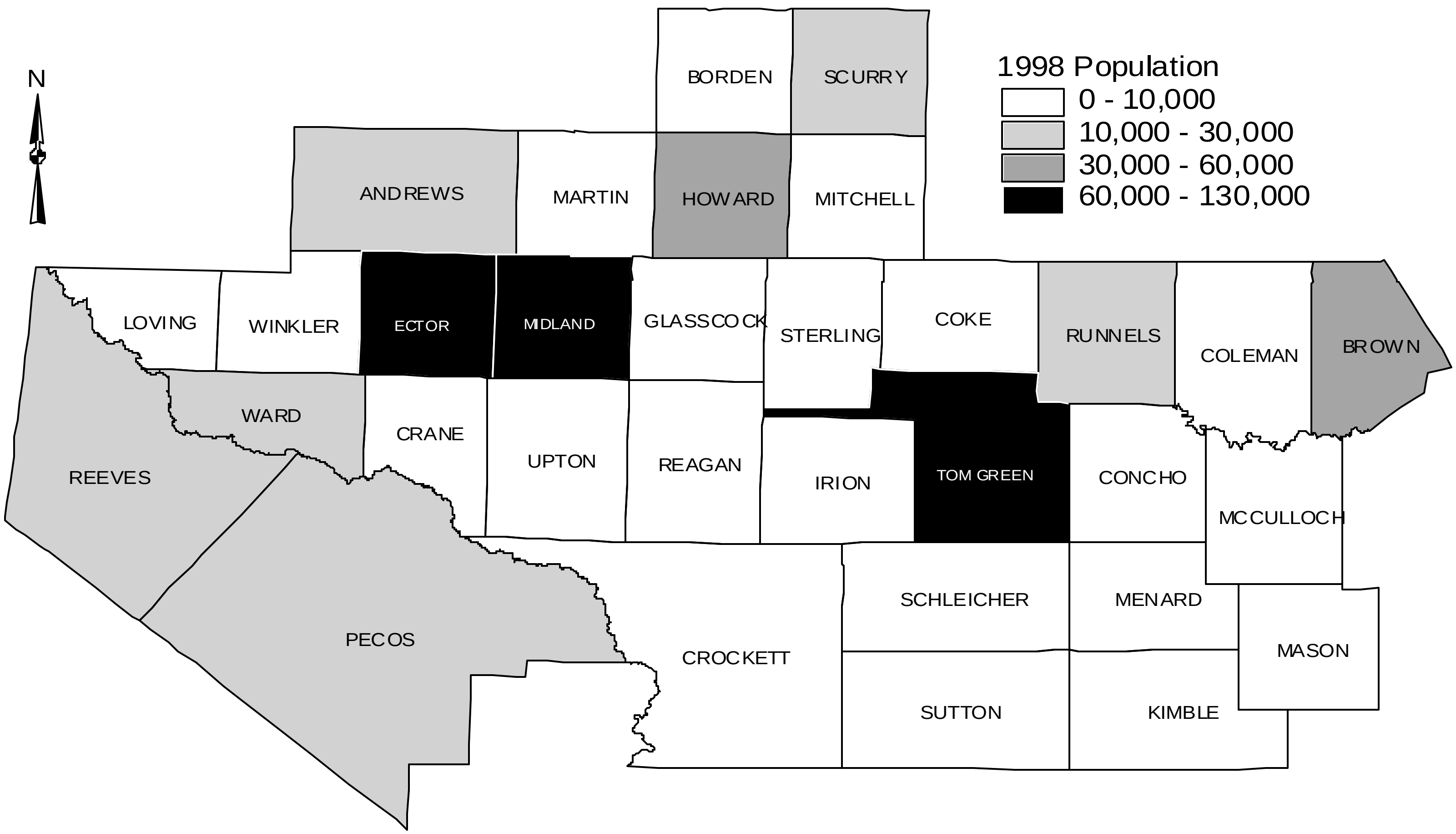


Table 1-2
Estimated 1998 Populations
of Cities with more than 10,000 Population in Region F

City	1998
Midland	99,734
Odessa	95,384
San Angelo	90,935
Big Spring	23,389
Brownwood	19,303
Snyder	11,865
Pecos	11,661
Total	356,271

Data are from the Texas State Data Center.

Figure 1-3 – Population Distribution by County



As of 1998, Region F included 3.0 percent of Texas' total population. Figure 1-3 shows the relative 1998 populations in Region F counties. The three most populous counties in Region F, Ector, Midland, and Tom Green, have 59 percent of the region's population. Brown and Howard Counties also have 1998 populations over 20,000 people. Table 1-2 lists the 7 cities in Region F with an estimated 1998 population of more than 10,000. These cities include 60 percent of the 1998 population of the region.

1.1.1 Economic Activity in Region F

Region F includes the Midland, Odessa, and San Angelo metropolitan statistical areas (MSAs). The largest employment sector in the Midland MSA is the service industry, followed by wholesale and retail trade and the oil and gas industry. The Odessa and San Angelo MSAs' largest employment sectors are wholesale and retail trade, services, and manufacturing (Dallas Morning News, 1993).

Table 1-3 lists 1996 payrolls for Region F by county and economic sector (U.S. Census Bureau, 1996) and Table 1-4 gives overall sales in 1992 for five economic categories (TWDB, May 1999 and U.S. Census Bureau - Economic, 1992). (These are the most recent years for which data were available when this report was written.) Figure 1-4 shows relative total payrolls by county. The largest economic centers in Region F are Ector, Midland and Tom Green counties, which have 68 percent of the region's sales, 71 percent of the payroll and 68 percent of the employment. Other major centers of economic activity are Brown and Howard Counties. The largest business sectors in terms of sales are wholesale trade, retail trade and manufacturing, which together accounted for 79 percent of the 1992 sales in Region F. The largest business sectors in Region F in terms of payroll in 1997 were services, mining (primarily oil and gas related industries), retail trade and manufacturing, which together account for 72 percent of the region's total payroll.

1.1.2 Water-Related Physical Features in Region F

Most of Region F is in the upper portion of the Colorado Basin and in the Pecos portion of the Rio Grande Basin. A small part of the region is in the Brazos Basin. Figure 1-1 shows the major streams in Region F, which include the Colorado River, Concho River, Pecan Bayou, San Saba River, Llano River and Pecos River.

Table 1-3
1996 County Payroll by Category ($1000)

	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett	Ector	Glasscock	Howard
Agriculture	(A)		$442	(A)	(A)		(A)	(A)	$1,816	(A)	(A)
Mining	$15,641		$1,568	$4,137	(A)		$12,346	$2,576	$61,667	(A)	$16,097
Construction	$4,239		$8,984	(A)	$823	(A)	$2,629	$1,858	$73,997	(A)	$17,857
Manufacturing	$9,704		$96,438	(A)	$6,648	(A)	(A)	(A)	$126,475	(A)	$31,811
Transportation & Public Utilities	$4,589	(A)	$8,656	$440	$2,175	$369	(A)	(A)	$52,576	(A)	$11,021
Wholesale Trade	(A)	(A)	$8,974	(A)	$1,464	$298	(A)	(A)	$115,863	(A)	$11,188
Retail Trade	$6,486	(A)	$31,897	$1,372	$4,981	$1,244	$2,160	$3,684	$129,184	$313	$25,982
Financial, Insurance and Real Estate	(A)		$6,741	(A)	$2,009	(A)	(A)	$1,462	$30,326	(A)	(A)
Services	$13,621		$61,722	$2,374	$8,637	$7,162	$7,085	$3,807	$225,953		$73,587
Unclassified	(A)		$130		(A)				$120		$20
Total Payroll	$59,626	(A)	$225,552	$10,870	$27,486	$9,803	$28,875	$15,499	$817,977	$2,107	$196,554
Total Employees	2,930	(B)	11,018	532	1,895	566	1,098	819	37,021	105	9,301

	Irion	Kimble	Loving	Martin	Mason	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan
Agriculture		(A)			(A)	(A)	(A)	$3,326	(A)	(A)	
Mining	$1,808	(A)		(A)	(A)	(A)		$349,090	(A)	$13,786	$8,228
Construction	$417	$1,376		$1,391	$945	$1,776	(A)	$49,079	$1,289	$1,939	(A)
Manufacturing		$6,171			(A)	$5,055	(A)	$76,220	(A)	$3,222	(A)
Transportation & Public Utilities	$2,343	(A)		(A)	$582	$2,890	$334	$67,883	$4,231	$8,925	(A)
Wholesale Trade	$1,009	$1,151	(A)	$1,877	$1,349	$1,791	$825	$119,988	$1,046	$3,767	$2,254
Retail Trade	(A)	$4,546		$2,064	$1,472	$7,632	$1,313	$127,208	$3,644	$10,527	$1,799
Financial, Insurance and Real Estate	(A)	$942		$843	$971	$2,466	$426	$58,123	$1,153	$2,561	$686
Services	(A)	$3,709	(A)	$3,628	$2,301	(A)	(A)	$348,069	$8,927	$16,134	$3,074
Unclassified		(A)		(A)		(A)	(A)	$314		(A)	(A)
Total Payroll	$6,773	$18,867	(A)	$11,887	$8,305	$35,718	$3,518	$1,199,300	$21,895	$61,399	$17,633
Total Employees	289	1,186	(B)	534	563	2,108	260	45,251	1,185	3,133	806

Table 1-3 (cont.)
1996 County Payroll by Category ($1000)

	Reeves	Runnels	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Total
Agriculture	(A)	$389	(A)	(A)		$38	$3,491		(A)		$9,502
Mining	$15,066	$1,570	$3,964	$31,393	(A)	$3,445	$13,855	$8,742	$15,776	$6,542	$587,297
Construction	$565	$1,063	$70	$14,771	(A)	$3,158	$40,436	(A)	$1,170	$1,679	$231,511
Manufacturing	$3,126	$24,777	$59	$5,999	(A)	(A)	$120,859	(A)	(A)	(A)	$516,564
Transportation & Public Utilities	$7,812	$1,919	(A)	$6,157	(A)	$2,498	$78,002	(A)	$10,151	$6,931	$280,484
Wholesale Trade	$2,147	$4,073	(A)	$6,605	(A)	$1,493	$39,296	$1,682	$3,867	(A)	$332,007
Retail Trade	$7,946	$5,402	$1,052	$12,911	(A)	$3,950	$119,596	$1,204	$6,480	$3,754	$529,803
Financial, Insurance and Real Estate	$2,312	$1,782	$580	$4,019	(A)	$1,442	$31,269	$793	$2,299	$1,519	$154,724
Services	$7,846	$7,596	$2,385	$19,493	(A)	$3,689	$219,542	$5,065	$10,569	$4,078	$1,070,053
Unclassified	(A)		(A)	(A)		(A)	$14	(A)			$598
Total Payroll	$46,996	$48,571	$9,451	$101,502	(A)	$19,750	$666,360	$19,875	$50,541	$25,667	$3,768,357
Total Employees	2,411	2,703	480	4,908	(C)	1,138	32,524	796	2,510	1,170	169,240

Notes: Data are from U.S. Census Bureau 1996 economic data

(A) Data withheld to avoid disclosing data for individual companies

(B) 0 to 19 employees

(C) 100 to 249 employees

Table 1-4
1992 Sales by Category in Region F
($1,000)

	Services	Retail Trade	Wholesale Trade	Manu-facturing	Mining	Agriculture	Total
Andrews	$24,569	$60,129	$27,330	(D)	(NA)	$10,014	$122,042
Borden	(NA)	(D)	(NA)	(NA)	(NA)	$23,278	$23,278
Brown	$105,118	$229,160	$84,202	$576,600	(NA)	$31,825	$1,026,905
Coke	$1,104	$16,820	$2,806	(NA)	(D)	$10,763	$31,493
Coleman	$8,505	$46,279	$34,373	(D)	(NA)	$19,189	$108,346
Concho	$7,685	$10,056	(D)	(NA)	(D)	$17,221	$34,962
Crane	$3,713	$19,489	$5,882	(D)	(D)	$2,947	$32,031
Crockett	$20,015	$20,015	$4,714	(D)	(NA)	$15,002	$59,746
Ector	$404,008	$877,562	$798,209	$1,000,200	$394,100	$4,737	$3,478,816
Glasscock	(D)	$1,742	(D)	(NA)	(NA)	$22,317	$24,059
Howard	$71,956	$199,047	$153,766	$452,300	(D)	$19,149	$896,218
Irion	$726	$2,559	(D)	$1,200	(NA)	$7,139	$11,624
Kimble	$5,265	$30,342	$23,382	$11,600	(NA)	$7,846	$78,435
Loving	$0	(NA)	(D)	(NA)	(NA)	$989	$989
McCulloch	$11,839	$51,892	$22,109	$17,900	(NA)	$21,346	$125,086
Martin	$3,550	$22,652	$18,134	(D)	(NA)	$30,358	$74,694
Mason	$3,016	$11,246	$20,816	(D)	(NA)	$22,472	$57,550
Menard	$447	$8,645	(D)	(D)	(NA)	$14,718	$23,810
Midland	$477,338	$919,533	$2,320,043	$259,500	(D)	$17,336	$3,993,750
Mitchell	$7,322	$33,452	$24,608	$1,300	(NA)	$21,437	$88,119
Pecos	$19,920	$79,500	$35,073	$6,700	$278,200	$28,291	$447,684
Reagan	$5,095	$16,064	$61,438	$0	(NA)	$12,265	$94,862
Reeves	$26,224	$67,775	$15,349	(D)	(NA)	$81,694	$191,042
Runnels	$10,125	$46,204	$18,682	$135,100	(NA)	$35,431	$245,542
Schleicher	$1,522	$6,722	$5,127	(D)	(NA)	$13,495	$26,866
Scurry	$24,129	$97,133	$56,917	$21,200	(NA)	$20,593	$219,972
Sterling	$404	$3,996	$3,644	(D)	(NA)	$8,549	$16,593
Sutton	$5,124	$26,742	$14,197	$0	(NA)	$11,333	$57,396
Tom Green	$331,043	$720,768	$480,887	$662,000	(NA)	$78,628	$2,273,326
Upton	$1,077	$10,743	$20,166	(D)	$103,700	$8,501	$144,187
Ward	$18,251	$50,681	$98,523	$5,600	(NA)	$2,036	$175,091
Winkler	$9,960	$34,559	$12,266	$900	(NA)	$3,402	$61,087
Regional Total	$1,609,050	$3,721,507	$4,362,643	$3,152,100	$776,000	$624,301	$14,245,601

Notes: Data are from the 1992 Economic Census and Agriculture Census (U.S. Census Bureau
(D) Data withheld to avoid disclosing individual company data
(NA) Data not available
Totals do not include (D) or (NA) data

Figure 1-4 – Total Payroll by County

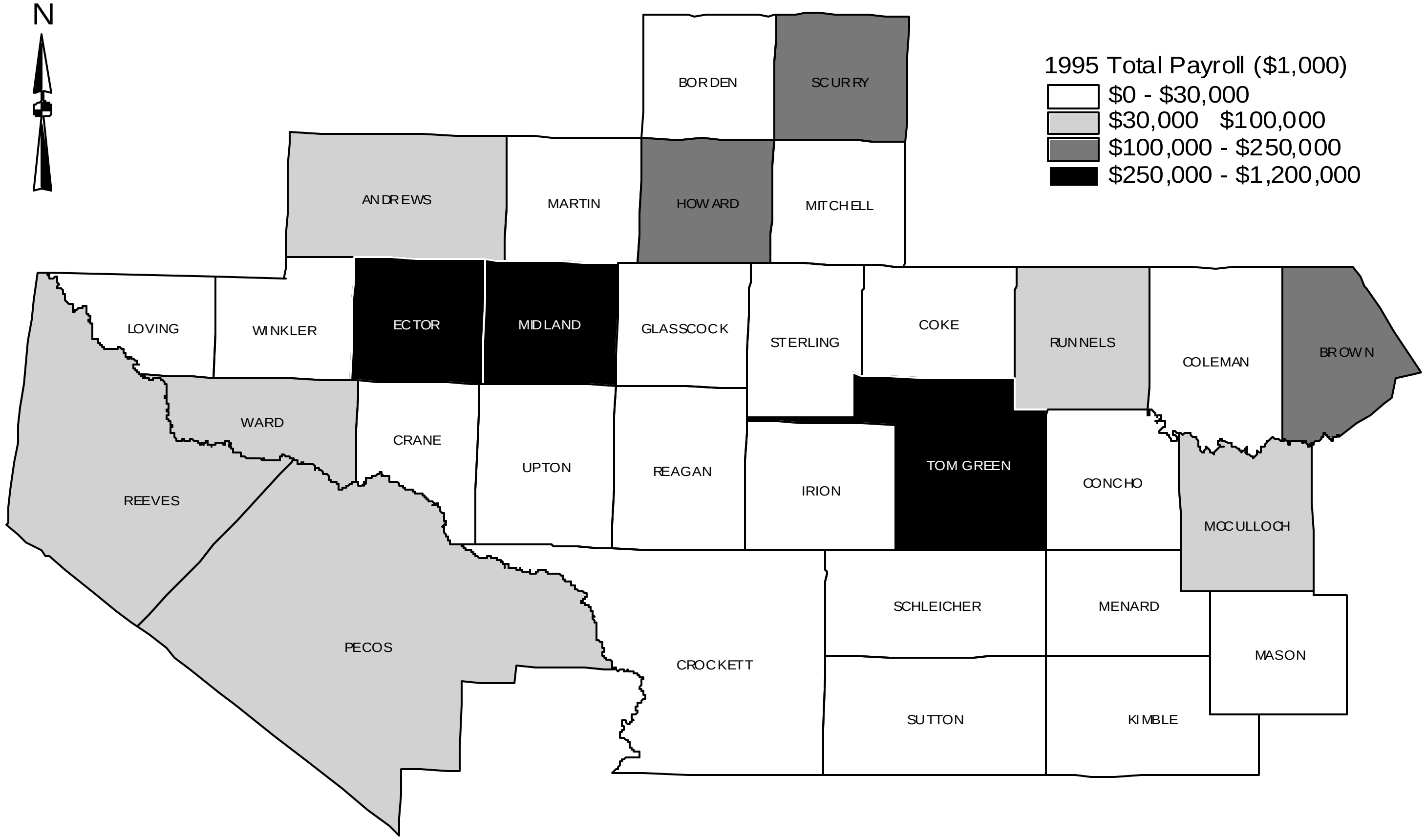


Figure 1-5

Mean Annual Precipitation

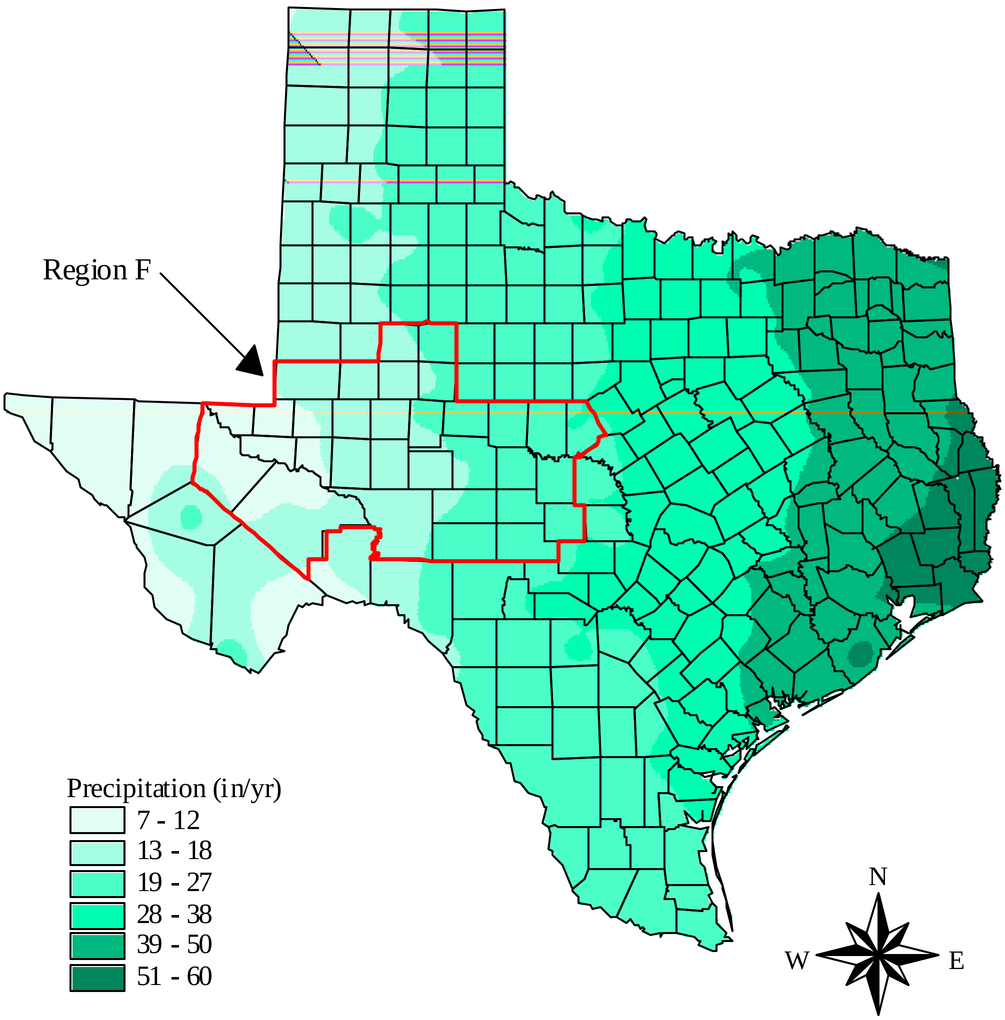
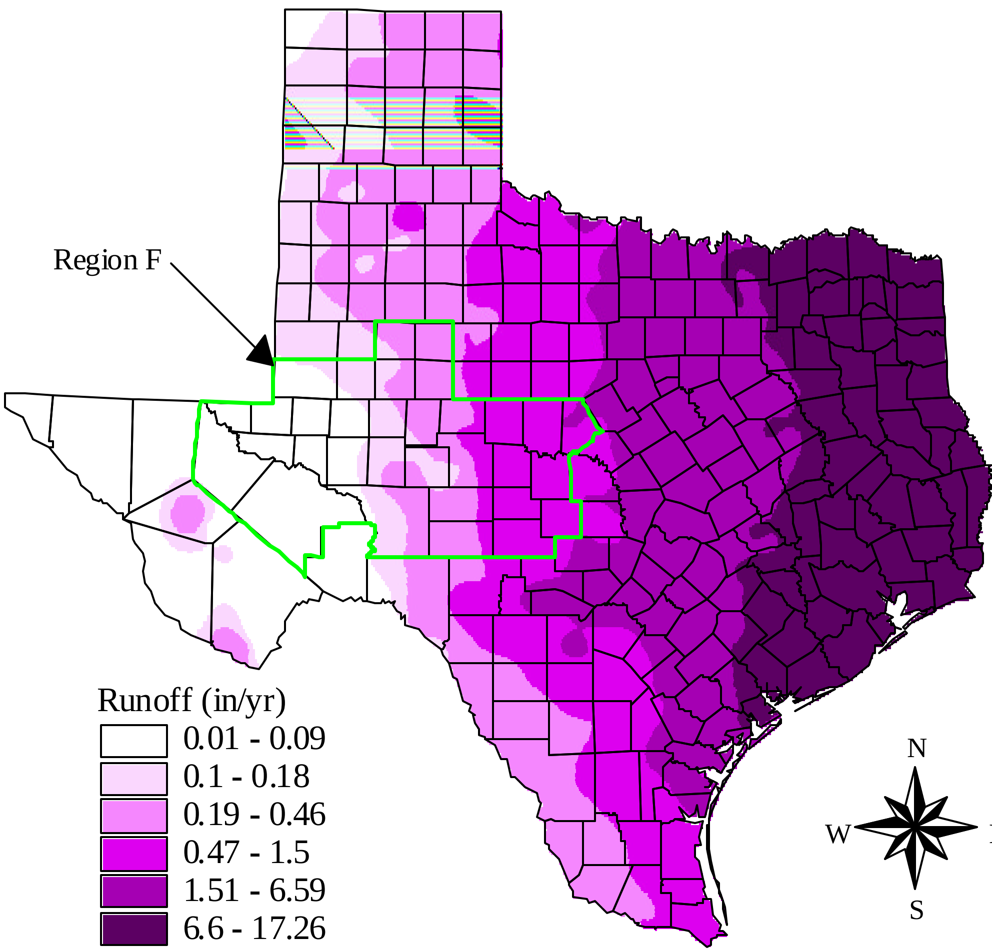


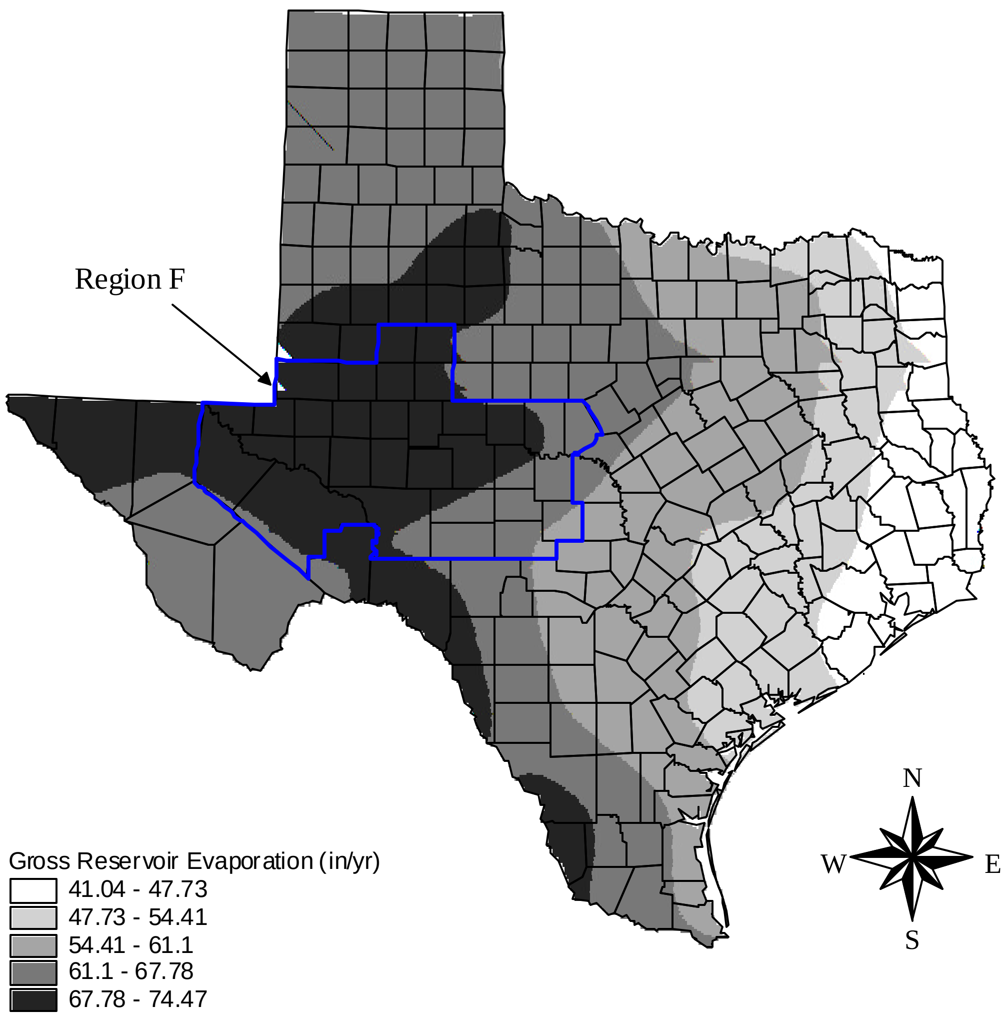
Figure 1-6

Mean Annual Runoff



Data are from U.S. Census Bureau 1992 Agriculture Census

Figure 1-7
Gross Reservoir Evaporation



Data are developed by Freese and Nichols, Inc. from TWDB Quadrangle Evaporation Data

Figure 1-5 shows the average annual precipitation in Texas. In Region F, precipitation increases west to east from slightly more than 10 inches per year in western Reeves County to more than 28 inches per year in Brown County. Figure 1-6 shows average annual runoff, which follows a similar pattern of increasing from the west to the east (U.S. Census Bureau - Agriculture, 1992). Figure 1-7 shows gross reservoir evaporation in Texas, which generally increases from southeast to northwest (Freese and Nichols, Inc., April 1998). (Gross reservoir evaporation indicates the amount lost to evaporation from the surface of a reservoir.) Some of the highest evaporation rates in the State are in Region F, and the rate of evaporation from a reservoir surface exceeds rainfall throughout Region F. The patterns of rainfall, runoff, and evaporation result in relatively more abundant water supplies in the eastern part of Region F than in the west.

Figure 1-8 shows the variations in annual streamflow for seven U.S. Geological Survey (USGS) streamflow gages in Region F (USGS, May 1999). The five gages on tributaries have watersheds with limited development and show the natural variation in streamflows in this region. The Colorado gage near Winchel is the most downstream gage on the main stem of the Colorado River in Region F. At this location, natural flow patterns have been altered by upstream reservoir development. Flows at the Pecos River gage near Girvin are largely controlled by releases from Red Bluff Reservoir. Figure 1-9 shows seasonal patterns of median streamflows for the same six gages (USGS, May 1999).

Table 1-5 lists 17 major water supply reservoirs in Region F, all of which are shown in Figure 1-1. These reservoirs provide most of the region's surface water supply. Reservoirs are necessary to provide a reliable surface water supply in this part of the state because of the wide variations in natural streamflow. Reservoir storage serves to capture high flows when they are available and save them for use during times of normal or low flow.

Figure 1-10 shows major aquifers in Region F, and Figure 1-11 shows the minor aquifers. There are 11 aquifers that supply water to the 32 counties of Region F. The major aquifers are the Edwards-Trinity Plateau, Ogallala, Cenozoic Pecos Alluvium and a small portion of the Trinity. The minor aquifers are Dockum, Hickory, Lipan, Ellenburger-San Saba, Marble Falls, Rustler and the Capitan Reef Complex. Edwards-Trinity High Plains is used only on a limited basis in Region F. More detailed information on these aquifers may be found in Chapter 3.

Table 1-5
Major Water Supply Reservoirs in Region F

Reservoir Name	Basin	Stream	County(ies)	Conservation Storage (Acre-Feet))	Owner	Water Rights Holder(s)
Lake J B Thomas	Colorado	Colorado River	Borden and Scurry	204,000	CRMWD	CRMWD
Lake Colorado City	Colorado	Morgan Creek	Mitchell	31,810	TXU	TXU
Champion Creek Reservoir	Colorado	Champion Creek	Mitchell	42,500	TXU	TXU
Oak Creek Reservoir	Colorado	Oak Creek	Coke	39,360	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	40,000	City of Coleman	City of Coleman
E V Spence Reservoir	Colorado	Colorado River	Coke	488,800	CRMWD	CRMWD
Lake Winters	Colorado	Elm Creek	Runnels	8,374	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	131,430	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	8,110	COE	City of Coleman
Lake Ballinger / Lake Moonen	Colorado	Valley Creek	Runnels	6,850	City of Ballinger	City of Ballinger
O H Ivie Reservoir	Colorado	Colorado River	Coleman, Concho and Runnels	554,300	CRMWD	CRMWD
O C Fisher Lake	Colorado	North Concho River	Tom Green	115,700	COE	City of San Angelo
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	186,200	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	Colorado	South Concho River	Tom Green	10,108	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	30,430	City of Brady	City of Brady
Mountain Creek	Colorado	Mountain Creek	Coke	949	Upper Colorado River Authority	Upper Colorado River Authority
Red Bluff Reservoir	Rio Grande	Pecos River	Loving and Reeves	289,700	Red Bluff Water Power Control District	Red Bluff Water Power Control District

Note: Data are from TNRCC Water Rights Database, Austin, 1999 and
TNRCC Water Right Permits and Certificates of Adjudication, Austin, Various Dates

FIGURE 1-8

FIGURE 1-9

FIGURE 1-10

FIGURE 1-11

1.2 Current Water Uses and Demand Centers in Region F

Table 1-6 shows the total water use by county in Region F from 1980 and 1984 through 1997, the most recent year for which data are available (TWDB CD, 1999). Water use in Region F has increased significantly since 1990, primarily due to increases in irrigated agriculture. Table 1-7 shows water use for the same period by Texas Water Development Board use category. Figure 1-12 is a graph of the historical water use for Region F by category.

Table 1-8 shows the uses by category and county in 1997, the most recent year for which water use data are available. Figure 1-13 shows the relative water use by county. About 74 percent of the current water use in Region F is for irrigated agriculture, with municipal supply as the second largest category, followed by mining, livestock watering, steam electric power generation and manufacturing.

In addition to the consumptive water uses discussed above, water is used for recreation and other purposes in Region F. Table 1-9 summarizes recreational opportunities at major reservoirs in the region. Reservoirs draw thousands of visitors each year in Region F. In addition, smaller lakes and streams in the region draw many visitors for fishing, boating, swimming, and other water-related recreational activities. Water in streams and lakes is also important to fish and wildlife in the region.

Table 1- 6
Historical Total Water Use by County in Region F
(Values in acre-feet)

County	1980	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Andrews	21,625	11,832	12,316	12,378	12,198	12,289	10,319	15,177	15,098	16,163	18,350	26,971	22,424	20,988	23,139
Borden	1,150	1,435	1,500	1,742	1,547	1,566	1,196	1,153	1,866	1,913	2,307	2,543	3,095	6,505	11,071
Brown	19,123	16,579	17,676	16,308	15,238	15,442	20,983	11,053	10,923	10,949	20,722	21,320	24,350	23,121	23,456
Coke	2,604	2,646	2,671	2,528	2,361	2,547	2,661	2,333	2,216	2,226	2,799	2,545	2,610	2,788	2,347
Coleman	6,801	5,468	4,222	4,674	4,124	3,954	3,981	3,680	3,633	3,779	4,318	4,147	4,016	5,085	4,262
Concho	2,432	3,246	4,753	4,076	5,027	4,366	4,570	3,867	4,668	5,033	8,677	5,698	7,757	6,054	3,553
Crane	2,784	5,130	2,892	1,602	2,556	2,798	2,671	2,683	3,849	3,651	3,840	4,016	3,828	3,756	4,346
Crockett	6,798	5,936	5,717	4,974	5,071	5,527	4,803	4,760	4,801	4,526	4,864	4,820	4,718	4,424	4,032
Ector	41,886	39,241	38,336	33,644	33,431	36,405	38,379	35,275	41,673	37,882	40,200	41,659	40,207	42,034	39,242
Glasscock	40,503	42,221	24,704	48,045	40,121	30,295	31,585	27,545	36,116	25,139	39,885	58,429	69,096	55,551	52,825
Howard	14,881	12,631	13,802	15,444	10,776	11,288	12,560	12,826	14,153	14,068	13,764	15,477	15,706	12,906	14,923
Irion	4,000	3,177	2,454	2,411	2,512	2,162	3,448	3,528	3,559	3,544	3,921	3,915	2,836	3,630	3,558
Kimble	6,524	5,986	5,766	4,866	4,635	4,427	4,237	4,084	3,970	3,844	5,102	3,354	3,367	3,025	2,712
Loving	189	42	40	46	48	652	93	151	154	71	652	669	668	652	667
Martin	21,525	18,369	16,417	13,263	8,875	10,363	14,004	14,297	7,637	15,101	11,001	9,427	13,535	14,497	16,232
Mason	17,830	15,489	18,256	18,035	16,625	20,159	19,444	19,458	19,184	14,312	15,219	14,237	13,238	12,267	10,919
McCulloch	8,295	15,691	7,779	7,294	7,218	6,842	7,118	6,203	5,935	5,948	7,241	7,156	6,924	6,021	6,201
Menard	4,670	3,419	2,751	2,766	2,330	2,121	4,174	1,635	1,834	2,382	6,898	7,080	5,780	5,048	4,642
Midland	45,656	53,158	51,562	43,830	36,569	45,568	52,237	50,921	39,653	45,035	53,948	71,756	95,360	84,290	63,214
Mitchell	9,492	9,484	11,693	9,837	9,305	9,146	8,260	7,459	7,289	6,376	6,720	6,323	5,648	7,386	6,202
Pecos	112,394	105,580	85,109	70,338	64,888	66,646	78,266	73,636	66,154	65,246	80,026	78,478	88,947	82,444	85,785
Reagan	24,440	36,352	25,300	26,810	22,725	25,028	35,734	39,945	35,153	27,315	26,946	34,080	46,120	46,866	49,463
Reeves	135,140	99,368	77,993	79,038	55,479	58,829	79,707	56,705	49,911	50,822	79,080	109,623	113,331	107,007	115,958
Runnels	9,639	7,318	11,353	8,937	8,172	10,170	7,307	5,665	8,114	5,570	8,370	6,924	7,986	11,427	9,200
Schleicher	2,497	2,575	2,636	2,509	1,690	1,896	2,817	2,233	2,345	2,556	2,836	3,222	2,794	3,010	2,971
Scurry	15,690	11,555	9,605	8,655	7,782	7,585	7,043	7,120	10,708	8,151	9,223	8,773	7,374	8,642	8,150
Sterling	2,335	2,097	2,478	1,860	1,339	1,493	1,867	1,886	2,139	2,225	1,906	1,958	1,894	1,880	1,918
Sutton	4,147	3,157	3,601	3,081	3,012	3,156	3,259	3,067	3,171	2,933	3,449	3,537	3,542	4,227	4,273
Tom Green	78,419	75,141	60,429	57,841	47,465	71,144	86,563	66,522	78,821	58,843	131,381	134,530	147,964	79,299	133,483
Upton	19,551	17,917	13,260	13,046	10,988	15,643	16,623	16,340	20,434	19,585	18,051	22,488	23,821	22,402	19,462
Ward	40,864	12,315	13,103	12,236	12,646	8,092	24,508	22,847	15,212	16,130	30,831	31,108	18,152	18,764	19,391
Winkler	8,362	5,182	5,473	3,331	4,321	4,770	3,640	3,176	5,786	5,763	4,430	4,425	3,874	3,796	3,651
Total	732,246	649,737	555,647	535,445	461,074	502,369	594,057	527,230	526,159	487,081	666,957	750,688	810,962	709,792	751,248

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).
1981-1983 data from the TWDB is incomplete and therefore is not included.

Table 1-7
Historical Water Use by Category in Region F
(values in acre-feet)

Year	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
1980	125,000	13,792	506,868	14,027	52,745	19,814	732,246
1984	134,063	18,363	425,139	13,118	40,423	18,631	649,737
1985	126,675	9,028	361,124	13,888	27,709	17,223	555,647
1986	116,089	9,686	356,896	15,419	21,345	16,010	535,445
1987	105,408	8,272	290,033	14,447	26,030	16,884	461,074
1988	116,057	9,412	326,897	9,262	24,996	15,745	502,369
1989	127,126	7,707	409,510	12,281	21,372	16,061	594,057
1990	116,551	7,725	352,901	12,075	21,372	16,606	527,230
1991	118,390	7,205	337,813	13,309	32,331	17,111	526,159
1992	113,933	8,329	299,722	12,417	32,256	20,424	487,081
1993	118,009	8,386	471,551	13,933	34,799	20,279	666,957
1994	127,488	7,918	544,511	13,723	36,945	20,103	750,688
1995	125,566	8,241	613,020	12,593	31,410	20,132	810,962
1996	130,198	7,790	505,474	13,243	31,685	21,402	709,792
1997	121,510	7,581	556,928	13,379	31,892	19,958	751,248
State Total in 1997	3,429,392	1,521,336	9,529,808	325,890	246,673	338,004	15,391,103
% of State Total in Region F	3.5%	0.5%	5.8%	4.1%	12.9%	5.9%	4.9%

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).

Figure 1-12
Historical Water Use by Category in Region F

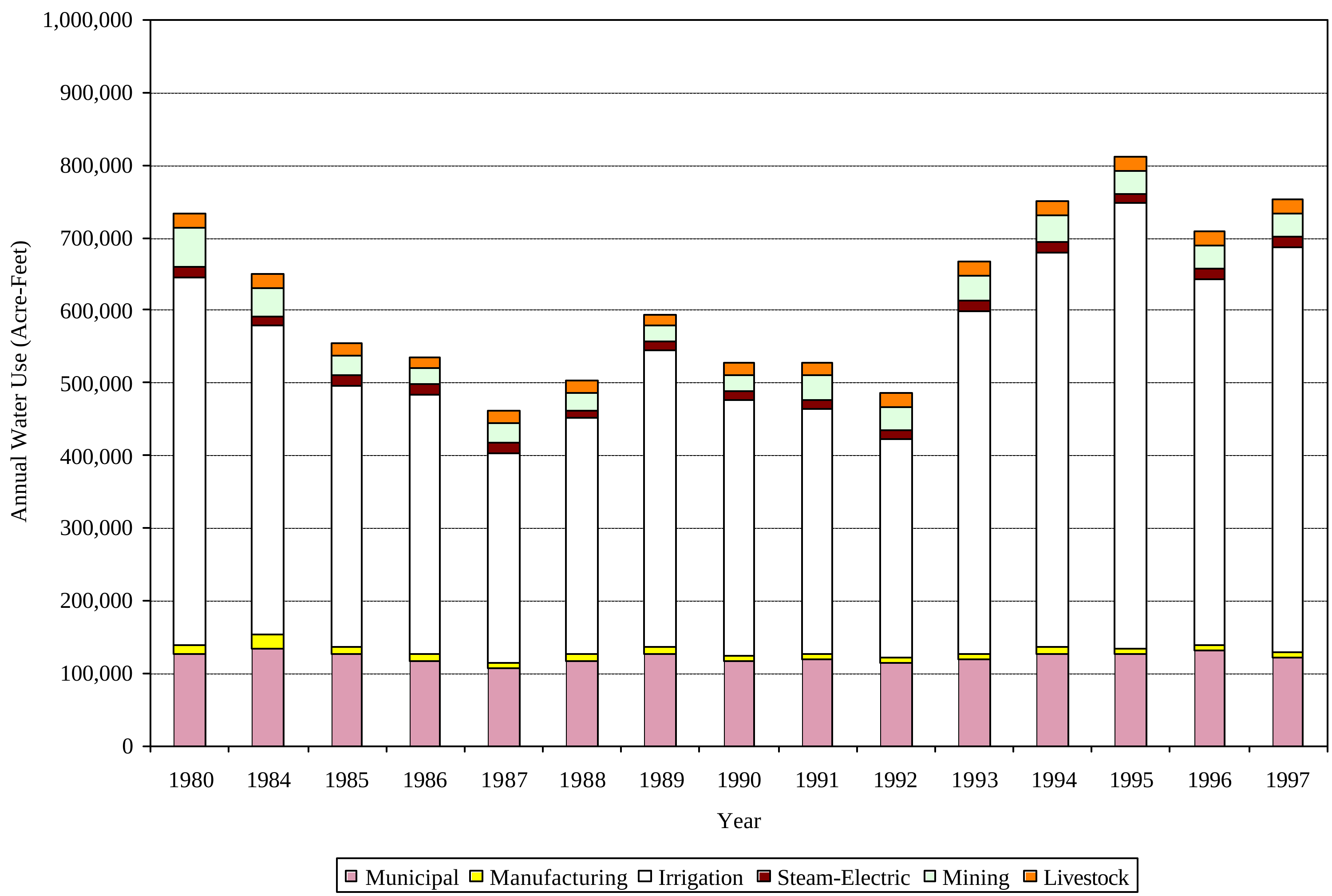


Table 1-8
1997 Use by Category and County
(values in acre-feet)

County	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
Andrews	3,219	30	16,550	0	2,896	444	23,139
Borden	116	40	9,666	0	972	277	11,071
Brown	5,859	476	13,197	0	2,427	1,497	23,456
Coke	550	0	542	515	280	460	2,347
Coleman	1,711	7	1,379	0	16	1,149	4,262
Concho	733	0	2,156	0	0	664	3,553
Crane	1,036	0	337	0	2,871	102	4,346
Crockett	1,665	0	374	979	407	607	4,032
Ector	20,266	2,121	8,632	0	7,924	299	39,242
Glasscock	171	11	52,443	0	7	193	52,825
Howard	7,085	1,749	2,377	1,553	1,793	366	14,923
Irion	228	0	2,828	0	126	376	3,558
Kimble	904	275	1,020	0	91	422	2,712
Loving	11	0	583	0	3	70	667
Martin	765	44	14,294	0	852	277	16,232
Mason	817	0	9,154	0	6	942	10,919
McCulloch	2,728	789	1,698	0	140	846	6,201
Menard	400	0	3,781	0	0	461	4,642
Midland	26,470	179	35,048	0	606	911	63,214
Mitchell	1,329	0	985	3,339	141	408	6,202
Pecos	4,348	4	80,062	0	253	1,118	85,785
Reagan	636	0	46,925	0	1,742	160	49,463
Reeves	3,295	1,386	108,943	0	212	2,122	115,958
Runnels	2,003	62	5,594	0	41	1,500	9,200
Schleicher	566	0	1,695	0	125	585	2,971
Scurry	3,915	0	800	0	2,804	631	8,150
Sterling	263	0	697	0	560	398	1,918
Sutton	1,417	0	2,261	0	75	520	4,273
Tom Green	21,955	401	108,372	804	150	1,801	133,483
Upton	853	0	15,617	0	2,844	148	19,462
Ward	3,992	7	8,918	6,189	158	127	19,391
Winkler	2,204	0	0	0	1,370	77	3,651
Total	121,510	7,581	556,928	13,379	31,892	19,958	751,248

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).

Figure 1-13
Water Use by County

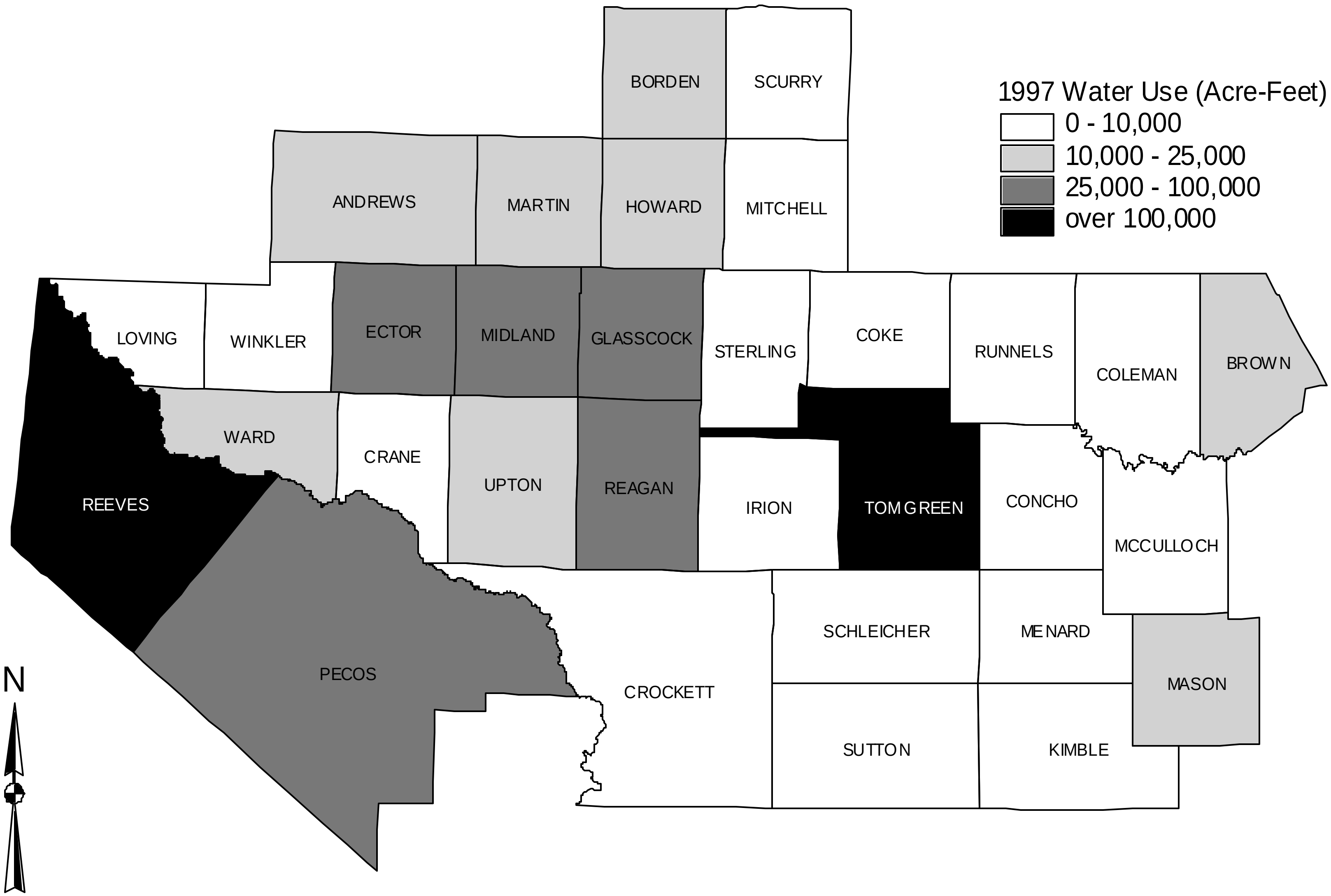


Table 1-9
Recreational Use of Reservoirs in Region F

Reservoir Name	County	Fishing	Boat Launch	Swimming Area	Marina	Picnic Area	Camping	Hiking Trails	Back-packing	Bicycle Trails	Equestrian Trails	Pavilion Area
Lake J. B. Thomas	Borden and Scurry	X	X			X	X					X
Lake Colorado City	Mitchell	X	X	X		X	X					
Champion Creek Reservoir	Mitchell											
Oak Creek Reservoir	Coke	X	X	X								
Lake Coleman	Coleman	X	X	X		X	X					
E. V. Spence Reservoir	Coke	X	X		X	X	X					X
Lake Winters/ New Lake Winters	Coleman	X	X	X	X	X	X	X				X
Lake Brownwood	Brown	X	X	X		X	X	X				
Hords Creek Lake	Coleman	X	X	X		X	X	X		X		
Lake Ballinger / Lake Moonen	Runnels	X	X	X		X	X		X			
O. H. Ivie Reservoir	Concho and Coleman	X	X		X	X	X	X				
O. C. Fisher Lake	Tom Green	X	X	X		X	X	X			X	X
Twin Buttes Reservoir	Tom Green	X	X	X		X	X					
Lake Nasworthy	Tom Green	X	X	X	X	X	X			X		X
Brady Creek Reservoir	McCulloch	X	X	X	X	X	X	X	X		X	X
Mountain Creek	Coke											
Red Bluff Reservoir	Reeves and Loving											
Lake Balmorhea	Reeves			X		X	X					

1.3 Current Sources of Water

Table 1-10 summarizes the total surface water and ground water use in Region F in 1980 and from 1984 through 1997 (TWDB CD, 1999), and Figure 1-14 shows the division of total water use between surface water and ground water. Total water use has increased since 1990 with an increase of 180,476 acre feet in groundwater use (48 percent) between 1990 and 1997 and an increase of 43,592 acre-feet in surface water use (29 percent) over the same period. Table 1-11 shows the ground water and surface water use by county and category for 1997, which is the most recent year for which data are available (TNRCC, 1999). Figure 1-15 shows the percentage of supply from ground water for Region F counties.

Table 1-10
Historic Sources of Supply in Region F

Year	Supply in Acre-Feet		
	Ground Water	Surface Water	Total
1980	539,884	192,362	732,246
1984	491,473	158,264	649,737
1985	412,728	142,919	555,647
1986	395,182	140,263	535,445
1987	334,074	127,000	461,074
1988	365,460	136,909	502,369
1989	418,306	175,751	594,057
1990	376,891	150,339	527,230
1991	371,311	154,848	526,159
1992	343,522	143,559	487,081
1993	476,492	190,465	666,957
1994	547,948	202,740	750,688
1995	607,802	203,160	810,962
1996	531,956	177,836	709,792
1997	557,367	193,881	751,248

Note: Data are from Texas Water Development Board (TWDB CD, 1999).

Figure 1-14
Historical Source of Supply in Region F

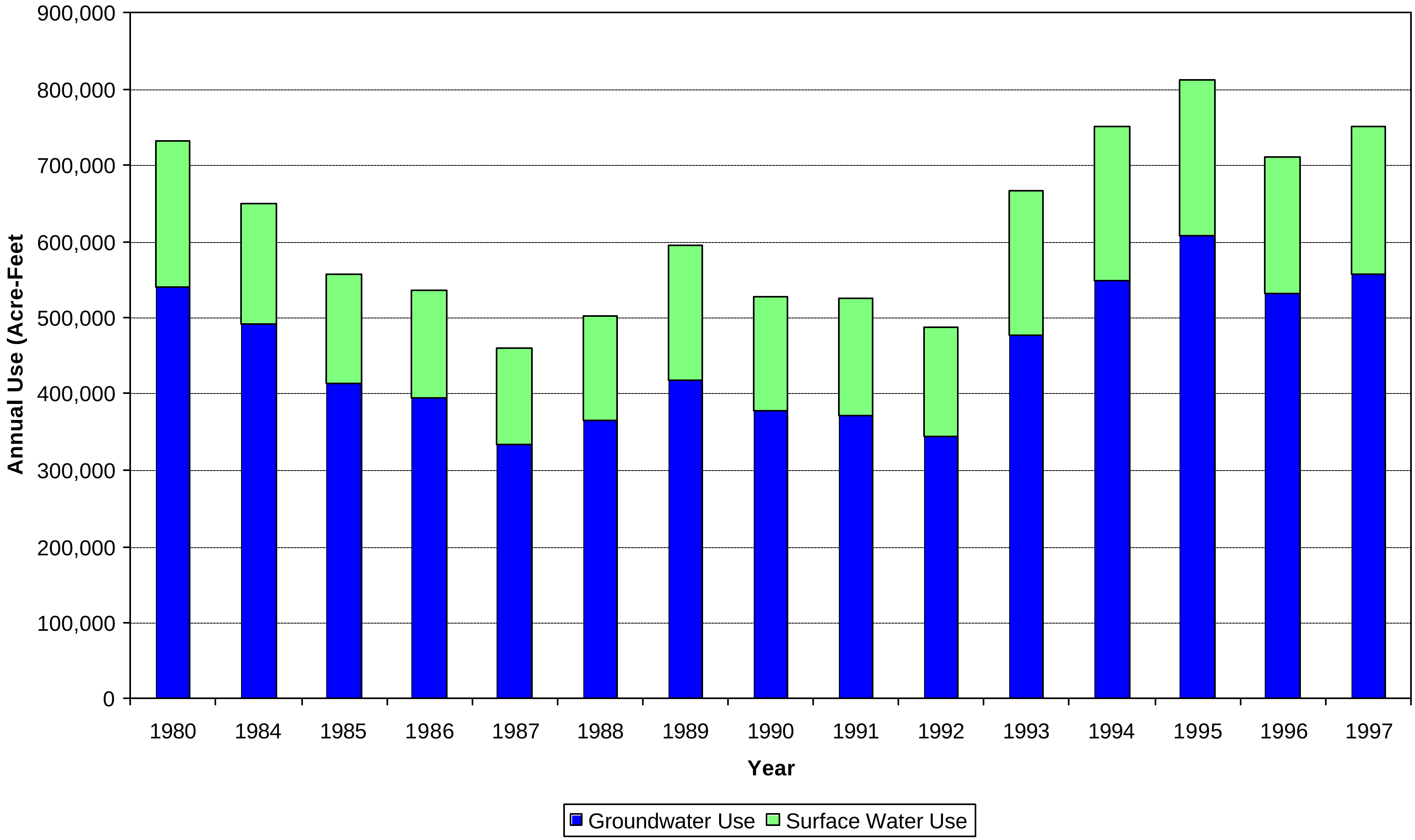


Figure 1-15
Percent of Total 1997 Supplies from Groundwater by County

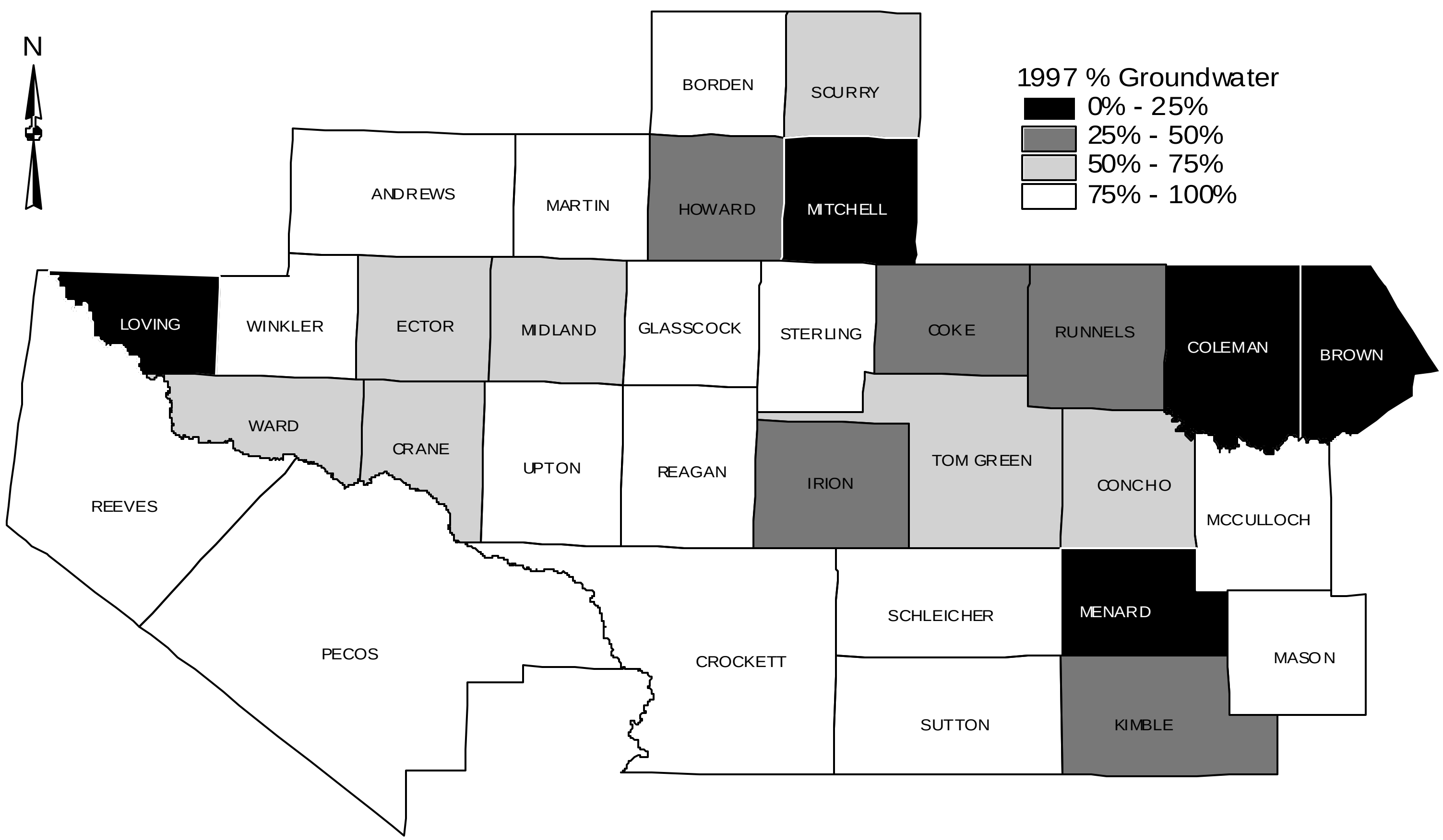


Table 1-11
Source of Supply by County and Category in 1997 for Region F
(Values in Acre-Feet)

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
Andrews	Ground	3,219	30	16,550	0	2,896	355	23,050
	Surface	0	0	0	0	0	89	89
	Total	3,219	30	16,550	0	2,896	444	23,139
Borden	Ground	114	0	8,216	0	972	28	9,330
	Surface	2	40	1,450	0	0	249	1,741
	Total	116	40	9,666	0	972	277	11,071
Brown	Ground	267	0	1,974	0	153	149	2,543
	Surface	5,592	476	11,223	0	2,274	1,348	20,913
	Total	5,859	476	13,197	0	2,427	1,497	23,456
Coke	Ground	58	0	434	0	170	46	708
	Surface	492	0	108	515	110	414	1,639
	Total	550	0	542	515	280	460	2,347
Coleman	Ground	0	0	0	0	1	115	116
	Surface	1,711	7	1,379	0	15	1,034	4,146
	Total	1,711	7	1,379	0	16	1,149	4,262
Concho	Ground	683	0	1,358	0	0	531	2,572
	Surface	50	0	798	0	0	133	981
	Total	733	0	2,156	0	0	664	3,553
Crane	Ground	1,036	0	337	0	1,437	97	2,907
	Surface	0	0	0	0	1,434	5	1,439
	Total	1,036	0	337	0	2,871	102	4,346
Crockett	Ground	1,665	0	374	979	73	485	3,576
	Surface	0	0	0	0	334	122	456
	Total	1,665	0	374	979	407	607	4,032
Ector	Ground	4,026	1,541	8,632	0	7,827	284	22,310
	Surface	16,240	580	0	0	97	15	16,932
	Total	20,266	2,121	8,632	0	7,924	299	39,242
Glasscock	Ground	171	11	52,443	0	7	154	52,786
	Surface	0	0	0	0	0	39	39
	Total	171	11	52,443	0	7	193	52,825
Howard	Ground	861	398	2,377	0	189	293	4,118
	Surface	6,224	1,351	0	1,553	1,604	73	10,805
	Total	7,085	1,749	2,377	1,553	1,793	366	14,923
Irion	Ground	228	0	990	0	126	301	1,645
	Surface	0	0	1,838	0	0	75	1,913
	Total	228	0	2,828	0	126	376	3,558
Kimble	Ground	195	3	235	0	91	338	862
	Surface	709	272	785	0	0	84	1,850
	Total	904	275	1,020	0	91	422	2,712
Loving	Ground	11	0	0	0	3	56	70
	Surface	0	0	583	0	0	14	597
	Total	11	0	583	0	3	70	667

Table 1-11 (cont.)

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
Martin	Ground	418	44	14,294	0	852	222	15,830
	Surface	347	0	0	0	0	55	402
	Total	765	44	14,294	0	852	277	16,232
Mason	Ground	817	0	9,154	0	6	471	10,448
	Surface	0	0	0	0	0	471	471
	Total	817	0	9,154	0	6	942	10,919
McCulloch	Ground	2,698	789	1,579	0	140	677	5,883
	Surface	30	0	119	0	0	169	318
	Total	2,728	789	1,698	0	140	846	6,201
Menard	Ground	73	0	454	0	0	369	896
	Surface	327	0	3,327	0	0	92	3,746
	Total	400	0	3,781	0	0	461	4,642
Midland	Ground	4,481	159	26,286	0	606	729	32,261
	Surface	21,989	20	8,762	0	0	182	30,953
	Total	26,470	179	35,048	0	606	911	63,214
Mitchell	Ground	171	0	985	0	141	41	1,338
	Surface	1,158	0	0	3,339	0	367	4,864
	Total	1,329	0	985	3,339	141	408	6,202
Pecos	Ground	4,348	4	77,198	0	253	1,062	82,865
	Surface	0	0	2,864	0	0	56	2,920
	Total	4,348	4	80,062	0	253	1,118	85,785
Reagan	Ground	636	0	46,925	0	1,742	128	49,431
	Surface	0	0	0	0	0	32	32
	Total	636	0	46,925	0	1,742	160	49,463
Reeves	Ground	3,094	1,386	99,428	0	212	2,016	106,136
	Surface	201	0	9,515	0	0	106	9,822
	Total	3,295	1,386	108,943	0	212	2,122	115,958
Runnels	Ground	286	0	2,238	0	41	150	2,715
	Surface	1,717	62	3,356	0	0	1,350	6,485
	Total	2,003	62	5,594	0	41	1,500	9,200
Schleicher	Ground	566	0	1,695	0	125	468	2,854
	Surface	0	0	0	0	0	117	117
	Total	566	0	1,695	0	125	585	2,971
Scurry	Ground	1,393	0	736	0	2,804	63	4,996
	Surface	2,522	0	64	0	0	568	3,154
	Total	3,915	0	800	0	2,804	631	8,150
Sterling	Ground	263	0	697	0	560	318	1,838
	Surface	0	0	0	0	0	80	80
	Total	263	0	697	0	560	398	1,918
Sutton	Ground	1,417	0	1,786	0	75	416	3,694
	Surface	0	0	475	0	0	104	579
	Total	1,417	0	2,261	0	75	520	4,273

Table 1-11 (cont.)

County	Source of Water	Municipal	Manu-facturing	Irrigation	Steam-Electric	Mining	Livestock	Total
Tom Green	Ground	1,945	1	73,413	0	150	180	75,689
	Surface	20,010	400	34,959	804	0	1,621	57,794
	Total	21,955	401	108,372	804	150	1,801	133,483
Upton	Ground	853	0	15,617	0	2,844	118	19,432
	Surface	0	0	0	0	0	30	30
	Total	853	0	15,617	0	2,844	148	19,462
Ward	Ground	3,992	7	354	6,189	158	121	10,821
	Surface	0	0	8,564	0	0	6	8,570
	Total	3,992	7	8,918	6,189	158	127	19,391
Winkler	Ground	2,204	0	0	0	1,370	73	3,647
	Surface	0	0	0	0	0	4	4
	Total	2,204	0	0	0	1,370	77	3,651
Total	Ground	42,189	4,373	466,759	7,168	26,024	10,854	557,367
	Surface	79,321	3,208	90,169	6,211	5,868	9,104	193,881
	Total	121,510	7,581	556,928	13,379	31,892	19,958	751,248

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).

1.3.1 Surface Water Sources

Table 1-12 lists the amount of surface water rights by category for each county in Region F. Table 1-13 does not include recreation, which is a non-consumptive category. Figure 1-16 shows the relative total water rights by county. Most of the surface water supply in Region F comes from major reservoirs. Table 1-13 lists the permitted diversions and the reported 1996 diversions from major water supply reservoirs in the region (TNRCC Individual Water Rights online).

There are no significant imports of surface water into Region F. The City of Sweetwater, which is in Region G, has rights to 5,328 acre-feet of water from Oak Creek Reservoir in Coke County. The West Central Texas Municipal Water District has a contract with the Colorado River Municipal Water District (CRMWD) for 15,000 acre feet of water from O.H. Ivie Reservoir to supply the City of Abilene, which is in Region G and the Brazos Basin. Facilities to transfer water from Lake O.H. Ivie to Abilene have not been constructed. Small amounts of surface water are also supplied to the Cities of Lawn and Rotan, both of which are in Region G.

Several rural water supply corporations also supply small amounts of surface water to neighboring regions.

Table 1-12
Surface Water Rights by County

	Permitted Surface Water Diversions (Acre -Feet per Year)					
County	**Municipal**	**Industrial**	**Irrigation**	**Mining**	**Other**	**Total**
Borden	200	0	63	0	0	263
Brown	15,996	5,004	17,481	0	0	38,481
Coke	44,865	6,000	1,009	9,494	0	61,368
Coleman	110,930	14,509	6,456	0	0	131,895
Concho	70	0	2,511	0	26	2,607
Ector	0	0	3,200	0	0	3,200
Howard	1,700	0	89	5,515	0	7,304
Irion	0	0	5,449	0	0	5,449
Kimble	1,000	2,466	8,490	100	0	12,056
Martin	0	0	2,500	0	0	2,500
Mason	0	0	388	0	0	388
McCulloch	3,000	500	2,351	0	0	5,851
Menard	1,016	0	8,935	3	0	9,954
Mitchell	2,700	9,550 *	123	0	0	12,373
Pecos	0	0	66,902	0	0	66,902
Reeves	1,890	0	412,352	0	0	414,242
Runnels	2,919	0	7,057	70	0	10,046
Schleicher	0	0	148	3	0	151
Scurry	30,000	0	503	0	0	30,503
Sterling	0	0	168	0	0	168
Sutton	0	0	99	3	0	102
Tom Green	107,934	8,002	40,980	0	0	156,916
Total	329,720	40,531	587,254	15,188	26	972,719

Note: Data are from TNRCC water rights list (TNRCC, 1999). Other counties have no permitted water rights on the TNRCC list. Does not include recreation.

* 5,500 acre-feet per year of this amount is permitted for multiple uses. It is currently being used primarily for steam electric power generation.

Figure 1-16
Total Permitted Surface Water Diversion by County

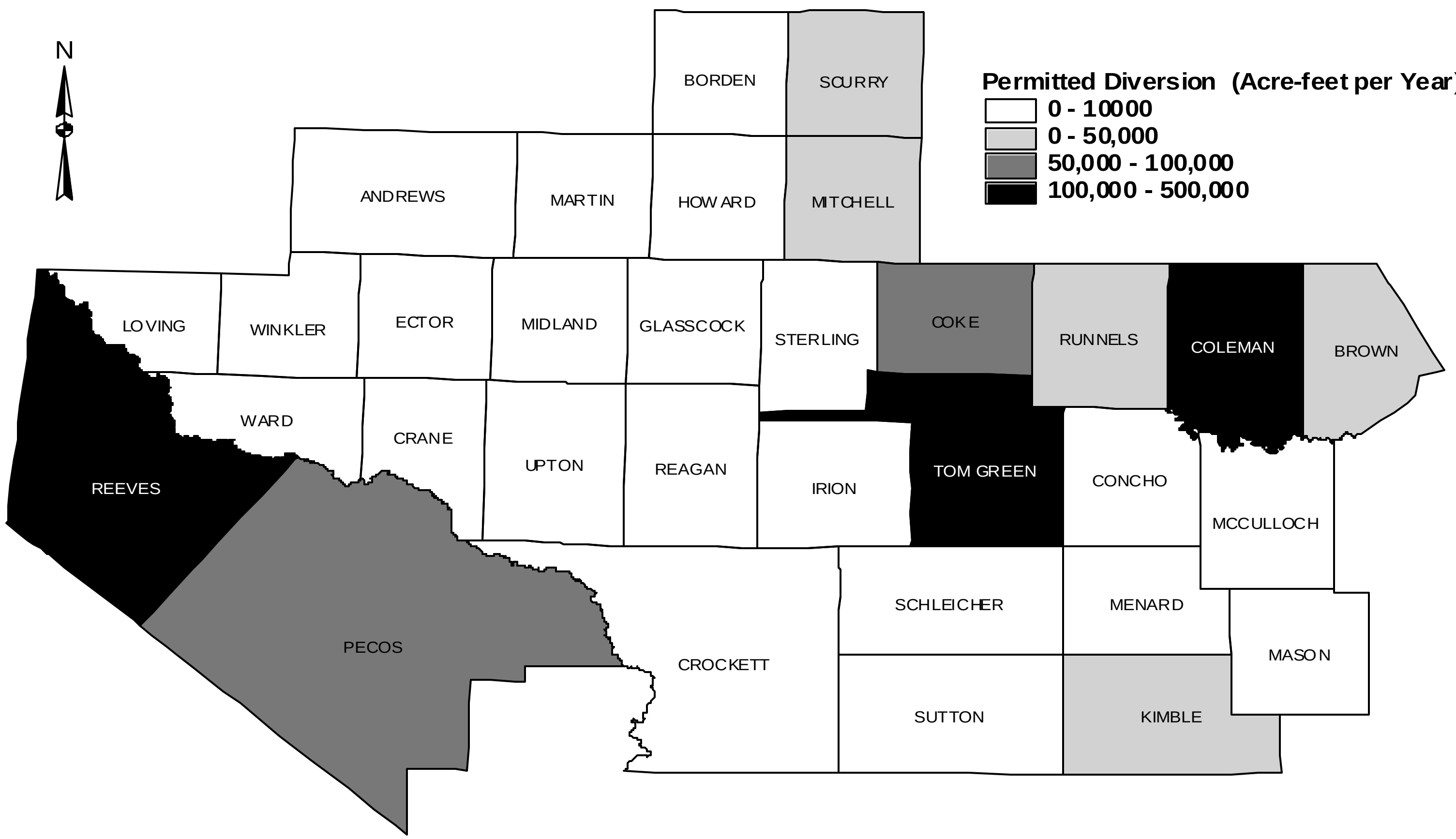


Table 1-13
Water Rights and Diversions of Major Reservoirs

Reservoir Name	County(ies)	Water Right Number(s)	Permitted Conservation Storage (Acre-Feet)	Permitted Diversion (Acre-Feet/Year)	1996 Use (Acre-Feet)
Lake J. B. Thomas	Borden and Scurry	1002	204,000	30,050	2,521
Lake Colorado City	Mitchell	1009	29,934	5,500	
Champion Creek Reservoir	Mitchell	1009	40,170	6,750	4,050
Oak Creek Reservoir	Coke	1031	30,000	10,000	5,160
Lake Coleman	Coleman	1702	40,000	9,000	1,610
E. V. Spence Reservoir	Coke	1008	488,760	38,573	1,932
Lake Winters/ New Lake Winters	Runnels	1095	8,347	1,755	792
Lake Brownwood	Brown	2454	114,000	29,712	10,157
Hords Creek Lake	Coleman	1705	7,959	2,260	282
Lake Ballinger / Lake Moonen	Runnels	1072	6,850	1,000	1,089
O. H. Ivie Reservoir	Coleman, Concho and Runnels	3866	554,340	113,000	43,264
O. C. Fisher Lake	Tom Green	1190	119,000	80,400	774
Twin Buttes Reservoir	Tom Green	1318	186,000	29,000	16,475
Lake Nasworthy	Tom Green	1319	12,500	25,000	5,932
Brady Creek Reservoir	McCulloch	1849	30,000	3,500	0
Mountain Creek	Coke	1024	950	250	43
Red Bluff Reservoir	Loving and Reeves	5438	300,000	292,500	58,960
Lake Balmorhea	Reeves	0060	13,583	41,400	0
Total			2,131,793	719,650	150,520

Note: Data are from TNRCC water rights list (TNRCC, 1999), TNRCC water rights permits (TNRCC, various dates), TNRCC summary of individual water rights for Region F (TNRCC Individual Water Rights online) and the Texas Water Development Board (TWDB CD, 1999).

1.3.2 Ground Water Sources

There are eleven aquifers that supply water to the 32 counties of Region F: four major aquifers (Edwards-Trinity Plateau, Ogallala, Cenozoic Pecos Alluvium, and Trinity) and seven minor aquifers (Dockum, Hickory, Lipan, Ellenburger-San Saba, Marble Falls, Rustler and the Capitan Reef Complex). Figure 1-10 shows the major aquifers and Figure 1-11 shows the minor aquifers in Region F. The Texas Water Development Board defines a major aquifer as an aquifer that supplies large quantities of water to large areas (Ashworth, 1995). Minor aquifers supply large quantities to small areas, or relatively small quantities to large areas. The Trinity aquifer is considered a major aquifer by the TWDB because it supplies large quantities of water in other regions. However, the Trinity aquifer covers only a small portion of Region F in Brown County and supplies a relatively small amount of water in the Region.

Table 1-14 lists historical ground water pumping by aquifer for Region F. Table 1-15 shows the 1997 pumping by county and aquifer (TWDB CD, 1999). The Edwards-Trinity Plateau, Cenezoic Pecos Alluvium and Ogallala are the largest sources of ground water in Region F, providing 37 percent, 27 percent and 15 percent of the total ground water pumped in 1997, respectively. The Lipan aquifer provided almost 12 percent of the 1997 totals, with all other aquifers contributing less than 9 percent. Ground water pumping is highest in Reeves, Pecos, Glasscock, Tom Green, and Reagan Counties. These five counties have 66 percent of the region's total pumping.

The potential recharge of aquifers varies geographically in Region F because of varying climatological conditions, surface soils and aquifer characteristics. Average annual precipitation in the extreme eastern portion of Region F is up to 27 inches per year, while in the far western portion of the region average annual rainfall can be less than 10 inches per year (See Figure 1-5). Evaporation rates increase from east (approximately 48 inches/year) to the west (68 plus inches/year) in Region F (See Figure 1-7). Generally, the low rainfall and high evaporation rates result in relatively low groundwater recharge rates in Region F. Low recharge rates, coupled with extended periods of drought, may limit the water availability within some aquifers in Region F. Certain aquifers like the Cenozoic Pecos Alluvium, and Edwards-Trinity Plateau have areas with favorable surface soils and subsurface geology and may have higher recharge rates during precipitation events.

Ground water is typically classified based on the quantity of dissolved minerals, or salinity, of the water. Table 1-16 summarizes the Texas Ground water Protection Committee's classification of ground water and the potential uses for each class of ground water.

A brief discussion of each aquifer in Region F is presented below. Descriptions of current use, pumping rates and water quality are based on evaluations of historical data reported to the TWDB, including analyses of available GIS data (TWDB, 1998 and TWDB CD, 1999).

1.3.2.1 Aquifers in Region F

Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer either outcrops in or underlies 21 counties in Region F, including Andrews, Borden, Coke, Concho, Crockett, Ector, Glasscock, Irion, Kimble, Mason, McCulloch, Menard, Midland, Pecos, Reagan, Reeves, Schleicher, Sterling, Sutton, Tom Green and Upton Counties. The aquifer extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas (TNRCC, June 1999).

From a regional standpoint, the Edwards, Glen Rose and Travis Peak Formations constitute a single aquifer. The upper portion of the aquifer is the Edwards and associated limestones. The central portion of the aquifer is the Glen Rose Formation of the Trinity Group (Upper Trinity) consisting of fossiliferous limestones, dolomites and marls. The lower portion of the aquifer is the Travis Peak Formation of the Trinity Group (Middle and Lower Trinity) and is comprised of alternating limestone, sandstone and shale sequences (Bluntzer, 1992). Formations of the Trinity Group change laterally across an imaginary line that runs eastward from southern Crockett County across the Sutton-Kimble County line and then northeastward to the northeast corner of Menard County. Water-bearing units of the Trinity Group south of this reference line consist of middle and lower Trinity Group formations. The Trinity Group water-bearing unit north of the line is the Antlers Sand that overlies Permian or Triassic rocks. Saturated thickness of the aquifer is generally less than 400 feet (Walker, 1979).

Water in the Edwards-Trinity (Plateau) aquifer generally flows in a south-southeasterly direction, but may vary locally. The aquifer is generally under water-table conditions. However, where the Trinity is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards aquifer, artesian conditions may exist. Reported well yields commonly range from less than 50 gallons per minute (gpm) from the thinnest saturated section to 1,000 gpm in locations where wells are completed in jointed or cavernous limestone. The rate of movement of ground water is usually very slow. The hydraulic gradient may range from 5 feet to more than 50 feet per mile. Normally the slope of the water table increases nearer to large drainage areas (Walker, 1979).

The chemical quality of the Edwards and associated limestones is generally better than that in the underlying aquifers on the Plateau, and the water is fairly uniform in quality. Water from the Edwards is characteristically very hard and is typically a calcium bicarbonate type with sulfate

Table 1-14
Historical Ground Water Pumping by Aquifer in Region F
(Values in Acre-Feet)

Year	Edwards-Trinity Plateau	Ogallala	Cenezoic Pecos Alluvium	Lipan	Hickory	Dockum	Trinity	Ellen-berger-San Saba	Marble Falls	Edwards-Trinity High Plains	Capitan Reef Complex	Rustler	Other	Total
1980	189,961	73,732	198,904	10,121	24,998	20,068	923	490	71	0	12,276	325	11,478	543,347
1984	219,015	58,748	127,125	22,794	23,584	20,884	1,610	461	166	69	653	504	17,228	492,841
1985	173,174	57,994	102,430	19,653	24,868	19,850	1,018	456	172	86	645	290	15,808	416,444
1986	181,191	49,987	93,613	17,333	24,184	15,967	1,934	434	181	105	62	266	14,214	399,471
1987	158,814	37,314	74,869	14,534	22,416	14,332	1,870	382	172	99	582	253	11,975	337,612
1988	159,764	46,467	78,622	22,672	25,576	14,091	1,960	395	166	97	583	200	17,104	367,697
1989	180,364	51,818	106,050	24,383	25,481	11,765	2,560	388	165	65	527	218	17,177	420,961
1990	175,452	60,767	70,971	24,588	24,038	10,833	1,473	399	153	64	486	195	10,688	380,107
1991	178,248	51,245	70,032	20,512	24,080	14,531	1,270	415	156	54	354	250	13,514	374,661
1992	160,712	62,488	64,018	13,850	18,924	12,776	1,332	593	187	54	351	274	9,781	345,340
1993	215,615	62,295	106,147	63,867	21,258	14,790	2,173	533	160	80	0	646	20,197	507,761
1994	194,394	89,386	152,091	60,581	20,414	13,743	1,978	490	142	4	0	1,460	15,519	550,202
1995	229,427	94,230	159,213	76,180	19,040	10,575	2,402	496	145	4	0	1,579	17,208	610,499
1996	209,904	90,362	150,347	35,230	17,346	12,250	2,348	429	141	3	0	1,487	13,453	533,300
1997	206,804	84,388	151,177	66,292	16,093	11,583	2,470	467	143	3	0	1,555	17,090	558,065

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).

Table 1-15
1997 Ground Water Pumping by County and Aquifer
(Values in Acre-Feet)

County	Edwards-Trinity Plateau	Ogallala	Cenezoic Pecos Alluvium	Lipan	Hickory	Dockum	Trinity	Ellen-berger-San Saba	Marble Falls	Edwards-Trinity High Plains	Rustler	Other	Total
Andrews	25	22,825	189	0	0	9	0	0	0	0	0	0	23,048
Borden	0	8,254	0	0	0	0	0	0	0	3	0	1,025	9,282
Brown	0	0	0	0	0	0	2,441	0	0	0	0	102	2,543
Coke	28	0	0	0	0	0	0	0	0	0	0	680	708
Coleman	0	0	0	0	0	0	29	0	0	0	0	87	116
Concho	206	0	0	1,358	510	0	0	0	0	0	0	444	2,518
Crane	0	0	2,893	0	0	14	0	0	0	0	52	0	2,959
Crockett	2,647	0	0	0	0	0	0	0	0	0	0	0	2,647
Ector	10,648	7,208	578	0	0	787	0	0	0	0	0	0	19,221
Glasscock	45,307	7,437	0	0	0	0	0	0	0	0	0	0	52,744
Howard	718	3,274	0	0	0	105	0	0	0	0	0	0	4,097
Irion	643	0	0	0	0	0 [b]	0	0	0	0	0	1,002	1,645
Kimble	862	0	0	0	0	0	0	0	0	0	0	0	862
Loving	0	0	55	0	0	9	0	0	0	0	0	0	64
Martin	0	16,364	0	0	0	0	0	0	0	0	0	0	16,364
Mason	0	0	0	0	10,186	0	0	134	129	0	0	0	10,449
McCulloch	15	0	0	0	5,397	0	0	327	14	0	0	167	5,920
Menard	851	0	0	0	0	0	0	6	0	0	0	39	896
Midland	12,940	19,026	0	0	0	0	0	0	0	0	0	0	31,966
Mitchell	0	0	0	0	0	1,336	0	0	0	0	0	2	1,338
Pecos[a]	54,137	0	28,303	0	0	0	0	0	0	0	1,400	5	83,845
Reagan	48,992	0	0	0	0	440	0	0	0	0	0	0	49,432
Reeves	780	0	102,960	0	0	1,046	0	0	0	0	103	0	104,889
Runnels	0	0	0	0	0	0	0	0	0	0	0	2,716	2,716
Schleicher	2,854	0	0	0	0	0	0	0	0	0	0	0	2,854
Scurry	0	0	0	0	0	4,468	0	0	0	0	0	268	4,736
Sterling	951	0	0	0	0	0	0	0	0	0	0	887	1,838
Sutton	3,694	0	0	0	0	0	0	0	0	0	0	0	3,694
Tom Green	1,087	0	0	64,934	0	0	0	0	0	0	0	9,666	75,687
Upton	19,419	0	0	0	0	13	0	0	0	0	0	0	19,432
Ward	0	0	15,679	0	0	227	0	0	0	0	0	0	15,906
Winkler	0	0	520	0	0	3,129	0	0	0	0	0	0	3,649
Total	206,804	84,388	151,177	66,292	16,093	11,583	2,470	467	143	3	1,555	17,090	558,065

Note: Data are from the Texas Water Development Board (TWDB CD, 1999).
(a) Edwards-Trinity water use in Pecos County may actually originate in other aquifers. (b) Some usage for livestock

Table 1-16
Texas Ground Water Protection Committee
Ground Water Classification System

Class	Quality (Dissolved Solids in mg/l)	Examples of Use
Fresh	Zero to 1,000	Drinking and all other uses
Slightly Saline	More than 1,000 to 3,000	Drinking if fresh water is unavailable, livestock watering, irrigation, industrial, mineral extraction, oil and gas production
Moderately Saline	More than 3,000 to 10,000	Potential/future drinking and limited livestock watering and irrigation if fresh or slightly saline water is unavailable, industrial, mineral extraction, oil and gas production
Very Saline to Brine	More than 10,000	Mineral extraction, oil and gas production

Note: Information is from the TNRCC Texas Groundwater Protection Committee (June 1999).

and chloride occurring in relatively small quantities (generally less than 50 milligrams per liter (mg/l)). The concentration of dissolved solids usually ranges from 200 to 400 mg/l (Walker, 1979).

The chemical quality of water from the Antlers is of the calcium bicarbonate/sulfate type. The salinity of ground water in the Antlers increases towards the west. The water is typically very hard, with dissolved solids ranging from 500 to 1,000 mg/l. Sulfate concentrations range from 20 mg/l in Sterling, Irion, Coke and Tom Green Counties to 300 mg/l in Ector County. The average concentrations of bicarbonate and chloride are 250 and 70 mg/l, respectively. Some counties have elevated levels of fluoride in the ground water (Walker, 1979).

Exposed bedrock or extremely thin soils are common over much of the Edwards Plateau. In addition, limestone is the predominant rock of the Edwards Plateau, and locally the limestone has undergone leaching, creating joints, crevices and solution openings. Consequently, the permeability may be high but irregularly distributed, and recharge to the water table is direct with little interference from the soils and other surface conditions. Rapid recharge of this type may cause water-table mounds that dissipate after rainfall periods (Walker, 1979). Recharge of the aquifer has been estimated to be 776,000 acre-feet per year (Muller, 1979).

Between 1984 and 1996 approximately 2.4 million acre-feet of ground water were pumped from the Edwards-Trinity (Plateau) aquifer in Region F (Refer to Table 1-14). This corresponds to an average pumpage of 185,000 acre-feet per year. Approximately 86 percent of the ground water was used for irrigation and livestock, 8 percent for public water supplies and 5 percent by the mining or petroleum industries. Over the past 50 years water levels have been lowered an average of 20 feet for Region F. Water levels in areas of Reagan, Upton, Midland and Glasscock counties have decreased an average of 5 feet since the 1980's.

Ogallala Aquifer

The Ogallala aquifer underlies the seven northwestern counties in Region F, including Andrews, Borden, Ector, Howard, Glasscock, Martin and Midland Counties. The aquifer extends south from South Dakota through Nebraska, Kansas, Wyoming, Colorado, New Mexico, Oklahoma and the Northern High Plains of Texas and terminates along the edge of the Southern High Plains in the Texas counties mentioned above (Knowles, 1984).

The Ogallala is composed primarily of heterogeneous sequences of coarse to medium grained sand and gravel in the lower strata grading into fine clay, silt and sand in the upper portion of the formation. Recent studies have revealed that the Ogallala Formation was deposited during the late Miocene to early Pliocene and consists of alluvial sediments partly filling paleovalleys that were subsequently covered by widespread thick eolian sediments. Cementation of the Ogallala sands varies throughout Region F and impacts well yields. Ground water generally moves slowly through the Ogallala Formation in a southeastwardly direction towards the caprock edge or eastern escarpment of the High Plains (Reeves, 1996).

Water quality of the Ogallala in the Southern High Plains is typically a sulfate-chloride type. The quality range is from fresh to moderately saline with dissolved solids ranging from 300 to 6,500 mg/l. The fluoride content ranges from 3 to greater than 7 mg/l. Sulfate, nitrate and selenium concentrations are also high in some locations. Upward leakage and subsequent mixing of water from the underlying Cretaceous aquifers probably influence the water quality (Hopkins, 1993).

A total of 813,000 acre-feet of ground water pumped from the Ogallala were used between 1984 and 1996 (Refer to Table 1-14). Average annual consumption was approximately 63,000 acre-feet. Agricultural-related consumption (irrigation and livestock) accounted for 64 percent of the total, municipal consumption was 22 percent and mining or oil industry related consumption was 13 percent of the total. Martin County accounted for 21 percent of the total Ogallala Aquifer pumpage within Region F during 1996 (TWDB Historical Pumpage Data, 1997). According to 1997 TWDB pumpage data, during the last ten years irrigation activities have dramatically increased (three to more than ten times 1987 levels) in Andrews, Borden, Ector and Glasscock Counties. Irrigation activity has nearly doubled in Howard and Midland counties and remained relatively constant in Martin County. Consequently, water levels have been lowered over 100 feet in some areas since the 1940s.

Recharge occurs principally by infiltration of precipitation on the surface and to a lesser extent by upward leakage from underlying formations. Highest recharge infiltration rates occur in areas overlain by sandy soils and in playa lake basins (Reeves, 1996).

Cenozoic Pecos Alluvium Aquifer

The Cenozoic Pecos Alluvium aquifer is located in the upper part of the Pecos River Valley of West Texas in Andrews, Crane, Crockett, Ector, Loving, Pecos, Reeves, Upton, Ward and Winkler Counties. The aquifer is the principal source of water for irrigation in Reeves and northwestern Pecos Counties and for industrial use, power generation and public water supply elsewhere (Ashworth, 1990).

The Cenozoic Pecos Alluvium is of Quaternary age and consists of up to 1,500 feet of alluvial fill. It occupies two hydrologically separate basins: the Pecos Trough in the west and the Monument Draw Trough in the east (TWDB, 1998\7). The aquifer is hydrologically connected to underlying water-bearing strata, including the Edwards-Trinity in Pecos and Reeves Counties and the Triassic Dockum in Ward and Winkler Counties. Ground water is semi-confined to confined and may be artesian locally because of confining clay beds (TWDB, 1997).

A total of 1,637,684 acre-feet of ground water were pumped from the Cenozoic Pecos Alluvium between 1984 and 1996 (Refer to Table 1-14). Average annual consumption was approximately 125,975 acre-feet. Agricultural related consumption (irrigation and livestock) accounted for 80 percent of the total, municipal consumption was 10 percent, power generation was 5 percent and mining or oil industry related consumption was 4 percent of the total. Reeves County was the largest user of the Cenozoic Pecos Alluvium ground water, consuming 67 percent of the total (TWDB Historical Pumpage Data, 1997).

The chemical quality of water in the aquifer is highly variable, differing naturally with location and depth, and is generally better in the Monument Draw Trough. Water from the aquifer is typically hard and contains dissolved solids concentrations ranging from less than 300 to more than 5,000 mg/l. Sulfate and chloride are the two major constituents of the higher concentrations of dissolved solids. Some quality deterioration may have resulted from past petroleum industry activities in Loving, Ward and Winkler Counties and from irrigation in Pecos, Reeves and Ward Counties (TWDB, 1997).

Water levels have declined an average of 80 feet since the 1950s in Reeves and Pecos counties. Water levels have remained relatively constant in Andrews, Crane, Crockett, Ector, Loving, Ward and Winkler Counties. Ground water that once supplemented the surface flow of the Pecos River has been redirected towards areas of intense pumpage resulting in a decrease of base flow in the Pecos River (TWDB, 1997).

Trinity Aquifer

The Trinity aquifer crops out in Brown and Coleman Counties and is the major ground water source for Brown County (Klemt, 1975). This aquifer was deposited during the Cretaceous Period and is comprised of (from oldest to youngest) the Twin Mountains, Glen Rose and Paluxy formations. In western Brown and Coleman Counties, the Glen Rose is thin or missing and the Paluxy and Twin Mountains coalesce to form the Antlers formation. The Paluxy Formation consists of sand and shale and is capable of producing small quantities of fresh to slightly saline water (TWDB, 1997). The Twin Mountains formation is composed of sand, gravel, shale, clay and occasional conglomerate, sandstone and limestone beds. It is the principal aquifer and yields moderate to large quantities of fresh to slightly saline water. Maximum thickness of the Trinity aquifer is believed to be more than 200 feet in this area (Thompson, 1967).

A total of 23,928 acre-feet of ground water were pumped from the Trinity aquifer in Brown and Coleman Counties between 1984 and 1996 (Refer to Table 1-14). Average annual use was approximately 1,841 acre-feet. Agricultural related consumption (irrigation and livestock) accounted for 80 percent of the total, municipal consumption was 15 percent, and mining or oil industry related consumption was 4 percent of the total. Brown County was the largest user of the Trinity aquifer ground water, consuming 98 percent of the total (TWDB Historical Pumpage Data, 1997).

Water quality from the Trinity aquifer is acceptable for most municipal, industrial and irrigation purposes. TWDB reports that dissolved solids range from 151 to 7,687 mg/l in Brown County; however, most wells have dissolved solids concentrations less than 1,000 mg/l (Thompson, 1967). The potential for updip movement of poor quality water also exists where large and ongoing water level declines have reversed the natural water level gradient and have allowed water of elevated salinity to migrate back updip toward pumpage centers (TWDB, 1997).

In some parts of the Trinity aquifer, saltwater contamination of the ground water has occurred from oil field brines and unplugged or improperly plugged oil or gas wells. Deterioration of ground water may also occur by pollution from organic matter, commonly sewage, which may result in bacterial contamination and high concentrations of nitrate (Thompson, 1967).

Dockum Aquifer

Ground water from the Dockum Group of Triassic age is pumped by 12 counties in Region F, including Andrews, Crane, Ector, Howard, Loving, Mitchell, Reagan, Reeves, Scurry, Upton, Ward and Winkler Counties. The Dockum Group underlies the Ogallala aquifer in parts of Andrews, Ector, Martin and Midland Counties, the Cenozoic Pecos Alluvium aquifer in Andrews, Crane, Ector, Loving, Pecos, Reeves, Ward and Winkler Counties and underlies the Edwards-Trinity (Plateau) aquifer in Andrews, Crane, Ector, Midland, Reagan, Upton and Winkler Counties.

The Dockum Group is thought to be a fluvial system where coarser sediments were deposited in channels and siltstones and mudstones were deposited on floodplains and in small isolated ponds (Dutton, 1986). The primary water-bearing zone in the Dockum Group, commonly called the “Santa Rosa”, consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Discontinuous water-producing sandstone lenses occur elsewhere within the Dockum. Dockum ground water is used for irrigation primarily in Mitchell and Scurry Counties and as a municipal water supply in Reeves and Winkler Counties. Elsewhere, the aquifer is used extensively for oil field water flooding operations (TWDB, 1997).

Total pumpage of the Dockum aquifer from Region F counties between 1984 and 1996 was 186,387 acre-feet, with an average annual pumpage of 14,337 acre-feet (Table 1-14). During

1996, 28 percent of the ground water consumed was used for municipal water supplies, 39 percent was used by the petroleum and/or mining industries and 33 percent was used for irrigation and livestock. Scurry County pumped 43 percent of the total during 1996 (TWDB Historical Pumpage Data, 1997).

The chemical quality of water from the Dockum aquifer ranges from fresh in outcrop areas to brine in the deeper central basin area. The ground water is dominated by sodium sulfate-type water in Andrews County and calcium sulfate-type water where the Cenozoic Pecos Alluvium overlies the Dockum (Dutton, 1986). An ongoing, unpublished TWDB study of the Dockum aquifer has produced detailed analyses of water chemistry and aquifer characteristics. According to this study, ground water pumped from the Santa Rosa in Region F had average dissolved solids ranging from 558 mg/l in Winkler County to over 2,500 mg/l in Andrews, Crane, Ector, Howard, Reagan and Upton Counties. Nitrate, selenium and sodium concentrations are generally above recommended levels in most of the counties (Bradley, 1999). The extent of the aquifer as delineated includes the area in which the Dockum ground water contains less than 5,000 mg/l dissolved solids (Ashworth, 1995).

In the Dockum, the direction of ground water flow is generally to the east and southeast. According to data from the TWDB study, the Dockum aquifer's permeability is typically low, and well yields range from 0.5 to 2,500 gpm with an average of 160 gpm (Bradley, 1999). Water level rises occurred in Andrews, Crane and Upton Counties between 1981 to 1996, while water level declines were observed in Loving, Winkler, Ward and Ector Counties (Bradley, 1999).

Hickory Aquifer

The Hickory aquifer underlies or crops out in Brown, Coleman, Concho, McCulloch, Mason, Menard and Kimble Counties. Five of these counties, Concho, Mason, McCulloch, Menard and Kimble, pump water from the Hickory aquifer (Bluntzer, 1992).

The Hickory Sandstone Member of the Cambrian Riley Formation is composed of some of the oldest sedimentary rocks in Texas. In most northern and western portions of the aquifer, the Hickory Sandstone Member can be differentiated into lower, middle and upper units, which reach a maximum thickness of 480 feet in southwestern McCulloch County. Block faulting has compartmentalized the Hickory aquifer. Apparent vertical fault displacement ranges from a few feet to as much as 2,000 feet. There is also evidence of significant lateral fault displacement.

Throughout its extent, the relief of the underlying Precambrian surface affects the thickness of the aquifer. Both faulting and underlying structures have caused significant variations in the occurrence, availability, movement, productivity and quality of ground water within the aquifer (TWDB, 1997).

Total ground water pumped from the Hickory aquifer between 1984 and 1996 in Region F (excluding Kimble County) was 291,209 acre-feet (Refer to Table 1-14). The average annual pumpage in those years was 22,400 acre-feet. Irrigation and livestock accounted for 79 percent of the total pumpage, while municipal water use accounted for 17 percent, manufacturing 3 percent and mining 1 percent of the total. Mason County pumped 65 percent of the total pumpage, 90 percent of which was used for irrigation (TWDB Historical Pumpage Data, 1997).

Ground water is generally fresh, with dissolved solids concentrations ranging from 300 to 500 mg/l. The middle Hickory unit is believed to be the source of alpha, beta and radium concentrations in excess of drinking water standards (Bluntzer, 1992). The water can also contain radon gas. The upper unit of the Hickory aquifer produces ground water containing concentrations of iron in excess of drinking water standards. Wells in the shallow Hickory and the outcrop areas have local concentrations of nitrate in excess of drinking water standards (TWDB, 1997).

Yields of large-capacity wells usually range between 200 and 500 gpm. Some wells have yields in excess of 1,000 gpm. Highest well yields are typically found northwest of the Llano Uplift, where the aquifer has the greatest saturated thickness (TWDB, 1997).

Lipan Aquifer

The Lipan aquifer underlies Concho, Runnels and Tom Green Counties (Ashworth, 1995). The water is principally used for irrigation, with limited amounts used for rural domestic and livestock purposes (Ashworth, 1995).

The Lipan aquifer is comprised of saturated alluvial deposits of the Leona Formation of Pleistocene age. The total thickness of the alluvium ranges from a few feet to about 125 feet. Also included in the aquifer are the updip portions of the underlying Choza Formation, Bullwagon Dolomite, and Standpipe Limestone of Permian age that are hydrologically connected to the Leona and contain fresh to slightly saline water. Ground water in the Lipan aquifer exists under water-table conditions. Saturated thickness of the Leona alluvial sediments ranges from zero to over 100 feet (TWDB, 1997).

Total pumpage of the Lipan aquifer in Tom Green and Concho Counties between 1984 and 1996 was 416,177 acre-feet with an average annual pumpage of 32,013 acre-feet (Table 1-14). Approximately 2 percent of the total was used for municipal consumption and 97 percent of the total was used for irrigation or livestock. In 1996, Tom Green County accounted for 89 percent of the total ground water pumpage (TWDB Historical Pumpage Data, 1997).

Ground water in the Leona Formation ranges from fresh to slightly saline and is very hard (Ashworth, 1995). Water in the underlying updip portions of the Choza, Bullwagon and Standpipe tends to be slightly saline. The chemical quality of ground water in the Lipan aquifer often does not meet drinking water standards; but it is generally suitable for irrigation. Most wells have nitrate levels in excess of 10 parts per million. Well yields generally range from 20 to 500 gpm with the average well yielding approximately 200 gpm.

Oil field activities and irrigation practices have affected the quality of the ground water in the Lipan aquifer. Leaking, abandoned oil wells have allowed brine to infiltrate into fresh-water zones in local areas. Seasonal heavy irrigation pumpage has encouraged the upward migration of poorer quality water from deeper zones. Additionally, irrigation return flow has concentrated minerals in the water through evaporation and the leaching of natural salts from the unsaturated zone (TWDB, 1997).

Ellenburger-San Saba Aquifer

The Ellenburger-San Saba aquifer underlies or crops out in Brown, Coleman, Kimble, Mason, McCulloch and Menard Counties (Bluntzer, 1992). This aquifer is used for water supply only in Mason, and McCulloch Counties.

The Ellenburger-San Saba aquifer is comprised of the Cambrian aged San Saba member of the Wilberns Formation and the Ordivician aged Ellenburger Group, which includes the Tanyard, Gorman and Honeycut formations. Discontinuous outcrops of the aquifer generally encircle older rocks in the core of the Llano Uplift. The maximum thickness of the aquifer is about 1,100 feet. In some areas, where the overlying beds are thin or absent, the Ellenburger-San Saba aquifer may be hydrologically connected to the Marble Falls aquifer. Local and regional block faulting has significantly compartmentalized the Ellenburger-San Saba. Dissolution along such faulting and related fractures has formed various sized cavities, which are the major water-bearing features of the aquifer. Ground water in the aquifer is mostly under artesian pressure, even in much of the outcrop areas, because of relatively impermeable carbonate rocks of the thick Ellenburger-San Saba sequence that function as confining layers (TWDB, 1997).

Total pumpage of the Ellenburger-San Saba aquifer from Mason, McCulloch and Menard Counties between 1984 and 1996 was 5,871 acre-feet with an average annual pumpage of 452 acre-feet (Refer to Table 1-14). Approximately 89 percent of the ground water pumped was used for livestock, while 11 percent was used for municipal consumption. Historically, only minor volumes of ground water from the Ellenburger-San Saba Aquifer has been used for irrigation. McCulloch County used 67 percent of the 1996 total ground water pumpage (TWDB Historical Pumpage Data, 1997).

Water produced from the aquifer has a range in dissolved solids between 200 and 3,000 mg/l, but is usually less than 1,000 mg/l. The quality of water deteriorates rapidly away from outcrop areas. Approximately 20 miles or more downdip from the outcrop water is typically unsuitable for most uses. In the northwestern portion of the aquifer, water quality deterioration is due to increases in sodium and chloride. In the southeastern portion, deterioration is due to increases in calcium and sulfate. All the ground water produced from the aquifer is inherently hard (TWDB, 1997).

The maximum yields of large-capacity wells used for municipal and irrigation purposes generally range between 200 and 600 gpm, most other wells generally yield less than 100 gpm (TWDB, 1997).

Marble Falls Aquifer

The Marble Falls aquifer crops out in Kimble, Mason and McCulloch Counties (Bluntzer, 1992). There is one public supply well in McCulloch County using the Marble Falls aquifer.

The Marble Falls Formation of the Pennsylvanian Bend Group occurs in several separated outcrops, primarily along the northern and eastern flanks of the Llano Uplift region of Central Texas. The downdip portion of the aquifer is of unknown extent. Ground water occurs in fractures, solution cavities, and channels in the limestones. Where underlying beds are thin or absent, the Marble Falls and Ellenburger-San Saba aquifers may be hydrologically connected (TWDB, 1997).

According to TWDB data, a total of 2,106 acre-feet were pumped from the Marble Falls aquifer from 1984 to 1996 (Refer to Table 1-14). Average annual pumpage is 162 acre-feet. Livestock and municipal use accounted for 71 and 29 percent of the ground water pumped. Mason County is the largest user of the Marble Falls aquifer ground water (TWDB Historical Pumpage Data, 1997).

The quality of water produced from the aquifer is generally suitable for most purposes. The downdip artesian portion of the aquifer is not extensive, and water becomes significantly mineralized within a relatively short distance downdip from the outcrop area. Because the fractured and dissolutioned limestones of the Marble Falls are relatively shallow, the aquifer is quite susceptible to pollution (TWDB, 1997).

Wells completed in McCulloch County have a range of yields from 3 to 35 gpm with an average of 15 gpm.

Rustler Aquifer

The Rustler aquifer underlies Crane, Loving, Pecos, Reeves and Ward Counties (Rickey, 1985). Ground water from the Rustler aquifer has been historically used for stock and irrigation.

The Rustler Formation consists of 200 to 500 feet of anhydrite and dolomite with a basal zone of sandstone and shale deposited in the Delaware Basin during the Permian age (Ashworth 1990). Water is produced primarily from highly permeable solution channels, caverns and collapsed breccia zones (Ashworth, 1995). Water in the aquifer occurs under artesian conditions except in the outcrop in the Rustler Hills to the west and in collapsed zones in the two troughs (Ashworth, 1990).

According to TWDB data, a total of 7,622 acre-feet were pumped from the Rustler aquifer from 1984 to 1996 (Refer to Table 1-14). Average annual pumpage is 586 acre-feet. Irrigation accounted for 69 percent of the total, oil field water flooding accounted for 15 percent, and livestock use accounted for 16 percent. Irrigation activity has increased dramatically since 1994. According to TWDB pumping data, 1,487 acre-feet of ground water were pumped in Region F in that year. Pecos County used 90 percent of this amount for irrigation.

Ground water from the Rustler aquifer is generally unsuitable for human consumption because it contains from 1,400 to greater than 100,000 mg/l of dissolved solids. The dissolved-solids concentrations increase down gradient, eastward into the basin, with a shift from sulfate to chloride as the predominant anion. Highly mineralized ground water may be caused by the dissolution of evaporites within the Rustler due to local flow or mixing from brine that has migrated upward from underlying saline aquifers (TWDB, 1997). In some locations the Rustler aquifer ground water has alpha and beta concentrations above drinking water standards.

Recharge that infiltrates the Rustler Formation outcrop in Culberson County moves eastward into the Delaware Basin. Ground water from the Rustler Formation may migrate into the overlying Edwards-Trinity and Cenozoic Pecos Alluvium. Except where porosity is well developed in the solution zones in the formation, storage capacity is relatively low. Acid treatment of wells usually results in yields ranging from 300 to 1,000 gpm (TWDB, 1997).

Capitan Reef Complex Aquifer

The Capitan Reef Complex aquifer underlies Pecos, Ward and Winkler Counties (Lee, 1986). According to TWDB records, no counties in Region F are presently using ground water from the Capitan Reef Complex aquifer (Refer to Table 1-14).

The Capitan Reef Complex formed along the margins of the Delaware Basin, an embayment covered by a shallow Permian sea. In Texas, the reef parallels the western and eastern edges of the basin in two arcuate strips 10 to 14 miles wide and is exposed in the Guadalupe, Apache and Glass Mountains. The aquifer is composed of up to approximately 2,000 feet of massive, vuggy to cavernous dolomite and limestone, bedded limestone and reef talus. Water-bearing formations include the Capitan Limestone, Goat Sheep Limestone, and most of the Carlsbad facies of the Artesia Group, which includes the Grayburg, Queen, Seven Rivers, Yates and Tansill formations (TWDB, 1997). Most of the ground water pumped from the aquifer is used for oil reservoir water-flooding operations in Ward and Winkler Counties (Ashworth, 1995).

The TWDB has ground water pumping data from Ward County from 1984 to 1992 (Refer to Table 1-14). A total of 4,243 acre-feet of ground water from the Capitan Reef Complex aquifer were used during this period. The average annual pumpage was 471 acre-feet per year. All of the ground water was used for oil reservoir flooding operations (TWDB Historical Pumpage Data, 1997).

The aquifer generally contains water of marginal quality, with total-dissolved solids ranging between 1,000 and 3,000 mg/l. High salt concentrations in some areas are probably caused by migration of brine waters injected for secondary oil recovery. The freshest water is located near areas of recharge where the reef is exposed at the surface in the three mountain ranges. Many of the wells in the aquifer are quite old and their casings may be deteriorated. Yields of wells commonly range from 400 to 1,000 gpm (TWDB, 1997).

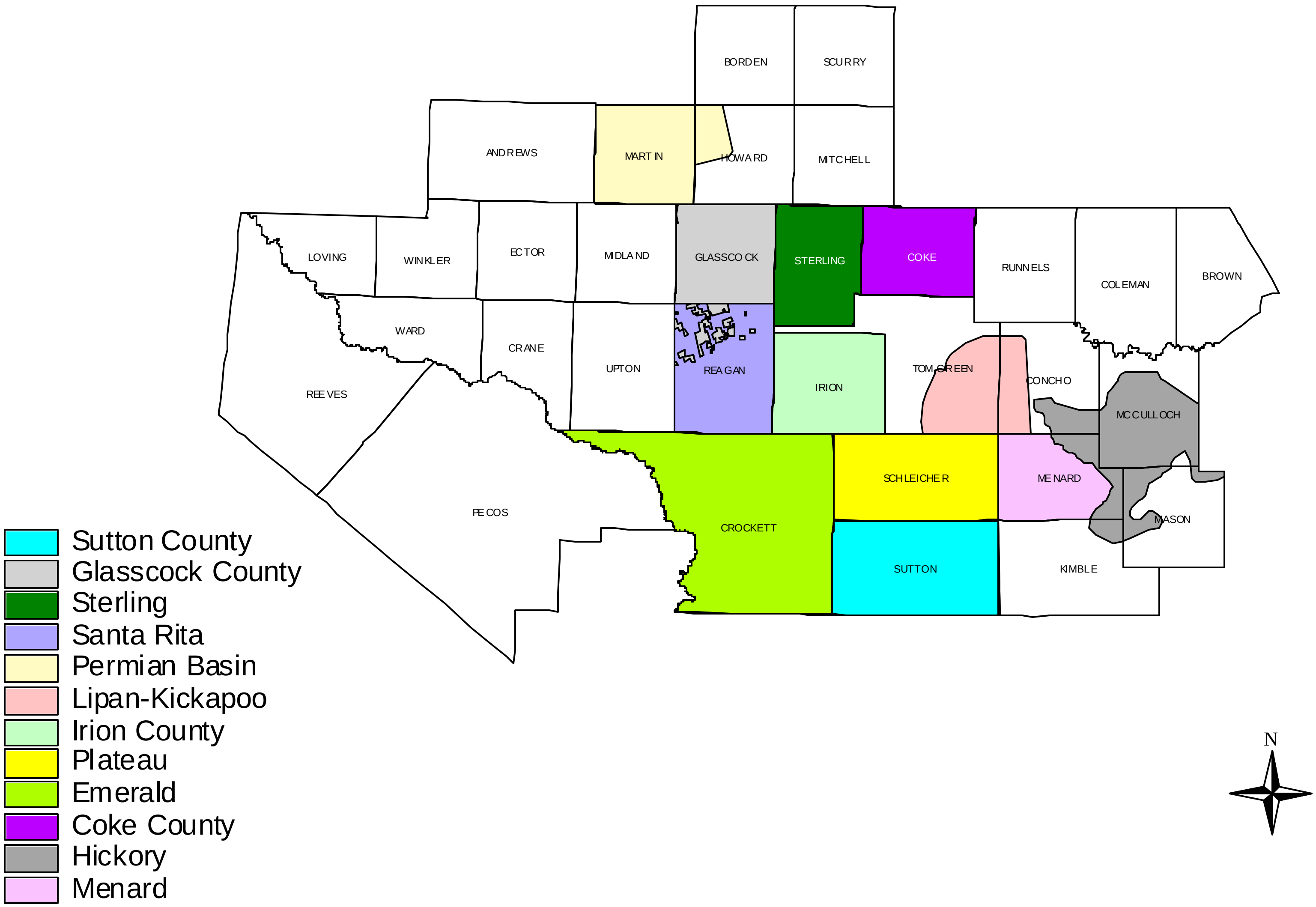
1.3.2.2 Underground Water Conservation Districts

There are 12 Ground Water Conservation Districts (GCDs) in Region F. Figure 1-17 is a map of the jurisdictional boundaries of the Districts (TWDB GIS Data). GCDs are the primary regulators of ground water in the State of Texas. These entities are required to develop and adopt comprehensive management plans, permit wells with capacities greater than 25,000 gallons per day, keep records of well completions, and make information available to State agencies. Among the optional powers granted GCDs are prevention of waste, conservation, recharge projects, research, distribution and sale of water for any purpose, and making rules regarding transportation of ground water outside of the district (TAES, 1996).

Ten of the GCDs in Region F form the West Texas Regional Groundwater Alliance, an organization that promotes the conservation, preservation and beneficial use of water and related resources in the Region. GCDs perform an important role in Region F's water supply. Seven of the GCDs are also members of the West Texas Weather Modification Association, a group that performs rainfall enhancement activities in a seven county area.

SB1 required that all GCDs submit new management plans. Eleven districts provided these plans to the regional water planning group. The following descriptions were extracted from these plans.

Figure 1-17: Region F
Underground Water Conservation Districts



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Coke County Underground Water Conservation District

The Coke County Underground Water Conservation District was founded in 1986 and includes all of Coke County. The Edwards-Trinity Plateau aquifer underlies a portion of the County. Other water-bearing strata are the Quaternary alluvium, the Cretaceous Fredricksburg and Trinity Groups, and the Permian Clear Fork, Pease River and Artesia Groups and Ochoa Series. Objectives from the 1998 Management Plan include providing field and in-house water analysis for well owners, locating wells for statistics and registration, and investigating reported wasteful uses of ground water. The District is a founding member of the West Texas Regional Groundwater Alliance (TAES, 1996).

Emerald Underground Water Conservation District

The Emerald Underground Water Conservation District was created in 1991 and encompasses the areas in Crockett County that are not included in the boundaries of the Crockett County Water Control and Improvement District Number One. The primary sources of ground water in the District are the Edwards-Trinity Plateau aquifer and alluvium along the Pecos River, Live Oak Creek, Howard Creek and Johnson Draw. Objectives from the District's 1998 management plan include providing water conservation information, publishing articles on water conservation, identifying reported wasteful practices and non-beneficial use, establishing a ground water level and water quality monitoring network, maintaining a database of monitoring information, and reviewing permit applications for fluid injection permits within the District's boundaries. The District is a founding member of the West Texas Regional Groundwater Alliance and a member of the West Texas Weather Modification Association (Emerald, 1998).

Glasscock County Underground Water Conservation District

The Glasscock County Underground Water Conservation District was established in 1981. The District covers Glasscock County and 65,000 acres in Reagan County. Ground water in the District originates in the Edwards-Trinity Plateau, Ogallala and Dockum aquifers. The goals identified in the District's 1998 Management Plan include responding to complaints of wasteful water use practices and providing surveying equipment for efficient irrigation planning. The District is a founding member of the West Texas Regional Groundwater Alliance and a member of the West Texas Weather Modification Association (Glasscock, 1998).

Hickory Underground Water Conservation District Number One

The Hickory Underground Water Conservation District was created in 1982 and includes parts of Mason, McCulloch, Menard, Kimble and San Saba Counties (San Saba County is not in Region F). The District does not have the authority to regulate production from other aquifers within the District's boundaries. Activities identified in the District's 1998 Management Plan include promoting water conservation through education, water monitoring, providing flow meters to allow users to evaluate their water use, evaluation of conjunctive use of aquifer water and water from Brady Reservoir. The District is a member of the West Texas Regional Groundwater Alliance (Hickory, 1998).

Irion County Water Conservation District

The Irion County Water Conservation District was formed in 1985 and covers all of Irion County. Ground water in the District is produced primarily from the Edwards-Trinity Plateau and Dockum aquifers and from alluvium along area rivers. Management objectives from the 1998 Management Plan include distribution of information on water conservation practices, providing water quality analyses and publishing the results of these analyses, sampling and analysis of newly drilled wells, education programs in local schools, water quality monitoring of area surface water resources to assess any potential impact on ground water quality, and participation in weather modification activities. The District is a founding member of the West Texas Regional Groundwater Alliance and a member of the West Texas Weather Modification Association (Irion, 1998).

Lipan-Kickapoo Water Conservation District

The Lipan-Kickapoo Water Conservation District was created in 1988. The District includes parts of Tom Green and Concho Counties. Ground water in the District comes primarily from the Lipan aquifer. The Edwards-Trinity Plateau aquifer produces some water in the southern portion of the District. Activities in the District's 1998 Management Plan include performing pivot irrigation flow tests and identifying wasteful water use practices. The District is a member of the West Texas Regional Groundwater Alliance (Lipan-Kickapoo, 1998).

Permian Basin Underground Water Conservation District

The Permian Basin Underground Water Conservation District was created in 1985 and includes Martin County and the northwestern portion of Howard County. Most of the ground water produced in the District comes from the Ogallala and Edwards-Trinity Plateau aquifers. Objectives included in the District's 1998 Management Plan include monitoring ground water levels, providing water quality testing, permitting non-exempt wells, closing open or uncovered wells, and inspecting salt water disposal wells within the District's boundaries (Permian, 1998).

Plateau Underground Water Conservation and Supply District

The Plateau Underground Water Conservation and Supply District was created in 1965 and includes all of Schleicher County. The primary source of ground water in the District is the Edwards-Trinity Plateau aquifer. Management objectives from the District's 1998 Management Plan include providing public education, providing field analysis of water samples, registering and permitting new water wells, participating in regional water planning through the Region F RWPG, participating in the West Texas Weather Modification Association and the West Texas Groundwater Alliance, performing a monitoring program for water levels and water quality, and identifying and responding to wasteful practices (Plateau, 1998).

Santa Rita Underground Water Conservation District

The Santa Rita Underground Water Conservation District was founded in 1990 and includes the portions of Reagan County that are not included in the Glasscock County Underground Water Conservation District. Production of ground water is primarily from the Edwards-Trinity Plateau and Dockum aquifers. Management objectives from the District's 1998 Management Plan include establishing a monitoring network, registering all new wells in the District, maintaining a database and map of well locations, investigate all reported wasteful practices, enforcing rules regarding drilling, completing, equipping and spacing of water wells, and continuing to plug abandoned wells. The District is a member of the West Texas Regional Groundwater Alliance and a member of the West Texas Weather Modification Association (Santa Rita, 1998).

Sterling County Underground Water Conservation District

The Sterling County Underground Water Conservation District was formed in 1986 and encompasses all of Sterling County. The primary source of ground water in the District is the Edwards-Trinity Plateau aquifer. Objectives in the District's 1998 Management Plan include identifying wasteful practices and providing recommendations for efficient use of ground water resources. The District is a member of the West Texas Regional Groundwater Alliance and a member of the West Texas Weather Modification Association (Sterling, 1998).

Sutton County Underground Water Conservation District

The Sutton County Underground Water Conservation District encompasses all of Sutton County. The primary source of ground water in the District is the Edwards-Trinity Plateau aquifer. Management goals from the 1998 Management Plan include providing public education, providing field analysis for water wells, registering water wells, participating in regional water planning by serving on the Region F RWPG board, participating in the West Texas Weather Modification Association and the West Texas Groundwater Alliance, monitoring water levels, responding to reports of wasteful practices, and maintaining a water quality monitoring program (Sutton, 1998).

1.3.3 Springs in Region F

Springs in Region F have been important sources of water supply since prehistoric times and had great influence on the initial patterns of settlement (Refer to Figure 1-18). However, ground water development and the resulting water level declines have caused many springs to disappear and greatly diminished the flow from those that remain (Gunnar Brune, 1981). Two springs still flow in Loving County: Allison Spring and Red Bluff Springs. These springs have moderately saline water. Reeves County once had 21 springs or spring groups; only six are currently flowing. One of these springs, San Solomon Springs near Balmorhea, is significant because of its recreational uses and habitat for endangered species (TPWD, 1998). The Diamond Y Springs in northern Pecos County flow continuously and are important because of its habitat for endangered species. Also in Pecos County, the historically significant Comanche Springs flow occasionally in January and February.

Several rivers in Region F have significant spring-fed flows, including the South Concho, Dove Creek, Spring Creek (Irion County), Rocky Creek (Irion County), Lipan Creek, San Saba River, Llano River and Clear Creek (Menard County).

Figure 1-18

1.4 Agricultural and Natural Resources in Region F

1.4.1 Wetlands

Wetlands are areas characterized by a degree of flooding or soil saturation, hydric soils, and plants adapted to growing in water or hydric soils (USGS, 1996). Wetlands are often dependent on water from streams and reservoirs. Wetlands are beneficial in several ways; they provide flood attenuation, bank stabilization, water-quality maintenance, fish and wildlife habitat, and opportunities for hunting, fishing, and other recreational activities (USGS, 1996). There are significant wetland resources in Region F, especially near rivers and reservoirs.

1.4.2 Endangered or Threatened Species

Table 1-17 lists “species of special concern” identified in Region F counties by the Texas Parks and Wildlife Department (TPWD). Species of special concern include those listed or proposed to be listed as threatened or endangered at the federal level. Also included are species listed as threatened or endangered at the state level. Species of special concern also include those considered by the TPWD as rare, having limited range within the state. The TPWD maintains a list of species of special concern in the Texas Biological and Conservation Data System (TPWD, March 1999).

Table 1-17
Species of Special Concern in Region F

Table 1-17 (Cont.)
Species of Special Concern in Region F

Table 1-17 (Cont.)
Species of Special Concern in Region F

Table 1-17 (Cont.)
Species of Special Concern in Region F

1.4.3 Stream Segments with Significant Natural Resources

Senate Bill 1 requires the State Water Plan to identify river and stream segments of unique ecological value. The identification of such resources may be done regionally by the RWPG. If not, the state plan must do so. Among the criteria for identifying a stream segment as one with unique ecological value are its biological and hydrologic functions. In addition, segments with riparian conservation areas, or high water quality, exceptional aquatic life, or high aesthetic quality may be identified as having unique ecological value. Finally, stream or river segments where water development projects would have significant detrimental effects on state or federally listed threatened or endangered species may be considered ecologically unique.

Using these criteria, the TPWD has developed a draft list of Texas streams and rivers satisfying at least one of the criteria defined in SB1 for ecologically unique river and stream segments. Those in Region F on the draft list include:

Clear Creek – The impounded headwater springs located in Menard County

- Endangered/Threatened: Only known location of Clear Creek gambusia

Colorado River – From the Brown/San Saba/Mills County line upstream to S.W. Freese Dam in Coleman/Concho County (within TNRCC stream segment 1410)

- Biological Function: Texas Natural Rivers System nominee
- Aquatic Life: Exceptional aesthetic value
- Endangered/Threatened: Concho water snake

Concho River – From a point 1.2 miles above the confluence of Fuzzy Creek in Concho County upstream to San Angelo Dam on the North Concho River in Tom Green County and to Nasworthy Dam on the South Concho River in Tom Green County (TNRCC stream segment 1421).

- Aquatic Life: Exceptional aesthetic value
- Endangered/Threatened: Concho water snake; one of only three known remaining populations of endemic Texas pimpleback

Devils River – From the Sutton/Val Verde County line upstream to the confluence with the Dry Devils River in Sutton County (within TNRCC stream segment 2309). Considered by TPWD to be a segment of highest importance.

- Aquatic Life: Ecoregion Stream; overall use
- Endangered/Threatened: Conchos pupfish; Proserpine shiner; Rio Grande darter

Diamond Y Springs – From the confluence with Leon Creek in Pecos County to its headwaters in Pecos County.

- Resource Conservation Area: Nature Conservancy
- Endangered/Threatened: Pecos gambusia; Leon Springs pupfish; Puzzle sunflower; only known location of Pecos Assiminea snail, Diamond Y Spring Snail, and Gonzales Spring snail.

East Sandia Springs (Reeves County).

- Endangered/Threatened: Pecos gambusia; Puzzle sunflower

Elm Creek – From Elm Creek Park Lake in Ballinger (Runnels County) upstream to the FM 2647 bridge in central Runnels County. Considered by TPWD to be a segment of highest importance.

- Aquatic Life: Ecoregion Stream, Dissolved oxygen; Benthic macroinvertebrates
- Endangered/Threatened: One of only four known remaining populations of endemic Texas fatmuckets, one of only three known remaining populations of endemic Texas pimpleback

Giffen Springs (Reeves County).

- Endangered/Threatened: Comanche Springs pupfish, Pecos gambusia

James River – From the confluence with the Llano River in the central part of Mason County to its headwaters south of Noxville in the southeastern part of Kimble County. Considered by TPWD to be a segment of highest importance.

- Aquatic Life: Ecoregion Stream; overall use

Leon Creek – From the confluence with the Pecos River in Pecos County to its headwaters in Pecos County.

- Endangered/Threatened: Leon Springs pupfish, Pecos gambusia; Puzzle sunflower

Live Oak Creek – From the confluence with the Pecos River about seven miles southeast of Sheffield in Crockett County to its headwaters about six miles north of Old Fort Lancaster in Crockett County.

- Aquatic Life: Ecoregion Stream, Dissolved oxygen; Benthic macroinvertebrates
- Endangered/Threatened: Proserpine shiner

Pecos River – From the Val Verde/Crockett County line upstream to the FM 11 bridge on the Pecos/Crane County line (within TNRCC stream segment 2311).

- Biological Function: Texas Natural River System nominee
- Aquatic Life: Exceptional aesthetic value
- Endangered/Threatened: Proserpine shiner

Pedernales River – From the Kimble/Gillespie County line upstream to FM 385 in Kimble County (within TNRCC stream segment 1414). Considered by TPWD to be a segment of highest importance.

- Biological Function: National Wild and Scenic Rivers System nominee; Significant natural area
- Aquatic Life: Exceptional aesthetic value

Salt Creek – From the confluence with the Pecos River in Reeves County upstream to the Reeves/Culberson County line.

- Endangered/Threatened: Pecos pupfish

San Saba River – From FM 864 in Menard County upstream to Fort McKavett in Menard County.

- Resource Conservation Area: Fort McKavett State Historical Park
- Endangered/Threatened: One of only four known remaining populations of endemic Texas fatmuckets; one of only three known remaining populations of endemic Texas pimpleback

San Solomon Springs (Reeves County).

- Resource Conservation Area: Balmorhea State Park
- Endangered/Threatened: Comanche Springs pupfish, Pecos gambusia

South Llano River – From the confluence with the North Llano River at Junction near the center of Kimble County upstream to the Kimble/Edwards County line (within TNRCC stream segment 1415). Considered by TPWD to be a segment of highest importance.

- Resource Conservation Area: South Llano River State Park and Wildlife Management Area
- Aquatic Life: Ecoregion Stream, Dissolved oxygen; Benthic macroinvertebrates; Fish
- Endangered/Threatened: Only major watershed containing a genetically pure population of Guadalupe bass (state fish of Texas)

Spring Creek – From the FM 2335 crossing in Tom Green County to its headwaters located four miles south of the corner common to Schleicher, Irion, and Crockett counties.

- Aquatic Life: Ecoregion Stream, Dissolved oxygen; Benthic macroinvertebrates
- Endangered/Threatened: One of only four known remaining populations of endemic Texas fatmuckets

Toyah Creek – From the confluence with the Pecos River in Reeves County upstream to FM 1450 in Reeves County.

- Endangered/Threatened: Comanche Springs pupfish

West Rocky Creek – From the confluence with the Middle Concho River in northeast Irion County upstream to its headwaters in south Sterling County.

- Aquatic Life: Ecoregion Stream; Benthic macroinvertebrates

1.4.4 Agriculture and Prime Farmland

Table 1-18 provides basic data regarding agricultural production in Region F, based on recent data available from the U.S. Department of Agriculture (USDA) (USDA, April 1999). Region F includes approximately 23,600,000 acres in farms and over 2,600,000 acres of cropland. Irrigated agriculture plays a significant role in Region F, with approximately 9 percent of the total cropland irrigated. The market value of agriculture products (crops and livestock), for 1997 for Region F is almost $600,000,000, with livestock accounting for about 60 percent and crops accounting for the remaining 40 percent of the total.

The National Resources Conservation Service (NRCS) defines prime farmland as “land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses”. As part of the National Resources Inventory, the NRCS has identified prime farmland throughout the country. Figure 1-19 shows the distribution of prime farmland in Region F (NRCS STATSGO Database). Each color in Figure 1-19 represents the percentage of the total acreage that is prime farmland of any kind. There are four categories of prime farmland in the NRCS STATSGO database for Texas: prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and prime farmland if irrigated.

A number of counties in Region F have significant prime farmland acreage. Those with the largest acreage include Runnels, Glasscock, Upton, Tom Green, Scurry, Sterling, Reagan, and Borden Counties. These eight counties accounted for about 40 percent of the harvested acres and 40 percent of the total crop value for Region F in 1997.

It is interesting to note that major agricultural production also occurs in some counties with a relatively small amount of prime farmland. For example, Andrews, Martin, Pecos, and Reeves Counties have 10 percent or less acreage identified as prime farmland. However, these four counties combined accounted for approximately 17 percent of the total harvested acreage and 30 percent of the crop value for the Region in 1997.

Table 1-18
1997 U.S. Department of Agriculture County Census Data for Region F

	Andrews	Borden	Brown	Coke	Coleman	Concho	Crane	Crockett
Farms	142	107	1,228	336	837	380	53	170
Land in Farms (acres)	828,859	514,623	516,058	482,480	736,739	635,584	491,112	1,935,171
Crop Land (acres)	70,169	70,235	140,675	55,097	199,049	129,083	27,897	(D)
Harvested Crop Land (acres)	28,624	27,160	44,156	12,723	78,044	70,484	20	(D)
Irrigated Crop Land (acres)	4,646	969	5,844	495	1,533	3,974	132	(D)
Market Value ($1,000)								
Crops	$5,529	$6,210	$4,052	$667	$3,819	$7,264	$0	$78
Livestock	$3,749	$6,226	$28,808	$7,324	$16,961	$12,502	$2,059	$15,118
Total	$9,278	$12,436	$32,860	$7,991	$20,780	$19,766	$2,059	$15,196

	Ector	Glasscock	Howard	Irion	Kimble	Loving	Martin	Mason
Farms	208	200	436	146	485	14	353	565
Land in Farms (acres)	462,315	436,528	543,576	651,708	773,046	352,072	539,196	595,265
Crop Land (acres)	(D)	132,043	201,989	(D)	33,190	0	271,844	65,222
Harvested Crop Land (acres)	(D)	96,043	108,740	4,471	7,385	0	159,460	13,046
Irrigated Crop Land (acres)	2,082	52,455	3,191	1,367	2,019	0	11,410	6,228
Market Value ($1,000)								
Crops	$181	$20,870	$21,848	$526	$838	$0	$36,491	$4,104
Livestock	$3,219	$2,870	$9,639	$5,454	$6,385	$880	$3,439	$15,471
Total	$3,400	$23,740	$31,487	$5,980	$7,223	$880	$39,930	$19,575

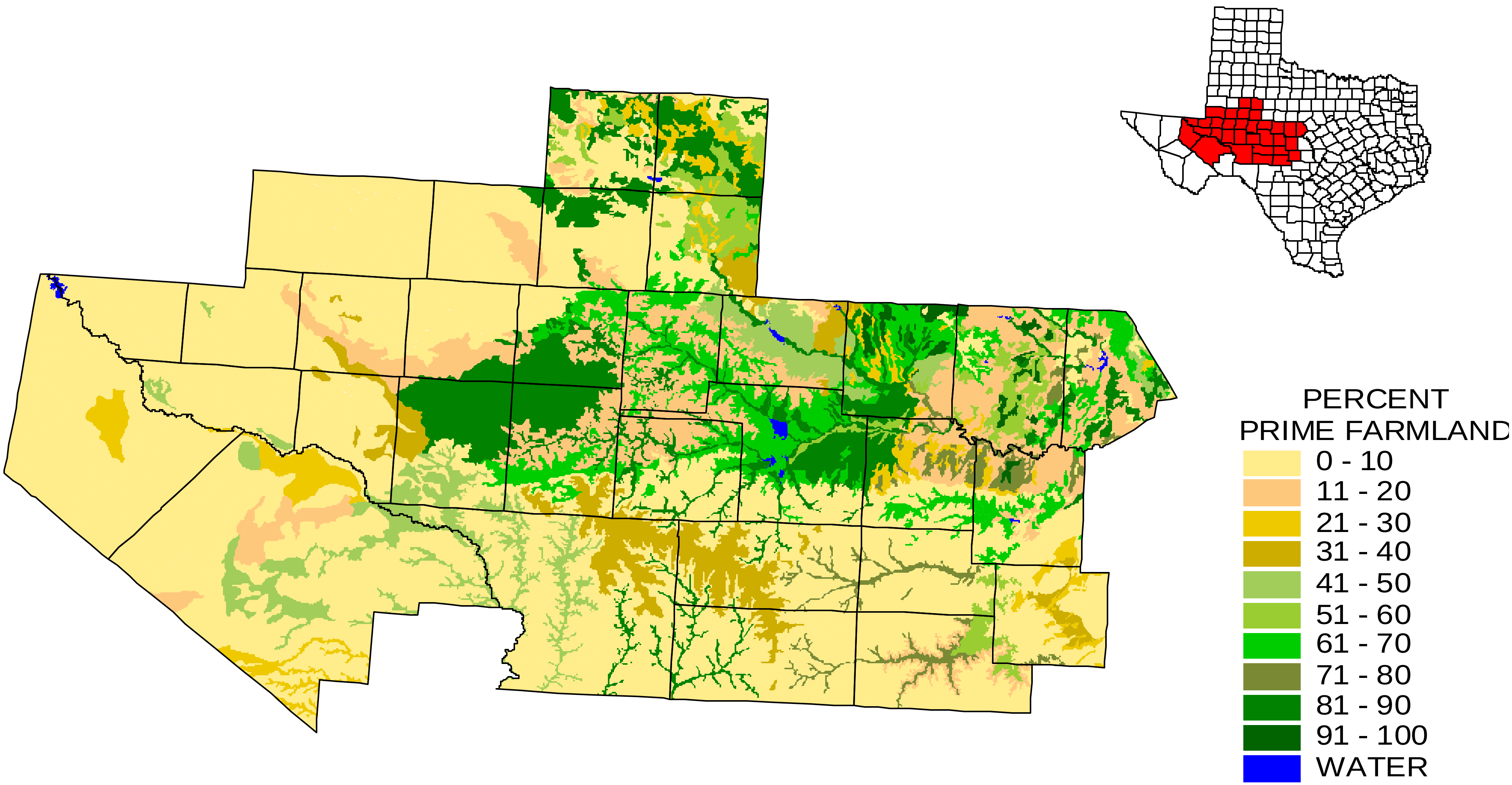
Table 1-18 (Cont'd)
1997 U.S. Department of Agriculture County Census Data for Region F

	McCulloch	Menard	Midland	Mitchell	Pecos	Reagan	Reeves	Runnels
Farms	545	291	411	378	284	123	176	896
Land in Farms (acres)	640,593	495,873	863,073	541,253	2,943,214	623,807	1,013,803	581,139
Crop Land (acres)	134,761	25,307	68,798	162,399	(D)	57,124	(D)	293,074
Harvested Crop Land (acres)	65,028	7,101	31,822	76,392	29,264	44,239	18,432	168,307
Irrigated Crop Land (acres)	1,703	1,851	12,223	1,428	24,614	23,977	18,396	2,403
Market Value ($1,000)								
Crops	$5,232	$777	$8,395	$12,890	$16,805	$8,232	$13,075	$15,547
Livestock	$12,802	$12,079	$10,347	$7,431	$23,426	$4,267	29,002	$11,854
Total	$18,034	$12,856	$18,742	$20,321	$40,231	$12,499	$42,077	$27,401

	Schleicher	Scurry	Sterling	Sutton	Tom Green	Upton	Ward	Winkler	Total
Farms	284	606	67	211	880	96	85	39	11,032
Land in Farms (acres)	738,704	478,576	705,614	924,748	958,722	746,269	363,034	487,734	23,600,488
Crop Land (acres)	44,656	209,982	13,952	8,976	217,069	(D)	(D)	(D)	2,632,591
Harvested Crop Land (acres)	20,435	82,398	2,941	2,235	164,986	17,875	2,094	(D)	1,383,905
Irrigated Crop Land (acres)	1,164	1,404	241	378	44,296	11,831	1,588	(D)	243,842
Market Value ($1,000)									
Crops	$1,763	$14,048	$171	$189	$26,962	$4,093	$865	(D)	$241,521
Livestock	$9,920	$10,307	$8,360	$8,994	$58,914	$3,559	$935	(D)	$352,301
Total	$11,683	$24,355	$8,531	$9,183	$85,876	$7,652	$1,800	$1,841	$595,663

NOTES: (D) – Data withheld to avoid disclosing data for individual farms
Data are from the U.S. Department of Agriculture (USDA, April 1999).

Figure 1-19
Prime Farmland as a Percentage of Total Area
Counties in Region F



Shrimp farming is a relatively new business in West Texas. Presently, 150 acres of ponds are located in Pecos and Ward Counties with plans to expand at a rate of 12 to 15 percent per year. Estimated water usage is 3,300 acre-feet per year of salt water from the Cenezoic Pecos Alluvium. Because the water used in this industry has a TDS range of 3,000 to 20,000 parts per million, it is not in direct competition with most other uses.

1.4.5 Mineral Resources

Oil and natural gas fields are significant natural resources throughout Region F. Figure 1-20 shows producing oil wells in Texas and Figure 1-21 shows producing gas wells in Texas. There is significant number of oil wells in most of Region F except Kimble and Mason Counties. Figure 1-22 shows the top 20 producing oil fields and the top 20 producing gas fields in Texas in 1997 (Texas Railroad Commission, April 1999). Eight of the top-producing oil fields and six of the top gas fields are located in Region F.

Other significant mineral resources in Region F include lignite resources in Brown and Coleman Counties and stone, sand and gravel in various parts of the Region.

1.5 Water Providers in Region F

Water providers in Region F include regional wholesale suppliers such as river authorities and some water districts, and retail suppliers (cities and towns, water supply corporations, special utility districts, and private water companies.) Cities and towns provide most of the retail water service in Region F, with significant contributions from other types of suppliers.

1.5.1 Regional Water Suppliers

There are three entities which provide regional water service in Region F and do not serve as retail suppliers: Colorado River Municipal Water District (CRMWD) Brown County Water Improvement District Number One (BCWID), and the Upper Colorado River Authority (UCRA).

Figures 1-20 & 1-21

Figure 1-22

Colorado River Municipal Water District (CRMWD). CRMWD supplies raw water to Big Spring, Odessa, Snyder, Midland and San Angelo, as well as several smaller cities in Ward, Ector, Midland, Howard and Coke Counties. CRMWD owns and operates Lakes J.B. Thomas, E.V. Spence, and O.H. Ivie, as well as several chloride control reservoirs. The district's water supply system also includes well fields in Ward and Martin Counties. Table 1-19 is a list of 1997 sales by the CRMWD, which totaled 56,790 acre-feet.

Brown County Water Improvement District Number One (BCWID). The 1997 sales by the BCWID totaled 9,915 acre-feet and are listed in Table 1-20. BCWID supplies raw water and treated water from Lake Brownwood to the Cities of Brownwood, Early, Bangs and Santa Anna, and rural areas of Brown County, as well as irrigation water in Brown County.

Upper Colorado River Authority (UCRA). The UCRA is the owner of water rights in O.C. Fisher Reservoir in Tom Green County and Mountain Creek Lake in Coke County. These rights have been contracted to the Cities of San Angelo and Robert Lee, respectively. Table 1-21 is a list of 1996 diversions from UCRA sources, which totaled 817 acre-feet.

Table 1-19
Fiscal Year 1997 Sales by the Colorado River Municipal Water District

Customer	Total Water Sales (Acre-Feet)
Odessa	20,890
Big Spring	6,844
Snyder	3,016
Midland	21,804
Stanton	346
San Angelo	9
Robert Lee	124
Grandfalls	258
Pyote/West Tx State School	215
Others	3,284
Total	56,790

Data are from the Colorado River Municipal Water District (CRMWD, 1997)

Table 1-20
1997 Sales by the Brown County Water Improvement District Number One
(Values in Acre-Feet)

Customer	1997 Treated Water Sales	1997 Raw Water Sales
Bangs	265	-
Early	-	819
Brownwood	3,916	-
Brooksmith WSC	659	306
Santa Anna	-	10
Thunderbird Bay	-	77
Other	-	18
Irrigation	-	3,845
Total	4,840	5,075

Data are from the Brown County Water Improvement District No. 1

Table 1-21
1996 Diversions from Upper Colorado River Authority Sources

Customer	1996 Water Sales (Acre-Feet)
San Angelo	774
Robert Lee	43
Total	817

Data are from the Texas Water Development Board (TWDB CD, 1999).

1.5.2 Water Supply from Cities and Towns

Cities and towns provide most of the retail water service in Region F, and some cities also serve as retail providers to connections outside of their city limits or as wholesale suppliers by selling treated water to other water suppliers. Table 1-22 lists the cities in Region F that had over 300 acre-feet of outside municipal sales in 1997. Table 1-23 lists cities in Region F with over 100 acre-feet of total outside sales in 1997.

Table 1-22
Outside Municipal Sales by Cities

City	1997 Municipal Sales to Other Suppliers (Acre-Feet)	Major Customers
Odessa	5,099	Ector County Utility District
Snyder	534	U&F WSC, Ira WSC, City of Rotan
Colorado City	494	Mitchell County Utility Company, Westbrook ISD
Coleman	462	Coleman County WSC
Big Spring	436	Howard County WCID #1

Data are from the Texas Water Development Board (TWDB CD, 1999).

Table 1-23
Water Supplied by Selected Cities in Region F

Supplier	Type	County	1997 Sales in Acre-Feet				
			Outside Municipal Sales	Industrial Sales	Municipal Sales within City	Other	Total
San Angelo	Municipal	Tom Green	359	378	19435	645	20817
Odessa	Municipal	Ector	5099	802	14996	0	20897
Big Spring	Municipal	Howard	436	604	5833	0	6873
Brownwood	Municipal	Brown	211	470	3235	0	3916
Snyder	Municipal	Scurry	534	0	3114	0	3648
Fort Stockton	Municipal	Pecos	130	0	3010	0	3140
Pecos	Municipal	Reeves	138	128	2692	0	2958
Andrews	Municipal	Andrews	235	30	2469	0	2734
Brady	Municipal	McCulloch	236	107	1753	0	2096
Coleman	Municipal	Coleman	462	7	1201	0	1670
Sonora	Municipal	Sutton	133	0	1126	0	1259
Colorado City	Municipal	Mitchell	494	0	729	0	1223
Crane	Municipal	Crane	164	63	815	0	1042
Ballinger	Municipal	Runnels	184	12	840	0	1036
Early	Municipal	Brown	294	5	504	0	803
Winters	Municipal	Runnels	183	50	515	0	748
Balmorhea	Municipal	Reeves	141	0	192	0	333

Data are from the Texas Water Development Board (TWDB CD, 1999).

1.5.3 Major Water Providers

Senate Bill 1 regulations require additional data development for major providers of water for municipal and manufacturing purposes. TWDB rules require that RWPG's identify the major water providers in their region based on the characteristics and needs of the region. A major water provider is "an entity which delivers and sells a significant amount of raw or treated water for municipal and/or manufacturing use on a wholesale and/or retail basis. The entity can be public or private (non-profit or for-profit). Examples include municipalities with wholesale customers, river authorities, and water districts" (TWDB Definition of Major Water Provider, February 1999).

There are no implications of designation as a "major water provider" except for the additional data tables required by TWDB. The major water provider data is a different way of grouping water supply information. An entity that is not designated as a major water provider will still be included in the regional water plan.

The criteria adopted by the Regional Water Planning Group to define a major water supplier are:

- A supplier who has the supply sources and infrastructure to provide more than 5,000 acre-feet of municipal or industrial water to more than one community in more than one county, and
- Is not already included in the Water Supply Plan as a city

Under these criteria, the major water providers in Region F are Colorado River Municipal Water District and Brown County Water Improvement District Number One. Table 1-24 gives some basic data on the suppliers recommended for designation as major water providers in Region F.

Table 1-24
Major Water Suppliers in Region F

Major Water Provider	1997 Wholesale Sales (Acre-Feet)			Number of Wholesale Customers		
	Raw	Treated	Total	Cities	Water Suppliers	Others
CRMWD	56,785	0	56,785	9	-	12
BCWID	5,075	4,840	9,915	4	3	-

2.0 CURRENT AND PROJECTED POPULATION AND WATER DEMAND DATA FOR THE REGION

2.1 Introduction

The population and water demand projections for Region F are based on the consensus-based projections from the 1997 State Water Plan. These projections were revised as part of the regional water supply plan. The revisions were adopted by the Region F Regional Water Planning Group (RWPG) on July 26, 1999, and approved by the Texas Water Development Board (TWDB) on September 15, 1999. Table 2-1 presents the population projections for Region F classified by water-use group, county and river basin. Table 2-2 is a summary of population projections by county. Table 2-3 presents the water demand projections for the Region classified by water-use group, county and river basin. Table 2-4 is a summary of the total water demand projections for each county. Tables 2-5 through 2-10 present county-by-county summaries of the municipal, manufacturing, irrigation, steam electric, mining and livestock water demands, respectively. Figure 2-1 compares the region's historical water use to the total water demand projections through 2050. Figure 2-2 presents the projected regional water demands for each category.

Table 2-1
Region F Population Projections by County, Category and River Basin

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Population**	**2000 Population**	**2010 Population**	**2020 Population**	**2030 Population**	**2040 Population**	**2050 Population**
Andrews	Andrews	Colorado	10,475	12,029	13,472	14,551	15,045	15,300	15,559
County-Other	Andrews	Colorado	4,005	3,719	3,793	3,871	3,902	3,939	3,721
County-Other	Andrews	Rio Grande	52	48	49	50	51	51	48
County Total			14,532	15,796	17,314	18,472	18,998	19,290	19,328
Gail	Borden	Colorado	200	193	186	172	152	129	109
County-Other	Borden	Brazos	38	41	42	39	34	29	24
County-Other	Borden	Colorado	524	573	588	541	475	399	335
County Total			762	807	816	752	661	557	468
Bangs	Brown	Colorado	1,601	1,595	1,615	1,626	1,631	1,634	1,635
Brownwood	Brown	Colorado	19,402	19,782	20,520	20,900	21,093	21,190	21,238
Early	Brown	Colorado	2,605	2,755	3,039	3,310	3,499	3,627	3,758
County-Other	Brown	Brazos	52	53	60	67	72	75	74
County-Other	Brown	Colorado	13,623	13,910	15,782	17,616	18,810	19,441	19,355
County Total			37,283	38,095	41,016	43,519	45,105	45,967	46,060
Bronte Village	Coke	Colorado	951	977	1,011	1,013	1,015	1,017	1,019
Robert Lee	Coke	Colorado	1,295	1,305	1,337	1,353	1,362	1,366	1,368
County-Other	Coke	Colorado	1,283	1,348	1,390	1,427	1,444	1,452	1,455
County Total			3,529	3,630	3,738	3,793	3,821	3,835	3,842

Table 2-1 (Cont)
Region F Population Projections by County, Category and River Basin

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Population**	**2000 Population**	**2010 Population**	**2020 Population**	**2030 Population**	**2040 Population**	**2050 Population**
Coleman	Coleman	Colorado	5,359	5,403	5,436	5,453	5,461	5,465	5,467
Santa Anna	Coleman	Colorado	1,238	1,235	1,235	1,235	1,235	1,235	1,235
County-Other	Coleman	Colorado	3,291	3,404	3,541	3,610	3,645	3,663	3,672
County Total			9,888	10,042	10,212	10,298	10,341	10,363	10,374
Eden	Concho	Colorado	1,702	1,631	1,690	1,750	1,772	1,807	1,855
County-Other	Concho	Colorado	1,468	1,485	1,539	1,594	1,613	1,552	1,688
County Total			3,170	3,116	3,229	3,344	3,385	3,359	3,543
Crane	Crane	Rio Grande	3,471	3,682	4,270	4,716	5,115	5,362	5,621
County-Other	Crane	Rio Grande	1,177	1,380	1,594	1,755	1,899	1,986	2,060
County Total			4,648	5,062	5,864	6,471	7,014	7,348	7,681
Ozona	Crockett	Rio Grande	3,424	3,540	3,701	3,846	3,894	3,937	3,980
County-Other	Crockett	Colorado	25	26	28	29	32	32	34
County-Other	Crockett	Rio Grande	1,095	1,150	1,202	1,271	1,373	1,418	1,450
County Total			4,544	4,716	4,931	5,146	5,299	5,387	5,464
Odessa	Ector	Colorado	93,580	100,144	111,610	124,486	139,866	151,325	163,755
County-Other	Ector	Colorado	29,336	31,909	35,622	39,327	43,138	46,362	44,782
County-Other	Ector	Rio Grande	295	335	374	413	453	487	471
County Total			123,211	132,388	147,606	164,226	183,457	198,174	209,008
Garden City	Glasscock	Colorado	337	373	406	431	442	448	454
County-Other	Glasscock	Colorado	1,123	1,241	1,414	1,540	1,596	1,645	1,685
County Total			1,460	1,614	1,820	1,971	2,038	2,093	2,139

Table 2-1 (Cont)
Region F Population by County, Category and River Basin

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Population**	**2000 Population**	**2010 Population**	**2020 Population**	**2030 Population**	**2040 Population**	**2050 Population**
Big Spring	Howard	Colorado	23,558	24,528	25,451	25,885	26,148	26,281	26,348
Coahoma	Howard	Colorado	1,306	1,369	1,435	1,477	1,492	1,500	1,504
County-Other	Howard	Colorado	8,421	8,533	9,214	9,784	9,884	9,933	9,958
County Total			33,285	34,430	36,100	37,146	37,524	37,714	37,810
Mertzon	Irion	Colorado	679	731	767	779	785	788	790
County-Other	Irion	Colorado	871	1,051	1,103	1,121	1,130	1,135	1,137
County Total			1,550	1,782	1,870	1,900	1,915	1,923	1,927
Junction	Kimble	Colorado	2,842	2,757	2,810	2,837	2,851	2,858	2,861
County-Other	Kimble	Colorado	1,662	1,689	1,808	1,869	1,900	1,916	1,924
County Total			4,504	4,446	4,618	4,706	4,751	4,774	4,785
Mentone	Loving	Rio Grande	51	51	45	35	29	24	20
County-Other	Loving	Rio Grande	46	54	53	49	45	38	29
County Total			97	105	98	84	74	62	49
Brady	McCulloch	Colorado	6,065	5,955	5,964	6,020	6,048	6,062	6,069
County-Other	McCulloch	Colorado	2,797	2,825	2,819	2,820	2,821	2,821	2,821
County Total			8,862	8,780	8,783	8,840	8,869	8,883	8,890
Stanton	Martin	Colorado	2,567	2,738	2,969	3,135	3,151	3,154	3,157
County-Other	Martin	Colorado	2,489	2,621	2,827	2,983	2,993	2,996	2,911
County Total			5,056	5,359	5,796	6,118	6,144	6,150	6,068
Mason	Mason	Colorado	2,110	2,157	2,172	2,179	2,183	2,185	2,186
County-Other	Mason	Colorado	1,468	1,535	1,598	1,630	1,646	1,654	1,658

Table 2-1 (Cont)
Region F Population by County, Category and River Basin

			Historical	Projected					
User Group Name	County	River Basin	1996 Population	2000 Population	2010 Population	2020 Population	2030 Population	2040 Population	2050 Population
County Total			3,578	3,692	3,770	3,809	3,829	3,839	3,844
Menard	Menard	Colorado	1,609	1,652	1,670	1,715	1,715	1,716	1,717
County-Other	Menard	Colorado	730	611	613	606	595	588	584
County Total			2,339	2,263	2,283	2,321	2,310	2,304	2,301
Midland	Midland	Colorado	97,549	109,885	127,222	144,454	161,267	181,036	203,228
Odessa	Midland	Colorado	538	239	274	299	332	373	419
County-Other	Midland	Colorado	18,680	19,056	19,217	19,890	20,864	22,564	19,447
County Total			116,767	129,180	146,713	164,643	182,463	203,973	223,094
Colorado City	Mitchell	Colorado	5,706	5,968	6,047	6,071	5,930	5,809	5,690
Loraine	Mitchell	Colorado	723	734	714	680	658	663	670
County-Other	Mitchell	Brazos	4	5	5	5	5	5	4
County-Other	Mitchell	Colorado	2,429	3,228	3,296	3,336	3,260	3,165	2,958
County Total			8,862	9,935	10,062	10,092	9,853	9,642	9,322
Fort Stockton	Pecos	Rio Grande	9,184	9,563	10,584	11,246	11,438	11,548	11,659
Iraan	Pecos	Rio Grande	1,294	1,768	2,048	2,212	2,293	2,360	2,429
County-Other	Pecos	Rio Grande	6,037	5,267	5,783	6,126	6,210	6,246	6,062
County Total			16,515	16,598	18,415	19,584	19,941	20,154	20,150
Big Lake	Reagan	Colorado	3,412	4,133	4,569	4,888	4,994	5,550	6,168
County-Other	Reagan	Colorado	855	888	985	1,059	1,088	1,217	830
County-Other	Reagan	Rio Grande	10	11	12	13	13	15	10
County Total			4,277	5,032	5,566	5,960	6,095	6,782	7,008

Table 2-1 (Cont)
Region F Population by County, Category and River Basin

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Population**	**2000 Population**	**2010 Population**	**2020 Population**	**2030 Population**	**2040 Population**	**2050 Population**
Balmorhea	Reeves	Rio Grande	824	832	830	812	778	729	670
Pecos	Reeves	Rio Grande	11,634	13,389	14,746	15,857	16,415	16,867	17,331
Toyah	Reeves	Rio Grande	115	118	117	114	110	103	95
County-Other	Reeves	Rio Grande	2,736	3,241	3,663	4,029	4,238	4,428	4,450
County Total			15,309	17,580	19,356	20,812	21,541	22,127	22,546
Ballinger	Runnels	Colorado	4,239	4,223	4,451	4,492	4,545	4,597	4,754
Miles	Runnels	Colorado	909	898	916	915	897	860	835
Winters	Runnels	Colorado	3,011	2,955	3,121	3,320	3,536	3,735	3,945
County-Other	Runnels	Colorado	3,769	3,602	3,841	4,311	4,833	5,340	5,765
County Total			11,928	11,678	12,329	13,038	13,811	14,532	15,299
Eldorado	Schleicher	Colorado	2,201	2,206	2,429	2,565	2,616	2,652	2,688
County-Other	Schleicher	Colorado	862	755	790	804	793	777	743
County-Other	Schleicher	Rio Grande	262	229	240	244	241	235	225
County Total			3,325	3,190	3,459	3,613	3,650	3,664	3,656
Snyder	Scurry	Colorado	12,061	13,482	14,516	15,330	15,942	16,342	16,752
County-Other	Scurry	Brazos	1,648	1,530	1,607	1,660	1,689	1,690	1,721
County-Other	Scurry	Colorado	5,318	4,941	5,188	5,359	5,451	5,455	5,555
County Total			19,027	19,953	21,311	22,349	23,082	23,487	24,028
Sterling City	Sterling	Colorado	1,008	1,217	1,362	1,468	1,512	1,541	1,571
County-Other	Sterling	Colorado	386	341	359	368	364	358	275
County Total			1,394	1,558	1,721	1,836	1,876	1,899	1,846

Table 2-1 (Cont)
Region F Population by County, Category and River Basin

			Historical	Projected					
User Group Name	County	River Basin	1996 Population	2000 Population	2010 Population	2020 Population	2030 Population	2040 Population	2050 Population
Sonora	Sutton	Rio Grande	3,045	3,097	3,479	3,736	3,854	3,933	4,014
County-Other	Sutton	Colorado	228	227	226	224	204	186	162
County-Other	Sutton	Rio Grande	1,258	1,253	1,249	1,237	1,129	1,030	897
County Total			4,531	4,577	4,954	5,197	5,187	5,149	5,073
San Angelo	Tom Green	Colorado	89,567	99,750	113,112	126,204	134,138	146,028	158,972
County-Other	Tom Green	Colorado	15,406	14,904	17,112	18,492	24,477	26,653	26,790
County Total			104,973	114,654	130,224	144,696	158,615	172,681	185,762
McCamey	Upton	Rio Grande	2,298	2,665	2,943	3,142	3,147	3,113	3,079
Rankin	Upton	Rio Grande	928	1,102	1,275	1,338	1,375	1,406	1,438
County-Other	Upton	Colorado	290	356	377	394	408	420	417
County-Other	Upton	Rio Grande	628	771	816	854	882	908	903
County Total			4,144	4,894	5,411	5,728	5,812	5,847	5,837
Barstow	Ward	Rio Grande	560	501	470	431	402	391	382
Grandfalls	Ward	Rio Grande	619	612	602	581	560	563	571
Monahans	Ward	Rio Grande	7,851	8,392	8,847	9,054	8,857	8,548	8,250
Thorntonville	Ward	Rio Grande	756	749	745	727	694	649	611
Wickett	Ward	Rio Grande	543	490	459	423	414	405	397
County-Other	Ward	Rio Grande	2,557	3,225	3,699	3,990	4,029	3,952	3,674
County Total			12,886	13,969	14,822	15,206	14,956	14,508	13,885

Table 2-1 (Cont.)
Region F Population by County, Category and River Basin

			<u>**Historical**</u>	<u>**Projected**</u>					
User Group Name	**County**	**River Basin**	**1996 Population**	**2000 Population**	**2010 Population**	**2020 Population**	**2040 Population**	**2040 Population**	**2050 Population**
Kermit	Winkler	Rio Grande	6,534	7,348	7,952	8,393	8,523	8,611	8,700
Wink	Winkler	Rio Grande	1,150	1,303	1,430	1,517	1,544	1,567	1,590
County-Other	Winkler	Colorado	5	6	6	6	6	6	5
County-Other	Winkler	Rio Grande	608	625	654	683	691	691	525
County Total			8,297	9,282	10,042	10,599	10,764	10,875	10,820
Region F		Brazos	1,742	1,629	1,714	1,771	1,800	1,799	1,823
Region F		Colorado	521,749	559,783	618,604	675,604	730,685	783,942	828,443
Region F		Rio Grande	71,042	76,791	83,931	88,894	90,696	91,601	91,641
Region Total			594,533	638,203	704,249	766,269	823,181	877,342	921,907

Freese and Nichols, Inc., 1999

Table 2-2
Population Projections for Region F Counties

	Historical	Projected					
County	1996 Population	2000 Population	2010 Population	2020 Population	2030 Population	2040 Population	2050 Population
Andrews	14,532	15,796	17,314	18,472	18,998	19,290	19,328
Borden	762	807	816	752	661	557	468
Brown	37,283	38,095	41,016	43,519	45,105	45,967	46,060
Coke	3,529	3,630	3,738	3,793	3,821	3,835	3,842
Coleman	9,888	10,042	10,212	10,298	10,341	10,363	10,374
Concho	3,170	3,116	3,229	3,344	3,385	3,359	3,543
Crane	4,648	5,062	5,864	6,471	7,014	7,348	7,681
Crockett	4,544	4,716	4,931	5,146	5,299	5,387	5,464
Ector	123,211	132,388	147,606	164,226	183,457	198,174	209,008
Glasscock	1,460	1,614	1,820	1,971	2,038	2,093	2,139
Howard	33,285	34,430	36,100	37,146	37,524	37,714	37,810
Irion	1,550	1,782	1,870	1,900	1,915	1,923	1,927
Kimble	4,504	4,446	4,618	4,706	4,751	4,774	4,785
Loving	97	105	98	84	74	62	49
McCulloch	8,862	8,780	8,783	8,840	8,869	8,883	8,890
Martin	5,056	5,359	5,796	6,118	6,144	6,150	6,068
Mason	3,578	3,692	3,770	3,809	3,829	3,839	3,844
Menard	2,339	2,263	2,283	2,321	2,310	2,304	2,301
Midland	116,767	129,180	146,713	164,643	182,463	203,973	223,094
Mitchell	8,862	9,935	10,062	10,092	9,853	9,642	9,322
Pecos	16,515	16,598	18,415	19,584	19,941	20,154	20,150
Reagan	4,277	5,032	5,566	5,960	6,095	6,782	7,008
Reeves	15,309	17,580	19,356	20,812	21,541	22,127	22,546
Runnels	11,928	11,678	12,329	13,038	13,811	14,532	15,299
Schleicher	3,325	3,190	3,459	3,613	3,650	3,664	3,656
Scurry	19,027	19,953	21,311	22,349	23,082	23,487	24,028
Sterling	1,394	1,558	1,721	1,836	1,876	1,899	1,846
Sutton	4,531	4,577	4,954	5,197	5,187	5,149	5,073
Tom Green	104,973	114,654	130,224	144,696	158,615	172,681	185,762
Upton	4,144	4,894	5,411	5,728	5,812	5,847	5,837
Ward	12,886	13,969	14,822	15,206	14,956	14,508	13,885
Winkler	8,297	9,282	10,042	10,599	10,764	10,875	10,820
Total	594,533	638,203	704,249	766,269	823,181	877,342	921,907

Freese and Nichols, Inc., 1999

Table 2-3
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Andrews	Andrews	Colorado	2,616	2,924	3,094	3,178	3,236	3,239	3,277
County-Other	Andrews	Colorado	800	578	557	535	521	511	487
County-Other	Andrews	Rio Grande	10	6	5	5	5	5	4
County Total Municipal			3,426	3,508	3,656	3,718	3,762	3,755	3,768
Manufacturing	Andrews	Colorado	47	36	38	39	39	45	51
Manufacturing	Andrews	Rio Grande	0	0	0	0	0	0	0
County Total Manufacturing			47	36	38	39	39	45	51
Steam Electric Power	Andrews	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Andrews	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Andrews	Colorado	3,192	4,221	2,497	1,486	1,140	923	866
Mining	Andrews	Rio Grande	120	143	149	168	188	211	237
County Total Mining			3,312	4,364	2,646	1,654	1,328	1,134	1,103
Irrigation	Andrews	Colorado	13,783	18,931	18,773	18,616	18,459	18,301	18,144
Irrigation	Andrews	Rio Grande	0	0	0	0	0	0	0
County Total Irrigation			13,783	18,931	18,773	18,616	18,459	18,301	18,144
Livestock	Andrews	Colorado	344	355	355	355	355	355	355
Livestock	Andrews	Rio Grande	76	79	79	79	79	79	79
County Total Livestock			420	434	434	434	434	434	434
County Total	Andrews	Colorado	20,782	27,045	25,314	24,209	23,750	23,374	23,180
		Rio Grande	206	228	233	252	272	295	320
			20,988	27,273	25,547	24,461	24,022	23,669	23,500

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Gail	Borden	Colorado	99	48	44	39	33	28	24
County-Other	Borden	Brazos	5	5	5	4	3	3	2
County-Other	Borden	Colorado	65	70	67	57	46	39	32
County Total Municipal			169	123	116	100	82	70	58
Manufacturing	Borden	Brazos	0	0	0	0	0	0	0
Manufacturing	Borden	Colorado	1	48	57	68	80	94	109
County Total Manufacturing			1	48	57	68	80	94	109
Steam Electric Power	Borden	Brazos	0	0	0	0	0	0	0
Steam Electric Power	Borden	Colorado	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Borden	Brazos	0	0	0	0	0	0	0
Mining	Borden	Colorado	990	934	778	701	677	665	672
County Total Mining			990	934	778	701	677	665	672
Irrigation	Borden	Brazos	1,636	3,961	3,956	3,951	3,945	3,940	3,935
Irrigation	Borden	Colorado	3,430	5,701	5,693	5,685	5,678	5,670	5,662
County Total Irrigation			5,066	9,662	9,649	9,636	9,623	9,610	9,597
Livestock	Borden	Brazos	11	11	11	11	11	11	11
Livestock	Borden	Colorado	268	264	264	264	264	264	264
County Total Livestock			279	275	275	275	275	275	275
County Total	Borden	Brazos	1,652	3,977	3,972	3,966	3,959	3,954	3,948
		Colorado	4,853	7,065	6,903	6,814	6,778	6,760	6,763
			6,505	11,042	10,875	10,780	10,737	10,714	10,711

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	County	River Basin	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Bangs	Brown	Colorado	197	273	263	249	243	236	234
Brownwood	Brown	Colorado	3,707	4,502	4,463	4,335	4,280	4,205	4,167
Early	Brown	Colorado	518	548	577	598	621	631	650
County-Other	Brown	Brazos	6	9	10	10	11	11	11
County-Other	Brown	Colorado	1,622	2,446	2,632	2,758	2,881	2,892	2,836
County Total Municipal			6,050	7,778	7,945	7,950	8,036	7,975	7,898
Manufacturing	Brown	Brazos	0	0	0	0	0	0	0
Manufacturing	Brown	Colorado	501	485	524	567	608	660	714
County Total Manufacturing			501	485	524	567	608	660	714
Steam Electric Power	Brown	Brazos	0	0	0	0	0	0	0
Steam Electric Power	Brown	Colorado	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Brown	Brazos	5	5	5	5	6	6	6
Mining	Brown	Colorado	2,422	295	273	191	171	144	128
County Total Mining			2,427	300	278	196	177	150	134
Irrigation	Brown	Brazos	0	0	0	0	0	0	0
Irrigation	Brown	Colorado	12,085	10,526	10,491	10,455	10,420	10,384	10,348
County Total Irrigation			12,085	10,526	10,491	10,455	10,420	10,384	10,348
Livestock	Brown	Brazos	46	35	35	35	35	35	35
Livestock	Brown	Colorado	2,012	1,563	1,563	1,563	1,563	1,563	1,563
County Total Livestock			2,058	1,598	1,598	1,598	1,598	1,598	1,598

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
County Total	Brown	Brazos	57	49	50	50	52	52	52
		Colorado	23,064	20,638	20,786	20,716	20,787	20,715	20,640
			23,121	20,687	20,836	20,766	20,839	20,767	20,692
Bronte Village	Coke	Colorado	385	228	224	214	209	208	206
Robert Lee	Coke	Colorado	193	399	391	377	371	369	368
County-Other	Coke	Colorado	206	178	178	171	175	171	172
County Total Municipal			784	805	793	762	755	748	746
Manufacturing	Coke	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Coke	Colorado	581	835	835	835	835	835	835
Mining	Coke	Colorado	304	261	218	159	121	93	74
Irrigation	Coke	Colorado	665	667	666	666	665	664	664
Livestock	Coke	Colorado	454	722	722	722	722	722	722
County Total	Coke	Colorado	2,788	3,290	3,234	3,144	3,098	3,062	3,041
Coleman	Coleman	Colorado	1,375	1,387	1,340	1,284	1,255	1,244	1,238
Santa Anna	Coleman	Colorado	137	258	244	230	225	219	219
County-Other	Coleman	Colorado	400	414	403	378	361	359	355
County Total Municipal			1,912	2,059	1,987	1,892	1,841	1,822	1,812
Manufacturing	Coleman	Colorado	1	1	1	2	2	2	3

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Steam Electric Power	Coleman	Colorado	0	0	0	0	0	0	0
Mining	Coleman	Colorado	16	15	16	16	17	17	17
Irrigation	Coleman	Colorado	1,379	1,376	1,364	1,353	1,341	1,330	1,319
Livestock	Coleman	Colorado	1,777	1,361	1,361	1,361	1,361	1,361	1,361
County Total	Coleman	Colorado	5,085	4,812	4,729	4,624	4,562	4,532	4,512
Eden	Concho	Colorado	457	530	531	529	531	533	545
County-Other	Concho	Colorado	364	269	261	255	252	238	254
County Total Municipal			821	799	792	784	783	771	799
Manufacturing	Concho	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Concho	Colorado	0	0	0	0	0	0	0
Mining	Concho	Colorado	0	0	0	0	0	0	0
Irrigation	Concho	Colorado	4,756	7,082	7,054	7,026	6,998	6,970	6,943
Livestock	Concho	Colorado	591	959	959	959	959	959	959
County Total	Concho	Colorado	6,168	8,840	8,805	8,769	8,740	8,700	8,701

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Crane	Crane	Rio Grande	787	771	842	882	934	961	1,007
County-Other	Crane	Rio Grande	227	555	602	631	669	689	709
County Total Municipal			1,014	1,326	1,444	1,513	1,603	1,650	1,716
Manufacturing	Crane	Rio Grande	0	0	0	0	0	0	0
Steam Electric Power	Crane	Rio Grande	0	0	0	0	0	0	0
Mining	Crane	Rio Grande	2,585	2,726	2,102	1,859	1,757	1,738	1,759
Irrigation	Crane	Rio Grande	22	337	337	337	337	337	337
Livestock	Crane	Rio Grande	135	145	145	145	145	145	145
County Total	Crane	Rio Grande	3,756	4,534	4,028	3,854	3,842	3,870	3,957
Ozona	Crockett	Rio Grande	1,582	1,647	1,663	1,668	1,675	1,681	1,695
County-Other	Crockett	Colorado	5	5	5	5	5	5	6
County-Other	Crockett	Rio Grande	210	221	219	220	234	234	239
County Total Municipal			1,797	1,873	1,887	1,893	1,914	1,920	1,940
Manufacturing	Crockett	Colorado	0	0	0	0	0	0	0
Manufacturing	Crockett	Rio Grande	0	6	8	10	11	15	17
County Total Manufacturing			0	6	8	10	11	15	17
Steam Electric Power	Crockett	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Crockett	Rio Grande	1,267	1,914	4,280	4,280	4,280	4,280	4,280
County Total Steam Electric			1,267	1,914	4,280	4,280	4,280	4,280	4,280

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Mining	Crockett	Colorado	0	0	0	0	0	0	0
Mining	Crockett	Rio Grande	398	402	280	226	202	185	190
County Total Mining			398	402	280	226	202	185	190
Irrigation	Crockett	Colorado	0	0	0	0	0	0	0
Irrigation	Crockett	Rio Grande	374	439	432	424	417	410	403
County Total Irrigation			374	439	432	424	417	410	403
Livestock	Crockett	Colorado	17	29	29	29	29	29	29
Livestock	Crockett	Rio Grande	571	959	959	959	959	959	959
County Total Livestock			588	988	988	988	988	988	988
County Total	Crockett	Colorado	22	34	34	34	34	34	35
		Rio Grande	4,402	5,582	7,833	7,777	7,767	7,749	7,766
			4,424	5,616	7,867	7,811	7,801	7,783	7,801
Odessa	Ector	Colorado	20,174	21,599	22,821	24,198	26,561	28,229	30,364
County-Other	Ector	Colorado	4,693	5,257	5,508	5,727	6,135	6,437	6,168
County-Other	Ector	Rio Grande	48	55	58	60	64	68	65
County Total Municipal			24,915	26,911	28,387	29,985	32,760	34,734	36,597
Manufacturing	Ector	Colorado	2,103	2,082	2,262	2,334	2,376	2,516	2,635
Manufacturing	Ector	Rio Grande	19	70	77	79	81	86	90
County Total Manufacturing			2,122	2,152	2,339	2,413	2,457	2,602	2,725
Steam Electric Power	Ector	Colorado	0	6,700	6,700	6,700	6,700	6,700	6,700
Steam Electric Power	Ector	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	6,700	6,700	6,700	6,700	6,700	6,700

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	County	River Basin	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Mining	Ector	Colorado	7,213	7,470	7,151	6,748	6,552	6,458	6,418
Mining	Ector	Rio Grande	120	143	143	144	145	146	147
County Total Mining			7,333	7,613	7,294	6,892	6,697	6,604	6,565
Irrigation	Ector	Colorado	6,971	8,516	8,415	8,315	8,215	8,115	8,015
Irrigation	Ector	Rio Grande	445	86	85	84	83	82	81
County Total Irrigation			7,416	8,602	8,500	8,399	8,298	8,197	8,096
Livestock	Ector	Colorado	169	149	149	149	149	149	149
Livestock	Ector	Rio Grande	79	69	69	69	69	69	69
County Total Livestock			248	218	218	218	218	218	218
County Total	Ector	Colorado	34,110	44,303	45,855	47,423	50,136	52,146	54,031
		Rio Grande	711	423	432	436	442	451	452
			34,821	44,726	46,287	47,859	50,578	52,597	54,483
Garden City	Glasscock	Colorado	42	43	43	42	42	41	41
County-Other	Glasscock	Colorado	156	160	167	169	169	168	170
County Total Municipal			198	203	210	211	211	209	211
Manufacturing	Glasscock	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Glasscock	Colorado	0	0	0	0	0	0	0
Mining	Glasscock	Colorado	7	5	3	1	1	0	0
Irrigation	Glasscock	Colorado	55,187	68,521	67,979	67,437	66,895	66,353	65,810

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Livestock	Glasscock	Colorado	159	241	241	241	241	241	241
County Total	Glasscock	Colorado	55,551	68,970	68,433	67,890	67,348	66,803	66,262
Big Spring	Howard	Colorado	5,146	7,092	7,045	6,846	6,798	6,715	6,732
Coahoma	Howard	Colorado	138	174	172	165	160	154	155
County-Other	Howard	Colorado	1,318	1,422	1,521	1,565	1,538	1,529	1,545
County Total Municipal			6,602	8,688	8,738	8,576	8,496	8,398	8,432
Manufacturing	Howard	Colorado	1,668	2,344	2,540	2,677	2,788	3,020	3,244
Steam Electric Power	Howard	Colorado	1,303	1,380	1,380	1,380	1,380	1,380	1,380
Mining	Howard	Colorado	1,816	452	431	421	426	431	440
Irrigation	Howard	Colorado	1,273	4,724	4,671	4,618	4,565	4,512	4,459
Livestock	Howard	Colorado	244	396	396	396	396	396	396
County Total	Howard	Colorado	12,906	17,984	18,156	18,068	18,051	18,137	18,351
Mertzon	Irion	Colorado	116	125	125	120	116	115	114
County-Other	Irion	Colorado	104	130	129	123	120	116	115
County Total Municipal			220	255	254	243	236	231	229
Manufacturing	Irion	Colorado	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Steam Electric Power	Irion	Colorado	0	0	0	0	0	0	0
Mining	Irion	Colorado	129	6	5	3	2	2	2
Irrigation	Irion	Colorado	2,959	3,296	3,227	3,157	3,087	3,018	2,948
Livestock	Irion	Colorado	322	487	487	487	487	487	487
County Total	Irion	Colorado	3,630	4,044	3,973	3,890	3,812	3,738	3,666
Junction	Kimble	Colorado	862	940	924	894	883	878	877
County-Other	Kimble	Colorado	211	217	230	227	223	218	219
County Total Municipal			1,073	1,157	1,154	1,121	1,106	1,096	1,096
Manufacturing	Kimble	Colorado	416	1,637	1,777	1,849	1,909	2,067	2,229
Steam Electric Power	Kimble	Colorado	0	0	0	0	0	0	0
Mining	Kimble	Colorado	91	105	100	99	98	100	103
Irrigation	Kimble	Colorado	1,020	1,128	1,089	1,049	1,009	970	930
Livestock	Kimble	Colorado	425	564	564	564	564	564	564
County Total	Kimble	Colorado	3,025	4,591	4,684	4,682	4,686	4,797	4,922

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Mentone	Loving	Rio Grande	6	7	5	4	3	3	2
County-Other	Loving	Rio Grande	6	6	6	5	4	4	3
County Total Municipal			12	13	11	9	7	7	5
Manufacturing	Loving	Rio Grande	0	0	0	0	0	0	0
Steam Electric Power	Loving	Rio Grande	0	0	0	0	0	0	0
Mining	Loving	Rio Grande	3	3	2	3	3	3	3
Irrigation	Loving	Rio Grande	583	582	580	578	576	574	572
Livestock	Loving	Rio Grande	54	65	65	65	65	65	65
County Total	Loving	Rio Grande	652	663	658	655	651	649	645
Brady	McCulloch	Colorado	1,750	1,928	1,871	1,827	1,803	1,779	1,775
County-Other	McCulloch	Colorado	988	987	950	916	901	888	885
County Total Municipal			2,738	2,915	2,821	2,743	2,704	2,667	2,660
Manufacturing	McCulloch	Colorado	831	844	903	963	1,027	1,090	1,153
Steam Electric Power	McCulloch	Colorado	0	0	0	0	0	0	0
Mining	McCulloch	Colorado	140	146	152	158	164	170	176
Irrigation	McCulloch	Colorado	1,563	2,964	2,928	2,891	2,855	2,818	2,782

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	County	River Basin	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Livestock	McCulloch	Colorado	749	1,229	1,229	1,229	1,229	1,229	1,229
County Total	McCulloch	Colorado	6,021	8,098	8,033	7,984	7,979	7,974	8,000
Stanton	Martin	Colorado	382	399	406	404	395	382	378
County-Other	Martin	Colorado	330	308	310	306	297	284	273
County Total Municipal			712	707	716	710	692	666	651
Manufacturing	Martin	Colorado	31	32	35	36	36	38	40
Steam Electric Power	Martin	Colorado	0	0	0	0	0	0	0
Mining	Martin	Colorado	852	1,228	1,015	990	987	978	1,006
Irrigation	Martin	Colorado	12,641	14,221	13,976	13,731	13,486	13,241	12,997
Livestock	Martin	Colorado	261	436	436	436	436	436	436
County Total	Martin	Colorado	14,497	16,624	16,178	15,903	15,637	15,359	15,130
Mason	Mason	Colorado	766	783	760	735	726	718	715
County-Other	Mason	Colorado	185	198	196	186	182	177	175
County Total Municipal			951	981	956	921	908	895	890
Manufacturing	Mason	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Mason	Colorado	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Mining	Mason	Colorado	6	12	8	4	1	0	0
Irrigation	Mason	Colorado	10,358	17,501	17,255	17,009	16,763	16,517	16,271
Livestock	Mason	Colorado	952	1,507	1,507	1,507	1,507	1,507	1,507
County Total	Mason	Colorado	12,267	20,001	19,726	19,441	19,179	18,919	18,668
Menard	Menard	Colorado	309	346	333	325	317	309	308
County-Other	Menard	Colorado	95	76	71	66	61	58	58
County Total Municipal			404	422	404	391	378	367	366
Manufacturing	Menard	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Menard	Colorado	0	0	0	0	0	0	0
Mining	Menard	Colorado	0	0	0	0	0	0	0
Irrigation	Menard	Colorado	4,173	6,080	6,061	6,041	6,021	6,002	5,982
Livestock	Menard	Colorado	471	586	586	586	586	586	586
County Total	Menard	Colorado	5,048	7,088	7,051	7,018	6,985	6,955	6,934
Midland	Midland	Colorado	26,501	28,679	31,637	34,142	37,574	41,571	46,667

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Odessa	Midland	Colorado	116	51	55	57	62	69	77
County-Other	Midland	Colorado	2,769	2,991	2,861	2,786	2,825	2,909	2,562
County Total Municipal			29,386	31,721	34,553	36,985	40,461	44,549	49,306
Manufacturing	Midland	Colorado	206	148	161	174	188	201	216
Steam Electric Power	Midland	Colorado	0	0	0	0	0	0	0
Mining	Midland	Colorado	656	669	318	159	80	26	0
Irrigation	Midland	Colorado	53,339	66,574	66,061	65,548	65,034	64,521	64,008
Livestock	Midland	Colorado	703	744	744	744	744	744	744
County Total	Midland	Colorado	84,290	99,856	101,837	103,610	106,507	110,041	114,274
Colorado City	Mitchell	Colorado	1,170	1,818	1,768	1,707	1,641	1,581	1,542
Loraine	Mitchell	Colorado	102	121	112	101	94	92	92
County-Other	Mitchell	Brazos	1	1	1	1	1	0	0
County-Other	Mitchell	Colorado	436	358	342	326	305	281	262
County Total Municipal			1,709	2,298	2,223	2,135	2,041	1,954	1,896
Manufacturing	Mitchell	Brazos	0	0	0	0	0	0	0
Manufacturing	Mitchell	Colorado	0	0	0	0	0	0	0
County Total Manufacturing			0	0	0	0	0	0	0
Steam Electric Power	Mitchell	Brazos	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Steam Electric Power	Mitchell	Colorado	4,071	4,000	4,400	5,280	6,336	7,603	9,124
County Total Steam Electric			4,071	4,000	4,400	5,280	6,336	7,603	9,124
Mining	Mitchell	Brazos	0	0	0	0	0	0	0
Mining	Mitchell	Colorado	141	223	106	53	26	9	0
County Total Mining			141	223	106	53	26	9	0
Irrigation	Mitchell	Brazos	25	0	0	0	0	0	0
Irrigation	Mitchell	Colorado	1,051	2,238	2,226	2,215	2,204	2,193	2,182
County Total Irrigation			1,076	2,238	2,226	2,215	2,204	2,193	2,182
Livestock	Mitchell	Brazos	0	0	0	0	0	0	0
Livestock	Mitchell	Colorado	389	530	530	530	530	530	530
County Total Livestock			389	530	530	530	530	530	530
County Total	Mitchell	Brazos	26	1	1	1	1	0	0
		Colorado	7,360	9,288	9,484	10,212	11,136	12,289	13,732
			7,386	9,289	9,485	10,213	11,137	12,289	13,732
Fort Stockton	Pecos	Rio Grande	3,171	2,892	3,047	3,086	3,101	3,092	3,108
Iraan	Pecos	Rio Grande	393	525	580	600	616	627	642
County-Other	Pecos	Rio Grande	1,025	730	746	733	722	705	671
County Total Municipal			4,589	4,147	4,373	4,419	4,439	4,424	4,421
Manufacturing	Pecos	Rio Grande	4	7	8	10	11	13	15
Steam Electric Power	Pecos	Rio Grande	0	6	6	6	6	6	6

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Mining	Pecos	Rio Grande	264	322	267	263	266	270	277
Irrigation	Pecos	Rio Grande	76,442	82,458	81,190	79,921	78,652	77,383	76,114
Livestock	Pecos	Rio Grande	1,145	1,351	1,351	1,351	1,351	1,351	1,351
County Total	Pecos	Rio Grande	82,444	88,291	87,195	85,970	84,725	83,447	82,184
Big Lake	Reagan	Colorado	668	880	921	942	945	1,032	1,140
County-Other	Reagan	Colorado	107	115	119	120	119	128	86
County-Other	Reagan	Rio Grande	1	1	1	1	1	2	1
County Total Municipal			776	996	1,041	1,063	1,065	1,162	1,227
Manufacturing	Reagan	Colorado	0	0	0	0	0	0	0
Manufacturing	Reagan	Rio Grande	0	0	0	0	0	0	0
County Total Manufacturing			0	0	0	0	0	0	0
Steam Electric Power	Reagan	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Reagan	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Reagan	Colorado	1,742	1,589	1,524	1,474	1,427	1,439	1,481
Mining	Reagan	Rio Grande	0	0	0	0	0	0	0
County Total Mining			1,742	1,589	1,524	1,474	1,427	1,439	1,481
Irrigation	Reagan	Colorado	44,188	46,697	45,937	45,177	44,417	43,657	42,897
Irrigation	Reagan	Rio Grande	0	0	0	0	0	0	0
County Total Irrigation			44,188	46,697	45,937	45,177	44,417	43,657	42,897

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Livestock	Reagan	Colorado	149	162	162	162	162	162	162
Livestock	Reagan	Rio Grande	11	12	12	12	12	12	12
County Total Livestock			160	174	174	174	174	174	174
County Total	Reagan	Colorado	46,854	49,443	48,663	47,875	47,070	46,418	45,766
		Rio Grande	12	13	13	13	13	14	13
			46,866	49,456	48,676	47,888	47,083	46,432	45,779
Balmorhea	Reeves	Rio Grande	166	97	90	83	76	68	62
Pecos	Reeves	Rio Grande	2,362	3,030	3,155	3,233	3,291	3,325	3,397
Toyah	Reeves	Rio Grande	109	102	102	102	102	102	102
County-Other	Reeves	Rio Grande	357	773	817	844	867	882	868
County Total Municipal			2,994	4,002	4,164	4,262	4,336	4,377	4,429
Manufacturing	Reeves	Rio Grande	1,391	12	13	13	13	14	15
Steam Electric Power	Reeves	Rio Grande	0	0	0	0	0	0	0
Mining	Reeves	Rio Grande	213	175	136	116	113	112	115
Irrigation	Reeves	Rio Grande	100,306	105,831	104,942	104,053	103,164	102,274	101,385
Livestock	Reeves	Rio Grande	2,103	2,254	2,254	2,254	2,254	2,254	2,254
County Total	Reeves	Rio Grande	107,007	112,274	111,509	110,698	109,880	109,031	108,198

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	County	River Basin	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Ballinger	Runnels	Colorado	915	912	917	885	875	869	894
Miles	Runnels	Colorado	98	129	124	117	111	103	99
Winters	Runnels	Colorado	560	550	552	562	582	603	632
County-Other	Runnels	Colorado	519	458	454	483	526	569	612
County Total Municipal			2,092	2,049	2,047	2,047	2,094	2,144	2,237
Manufacturing	Runnels	Colorado	58	47	56	68	80	95	112
Steam Electric Power	Runnels	Colorado	0	0	0	0	0	0	0
Mining	Runnels	Colorado	41	35	28	26	25	25	25
Irrigation	Runnels	Colorado	7,259	7,250	7,221	7,191	7,161	7,132	7,102
Livestock	Runnels	Colorado	1,977	1,716	1,716	1,716	1,716	1,716	1,716
County Total	Runnels	Colorado	11,427	11,097	11,068	11,048	11,076	11,112	11,192
Eldorado	Schleicher	Colorado	447	465	484	486	486	484	488
County-Other	Schleicher	Colorado	116	101	98	94	89	84	80
County-Other	Schleicher	Rio Grande	35	31	30	28	27	25	24
County Total Municipal			598	597	612	608	602	593	592
Manufacturing	Schleicher	Colorado	0	0	0	0	0	0	0
Manufacturing	Schleicher	Rio Grande	0	0	0	0	0	0	0
County Total Manufacturing			0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Steam Electric Power	Schleicher	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Schleicher	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Schleicher	Colorado	150	147	125	107	104	102	105
Mining	Schleicher	Rio Grande	0	0	0	0	0	0	0
County Total Mining			150	147	125	107	104	102	105
Irrigation	Schleicher	Colorado	1,176	1,500	1,471	1,441	1,412	1,383	1,353
Irrigation	Schleicher	Rio Grande	435	307	301	295	289	283	277
County Total Irrigation			1,611	1,807	1,772	1,736	1,701	1,666	1,630
Livestock	Schleicher	Colorado	483	440	440	440	440	440	440
Livestock	Schleicher	Rio Grande	168	154	154	154	154	154	154
County Total Livestock			651	594	594	594	594	594	594
County Total	Schleicher	Colorado	2,372	2,653	2,618	2,568	2,531	2,493	2,466
	Schleicher	Rio Grande	638	492	485	477	470	462	455
			3,010	3,145	3,103	3,045	3,001	2,955	2,921
Snyder	Scurry	Colorado	2,749	3,035	3,122	3,160	3,214	3,240	3,303
County-Other	Scurry	Brazos	197	195	193	186	182	174	175
County-Other	Scurry	Colorado	635	631	622	600	586	562	566
County Total Municipal			3,581	3,861	3,937	3,946	3,982	3,976	4,044
Manufacturing	Scurry	Brazos	0	0	0	0	0	0	0
Manufacturing	Scurry	Colorado	0	112	392	392	392	392	392
County Total Manufacturing			0	112	392	392	392	392	392

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Steam Electric Power	Scurry	Brazos	0	0	0	0	0	0	0
Steam Electric Power	Scurry	Colorado	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Scurry	Brazos	1,915	2,668	2,307	2,155	2,135	2,157	2,219
Mining	Scurry	Colorado	889	1,026	812	765	732	712	715
County Total Mining			2,804	3,694	3,119	2,920	2,867	2,869	2,934
Irrigation	Scurry	Brazos	245	931	901	872	842	812	783
Irrigation	Scurry	Colorado	1,293	2,394	2,318	2,242	2,165	2,089	2,013
County Total Irrigation			1,538	3,325	3,219	3,114	3,007	2,901	2,796
Livestock	Scurry	Brazos	266	355	355	355	355	355	355
Livestock	Scurry	Colorado	453	604	604	604	604	604	604
County Total Livestock			719	959	959	959	959	959	959
County Total	Scurry	Brazos	2,623	4,149	3,756	3,568	3,514	3,498	3,532
		Colorado	6,019	7,802	7,870	7,763	7,693	7,599	7,593
			8,642	11,951	11,626	11,331	11,207	11,097	11,125
Sterling City	Sterling	Colorado	239	273	288	294	298	299	303
County-Other	Sterling	Colorado	49	42	41	39	38	35	27
County Total Municipal			288	315	329	333	336	334	330
Manufacturing	Sterling	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Sterling	Colorado	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Mining	Sterling	Colorado	562	570	422	405	397	393	396
Irrigation	Sterling	Colorado	697	886	851	817	782	748	714
Livestock	Sterling	Colorado	333	571	571	571	571	571	571
County Total	Sterling	Colorado	1,880	2,342	2,173	2,126	2,086	2,046	2,011
Sonora	Sutton	Rio Grande	1,148	1,114	1,196	1,235	1,256	1,269	1,290
County-Other	Sutton	Colorado	41	50	47	44	39	35	30
County-Other	Sutton	Rio Grande	227	274	260	245	218	195	169
County Total Municipal			1,416	1,438	1,503	1,524	1,513	1,499	1,489
Manufacturing	Sutton	Colorado	0	0	0	0	0	0	0
Manufacturing	Sutton	Rio Grande	0	0	0	0	0	0	0
County Total Manufacturing			0	0	0	0	0	0	0
Steam Electric Power	Sutton	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Sutton	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Sutton	Colorado	33	35	36	37	38	39	40
Mining	Sutton	Rio Grande	42	46	45	44	45	45	46
County Total Mining			75	81	81	81	83	84	86
Irrigation	Sutton	Colorado	475	697	684	671	658	645	632
Irrigation	Sutton	Rio Grande	1,786	1,551	1,522	1,493	1,464	1,435	1,406

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	County	River Basin	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
County Total Irrigation			2,261	2,248	2,206	2,164	2,122	2,080	2,038
Livestock	Sutton	Colorado	216	314	314	314	314	314	314
Livestock	Sutton	Rio Grande	259	376	376	376	376	376	376
County Total Livestock			475	690	690	690	690	690	690
County Total	Sutton	Colorado	765	1,096	1,081	1,066	1,049	1,033	1,016
		Rio Grande	3,462	3,361	3,399	3,393	3,359	3,320	3,287
			4,227	4,457	4,480	4,459	4,408	4,353	4,303
San Angelo	Tom Green	Colorado	19,352	24,693	26,607	28,273	29,450	31,733	34,368
County-Other	Tom Green	Colorado	2,660	2,473	2,624	2,636	3,244	3,435	3,421
County Total Municipal			22,012	27,166	29,231	30,909	32,694	35,168	37,789
Manufacturing	Tom Green	Colorado	508	718	777	832	889	976	1,064
Steam Electric Power	Tom Green	Colorado	272	1,020	3,680	3,680	3,680	3,680	3,680
Mining	Tom Green	Colorado	150	79	81	84	87	90	93
Irrigation	Tom Green	Colorado	54,146	120,102	119,808	119,515	119,221	118,928	118,634
Livestock	Tom Green	Colorado	2,211	2,124	2,124	2,124	2,124	2,124	2,124
County Total	Tom Green	Colorado	79,299	151,209	155,701	157,144	158,695	160,966	163,384
McCamey	Upton	Rio Grande	517	579	607	612	603	586	576

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Rankin	Upton	Rio Grande	179	236	259	259	262	263	267
County-Other	Upton	Colorado	46	61	61	60	61	61	60
County-Other	Upton	Rio Grande	101	132	132	130	131	132	130
County Total Municipal			843	1,008	1,059	1,061	1,057	1,042	1,033
Manufacturing	Upton	Colorado	0	0	0	0	0	0	0
Manufacturing	Upton	Rio Grande	0	0	0	0	0	0	0
County Total Manufacturing			0	0	0	0	0	0	0
Steam Electric Power	Upton	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Upton	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Upton	Colorado	2,267	1,817	1,362	1,282	1,266	1,281	1,319
Mining	Upton	Rio Grande	614	588	525	510	491	481	494
County Total Mining			2,881	2,405	1,887	1,792	1,757	1,762	1,813
Irrigation	Upton	Colorado	18,315	19,824	19,547	19,270	18,994	18,717	18,440
Irrigation	Upton	Rio Grande	185	0	0	0	0	0	0
County Total Irrigation			18,500	19,824	19,547	19,270	18,994	18,717	18,440
Livestock	Upton	Colorado	64	39	39	39	39	39	39
Livestock	Upton	Rio Grande	114	67	67	67	67	67	67
County Total Livestock			178	106	106	106	106	106	106
County Total	Upton	Colorado	20,692	21,741	21,009	20,651	20,360	20,098	19,858
		Rio Grande	1,710	1,602	1,590	1,578	1,554	1,529	1,534
			22,402	23,343	22,599	22,229	21,914	21,627	21,392

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Barstow	Ward	Rio Grande	289	103	92	80	72	69	67
Grandfalls	Ward	Rio Grande	194	216	204	187	179	177	179
Monahans	Ward	Rio Grande	2,642	2,839	2,874	2,819	2,728	2,585	2,495
Thorntonville	Ward	Rio Grande	172	164	155	143	134	122	114
Wickett	Ward	Rio Grande	142	218	197	174	168	163	159
County-Other	Ward	Rio Grande	509	568	632	673	667	639	597
County Total Municipal			3,948	4,108	4,154	4,076	3,948	3,755	3,611
Manufacturing	Ward	Rio Grande	5	4	4	5	6	6	7
Steam Electric Power	Ward	Rio Grande	5,749	5,500	6,050	7,260	8,712	10,454	12,545
Mining	Ward	Rio Grande	160	635	495	318	231	190	194
Irrigation	Ward	Rio Grande	8,808	11,273	11,136	10,999	10,862	10,725	10,588
Livestock	Ward	Rio Grande	94	293	293	293	293	293	293
County Total	Ward	Rio Grande	18,764	21,813	22,132	22,951	24,052	25,423	27,238
Kermit	Winkler	Rio Grande	1,839	2,387	2,467	2,491	2,492	2,489	2,505
Wink	Winkler	Rio Grande	334	339	354	360	361	360	363
County-Other	Winkler	Colorado	1	1	1	1	1	1	1
County-Other	Winkler	Rio Grande	108	147	146	145	143	141	110
County Total Municipal			2,282	2,874	2,968	2,997	2,997	2,991	2,979
Manufacturing	Winkler	Colorado	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Manufacturing	Winkler	Rio Grande	0	8	10	11	12	14	17
County Total Manufacturing			0	8	10	11	12	14	17
Steam Electric Power	Winkler	Colorado	0	0	0	0	0	0	0
Steam Electric Power	Winkler	Rio Grande	0	0	0	0	0	0	0
County Total Steam Electric			0	0	0	0	0	0	0
Mining	Winkler	Colorado	0	0	0	0	0	0	0
Mining	Winkler	Rio Grande	1,437	2,040	1,779	1,605	1,436	1,360	1,398
County Total Mining			1,437	2,040	1,779	1,605	1,436	1,360	1,398
Irrigation	Winkler	Colorado	0	0	0	0	0	0	0
Irrigation	Winkler	Rio Grande	0	1,500	1,500	1,500	1,500	1,500	1,500
County Total Irrigation			0	1,500	1,500	1,500	1,500	1,500	1,500
Livestock	Winkler	Colorado	1	2	2	2	2	2	2
Livestock	Winkler	Rio Grande	76	190	190	190	190	190	190
County Total Livestock			77	192	192	192	192	192	192
County Total	Winkler	Colorado	2	3	3	3	3	3	3
		Rio Grande	3,794	6,611	6,446	6,302	6,134	6,054	6,083
			3,796	6,614	6,449	6,305	6,137	6,057	6,086
Basin Total Municipal		Brazos	209	210	209	201	197	188	188
Basin Total Municipal		Colorado	111,207	126,128	132,713	137,948	145,837	154,098	163,449
Basin Total Municipal		Rio Grande	18,896	20,765	21,543	21,738	21,805	21,663	21,620
Region Total Municipal			130,312	147,103	154,465	159,887	167,839	175,949	185,257
Basin Total Manufacturing		Brazos	0	0	0	0	0	0	0

Table 2-3 (Cont.)
Water Demand Projections for Region F by County, Category and River Basin
(Values in Acre-Feet per Year)

			Historical	Projected					
User Group Name	**County**	**River Basin**	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Basin Total Manufacturing		Colorado	6,371	8,534	9,523	10,001	10,414	11,196	11,962
Basin Total Manufacturing		Rio Grande	1,419	107	120	128	134	148	161
Region Total Manufacturing			7,790	8,641	9,643	10,129	10,548	11,344	12,123
Basin Total Steam electric		Brazos	0	0	0	0	0	0	0
Basin Total Steam electric		Colorado	6,227	13,935	16,995	17,875	18,931	20,198	21,719
Basin Total Steam electric		Rio Grande	7,016	7,420	10,336	11,546	12,998	14,740	16,831
Region Total Steam electric			13,243	21,355	27,331	29,421	31,929	34,938	38,550
Basin Total Mining		Brazos	1,920	2673	2312	2160	2141	2163	2225
Basin Total Mining		Colorado	23,809	21,340	17,461	15,369	14,539	14,097	14,076
Basin Total Mining		Rio Grande	5,956	7,223	5,923	5,256	4,877	4,741	4,860
Region Total Mining			31,685	31,236	25,696	22,785	21,557	21,001	21,161
Basin Total Irrigation		Brazos	1,906	4892	4857	4823	4787	4752	4718
Basin Total Irrigation		Colorado	314,182	439,396	435,766	432,136	428,505	424,878	421,249
Basin Total Irrigation		Rio Grande	189,386	204,364	202,025	199,684	197,344	195,003	192,663
Region Total Irrigation			505,474	648,652	642,648	636,643	630,636	624,633	618,630
Basin Total Livestock		Brazos	323	401	401	401	401	401	401
Basin Total Livestock		Colorado	16,194	18,094	18,094	18,094	18,094	18,094	18,094
Basin Total Livestock		Rio Grande	4,885	6,014	6,014	6,014	6,014	6,014	6,014
Region Total Livestock			21,402	24,509	24,509	24,509	24,509	24,509	24,509

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Table 2-4
Total Water Demand Projections for Region F Counties
(Values in Acre-Feet Per Year)

	Historical	Projected					
County	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Andrews	20,988	27,273	25,547	24,461	24,022	23,669	23,500
Borden	6,505	11,042	10,875	10,780	10,737	10,714	10,711
Brown	23,121	20,687	20,836	20,766	20,839	20,767	20,692
Coke	2,788	3,290	3,234	3,144	3,098	3,062	3,041
Coleman	5,085	4,812	4,729	4,624	4,562	4,532	4,512
Concho	6,168	8,840	8,805	8,769	8,740	8,700	8,701
Crane	3,756	4,534	4,028	3,854	3,842	3,870	3,957
Crockett	4,424	5,616	7,667	7,811	7,801	7,783	7,801
Ector	42,034	52,196	53,438	54,607	57,130	59,055	60,901
Glasscock	55,551	68,970	68,433	67,890	67,348	66,803	66,262
Howard	12,906	17,984	18,156	18,068	18,051	18,137	18,351
Irion	3,630	4,044	3,973	3,890	3,812	3,738	3,666
Kimble	3,025	4,591	4,684	4,682	4,686	4,797	4,922
Loving	652	663	658	655	651	649	645
Martin	14,497	16,624	16,178	15,903	15,637	15,359	15,130
Mason	12,267	20,001	19,726	19,441	19,179	18,919	18,668
McCulloch	6,021	8,098	8,033	7,984	7,979	7,974	8,000
Menard	5,048	7,088	7,051	7,018	6,985	6,955	6,934
Midland	84,290	99,856	101,837	103,610	106,507	110,041	114,274
Mitchell	7,386	9,289	9,485	10,213	11,137	12,289	13,732
Pecos	82,444	88,291	87,195	85,970	84,725	83,447	82,184
Reagan	46,866	49,456	48,676	47,888	47,083	46,432	45,779
Reeves	107,007	112,274	111,509	110,698	109,880	109,031	108,198
Runnels	11,427	11,097	11,068	11,048	11,076	11,112	11,192
Schleicher	3,010	3,145	3,103	3,045	3,001	2,955	2,921
Scurry	8,642	11,951	11,626	11,331	11,207	11,097	11,125
Sterling	1,880	2,342	2,173	2,126	2,086	2,046	2,011
Sutton	4,227	4,457	4,480	4,459	4,408	4,353	4,303
Tom Green	79,299	151,209	155,701	157,144	158,695	160,966	163,384
Upton	22,402	23,343	22,599	22,229	21,914	21,627	21,392
Ward	18,764	21,813	22,132	22,951	24,052	25,423	27,238
Winkler	3,796	6,614	6,449	6,305	6,137	6,057	6,086
Total	709,906	881,490	884,084	883,364	887,007	892,359	900,213

Freese and Nichols, Inc., 1999

Table 2-5
Municipal Water Demand Projections for Region F Counties
(Values in Acre-Feet Per Year)

	Historical	Projected					
County	1996 Water Use	2000 Water Use	2010 Water Use	2020 Water Use	2030 Water Use	2040 Water Use	2050 Water Use
Andrews	3,426	3,508	3,656	3,718	3,762	3,755	3,768
Borden	169	123	116	100	82	70	58
Brown	6,050	7,778	7,945	7,950	8,036	7,975	7,898
Coke	784	805	793	762	755	748	746
Coleman	1,912	2,059	1,987	1,892	1,841	1,822	1,812
Concho	821	799	792	784	783	771	799
Crane	1,014	1,326	1,444	1,513	1,603	1,650	1,716
Crockett	1,797	1,873	1,887	1,893	1,914	1,920	1,940
Ector	24,915	26,911	28,387	29,985	32,760	34,734	36,597
Glasscock	198	203	210	211	211	209	211
Howard	6,602	8,688	8,738	8,576	8,496	8,398	8,432
Irion	220	255	254	243	236	231	229
Kimble	1,073	1,157	1,154	1,121	1,106	1,096	1,096
Loving	12	13	11	9	7	7	5
McCulloch	2,738	2,915	2,821	2,743	2,704	2,667	2,660
Martin	712	707	716	710	692	666	651
Mason	951	981	956	921	908	895	890
Menard	404	422	404	391	378	367	366
Midland	29,386	31,721	34,553	36,985	40,461	44,549	49,306
Mitchell	1,709	2,298	2,223	2,135	2,041	1,954	1,896
Pecos	4,589	4,147	4,373	4,419	4,439	4,424	4,421
Reagan	776	996	1,041	1,063	1,065	1,162	1,227
Reeves	2,994	4,002	4,164	4,262	4,336	4,377	4,429
Runnels	2,092	2,049	2,047	2,047	2,094	2,144	2,237
Schleicher	598	597	612	608	602	593	592
Scurry	3,581	3,861	3,937	3,946	3,982	3,976	4,044
Sterling	288	315	329	333	336	334	330
Sutton	1,416	1,438	1,503	1,524	1,513	1,499	1,489
Tom Green	22,012	27,166	29,231	30,909	32,694	35,168	37,789
Upton	843	1,008	1,059	1,061	1,057	1,042	1,033
Ward	3,948	4,108	4,154	4,076	3,948	3,755	3,611
Winkler	2,282	2,874	2,968	2,997	2,997	2,991	2,979
Total	130,312	147,103	154,465	159,887	167,839	175,949	185,257

Freese and Nichols, Inc., 1999

Table 2-6
Manufacturing Water Demand Projections for Region F Counties
(Values in Acre – Feet Per Year)

	Historical	Projected					
County	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Andrews	47	36	38	39	39	45	51
Borden	1	48	57	68	80	94	109
Brown	501	485	524	567	608	660	714
Coke	0	0	0	0	0	0	0
Coleman	1	1	1	2	2	2	3
Concho	0	0	0	0	0	0	0
Crane	0	0	0	0	0	0	0
Crockett	0	6	8	10	11	15	17
Ector	2,122	2,152	2,339	2,413	2,457	2,602	2,725
Glasscock	0	0	0	0	0	0	0
Howard	1,668	2,344	2,540	2,677	2,788	3,020	3,244
Irion	0	0	0	0	0	0	0
Kimble	416	1,637	1,777	1,849	1,909	2,067	2,229
Loving	0	0	0	0	0	0	0
Martin	31	32	35	36	36	38	40
Mason	0	0	0	0	0	0	0
McCulloch	831	844	903	963	1,027	1,090	1,153
Menard	0	0	0	0	0	0	0
Midland	206	148	161	174	188	201	216
Mitchell	0	0	0	0	0	0	0
Pecos	4	7	8	10	11	13	15
Reagan	0	0	0	0	0	0	0
Reeves	1,391	12	13	13	13	14	15
Runnels	58	47	56	68	80	95	112
Schleicher	0	0	0	0	0	0	0
Scurry	0	112	392	392	392	392	392
Sterling	0	0	0	0	0	0	0
Sutton	0	0	0	0	0	0	0
Tom Green	508	718	777	832	889	976	1,064
Upton	0	0	0	0	0	0	0
Ward	5	4	4	5	6	6	7
Winkler	0	8	10	11	12	14	17
Total	7,790	8,641	9,643	10,129	10,548	11,344	12,123

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Table 2-7
Irrigation Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

	Historical	Projected					
County	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Andrews	13,783	18,931	18,773	18,616	18,459	18,301	18,144
Borden	5,066	9,662	9,649	9,636	9,623	9,610	9,597
Brown	12,085	10,526	10,491	10,455	10,420	10,384	10,348
Coke	665	667	666	666	665	664	664
Coleman	1,379	1,376	1,364	1,353	1,341	1,330	1,319
Concho	4,756	7,082	7,054	7,026	6,998	6,970	6,943
Crane	22	337	337	337	337	337	337
Crockett	374	439	432	424	417	410	403
Ector	7,416	8,602	8,500	8,399	8,298	8,197	8,096
Glasscock	55,187	68,521	67,979	67,437	66,895	66,353	65,810
Howard	1,273	4,724	4,671	4,618	4,565	4,512	4,459
Irion	2,959	3,296	3,227	3,157	3,087	3,018	2,948
Kimble	1,020	1,128	1,089	1,049	1,009	970	930
Loving	583	582	580	578	576	574	572
McCulloch	1,563	2,964	2,928	2,891	2,855	2,818	2,782
Martin	12,641	14,221	13,976	13,731	13,486	13,241	12,997
Mason	10,358	17,501	17,255	17,009	16,763	16,517	16,271
Menard	4,173	6,080	6,061	6,041	6,021	6,002	5,982
Midland	53,339	66,574	66,061	65,548	65,034	64,521	64,008
Mitchell	1,076	2,238	2,226	2,215	2,204	2,193	2,182
Pecos	76,442	82,458	81,190	79,921	78,652	77,383	76,114
Reagan	44,188	46,697	45,937	45,177	44,417	43,657	42,897
Reeves	100,306	105,831	104,942	104,053	103,164	102,274	101,385
Runnels	7,259	7,250	7,221	7,191	7,161	7,132	7,102
Schleicher	1,611	1,807	1,772	1,736	1,701	1,666	1,630
Scurry	1,538	3,325	3,219	3,114	3,007	2,901	2,796
Sterling	697	886	851	817	782	748	714
Sutton	2,261	2,248	2,206	2,164	2,122	2,080	2,038
Tom Green	54,146	120,102	119,808	119,515	119,221	118,928	118,634
Upton	18,500	19,824	19,547	19,270	18,994	18,717	18,440
Ward	8,808	11,273	11,136	10,999	10,862	10,725	10,588
Winkler	0	1,500	1,500	1,500	1,500	1,500	1,500
Total	505,474	648,652	642,648	636,643	630,636	624,633	618,630

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Table 2-8
Steam Electric Water Demand Projections for Region F Counties
(Values in Acre – Feet per Year)

	Historical	Projected					
County	**1996 Water Use**	**2000 Water Demand**	**2010 Water Demand**	**2020 Water Demand**	**2030 Water Demand**	**2040 Water Demand**	**2050 Water Demand**
Andrews	0	0	0	0	0	0	0
Borden	0	0	0	0	0	0	0
Brown	0	0	0	0	0	0	0
Coke	581	835	835	835	835	835	835
Coleman	0	0	0	0	0	0	0
Concho	0	0	0	0	0	0	0
Crane	0	0	0	0	0	0	0
Crockett	1,267	1,914	4,280	4,280	4,280	4,280	4,280
Ector	0	6,700	6,700	6,700	6,700	6,700	6,700
Glasscock	0	0	0	0	0	0	0
Howard	1,303	1,380	1,380	1,380	1,380	1,380	1,380
Irion	0	0	0	0	0	0	0
Kimble	0	0	0	0	0	0	0
Loving	0	0	0	0	0	0	0
McCulloch	0	0	0	0	0	0	0
Martin	0	0	0	0	0	0	0
Mason	0	0	0	0	0	0	0
Menard	0	0	0	0	0	0	0
Midland	0	0	0	0	0	0	0
Mitchell	4,071	4,000	4,400	5,280	6,336	7,603	9,124
Pecos	0	6	6	6	6	6	6
Reagan	0	0	0	0	0	0	0
Reeves	0	0	0	0	0	0	0
Runnels	0	0	0	0	0	0	0
Schleicher	0	0	0	0	0	0	0
Scurry	0	0	0	0	0	0	0
Sterling	0	0	0	0	0	0	0
Sutton	0	0	0	0	0	0	0
Tom Green	272	1,020	3,680	3,680	3,680	3,680	3,680
Upton	0	0	0	0	0	0	0
Ward	5,749	5,500	6,050	7,260	8,712	10,454	12,545
Winkler	0	0	0	0	0	0	0
Total	13,243	21,355	27,331	29,421	31,929	34,938	38,550

Freese and Nichols, Inc., 1999

Table 2-9
Mining Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

	Historical	Projected					
County	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Andrews	3,312	4,364	2,646	1,654	1,328	1,134	1,103
Borden	990	934	778	701	677	665	672
Brown	2,427	300	278	196	177	150	134
Coke	304	261	218	159	121	93	74
Coleman	16	15	16	16	17	17	17
Concho	0	0	0	0	0	0	0
Crane	2,585	2,726	2,102	1,859	1,757	1,738	1,759
Crockett	398	402	280	226	202	185	190
Ector	7,333	7,613	7,294	6,892	6,697	6,604	6,565
Glasscock	7	5	3	1	1	0	0
Howard	1,816	452	431	421	426	431	440
Irion	129	6	5	3	2	2	2
Kimble	91	105	100	99	98	100	103
Loving	3	3	2	3	3	3	3
McCulloch	140	146	152	158	164	170	176
Martin	852	1,228	1,015	990	987	978	1,006
Mason	6	12	8	4	1	0	0
Menard	0	0	0	0	0	0	0
Midland	656	669	318	159	80	26	0
Mitchell	141	223	106	53	26	9	0
Pecos	264	322	267	263	266	270	277
Reagan	1,742	1,589	1,524	1,474	1,427	1,439	1,481
Reeves	213	175	136	116	113	112	115
Runnels	41	35	28	26	25	25	25
Schleicher	150	147	125	107	104	102	105
Scurry	2,804	3,694	3,119	2,920	2,867	2,869	2,934
Sterling	562	570	422	405	397	393	396
Sutton	75	81	81	81	83	84	86
Tom Green	150	79	81	84	87	90	93
Upton	2,881	2,405	1,887	1,792	1,757	1,762	1,813
Ward	160	635	495	318	231	190	194
Winkler	1,437	2,040	1,779	1,605	1,436	1,360	1,398
Total	31,685	31,236	25,696	22,785	21,557	21,001	21,161

Freese and Nichols, Inc., 1999

Table 2-10
Livestock Water Demand Projections for Region F Counties
(Values in Acre-Feet per Year)

	Historical	Projected					
County	1996 Water Use	2000 Water Demand	2010 Water Demand	2020 Water Demand	2030 Water Demand	2040 Water Demand	2050 Water Demand
Andrews	420	434	434	434	434	434	434
Borden	279	275	275	275	275	275	275
Brown	2,058	1,598	1,598	1,598	1,598	1,598	1,598
Coke	454	722	722	722	722	722	722
Coleman	1,777	1,361	1,361	1,361	1,361	1,361	1,361
Concho	591	959	959	959	959	959	959
Crane	135	145	145	145	145	145	145
Crockett	588	988	988	988	988	988	988
Ector	248	218	218	218	218	218	218
Glasscock	159	241	241	241	241	241	241
Howard	244	396	396	396	396	396	396
Irion	322	487	487	487	487	487	487
Kimble	425	564	564	564	564	564	564
Loving	54	65	65	65	65	65	65
McCulloch	749	1,229	1,229	1,229	1,229	1,229	1,229
Martin	261	436	436	436	436	436	436
Mason	952	1,507	1,507	1,507	1,507	1,507	1,507
Menard	471	586	586	586	586	586	586
Midland	703	744	744	744	744	744	744
Mitchell	389	530	530	530	530	530	530
Pecos	1,145	1,351	1,351	1,351	1,351	1,351	1,351
Reagan	160	174	174	174	174	174	174
Reeves	2,103	2,254	2,254	2,254	2,254	2,254	2,254
Runnels	1,977	1,716	1,716	1,716	1,716	1,716	1,716
Schleicher	651	594	594	594	594	594	594
Scurry	719	959	959	959	959	959	959
Sterling	333	571	571	571	571	571	571
Sutton	475	690	690	690	690	690	690
Tom Green	2,211	2,124	2,124	2,124	2,124	2,124	2,124
Upton	178	106	106	106	106	106	106
Ward	94	293	293	293	293	293	293
Winkler	77	192	192	192	192	192	192
Total	21,402	24,509	24,509	24,509	24,509	24,509	24,509

Freese and Nichols, Inc., 1999

Figure 2-1
Historical and Projected Population in Region F

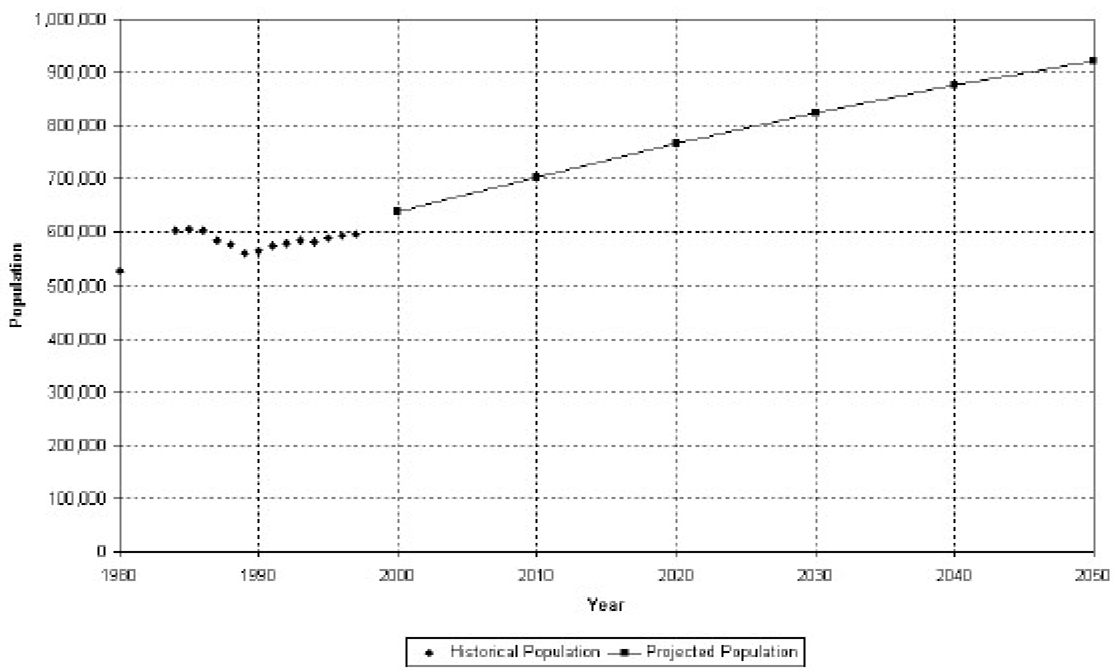
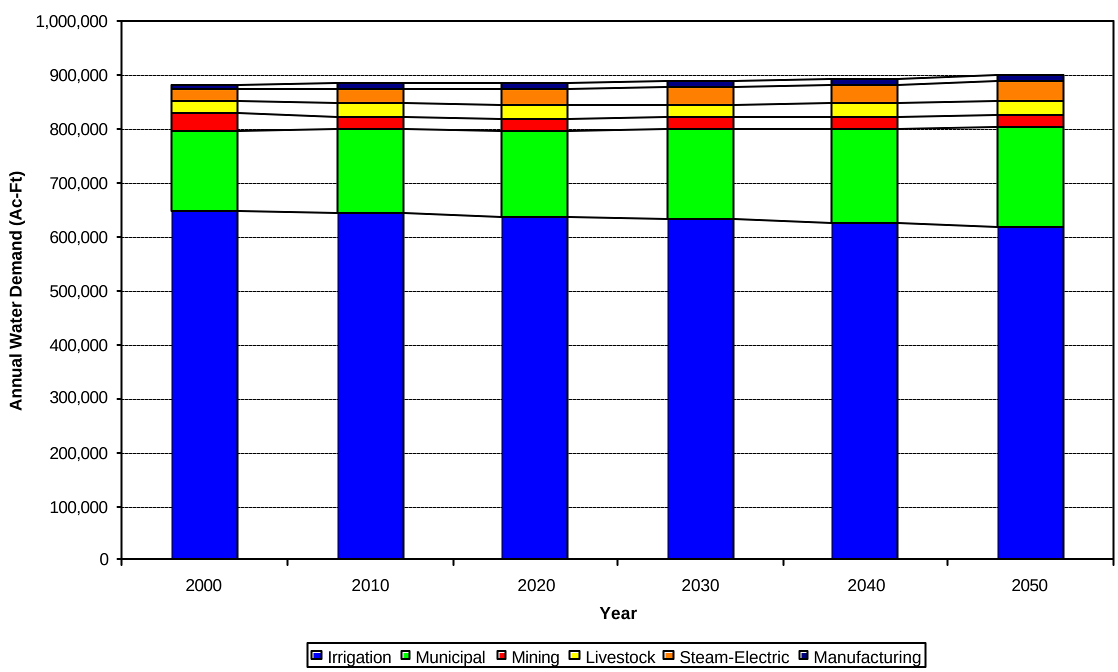


Figure 2-2
Projected Water Demands in Region F



2.2. Consensus-Based Population and Water Demand Projections

The consensus-based projections were developed in the early 1990s by the TWDB in conjunction with the Texas Natural Resource Conservation Commission (TNRCC) and the Texas Parks and Wildlife Department (TPWD). The projections are called "consensus-based" since they have been reviewed and approved by a Technical Advisory Committee consisting of representatives from the three state agencies, state universities, various water interests and the general public.

There are six categories of water use in the consensus-based projections:

- *Municipal* – residential and commercial uses, including landscape irrigation
- *Manufacturing* – various types of heavy industrial use
- *Irrigation* - irrigated commercial agriculture
- *Steam electric Power Generation* – water consumed in the production of electricity
- *Livestock Watering* – water used in commercial livestock production
- *Mining* – water used in the commercial production of various minerals as well as water used in the production of oil and gas

Each category has annual water demand projections for the years 2000, 2010, 2020, 2030, 2040 and 2050. Water use for years in between can be estimated by interpolation. These projections are not the same as the average day and peak-day projections used in planning municipal water supply distribution. Average day projections are the amount of water expected to be delivered during a normal day, and peak-day projections are the maximum amount of water expected to be delivered during the highest demand day, typically expressed in million gallons per day (MGD). The consensus-based water demand projections are the maximum amounts of water required to meet needs for an entire year and are usually expressed in acre-feet (one acre-foot equals 325,851 gallons).

The projection represents the maximum expected demand for any given year. In most years, demands will probably be less than those used in the planning process. However, it is desirable to use the highest expected demand so that several years of high demands in a row will not completely exhaust a water supply.

Revisions to the 1997 Consensus-Based Projections for Region F

The Region F scope of work called for a review of the consensus-based projections. The projections for municipal, manufacturing, steam electric power generation and mining were reviewed in a three-step process:

- A survey was sent to cities with population of greater than about 300, water providers, county judges, industries and steam electric power generators. These surveys asked each entity to evaluate their consensus-based projections. The consultant team compiled the survey data and responded to requests for revision.
- The consensus-based projections were compared to historical data and other projections and evaluated for anomalies such as recent water use exceeding future predictions, changes in trends in per capita water use since 1990, etc. If any of the anomalies indicated that the projections should be revised, the consultants contacted the affected entities for further review.
- A report was prepared summarizing the results of the survey and evaluations, noting any projections that merited revision. The report was sent to the members of the RWPG for review and comment. From this report, submittals were developed which were sent to the TWDB for approval.

The assessment of agricultural irrigation and livestock watering used a similar process:

- Agricultural extension agents in the Region were contacted to evaluate the accuracy of the historical water use numbers and review predictions of future water demand. Responses were compiled by the consultant team.
- Historical data were used to develop six different scenarios for the irrigation water use projection. These scenarios were presented to the RWPG, which adopted a scenario based on the maximum irrigation volume used in the Region between 1990 and 1997. More detailed information may be found in Alan Plummer Associates *Revisions to Irrigation Water Demand Projections for Region F*.
- A report was prepared and submitted to the TWDB.

Table 2-11 compares the TWDB projections with the revised amount for each category of water use in Region F. The proposed revisions to the population and water demand projections were adopted by the RWPG on July 26, 1999, and approved by the TWDB on September 15, 1999.

Table 2-11
Summary of Changes to 1997 Consensus-Based Projections

Data Category		Projections					
		2000	**2010**	**2020**	**2030**	**2040**	**2050**
Population	1997	631,807	692,907	749,153	797,323	845,717	884,707
	Changed To	638,203	704,249	766,269	823,181	877,342	921,907
Municipal (ac-ft)	1997	144,724	151,134	155,518	161,782	168,807	177,056
	Changed To	147,103	154,465	159,887	167,839	175,949	185,257
Manufacturing (ac-ft)	1997	8,529	9,251	9,737	10,156	10,952	11,731
	Changed To	8,641	9,643	10,129	10,548	11,344	12,123
Irrigation (ac-ft)	1997	343,015	336,740	330,601	324,603	318,734	312,992
	Changed To	648,652	642,648	636,643	630,636	624,633	618,630
Steam electric (ac-ft)	1997	12,800	12,800	12,800	12,800	12,800	12,800
	Changed To	17,349	22,925	24,135	25,587	27,329	29,420
Mining (ac-ft)	1997	31,236	25,696	22,785	21,557	21,001	21,161
	Changed To	31,236	25,696	22,785	21,557	21,001	21,161
Livestock (ac-ft)	1997	20,424	20,424	20,424	20,424	20,424	20,424
	Changed To	24,509	24,509	24,509	24,509	24,509	24,509

Freese and Nichols, Inc., 1999, TWDB CD, 1999

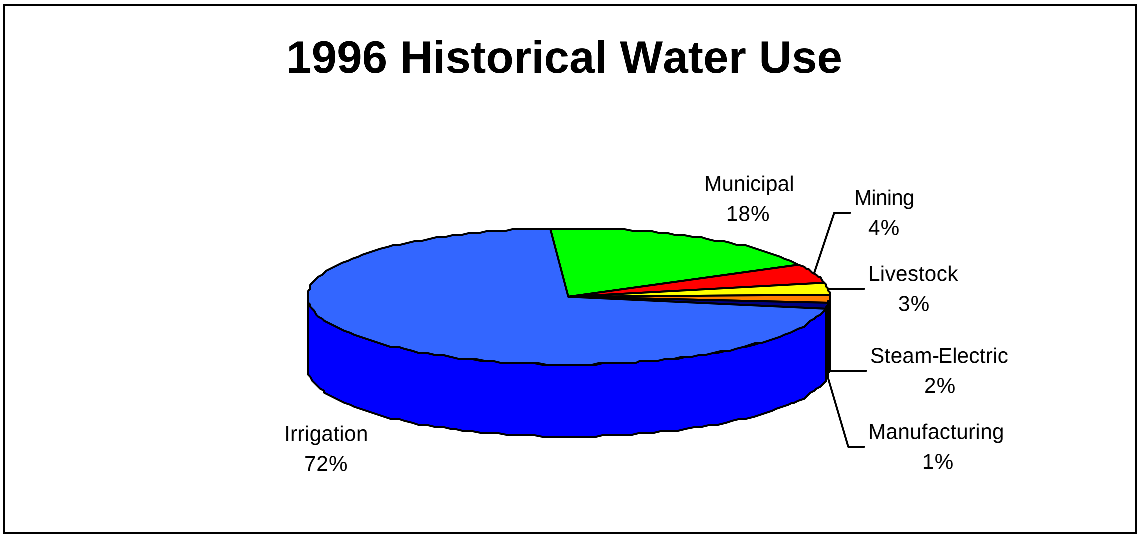
Figure 2-3 illustrates the relative proportion of water demand for each water use category in the years 1996, 2000 and 2050. The largest use categories are projected to be irrigation and municipal.

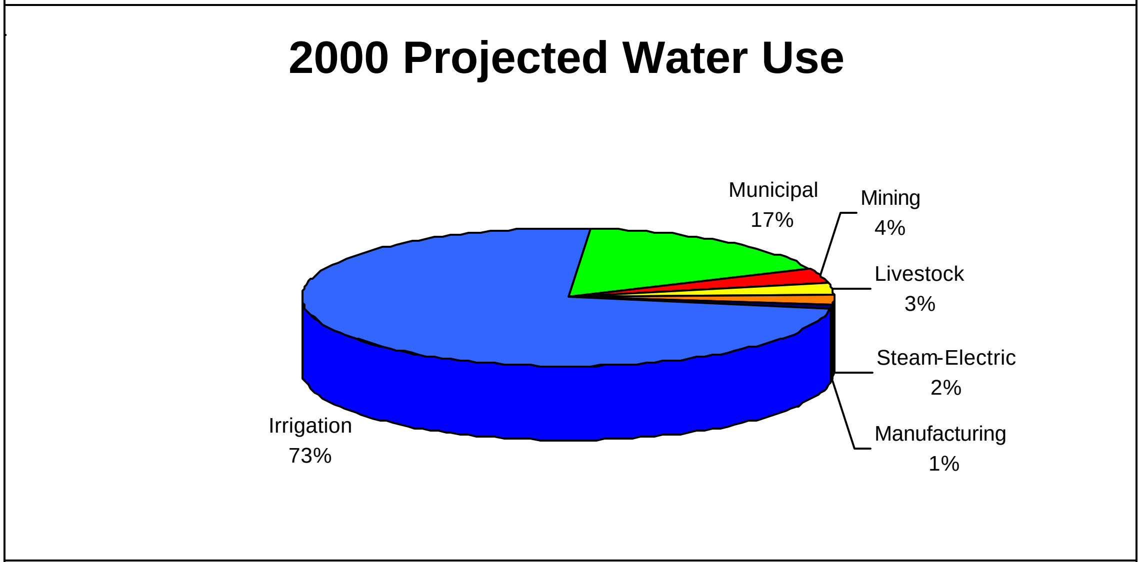
2.3. Municipal Water Demand Projections

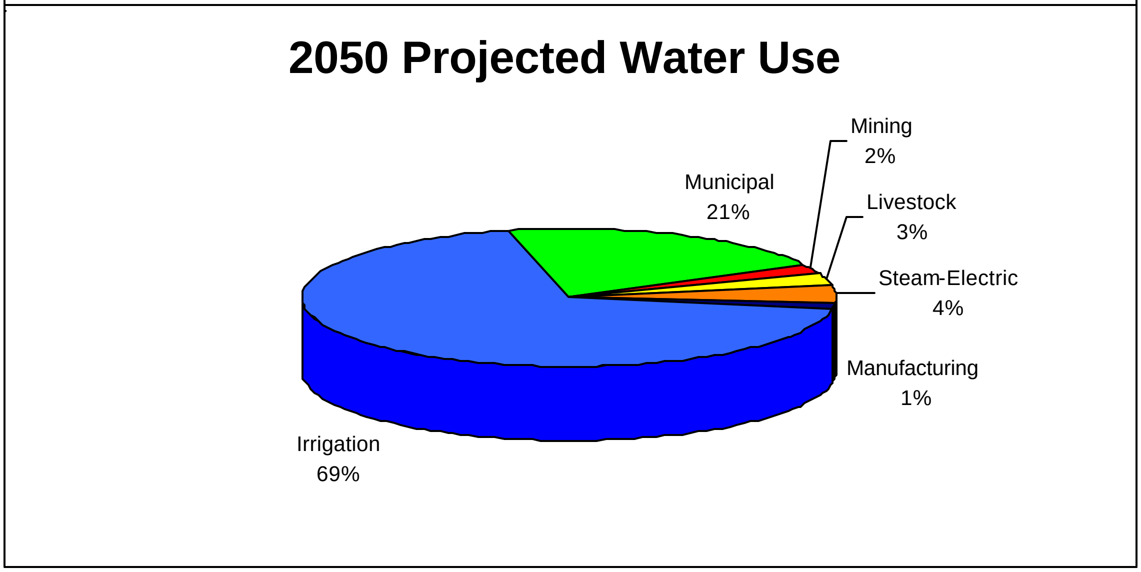
Municipal water demand includes both residential and commercial use, including water used for landscape irrigation. Residential use includes water used in single and multi-family households (TWDB, 1996). Commercial use includes business establishments, public spaces and institutions, but does not include most industrial water use. Industrial water demand projections are included in the manufacturing category. Municipal projections were developed for each county, river basin and city of more than 500 people. Rural populations and towns of less than 500 people are included in the category of County Other. The municipal projections are the only projections developed

Figure 2-3

Proportion of Total Water Demand by Category in Region F







for an area smaller than a county. Tables 2-1 and 2-2 present the population projections for each Region F county.

The consensus-based municipal projections are derived in three steps:

- Population projections
- Per capita water use forecasts
- Total municipal water use calculation (product of population and per capita water use)

Each of the steps is discussed separately in the next three sections.

2.3.1 Population Projections

The population projections for each county start with data from the 1990 census compiled by Dr. Steve Murdoch, Chief Demographer for the Texas State Data Center at Texas A&M University. The consensus-based projections use a standard projection method known as the *cohort-component method*. This method is based upon historical birth and survival rates of the region's population (TWDB, 1996). More information on the methodology used for the population projections may be found in the TWDB publication *Water for Texas – Today and Tomorrow: A 1996 Consensus-Based Update to the Texas Water Plan Vol. III, Water Use Planning Data Appendix*.

The Region's total population is projected to increase from 638,203 in 2000 to 921,907 in 2050. This equates to an average growth rate of 0.74 percent per year. This compares to a statewide increase from 20,230,584 in 2000 to 36,670,967 in 2050, a growth rate of 1.2 percent per year (TWDB CD, 1999) (statewide data do not include revisions by Region F or any other planning group).

The relative distribution of population in Region F is expected to remain stable throughout the 50-year planning period. Almost 80 percent of the people in Region F live in urban areas or small to moderate sized rural communities. Three counties, Midland, Ector and Tom Green, have significant urban populations with three city centers (Midland, Odessa and San Angelo) accounting for nearly half of the Region's population. Each of these cities had a 1998 population between 90,000 and 100,000. They are expected to contribute 76 percent of the population growth in Region F.

Twenty-nine of the 32 counties that comprise Region F are generally rural. Twenty-one counties have populations of less than 10,000. Two of these counties, Loving and Borden, have populations of less than 1,000. These counties are expected to remain primarily rural throughout the planning period.

2.3.2 Per Capita Water Use

Future water use is calculated by multiplying the population of a region, county or city by a calculated per capita water use. *Per capita water use*, expressed in gallons per capita per day (gpcd), is municipal water use divided by the population of the area. It includes the amount of water used by each person in their daily activities, water used for commercial purposes and landscape watering.

The consensus-based projections assume that per capita water use will show a downward trend over the planning period. This assumed downward trend is the result of implementation of the State Water-Efficiency Plumbing Act, water conservation programs promoted by state and federal regulations, and the increasing cost of water. Table 2-12 gives the maximum savings applied to the consensus-based projections. The actual amount of conservation savings and the timing of these reductions were determined in the development of the consensus-based projections and can vary somewhat from county to county and from water supplier to water supplier (TWDB, 1996). Table 2-13 shows the average per capita water use for each decade in Region F and compares these values to average values for the State as a whole. By 2040, average per capita water use for Region F is expected to decline from 206 gpcd to 179 gpcd, a reduction of 13 percent. This compares to the statewide average of 180 gpcd for the year 2000 declining to 151 gpcd by 2050, a reduction of 14 percent.

Table 2-12
Municipal Water Conservation Savings

Method of Water Conservation	Expected Conservation
Indoor plumbing	20.5 gallons per capita per day
Seasonal water reduction	7% of total seasonal use*
Dry-year irrigation reduction	10.5% of dry-year seasonal use*
Other savings	5% of annual use

Note: Data are from TWDB, 1996 and Freese and Nichols, Inc., 1999
* Seasonal use is defined as the water used above base winter water use

Table 2-13
Comparison of Per Capita Water Use and Municipal Conservation Trends

Region F	2000	2010	2020	2030	2040	2050
Per Capita Use (gpcd)	206	196	186	182	179	179
Decline from Year 2000	0	10	20	24	27	27
% Decline	0%	5%	10%	12%	13%	13%
Statewide						
Per Capita Use (gpcd)	180	170	160	155	152	151
Decline from Year 2000	0	10	20	25	28	29
% Decline	0%	5%	10%	12%	14%	14%

Note: Data are from Freese and Nichols, Inc., 1999 and TWDB CD, 1999. Statewide data do not include any changes made by Region F or any other Planning Group.

2.3.3 Municipal Water Demand

Municipal water demand projections are calculated by multiplying the population projections by the daily per capita water use. As shown in Table 2-5, the total municipal water demand for Region F is expected to increase from 147,100 acre-feet per year in 2000 to 185,257 acre-feet per year in 2050, an increase of 26 percent over the planning period. This compares to an expected 52 percent increase in municipal demand statewide.

2.4. Manufacturing Projections

Manufacturing use is the water used by industries in producing various products. The projections rely on relationships between water use and unit production of a product derived during the development of the consensus-based projections. Long-term projections of industrial growth at the regional level are from projections by the U.S. Bureau of Economic Analysis. Industrial growth was distributed to each county by the TWDB. It was assumed that the types of industry located in a particular county would remain the same throughout the planning period.

The consensus-based manufacturing projections assume that manufacturing use per unit of output will be reduced over time due to improvements in technology and other water conservation efforts. Table 2-14 gives the assumed reductions from 1990 water use over time for five key industries.

Table 2-14
Assumed Reduction in Water Use for Key Industries

Type of Industry	Reduction in 2000	Reduction in 2010	Reduction in 2020	Reduction from 2030 to 2050
Food and Kindred Products (SIC 20)	4%	8%	13%	17%
Chemical and Allied Products (SIC 28)	4%	8%	13%	17%
Pulp and Paper Products (SIC 26)	7%	14%	22%	30%
Semiconductors (SIC 36)	9%	18%	29%	40%
Petroleum Refining (SIC 29)	4%	8%	13%	17%

Note: Data are from TWDB, 1996.

Manufacturing water demand accounts for only one percent of the Region's total water use and is concentrated in a few counties. Ector, Howard and Kimble Counties are expected to have the largest manufacturing demands for the Region with a combined total use of over 8,000 acre-feet per year by 2050. Total manufacturing water use is expected to increase from 8,641 acre-feet in 2000 to 12,123 acre-feet by 2050, an increase of 3,482 acre-feet (see Table 2-6). Although this is a 40 percent increase in manufacturing demands from 2000 to 2050, manufacturing is expected to remain a relatively small amount of the Region's total demands. Statewide, manufacturing demand is expected to increase by 45 percent over the same planning period.

2.5. Irrigation Projections

Irrigated agriculture is the largest demand for water in Region F. Irrigation use can vary substantially from year to year depending on the number of irrigated acres, weather, crop prices, government programs and other factors. These projections are for dry-year conditions and represent the maximum demand expected during the planning period. During most of the planning period, irrigation demand will probably be less than predicted.

The irrigation projections adopted for Region F are substantially different from the consensus-based projections used in the 1997 State Water Plan. The revised projections are based on the maximum reported irrigation water use in each county between 1990 and 1997. From this starting point, the annual water use for irrigation was reduced over time by the amounts of water savings assumed in the consensus-based projections. Table 2-15 summarizes the reduction in irrigation demand for the region for each decade and compares these reductions to statewide totals.

Agricultural use accounted for 72 percent of Region F's total water use in 1996 and is projected to be 76 percent of the Region's demand in the year 2000. By 2050, irrigation is expected to be 68 percent of the Region's water demand (see Table 2-7). Statewide irrigation demand is projected to be 58 percent of total demand in the year 2000 and 44 percent of statewide demand in 2050 (statewide figures do not include revisions by Region F or any other regional planning group). The counties with the largest irrigation water demands are Tom Green, Reeves, Pecos, Glasscock, Midland and Reagan Counties. These counties are expected to account for 76 percent of the Region's irrigation demand.

Table 2-15
Comparison of Region F Irrigation Demand Projections to Statewide Projections

Region F	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Irrigation (ac-ft)	648,652	642,648	636,643	630,636	624,633	618,630
Decline from Year 2000	0	6,004	12,009	18,016	24,019	30,022
% Decline	0%	1%	2%	3%	4%	5%
Statewide						
Irrigation (ac-ft)	9,640,572	9,283,905	8,951,842	8,649,780	8,362,736	8,088,387
Decline from Year 2000	0	356,667	688,730	990,792	1,277,836	1,552,185
% Decline	0%	4%	7%	10%	13%	16%

Note: Data are from Freese and Nichols, Inc., 1999 and TWDB CD, 1999. Statewide data do not include any changes made by Region F or any other Planning Group.

2.6. Steam Electric Power Generation

The steam electric power generation water demand projections are based on information obtained in the survey of steam electric power generators and major water suppliers. The results of the survey indicated that West Texas Utilities plans to expand two existing facilities in Region F: the Rio Pecos Station in Crockett County and San Angelo Power Station in Tom Green County. Projections for other plants were also increased to account for area growth. In addition, a new plant is proposed in Ector County in the near future. Based on these projections, steam electric water demand is expected to increase 81 percent over the planning period, with a projected demand of 38,550 acre-feet per year in 2050. This makes steam electric demands the third highest use category in the region, behind agricultural irrigation and municipal. Table 2-8 summarizes the projections for steam electric demands. Statewide, steam electric demand is expected to increase from 529,600 acre-feet per year in 2000 to 937,900 acre-feet per year in 2050 (TWDB CD, 1999).

2.7. Mining Projections

The mining category includes water used in both the production of minerals and the production of oil and gas. The consensus-based mining water demand projections are based on water-use survey data for various types of mineral production. The historical data was used to calculate factors relating output to water use. These factors were applied to projections of future output for each commodity. It was assumed that the geographical location of production would remain constant throughout the 50-year planning period. Future water conservation measures are not built into the analysis. Table 2-16 compares Region F's mining projections to statewide projections.

Table 2-16
Comparison of Region F Mining Projections to Statewide Totals

Region F	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Mining (ac-ft)	31,236	25,696	22,785	21,557	21,001	21,161
Change from Year 2000	0	-5,540	-8,451	-9,679	-10,235	-10,075
% Change	0%	-18%	-27%	-31%	-33%	-32%
Statewide	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Mining (ac-ft)	148,839	205,373	186,677	181,854	191,480	193,588
Change from Year 2000	0	56,534	37,838	33,015	42,641	44,749
% Change	0%	38%	25%	22%	29%	30%

Note: Data are from Freese and Nichols, Inc., 1999 and TWDB CD, 1999. TWDB data does not include any changes made by Region F or any other Planning Group.

The oil and gas industry has played an important role in the development of West Texas and still accounts for a large percentage of its total payroll. However, oil field flooding, the primary water use associated with production of oil and gas, has declined over the years and is projected to continue to decline over the planning period. Other mining activities, such as sand, gravel and stone production, represent a small portion of the Region's economy and water demands. As a result, the mining water demands are projected to decrease by over 10,000 acre-feet per year by 2050. In 1990, statewide mining uses accounted for less than one percent of water use. By 2050, mining is expected to be only about two percent of the State's total water use.

2.8. Livestock Watering

Livestock watering accounted for slightly less than two percent of the water use in Texas in 1990. The projections use information developed by the Texas A&M Agricultural Extension Service to relate the water needs per head for each type of livestock and each type of livestock operation. The number of head in each county was estimated from information provided by the Texas Agricultural Statistics Service. Total water use for each county was calculated by multiplying the number of head by the estimated water need per head of livestock. Livestock water use was considered to be constant after the year 2000 (TWDB, 1996). Projections are only available for counties, river basins and regions. They are not available for specific livestock operations.

The Region F RWPG increased the consensus-based projections by 20 percent for the Region to account for the possibility of increased dairy operations and for water provided for wildlife - particularly deer and other animals that are hunted for sport. In many cases, there is not enough naturally available water to support wildlife population in the region, and hunting is an important source of income in most of the region. Livestock demand in Region F is expected to be 24,509 acre-feet per year throughout the planning period (see Table 2-10). Statewide livestock demand is expected to be 330,305 acre-feet per year.

2.9 Next Regional Water Plan

The following have been identified for further study during the next regional planning cycle:

- City of Eden – Population and water use
- Concho County – Population
- McCulloch County – Mining use
- Kimble County – Non-resident population water use

List of References

Freese and Nichols, Inc.: *Revisions to Population and Water Demand Projections for Region F*, 1999

Texas Water Development Board: *Historical and Projected Population and Water Use Data for Regional Planning Groups, Updated Version, 4/26/99, with 1997 Data Included*, published as a CDROM, Austin, 1999.

Texas Water Development Board: *Water for Texas – Today and Tomorrow: A 1996 Consensus-Based Update to the Texas Water Plan, Volume III, Water Use Planning Data Appendix*, Austin, 1996.

3.0 EVALUATION OF CURRENT SUPPLIES

3.1 Existing Ground Water Supplies

In 1997, ground water sources supplied 74 percent of all water used in the region. This source is primarily found in four major and seven minor aquifers that vary in quantity and quality. A description of these aquifers with regard to their location, geologic and hydrologic characteristics, historical yields and chemical quality may be found in Chapter 1. The following discussion will consider the quantity of water held in storage in each of these aquifers.

Ground water availability can be defined in various ways. For this amount to be meaningful, however, it should be defined based on locally accepted water use considerations. Previous estimates of the amount of ground water available for use were based on numerous local and regional aquifer studies that employed various methods of calculating water supplies. In some cases, only recharge was considered as the amount available on an annual basis. This consideration, called "safe yield", maintains a static storage level in the aquifer. In other cases, annual recharge along with a specified amount of depletion of water held in storage in the aquifer is allowed. In this case, a long-term water-level decline trend is expected.

For this study, ground water availability for each aquifer is based on an assessment of historical water use practices. The process used to estimate an availability amount for each aquifer includes a calculation of the quantity of water held in storage, the potential for recharge to the aquifer, and an assessment of the practicality of withdrawing water from the aquifer. The resulting availability was quantified based on ranges of water quality of less than 1,000 milligrams per liter (mg/l) and 1,000 to 3,000 mg/l total dissolved solids (TDS). Water with TDS levels greater than 3,000 mg/l is not considered useable for water supply.

For the current planning period, the volumes of water in storage in the Edwards-Trinity (Plateau), Ogallala, Cenozoic Pecos Alluvium, Hickory, Dockum, Ellenburger-San Saba, Lipan, and Trinity aquifers were calculated using ArcView, a geographic information system. The process involved the calculation of the volume of water contained between the geologic top and bottom of each aquifer as captured from USGS, TWDB and UTBEG reports and publications.

TWDB well data and recent water levels were used to establish water chemistry and saturated thickness. Specific yield/storage coefficient values for water table aquifers were obtained from reports and computer models or interpreted from pumping tests and multiplied by saturated thickness. Artesian head storage for confined aquifers was also calculated. For overlapping aquifers corrections were made to the volumetric calculations to better estimate the water in storage. Water in storage was not calculated for the Rustler, Marble Falls and Capitan Reef Complex aquifers because insufficient data are currently available.

The average annual effective recharge was not re-evaluated as part of this study; TWDB estimates were retained. The effective recharge, calculated total water in storage, and amount of retrievable ground water from storage for each aquifer and county are listed in tables following each aquifer description. These numbers represent average conditions. Ground water availability at a specific location can vary from the average. Also, for many aquifers within the region, the formations extend over very large rural areas, and data are not sufficient to effectively calculate ground water storage and availability throughout the aquifer's entire extent. The quantities of water reported in the tables are based on the entire extent of an aquifer within each county. The entire quantity of water cannot be extracted from a limited area.

For this study, the available supply from an aquifer is defined as annual effective recharge plus a portion of water taken from storage. The annual availability from the aquifers within Region F was generally defined based on location and historical aquifer use. The region was divided into three availability categories: 1) limited to annual effective recharge only, 2) annual recharge plus an annual amount equal to 75 percent of the retrievable storage over 100 years, and 3) annual recharge plus an annual storage depletion equal to 75 percent of the retrievable storage over 50 years. Figure 3-1 shows the distribution of counties by category. A summary of the annual ground water availability by aquifer and county using these assumptions is presented in Table 3-1. For the counties with high storage use, these assumptions do not imply that the 75 percent of the retrievable ground water supplies will be gone in 50 years. The actual quantities of water available on an annual basis are dependent on previous use. The demands used in this analysis are drought year demands. In most years the demands may be less than predicted, thereby reducing the amount of mining of the aquifer. However, aquifers that are heavily mined (i.e., greater than the estimated annual availability) may have less water available for future use.

FIGURE 3-1

Table 3-1 Annual Ground Water Availability

County	Aquifer	Basin	Annual Recharge	Annual Supply from Storage [1]	Annual Availability[2] (ac-ft/yr)
Andrews	Cenozoic Pecos Alluvium	Rio Grande	1,000	504	1,504
	Dockum	Colorado	0	905	905
		Rio Grande	0	5,792	5,792
	Ogallala	Colorado	22,427	8,852	31,279
		Rio Grande	3,293	1,040	4,333
	Edwards-Trinity	Colorado	786	435	1,221
Borden	Dockum	Colorado	0	117	117
	Ogallala	Brazos	0	108	108
		Colorado	300	482	782
Brown	Ellenburger-San Saba	Colorado	0	0	0
	Hickory	Colorado	0	0	0
	Trinity	Colorado	2,026	0	2,026
Coke	Dockum	Colorado	12	0	12
	Edwards-Trinity	Colorado	3,145	0	3,145
Coleman	Ellenburger-San Saba	Colorado	0	0	0
	Hickory	Colorado	0	0	0
Concho	Edwards-Trinity	Colorado	7,601	409	8,010
	Hickory	Colorado	0	14,299	14,299
	Lipan	Colorado	5,984	529	6,513
Crane	Cenozoic Pecos Alluvium	Rio Grande	3,000	0	3,000
	Dockum	Rio Grande	0	0	0
	Edwards-Trinity	Rio Grande	5,139	0	5,139
Crockett	Dockum	Rio Grande	0	0	0
	Edwards-Trinity	Colorado	2,157	0	2,157
		Rio Grande	82,426	0	82,426
Ector	Cenozoic Pecos Alluvium	Rio Grande	800	1,845	2,645
	Dockum	Colorado	0	2,498	2,498
		Rio Grande	0	3,479	3,479
	Edwards-Trinity	Colorado	4,593	1,103	5,696
		Rio Grande	546	135	681
	Ogallala	Colorado	4,850	999	5,849
Glasscock	Dockum	Colorado	0	140	140
	Ogallala	Colorado	940	2,988	3,928
	Edwards-Trinity	Colorado	13,629	3,518	17,147

Table 3-1 Annual Ground water Availability (Cont.)

County	Aquifer	Basin	Annual Recharge	Annual Supply from Storage	Annual Availability (ac-ft/yr)
Howard	Dockum	Colorado	0	900	900
	Edwards-Trinity	Colorado	1,573	94	1,667
	Ogallala	Colorado	2,610	7,799	10,409
Irion	Dockum	Colorado	0	0	0
	Edwards-Trinity	Colorado	19,133	0	19,133
Kimble	Edwards-Trinity	Colorado	26,734	0	26,734
	Ellenburger-San Saba	Colorado	216	0	216
	Hickory	Colorado	0	0	0
Loving	Cenozoic Pecos Alluvium	Rio Grande	4,320	3,906	8,226
	Dockum	Rio Grande	0	860	860
Martin	Ogallala	Colorado	7,760	11,642	19,402
	Edwards-Trinity	Colorado	7,760	503	8,263
Mason	Edwards-Trinity	Colorado	2,359	623	2,982
	Ellenburger-San Saba	Colorado	3,537	1,113	4,650
	Hickory	Colorado	21,521	54,971	76,492
McCulloch	Edwards-Trinity	Colorado	4,456	514	4,970
	Ellenburger-San Saba	Colorado	3,596	12,926	16,522
	Hickory	Colorado	3,419	122,726	126,145
Menard	Edwards-Trinity	Colorado	19,133	0	19,133
	Ellenburger-San Saba	Colorado	159	0	159
	Hickory	Colorado	0	0	0
Midland	Dockum	Colorado	0	45	45
	Ogallala	Colorado	3,270	1,397	4,667
	Edwards-Trinity	Colorado	12,319	1,313	13,632
Mitchell	Dockum	Colorado	8,744	5,274	14,018
Pecos	Dockum	Rio Grande	0	1,089	1,089
	Cenozoic Pecos Alluvium	Rio Grande	11,880	8,528	20,408
	Edwards-Trinity	Rio Grande	102,780	23,835	126,615
Reagan	Dockum	Rio Grande	0	54	54
	Edwards-Trinity	Colorado	19,797	9,364	29,161
		Rio Grande	1,647	720	2,367
Reeves	Dockum	Rio Grande	0	3,065	3,065
	Cenozoic Pecos Alluvium	Rio Grande	37,800	20,421	58,221
	Edwards-Trinity	Rio Grande	41,112	41,936	83,048
Runnels	Lipan	Colorado	4,536	0	4,536
Schleicher	Edwards-Trinity	Colorado	26,145	0	26,145
		Rio Grande	8,508	0	8,508
Scurry	Dockum	Brazos	7,898	1,940	9,838
		Colorado	3,226	3,159	6,385

Table 3-1 Annual Ground water Availability (Cont.)

County	Aquifer	Basin	Annual Recharge	Annual Supply from Storage	Annual Availability (ac-ft/yr)
Sterling	Dockum	Colorado	0	0	0
	Edwards-Trinity	Colorado	16,774	0	16,774
Sutton	Edwards-Trinity	Colorado	17,355	0	17,355
		Rio Grande	21,183	0	21,183
Tom Green	Dockum	Colorado	0	54	54
	Edwards-Trinity	Colorado	19,133	664	19,797
	Lipan	Colorado	24,916	12,570	37,486
Upton	Cenozoic Pecos Alluvium	Rio Grande	0	275	275
	Dockum	Rio Grande	0	797	797
	Edwards-Trinity	Colorado	13,263	1,303	14,566
		Rio Grande	17,039	1,292	18,331
Ward	Cenozoic Pecos Alluvium	Rio Grande	7,000	11,304	18,304
	Dockum	Rio Grande	0	2,340	2,340
Winkler	Cenozoic Pecos Alluvium	Rio Grande	5,000	48,267	53,267
	Dockum	Rio Grande	0	10,746	10,746
	Edwards-Trinity	Colorado	0	94	94

1. Annual supply from storage is based on a percent of the retrievable storage as shown on Figure 3-1.
2. Small amounts of water may be available from some aquifers showing an availability of “0”, because supply is limited to recharge only.

3.1.1 Edwards-Trinity (Plateau) Aquifer

Occurring in 21 counties, the Edwards-Trinity (Plateau) aquifer is the most extensive aquifer in Region F (Figures 3-2 and 3-3). Approximately 74 percent of the water withdrawn from the aquifer is used for irrigation and livestock watering. Regionally, this aquifer is categorized by the TWDB as one aquifer; however, the Edwards and Trinity components are not everywhere hydrologically connected and can be considered as separate aquifers. The largest single area of pumpage from the Edwards in Region F is in the Belding Farms area of Pecos County, while the greatest withdrawal from the Trinity (Antlers) is in the Saint Lawrence irrigation area in Glasscock, Reagan, Upton and Midland Counties.

Volumetric calculations of water in storage for the Edwards-Trinity (Plateau) were conducted using the USGS ground water model (USGS Report 93-4039). Assuming the aquifer to be unconfined, the geologic base of over 1000 wells along with the most recent TWDB water level

FIGURE 3-2

FIGURE 3-3

measurements were used to construct volumetric maps of the aquifer. Consideration was given to wells completed in the Edwards Limestone versus the Trinity Group due to variations of specific yields of the different formations (0.04 for the Edwards and associated limestones and 0.02 for the Trinity Group and Antlers Sand). Also, corrections to the volumetric calculations were made to account for the overlap of the Edwards Trinity with the Ogallala and Cenozoic Pecos Alluvium aquifers.

The geographical distribution of water quality is illustrated in Figure 3-2 and the USGS based saturated thickness of the aquifers in Figure 3-3. The calculated quantity of water in storage in the Edwards-Trinity (Plateau) aquifer in Region F is 48,013,000 acre-feet. Approximately 29,744,000 acre-feet of the ground water have TDS concentrations below 1,000 mg/l and 18,269,000 acre-feet of ground water have TDS concentrations between 1,000 and 3,000 mg/l. Average annual effective recharge calculated by the TWDB is 518,225 acre-feet per year. The estimated annual effective recharge and quantity in storage by river basin, county and water quality range and are listed in Table 3-2.

The amount of water in storage that could reasonably be retrieved was calculated based on available transmissivity and specific capacity data. The retrievable availability from the Edwards-Trinity (Plateau) aquifer in Region F is estimated to be 25 percent of water in storage. This corresponds to an estimated 12,003,000 acre-feet of water with TDS concentrations less than 3,000 mg/l (Table 3-2).

3.1.2 Ogallala Aquifer

The Ogallala aquifer occurs in the seven northernmost counties of Region F (Figures 3-4 and 3-5) and is primarily used for irrigation and municipal supply. The formation is hydrologically connected to the underlying Edwards-Trinity (Plateau) aquifer in southern Andrews and Martin Counties, and northern Ector, Midland and Glasscock Counties. The southernmost extent of the Ogallala in Ector and Midland Counties is thin, and its exact contact with the underlying Edwards-Trinity is not well defined. Recent local irrigation and water use has lowered water levels in some locations in Borden, Ector and Midland counties.

Table 3-2 Edwards Trinity (Plateau) Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 0-1000 mg/l (Acre - feet)[2]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable	Total County Acreage	Percent of County <3000 mg/l TDS
Andrews*	Colorado	786	105,159	116,000	0	0	116,000	29,000	957,250	11.0
Coke	Colorado	3,145	183,978	137,000	0	0	137,000	34,250	592,085	31.1
Concho	Colorado	7,601	235,419	218,000	0	0	218,000	54,500	632,465	37.2
Crane	Rio Grande	5,139	0	0	13,357	22,000	22,000	5,500	509,040	2.6
Crockett	Colorado	2,157	38,356	179,000	6,256	39,000	218,000	54,500	1,789,465	2.5
Crockett	Rio Grande	82,426	1,393,508	4,550,000	326,751	1,060,000	5,610,000	1,402,500	1,789,465	96.1
Ector*	Colorado	4,593	213,465	176,000	131,793	118,000	294,000	73,500	573,364	60.2
Ector	Rio Grande	546	4,214	2,000	37,005	34,000	36,000	9,000	573,364	7.2
Glasscock*	Colorado	13,629	452,772	840,000	52,909	98,000	938,000	234,500	575,082	87.9
Howard	Colorado	1,573	41,249	25,000	0	0	25,000	6,250	578,023	7.1
Irion	Colorado	19,133	433,016	1,098,000	139,940	354,000	1,452,000	363,000	669,582	85.6
Kimble	Colorado	26,734	772,885	1,790,000	16,311	38,000	1,828,000	457,000	798,864	98.8
Martin*	Colorado	7,760	59,146	44,000	31,085	90,000	134,000	33,500	583,042	15.5
Mason	Colorado	2,359	96,976	332,000	0	0	332,000	83,000	594,060	16.3
McCulloch	Colorado	4,456	163,252	274,000	0	0	274,000	68,500	683,996	23.9
Menard	Colorado	19,133	566,709	1,199,000	0	0	1,199,000	299,750	575,055	98.5
Midland*	Colorado	12,319	292,881	350,000	276,557	350,000	700,000	175,000	578,196	98.5
Pecos**	Rio Grande	102,780	1,600,458	9,843,000	791,700	2,869,000	12,712,000	3,178,000	3,043,515	78.6
Reagan	Colorado	19,797	171,590	669,000	465,346	1,828,000	2,497,000	624,250	750,056	84.9
Reagan	Rio Grande	1,647	0	0	52,637	192,000	192,000	48,000	750,056	7.0
Reeves**	Rio Grande	41,112	138,597	1,465,000	605,459	9,718,000	11,183,000	2,795,750	1,690,202	44.0

Table 3-2 (Cont.) Edwards Trinity (Plateau) Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	0-1000 mg/l (Acre - feet)[2]	1000-3000 mg/l (Acres)[1]	1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Schleicher	Colorado	26,145	630,510	1,840,000	0	0	1,840,000	460,000	836,084	75.4
Schleicher	Rio Grande	8,508	205,574	998,000	0	0	998,000	249,500	836,084	24.6
Sterling	Colorado	16,774	125,155	242,000	103,010	198,000	440,000	110,000	590,060	38.7
Sutton	Colorado	17,355	416,540	1,068,000	0	0	1,068,000	267,000	926,274	45.0
Sutton	Rio Grande	21,183	509,496	1,964,000	0	0	1,964,000	491,000	926,274	55.0
Tom Green	Colorado	19,133	394,958	177,000	0	0	177,000	44,250	982,771	40.2
Upton	Colorado	13,263	26,331	59,000	276,467	636,000	695,000	173,750	779,341	38.9
Upton	Rio Grande	17,039	35,292	64,000	353,400	625,000	689,000	172,250	779,341	49.9
Winkler	Colorado	0	13,537	25,000	0	0	25,000	6,250	537,648	2.5

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 25% recovery of total water in storage

Total Storage in Acre - feet (<3000 mg/l TDS) **48,013,000**

Retrievable Availability Acre-feet (< 3000 mg/l TDS) **12,003,000**

* Edwards-Trinity (Plateau) / Ogallala aquifers overlap corrected

** Edwards-Trinity (Plateau) / Cenozoic Pecos Alluvium overlap corrected

FIGURE 3-4

FIGURE 3-5

Table 3-3: Ogallala Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS)				Water in Storage (Acre - feet)		Total County Acreage	Percent of County <3000 mg/l TDS
			0-1000 mg/l		1000-3000 mg/l					
			(Acres)[1]	(Acre - feet)[2]	(Acres)[1]	(Acre - feet)[2]	Total	Retrievable[3]		
Andrews	Colorado	22,427	200,617	482,000	580,518	1,485,000	1,967,000	590,100	957,250	82
Andrews	Rio Grande	3,293	9,963	37,000	90,868	194,000	231,000	69,300	957,250	11
Borden	Brazos	0	0	0	3,835	24,000	24,000	7,200	573,114	1
Borden	Colorado	300	841	10,000	15,339	97,000	107,000	32,100	573,114	3
Ector	Colorado	4,850	0	0	128,475	222,000	222,000	66,600	573,364	22
Glasscock	Colorado	940	5,044	99,000	99,994	565,000	664,000	199,200	575,082	18
Howard	Colorado	2,610	101,975	451,000	160,800	1,282,000	1,733,000	519,900	578,023	45
Martin	Colorado	7,760	71,176	134,000	488,415	2,453,000	2,587,000	776,100	583,042	96
Midland	Colorado	3,270	58,225	100,000	253,308	521,000	621,000	186,300	578,196	54

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 30% recovery of total water in storage

Total Storage in Acre - feet (<3000 mg/l TDS) **8,156,000**

Retrievable Availability Acre-feet (< 3000 mg/l TDS) **2,446,800**

The TWDB developed a computer flow model to simulate conditions in the Ogallala aquifer in the early 1980s (Knowles, 1984) and revised the model in 1993 (TWDB Report 341). Texas Tech University modified the TWDB model to a MODFLOW format. The most recent TWDB water levels were used with the modified model outputs to calculate the ground water storage of the Ogallala Aquifer. An average specific yield of 0.15 was used in the calculations of the water in storage. A correction was applied to the volumetric calculations to account for Ogallala overlap with the Edwards-Trinity Plateau aquifer.

The water quality of the aquifer is illustrated in Figure 3-4 and the saturated thickness of the aquifer in Figure 3-5. The total quantity of water in storage with less than 3,000 mg/l TDS is estimated to be 8,154,000 acre-feet (Table 3-3). There are approximately 1,312,000 acre-feet of ground water with TDS concentrations less than 1,000 mg/l and 6,843,000 acre-feet with TDS concentrations between 1,000 and 3,000 mg/l. The retrievable availability is estimated to be 30 percent of the water in storage, corresponding to an estimated 2,446,800 acre-feet of water with less than 3,000 mg/l TDS. In addition, there are 45,450 acre-feet of annual recharge available from the Ogallala in Region F.

3.1.3 Cenozoic Pecos Alluvium Aquifer

The Cenozoic Pecos Alluvium aquifer occupies two structural basins in the westernmost counties of Region F (Figures 3-6 and 3-7). The eastern basin (Monument Draw Trough) contains relatively good quality water that is used for a variety of purposes, including public drinking water supply. The western basin (Pecos Trough) contains poorer quality water and is used most extensively for irrigation of salt-tolerant crops.

Recharge to the Cenozoic Pecos Alluvium aquifer occurs by infiltration of precipitation, seepage from the Pecos River and tributaries, lateral subsurface flow from adjacent formations, and infiltration from irrigation water used on fields and in canals (Ashworth, 1990). The TWDB estimates total annual effective recharge to the aquifer to be 70,800 acre-feet.

Lateral subsurface flow from the Rustler aquifer into the western Pecos Trough has significantly affected the chemical quality of ground water in the overlying aquifer. Most of this basin contains water with greater than 1,000 mg/l TDS, and a significant portion is above 3,000 mg/l TDS. The eastern Monument Draw Trough is underlain by the Dockum aquifer but is not

FIGURE 3-6

FIGURE 3-7

as significantly affected by its quality difference. Poorer water quality with increasing depth was not found in either the Pecos or Monument Troughs after reviewing TWDB well data. However, the poorest water quality in the Pecos Trough was within 200 feet of the surface, suggesting possible surface sources of contamination.

Water quality deterioration has limited the use of some of the water in the aquifer. Past oil-field related contamination has diminished the quality of water in parts of Ward and Winkler Counties, while irrigation return flow has increased dissolved constituents in some wells in south-central Reeves County, the Coyanosa area of Pecos County and the Barstow area of Ward County. The geographical distribution of water quality is illustrated in Figure 3-6.

Water levels in the past fifty years have generally been stable. However, in Reeves and Pecos Counties water levels have dropped an average of 80 feet. Figure 3-7 is an illustration of the saturated thickness of the Cenozoic Pecos Alluvium. Volumetric calculations indicate that the total ground water in storage in the Cenozoic Pecos Alluvium aquifer with less than 3,000 mg/l TDS is approximately 11,944,000 acre-feet, based on an average specific yield of the permeable saturated material of 0.15. Of this amount, 3,617,000 acre-feet of ground water have TDS concentrations below 1,000 mg/l, and 8,327,000 acre-feet have concentrations between 1,000 and 3,000 mg/l TDS. Annual effective recharge and water in storage by TDS level are listed for each county in Table 3-4. The retrievable availability is estimated to be 60 percent of the water in storage. The Cenozoic Pecos Alluvium has an estimated 7,166,400 acre-feet of retrievable water in storage with TDS concentrations below 3,000 mg/l.

Table 3-4: Cenozoic Pecos Alluvium

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	0-1000 mg/l (Acre - feet)[2]	1000-3000 mg/l (Acres)[1]	1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Andrews	Rio Grande	1,000	0	0	33,908	56,000	56,000	33,600	957,250	4
Crane	Rio Grande	3,000	95,968	144,000	173,671	261,000	405,000	243,000	509,040	53
Ector	Rio Grande	800	0	0	124,613	205,000	205,000	123,000	573,364	22
Loving	Rio Grande	4,320	0	0	119,199	434,000	434,000	260,400	432,423	28
Pecos*	Rio Grande	11,880	12,390	42,000	278,760	1,853,000	1,895,000	1,137,000	3,043,515	10
Reeves*	Rio Grande	37,800	34,806	10,000	718,358	2,259,000	2,269,000	1,361,400	1,690,202	45
Upton	Rio Grande	0	0	0	41,134	61,000	61,000	36,600	779,341	5
Ward	Rio Grande	7,000	111,982	617,000	138,325	639,000	1,256,000	753,600	531,213	47
Winkler	Rio Grande	5,000	265,972	2,804,000	207,726	2,559,000	5,363,000	3,217,800	537,648	88

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 60% recovery of total water in storage

Total Storage in Acre - feet (<3000 mg/l TDS) **11,944,000**
Retrievable Availability Acre-feet (< 3000 mg/l TDS) **7,166,400**

*Cenozoic Pecos Alluvium / Edwards-Trinity Plateau overlap corrected

3.1.4 Hickory Aquifer

The Hickory aquifer is located in the eastern portion of Region F and outcrops in Mason and McCulloch Counties (Figures 3-8 and 3-9). This aquifer supplies ground water to Concho, Kimble, Mason, McCulloch and Menard Counties. The Hickory Formation is comprised of sands and gravels eroded from the granites of the Llano uplift in central Texas. Water quality is generally good adjacent to and within the Hickory outcrop. Water quality deteriorates moving away from and downdip of the outcrop, with increasing concentrations of salts and natural radioactive decay products. The radioactive decay products are derived from the breakdown of the feldspar minerals in the Hickory sands and gravels.

Annual effective recharge of the Hickory aquifer occurs at the outcrop and was calculated by the TWDB to be 24,940 acre-feet. The majority of this recharge occurs in Mason County. Over the past twenty years, water levels have decreased up to 20 feet locally, but generally the decrease has been less than 10 feet.

Water in storage within the Hickory aquifer was calculated by using geologic picks of the base of the Hickory from previous geological studies submitted to the Hickory Underground Water Conservation District and recent TWDB water level data. The Hickory aquifer is generally a confined aquifer but is unconfined at the outcrops in Mason and McCulloch Counties. Volumetric calculations included artesian storage as well as confined and unconfined storage of the aquifer. The geographical distribution of total dissolved solids water quality is illustrated in Figure 3-8, and Figure 3-9 illustrates the geographic distribution of the confined and unconfined aquifer saturated thickness

Total ground water in storage in the Hickory aquifer was calculated based on an average specific yield of 0.15. Ground water in storage with TDS concentrations less than 1,000 mg/l is approximately 53,350,000 acre-feet, and there is approximately 25,290,000 acre-feet with TDS concentrations between 1,000 and 3,000 mg/l. The total amount of ground water in storage with concentrations less than 3,000 mg/l is 78,640,000 acre-feet, of which approximately 50 percent is retrievable. An estimated 39,341,000 acre-feet of water is available from storage. However, block faulting has compartmentalized the Hickory aquifer and could limit the availability and production of ground water locally. Table 3-5 lists the ground water storage by river basin, county and water quality.

FIGURE 3-8

FIGURE 3-9

Table 3-5: Hickory Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 0-1000 mg/l (Acre - feet)[2]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Brown	Colorado	0	0	0	18,817	500,000	500,000	250,000	610,155	3
Coleman	Colorado	0	0	0	40,570	1,082,000	1,082,000	541,000	816,874	5
Concho	Colorado	0	28,468	1,236,000	58,814	2,577,000	3,813,000	1,906,500	632,465	14
Kimble	Colorado	0	153,290	4,096,000	301,199	7,922,000	12,018,000	6,009,000	798,864	57
Mason	Colorado	21,521	374,396	14,659,000	0	0	14,659,000	7,329,500	594,060	63
McCulloch	Colorado	3,419	479,670	25,603,000	131,552	7,124,000	32,727,000	16,363,500	683,996	89
Menard	Colorado	0	158,887	7,757,000	124,793	6,126,000	13,883,000	6,941,500	575,055	49

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 50% recovery of total water in storage

Total Storage in Acre - feet (<3000 mg/l TDS) **78,640,000**

Retrievable Availability Acre-feet (< 3000 mg/l TDS) **39,341,000**

3.1.5 Dockum Aquifer

Although the Dockum aquifer underlies much of the region (Figures 3-10 and 3-11), its low water-yielding potential and generally poor quality results in its minor aquifer classification. Most Dockum water used for irrigation is withdrawn in Mitchell and Scurry Counties, while public supply use of Dockum water occurs mostly in Reeves and Winkler Counties.

The primary water-bearing zone in the Dockum (the Santa Rosa) abuts the overlying Trinity aquifer along a defined corridor that traverses Sterling, Irion, Reagan and Crockett Counties. Within this corridor, the Trinity and Dockum are hydrologically connected, thus forming a thicker aquifer section. A similar hydrologic relationship occurs in Ward and Winkler Counties, where the Santa Rosa unit of the Dockum is in direct contact with the overlying Cenozoic Pecos Alluvium aquifer. Local ground water reports use the term Allurosa aquifer in reference to this combined section of water-bearing sands.

Recharge occurs rapidly where the Dockum outcrops or is near the surface in Scurry, Mitchell, Sterling and Coke counties. The TWDB estimates that 19,880 acre-feet of annual effective recharge occur in these four counties. Elsewhere, the Dockum is buried at depths that generally eliminate recharge. Ground water pumped from the aquifer in these areas will come directly from storage and result in water level declines. Water levels have generally been lowered from a few feet to 10 feet in the past twenty years, however, locally water levels have dropped as much as 50 feet.

The net sand thickness of the Dockum aquifer was obtained from the Bureau of Economic Geology Report of Investigations 161, and the water level data was from the TWDB. The Dockum aquifer is confined for most of Region F and is unconfined only in parts of Scurry, Mitchell, Sterling and Coke counties. Volumetric calculations included artesian storage as well as confined and unconfined storage of the aquifer.

FIGURE 3-10

FIGURE 3-11

Table 3-6: Dockum Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	0-1000 mg/l (Acre - feet)[2]	1000-3000 mg/l (Acres)[1]	1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Andrews	Colorado	0	0	0	76,651	201,000	201,000	60,300	957,250	8
Andrews	Rio Grande	0	0	0	394,859	1,287,000	1,287,000	386,100	957,250	41
Borden	Colorado	0	0	0	20,869	26,000	26,000	7,800	573,114	4
Crane	Rio Grande	0	0	0	239,846	523,000	523,000	156,900	509,040	47
Coke	Colorado	12	6,241	1,200	0	0	1,200	360	592,085	1
Crockett	Rio Grande	0	0	0	170,213	219,000	219,000	65,700	1,789,465	10
Ector	Colorado	0	0	0	172,688	555,000	555,000	166,500	573,364	30
Ector	Rio Grande	0	0	0	228,877	773,000	773,000	231,900	573,365	40
Glasscock	Colorado	0	0	0	46,457	31,000	31,000	9,300	575,082	8
Howard	Colorado	0	1,729	1,000	161,025	199,000	200,000	60,000	578,023	28
Irion	Colorado	0	0	0	209,003	107,000	107,000	32,100	669,582	31
Loving	Rio Grande	0	32,433	27,000	132,685	164,000	191,000	57,300	432,423	38
Midland	Colorado	0	0	0	5,850	20,000	20,000	6,000	578,196	1
Mitchell	Colorado	8,744	126,140	488,000	205,207	684,000	1,172,000	351,600	583,562	57
Pecos	Rio Grande	0	366,114	478,000	8,814	6,000	484,000	145,200	3,043,515	12
Reagan	Rio Grande	0	0	0	7,525	12,000	12,000	3,600	750,056	1
Reeves	Rio Grande	0	204,656	468,000	137,524	213,000	681,000	204,300	1,690,202	20
Scurry	Brazos	7,898	151,872	398,000	7,825	33,000	431,000	129,300	580,459	28
Scurry	Colorado	3,226	145,982	262,000	74,985	440,000	702,000	210,600	580,459	38
Sterling	Colorado	0	334,014	173,000	191,529	117,000	290,000	87,000	590,060	89
Tom Green	Colorado	0	0	0	23,236	12,000	12,000	3,600	982,771	2

Table 3-6: Dockum Aquifer (Cont)

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	0-1000 mg/l (Acre - feet)[2]	1000-3000 mg/l (Acres)[1]	1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Upton	Rio Grande	0	0	0	96,828	354,000	354,000	106,200	779,341	12
Ward	Rio Grande	0	200,682	297,000	190,333	223,000	520,000	156,000	531,213	74
Winkler	Rio Grande	0	307,070	1,490,000	204,543	898,000	2,388,000	716,400	537,648	95

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 30% recovery of total water in storage

Total Storage in Acre-Feet (<3000 mg/l TDS)	**11,178,000**
Retrievable Availability Acre-Feet (< 3000 mg/l TDS)	**3,354,000**

The geographical distribution of water quality within the Dockum aquifer is shown in Figure 3-10 and saturated thickness of the aquifer in Figure 3-11. A specific yield of 0.01 to 0.03 was used to calculate ground water in storage (Bradley, 1999). The quantity of Dockum water in storage with less than 1,000 mg/l TDS is approximately 4,083,000 acre-feet, and 7,095,000 acre-feet with TDS concentrations between 1,000 to 3000 mg/l. There is a total of 11,178,000 acre-feet of water in storage with TDS concentrations less than 3000 mg/l (Table 3-6). Of this amount, approximately 30 percent is considered retrievable. An estimated 3,354,000 acre-feet of water in storage and 19,880 acre-feet per year of recharge are available from the Dockum aquifer in Region F.

3.1.6 Lipan Aquifer

The Lipan aquifer lies within Concho, Runnels and Tom Green Counties (Figures 3-12 and 3-13) and is principally used for irrigation. Most of the irrigation is in Tom Green County. Typical irrigation practice in the area is to withdraw water held in storage in the aquifer during the growing season with expectation of recharge recovery during the winter months. The range of water levels has remained generally unchanged for the last twenty years. Thus, ground water availability for this aquifer is a function of average annual recharge, although storage may not recover completely in a dry year. The average annual effective recharge of the Leona Formation, a formation included in the Lipan aquifer, is 35,436 acre-feet. The Lipan-Kickapoo Water Conservation District controls overuse by limiting well density and spacing. Figure 3-12 is an illustration of the geographic distribution of water quality within the aquifer.

Volumetric calculations of the water in storage in the Lipan aquifer were generated from TWDB well depths and depth to water measurements. Most wells in the aquifer penetrate through the Leona Sands (Lipan) and partially penetrate into the underlying Permian aquifers (San Angelo Sandstone, Choza Formation, or the Bullwagon Dolomite Member). The volumetric calculations also include the saturated sections of these aquifers. Figure 3-13 illustrates the geographic distribution of the saturated thickness of the aquifers. A specific yield of 0.15 (estimated value) was used to calculate the water in storage. The water in storage in the aquifer with TDS concentrations less than 1,000 mg/l is estimated to be 50,000 acre-feet for all three counties. Approximately 1,880,000 acre-feet of ground water have TDS concentrations between 1,000 and 3,000 mg/l. There is a total of 1,930,000 acre-feet of ground water in storage with

FIGURE 3-12

FIGURE 3-13

TDS concentrations less than 3,000 mg/l. The retrievable availability is estimated to be 50 percent of the water in storage. The Lipan aquifer has an estimated 964,750 acre-feet of retrievable water in storage and 35,436 acre feet per year of effective recharge. The estimated volume of water in storage by TDS level and average annual recharge for each county is listed in Table 3-7.

3.1.7 Trinity Aquifer

The Trinity aquifer is a major ground water source for eastern Brown County (Figure 3-14). Small isolated outcrops of Trinity Age rocks also occur in south central Brown County and northwest Coleman County, with wells that are completed into the Trinity. However, these two areas are not classified as the contiguous Trinity aquifer by TWDB as shown in Figure 3-14. Almost 24,000 acre-feet of water were pumped from the Trinity aquifer in Brown and Coleman Counties from 1984 through 1996. Average annual use has generally increased except for a decline in usage from 1990 to 1992 when rainfall greatly exceeded normal levels. Irrigation and livestock account for about 80 percent of the total usage of the Trinity aquifer water, and municipal and mining/oil industry usage account for 15 and 4 percent, respectively.

Water quality is variable but generally acceptable for most uses. Water samples taken by the TWDB since 1980 from wells reportedly completed into the Trinity aquifer have analyzed near or below 1,000 mg/l TDS. However, a number of samples from other wells analyzed in the 1960s have reported levels in excess of 3,000 mg/l total dissolved solids. There are two possible sources for these higher TDS levels. The first is believed to be a result of wells being completed in both the deeper portion of the Trinity and underlying Paleozoic rocks that have higher dissolved solids concentrations. The second possible source is associated with saltwater contamination from nearby oil and gas wells or unlined brine-disposal pits, which were outlawed in 1969.

FIGURE 3-14

Table 3-7: Lipan Aquifer

County	Basin	Annual Effective Recharge (Acre-Feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 0-1000 mg/l (Acre–Feet)[2]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acre-Feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Concho	Colorado	5,984	1,670	10,000	70,132	131,000	141,000	70,500	632,465	11
Runnels	Colorado	4,536	265	1,500	54,164	111,000	112,500	56,250	674,994	8
Tom Green	Colorado	24,916	35,847	38,000	263,140	1,638,000	1,676,000	838,000	982,771	30

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 50% recovery of total water in storage

Total Storage in Acre-Feet (<3000 mg/l TDS) **1,929,500**
Retrievable Availability Acre-Feet (< 3000 mg/l TDS) **964,750**

Table 3-8: Trinity Aquifer

County	Basin	Annual Effective Recharge (Acre–Feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 0-1000 mg/l (Acre-Feet)[2]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acre-Feet)[2]	Water in Storage (Acre - Feet) Total	Water in Storage (Acre - Feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Brown	Colorado	2,026	170,843	154,000	---	---	154,000	38,500	610,155	28

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 25% recovery of total water in storage

Total Storage in Acre-Feet (<3000 mg/l TDS) **154,000**
Retrievable Availability Acre-Feet (< 3000 mg/l TDS) **38,500**

Water levels reported for the Trinity aquifer in this area prior to 1990 were generally on a downward trend. However, higher than normal recharge and lower than normal pumpage from 1990 to 1992 resulted in significant rises in water levels. Because of the relatively thin amount of net saturated sand thickness of about 20 to 40 feet for the aquifer in this area, ground water availability on a sustained basis should be based on 2,026 acre-feet of annual effective recharge as calculated by the TWDB.

For practical purposes, some aquifer mining may be used on a short-term basis. Total aquifer storage for the Trinity aquifer in Brown County is estimated using 30 feet of net saturated sand over the contiguous aquifer area and a storage coefficient of 0.03 to derive a total quantity of approximately 154,000 acre-feet of water in storage (Table 3-8). The retrievable availability of the water in storage is estimated to be 25 percent, resulting in an estimated 38,500 acre-feet of water.

3.1.8 Ellenburger-San Saba Aquifer

Including the downdip boundary as designated by the TWDB, the Ellenburger-San Saba aquifer occurs in Brown, Coleman, Kimble, Mason, McCulloch and Menard Counties within the region (Figures 3-15 and 3-16). Currently, most pumpage from the aquifer occurs in McCulloch County. In Brown and Coleman Counties, the aquifer is present in only the extreme southern part, and most of the aquifer in this area contains water in excess of 1,000 mg/l TDS. The downdip boundary of the aquifer, which represents the extent of water with less than 3,000 mg/l TDS, is roughly estimated due to lack of data.

The TWDB estimates that the average annual effective recharge is approximately 7,508 acre-feet for the Ellenburger-San Saba aquifer. Most of the recharge is occurring in Mason and McCulloch Counties. The TWDB does not include Brown and Coleman Counties in this estimate.

FIGURE 3-15

FIGURE 3-16

Table 3-9: Ellenburger-San Saba Aquifer

County	Basin	Annual Effective Recharge (Acre - feet)	Total Dissolved Solids (TDS) 0-1000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 0-1000 mg/l (Acre - feet)[2]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acres)[1]	Total Dissolved Solids (TDS) 1000-3000 mg/l (Acre - feet)[2]	Water in Storage (Acre - feet) Total	Water in Storage (Acre - feet) Retrievable[3]	Total County Acreage	Percent of County <3000 mg/l TDS
Brown	Colorado	0	0	0	14,775	84,000	84,000	58,800	610,155	2
Coleman	Colorado	0	19,060	86,000	45,281	150,000	236,000	165,200	816,874	8
Kimble	Colorado	216	73,719	186,000	0	0	186,000	130,200	798,864	9
Mason	Colorado	3,537	152,318	212,000	0	0	212,000	148,400	594,060	26
McCulloch	Colorado	3,596	554,672	2,081,000	74,495	381,000	2,462,000	1,723,400	683,996	92
Menard	Colorado	159	95,899	74,000	0	0	74,000	51,800	575,055	17

1) Areal extent of aquifer
2) Aquifer storage volume
3) Assumes optimal well spacing and 70% recovery of total water in storage

Total Storage in Acre - feet (<3000 mg/l TDS) **3,254,000**

Retrievable Availability Acre-feet (< 3000 mg/l TDS) **2,277,800**

Volumetric calculations of the water in storage in the Ellenburger-San Saba aquifer were generated from TWDB well depths and the depth to water measurements. Figure 3-15 illustrates the distribution of water quality within the aquifer, and Figure 3-16 illustrates the saturated thickness of the aquifer. The amount of ground water held in storage in the aquifer with less than 1,000 mg/l TDS is estimated to be 2,639,000 acre-feet (Table 3-9). There are approximately 615,000 acre-feet in storage with a TDS concentration between 1,000 and 3,000 mg/l, making a total of 3,254,000 acre-feet of ground water in storage with TDS concentrations below 3,000 mg/l. Most of this water is assumed to be in the downdip artesian part of the aquifer, and very little information exists to substantiate this amount. The faulting and compartmentalization of the aquifer control the amount of water available at any location. The retrievable availability is estimated to be 70 percent of the water in storage. The Ellenburger-San Saba aquifer has an estimated 2,277,800 acre-feet of retrievable water in storage in Region F.

3.1.9 Rustler Aquifer

The Rustler Formation outcrops outside of the region, in Culberson County, but the majority of its recognized downdip extent occurs in Loving, Pecos, Reeves and Ward Counties (Figure 3-17). Throughout most of its extent, the aquifer is relatively deep below the land surface, and it generally contains water with dissolved constituents in excess of 3,000 mg/l TDS. Only in western Pecos, eastern Loving and southeastern Reeves Counties has water been identified that contains less than 3,000 mg/l TDS. No ground water from the Rustler aquifer has been located that meets safe drinking water standards. Rustler ground water is primarily used for livestock watering and a minor amount of irrigation.

Because the Rustler Formation does not outcrop within the region, actual recharge does not occur to the aquifer within the region. The TWDB has assigned 3,000 acre-feet (recharge from outcrop west of Region F) of retrievable ground water from the aquifer. Water that exists in the aquifer has moved laterally downdip from the outcrop area and possibly through cross-formational flow from other formations. Due to the lack of hydrological and well data, no volumetric calculations were done for the Rustler aquifer.

FIGURE 3-17

3.1.10 Marble Falls Aquifer

The Marble Falls is the smallest aquifer in the region, occurring in very limited outcrop areas in Kimble, Mason and McCulloch Counties (Figure 3-18). A limited amount of well data suggests that water quality is acceptable for most uses only in wells located on the outcrop and in wells that are less than 300-feet deep in the downdip portion of the aquifer.

The TWDB reports 3,912 acre-feet as the average annual effective recharge in McCulloch County and makes no estimates for Kimble and Mason Counties. There is currently insufficient data available to calculate water in storage for this aquifer. Since no severe water level declines have been reported in existing wells, it is reasonable to speculate that water availability from the Marble Falls aquifer is at least equivalent to an average annual withdrawal rate of 162 acre-feet.

3.1.11 Capitan Reef Complex Aquifer

The Capitan Reef Complex aquifer underlies the Cenozoic Pecos Alluvium, Edwards-Trinity (Plateau), Dockum and Rustler aquifers in Pecos, Ward and Winkler Counties (Figure 3-19). Very little reliance has been placed on this aquifer due to its depth, limited extent and marginal quality. Because of these limitations, the TWDB has not assigned an availability amount to this aquifer within the region.

Due to the structural complexity of this aquifer and the lack of hydrologic data, the amount of water held in storage has not been calculated. A conservative estimate of availability is equivalent to the 471 acre-feet of average annual historical pumpage from the aquifer in Ward County. A similar quantity is likely in Winkler and Pecos Counties; however, quality limitations may restrict its use. The Capitan Reef Complex aquifer in these counties requires significantly more research before a reasonable estimate of ground water availability can be made.

FIGURE 3-18

FIGURE 3-19

3.2 Existing Surface Water Supplies

3.2.1 Region F Reservoirs

There are 17 major water supply reservoirs in Region F. These reservoirs are the primary source of surface water supplies in the region. A map showing the location of each reservoir may be found in Figure 1-1 of Chapter 1. General information on these reservoirs is presented in Table 3-10. As part of this study, both the stand-alone firm yield and the safe yield for each reservoir were calculated. System analyses were also conducted for the CRMWD system (Thomas, Spence and Ivie), the Colorado City/Champion Creek system and the San Angelo system (Fisher, Nasworthy and Twin Buttes). Table 3-11 gives the firm yield results for these reservoirs and Table 3-12 gives the safe yield results. Additional yield provided by system operations is also shown on these tables.

The *yield* of a reservoir is the annual amount of water that could reliably be obtained during a repeat of the worst historical drought experienced in the period of available hydrologic record. There are two commonly accepted definitions of the amount of water that can be reliably obtained from a reservoir: the *firm yield* and *safe yield*. The difference between firm and safe yields is that the safe yield leaves some supply in storage at the end of the drought, while the firm yield assumes no reserves. Figure 3-20 compares the firm yields to the safe yields for the region. Figure 3-21 is a graphical comparison of the contents of a reservoir in a firm yield simulation and a safe yield simulation.

Regulation TAC §357.7(a)3, part of the rules governing Senate Bill One sponsored water plans, defines the firm yield as the amount of water available from a reservoir. Firm yield analyses are required as part of the Senate Bill One planning. However, in previous studies within the region safe yields have been commonly used to evaluate reservoir supply, and they are included for comparison.

Two other important concepts are the *drought of record* and the *critical period* of the reservoir. The *drought of record* is the time period between the last time a reservoir was full and the next time it is again full. The *critical period* is the time between the last time a reservoir was full and the point where it reaches the minimum storage volume. The sequence of flows during the critical period defines the amount of water available from the reservoir. These concepts are

Figure 3-20
Projected Yields of Region F Reservoirs

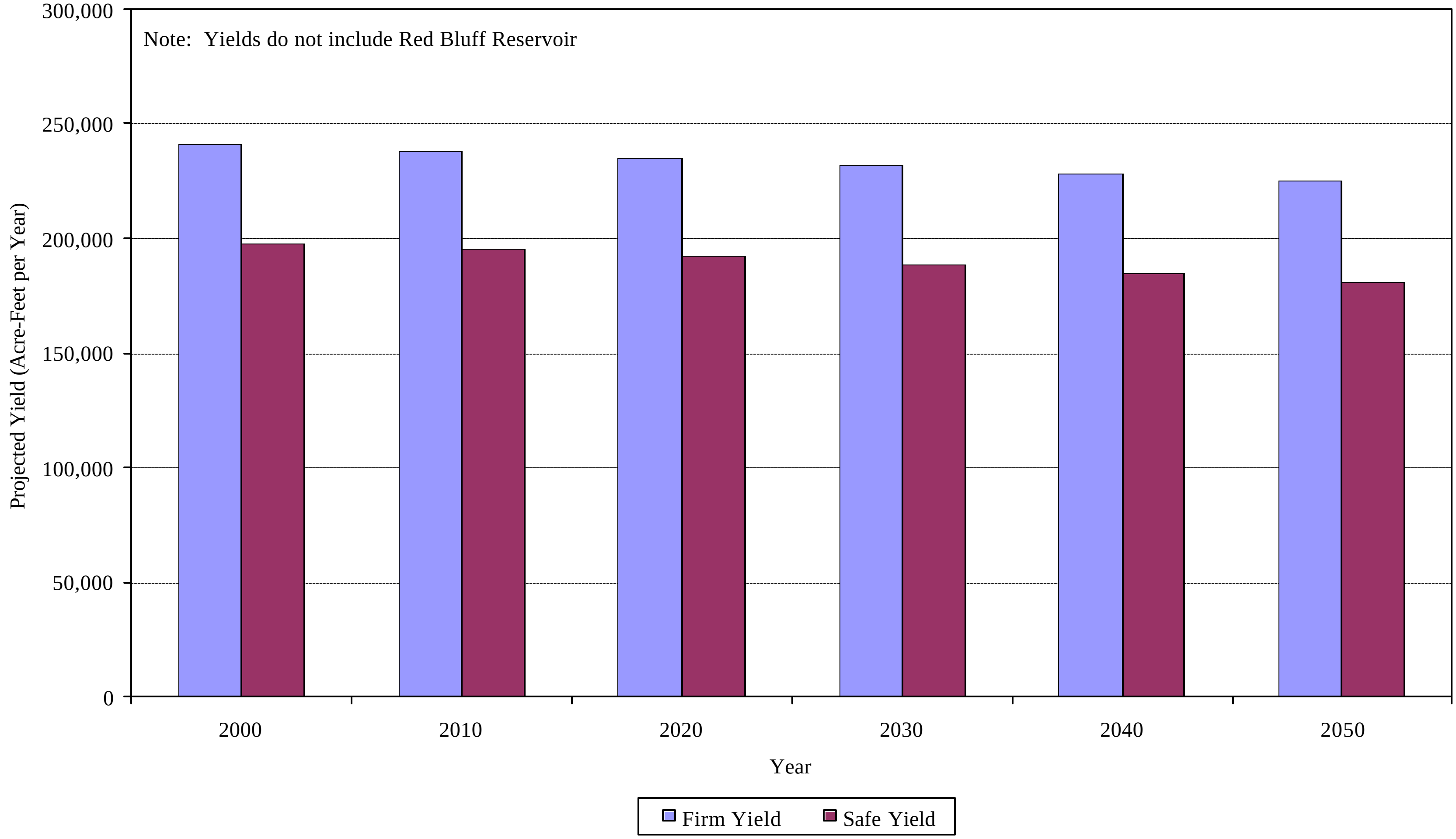


Figure 3-21
Comparison of Reservoir Content for Firm Yield versus Safe Yield Analyses

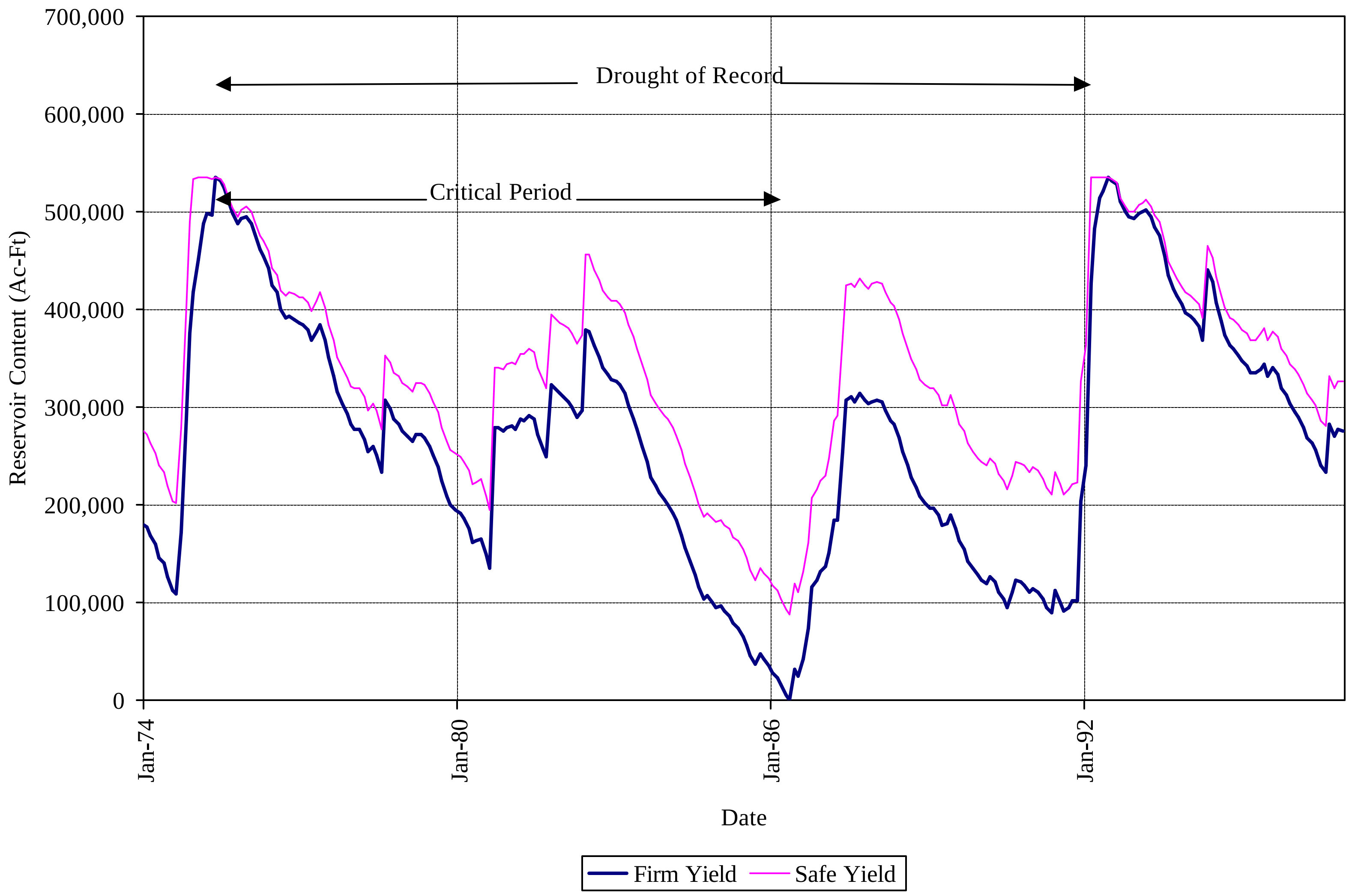


Table 3-10
Major Water Supply Reservoirs in Region F

Reservoir Name	Basin	Stream	County(ies)	Useable Conservation Storage (Acre-Feet)[1]	Owner	Water Rights Holder(s)
Lake J.B. Thomas	Colorado	Colorado River	Borden and Scurry	202,300	CRMWD	CRMWD
Lake Colorado City	Colorado	Lake Colorado City	Mitchell	31,485	TXU	TXU
Champion Creek Reservoir	Colorado	Champion Creek	Mitchell	41,620	TXU	TXU
Oak Creek Reservoir	Colorado	Oak Creek	Coke	39,260	City of Sweetwater	City of Sweetwater
Lake Coleman	Colorado	Jim Ned Creek	Coleman	40,000	City of Coleman	City of Coleman
E. V. Spence Reservoir	Colorado	Colorado River	Coke	488,760	CRMWD	CRMWD
Lake Winters/ New Lake Winters	Colorado	Elm Creek	Runnels	8,374	City of Winters	City of Winters
Lake Brownwood	Colorado	Pecan Bayou	Brown	131,430	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Colorado	Hords Creek	Coleman	8,640	COE	City of Coleman
Lake Ballinger / Lake Moonen	Colorado	Valley Creek	Runnels	6,850	City of Ballinger	City of Ballinger
O.H. Ivie Reservoir	Colorado	Colorado River	Coleman, Concho and Runnels	554,300	CRMWD	CRMWD
O.C. Fisher Lake	Colorado	North Concho River	Tom Green	115,700	COE	Upper Colorado River Authority (Contracted to the City of San Angelo)
Twin Buttes Reservoir	Colorado	South Concho River	Tom Green	177,850	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	Colorado	South Concho River	Tom Green	12,390	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Colorado	Brady Creek	McCulloch	29,110	City of Brady	City of Brady
Mountain Creek	Colorado	Mountain Creek	Coke	949	Upper Colorado River Authority	Upper Colorado River Authority (Contracted to the City of Robert Lee)
Red Bluff Reservoir	Rio Grande	Pecos River	Loving and Reeves	307,000	Red Bluff Water Power Control District	Red Bluff Water Power Control District

1. Source: TWDB Report 126, Part III and TNRCC Water Rights List

Table 3-11
Firm Yields of Region F Reservoirs
(Values in Acre-Feet per Year)

Reservoir	Supply from 1997 Water Plan	2000 Firm Yield	2010 Firm Yield	2020 Firm Yield	2030 Firm Yield	2040 Firm Yield	2050 Firm Yield
Thomas*	50,800	9,900	9,870	9,840	9,241	8,641	8,042
Spence*		38,776	38,688	38,600	38,530	38,460	38,390
Ivie	101,000	96,169	95,174	94,180	93,397	92,613	91,830
Total CRMWD System Yield	151,800	144,845	143,732	142,620	141,168	139,714	138,262
Colorado City	5,500	4,550	4,386	4,221	4,031	3,840	3,650
Champion Creek	5,000	4,081	4,038	3,995	3,955	3,916	3,876
Additional System Yield		330	330	330	330	330	330
Total TXU System Yield	10,500	8,961	8,753	8,596	8,216	8,086	7,856
Mountain Creek		342	334	325	314	304	293
Oak Creek	4,800	5,684	5,534	5,383	5,251	5,119	4,987
Ballinger/Moonen	1,600	3,566	3,369	3,172	2,985	2,799	2,612
Winters	1,160	1,407	1,397	1,387	1,370	1,352	1,335
Fisher	13,200	2,973	2,815	2,656	2,470	2,285	2,099
Twin Buttes	31,400	8,900	8,850	8,800	8,700	8,600	8,500
Nasworthy	500	7,900	7,800	7,700	7,650	7,600	7,550
Additional System Yield		2,127	2,110	2,092	2,064	2,035	2,007
Total San Angelo System Yield	45,100	21,900	21,575	21,248	20,884	20,520	20,156
Coleman	7,090	8,822	8,669	8,515	8,362	8,208	8,055
Hords Creek	1,200	1,425	1,412	1,400	1,389	1,379	1,368
Brownwood	31,400	41,800	41,000	40,200	39,400	38,800	38,200
Brady Creek	3,100	2,252	2,206	2,160	2,111	2,061	2,012
Red Bluff	31,000	31,000	31,000	31,000	31,000	31,000	31,000
Regional Total	***289,750***	***277,109***	***274,138***	***271,161***	***268,340***	***265,720***	***263,099***

*Yield of these reservoirs reported together in the 1997 Water Plan.

Table 3-12
Safe Yields of Region F Reservoirs
(Values in Acre-Feet per Year)

Reservoir	2000 Safe Yield	2010 Safe Yield	2020 Safe Yield	2030 Safe Yield	2040 Safe Yield	2050 Safe Yield
Thomas	8,150	8,125	8,100	8,081	8,061	8,042
Spence	34,450	34,385	34,320	34,258	34,196	34,134
Ivie	85,890	84,980	84,070	81,837	79,603	77,370
Colorado City	3,384	3,255	3,125	2,972	2,818	2,665
Champion Creek	3,473	3,433	3,394	3,358	3,321	3,285
Mountain Creek	197	186	174	162	149	137
Oak Creek	4,273	4,141	4,008	3,887	3,766	3,645
Ballinger/Moonen	2,117	1,900	1,682	1,590	1,497	1,405
Winters	997	985	973	959	945	931
Fisher	2,257	2,097	1,937	1,779	1,620	1,462
Twin Buttes	10,000	9,800	9,600	9,533	9,466	9,400
Nasworthy	3,500	3,400	3,300	3,250	3,200	3,150
Coleman	7,022	6,900	6,778	6,656	6,534	6,412
Hords Creek	1,176	1,165	1,153	1,141	1,130	1,118
Brownwood	29,000	28,400	27,800	27,200	26,700	26,200
Brady Creek	1,802	1,764	1,725	1,685	1,644	1,604
Red Bluff	N/A	N/A	N/A	N/A	N/A	N/A
Regional Total	**197,688**	**194,916**	**192,139**	**188,348**	**184,650**	**180,960**

illustrated in Figure 3-21. The drought of record is the time between the spills in May 1975 and June 1992. The critical period is the time between June 1975 and the minimum content in May of 1986.

One of the reservoirs included for evaluation in the scope of work was Red Bluff Reservoir on the Pecos River. It was determined that there is not sufficient information available to perform a meaningful operation study of this reservoir at this time. The provisions of the 1946 Pecos River Compact between Texas and New Mexico control inflows to this reservoir. The Compact requires that the State of New Mexico not deplete by man's activities the flow of the Pecos River below the amount available to Texas in 1947. The provisions of this compact have been subject to extensive litigation. Pending further investigation into this issue, it is recommended that Region F use the average allocation from Red Bluff between 1950 and 1987, specifically 32,000 acre-feet per year (HDR, 1999).

The firm yield of three of the reservoirs, Ballinger/Moonen (which are actually two reservoirs but were evaluated together), Brownwood and Mountain Creek exceed the permitted water rights for these reservoirs. Therefore, the actual supply from these reservoirs is limited to their water rights. For Lake Colorado City, which is primarily used for steam electric generation, the supply is limited by the amount of storage in the reservoir required for sufficient cooling. For Red Bluff Reservoir, it is estimated that 50 percent of the released water is lost in the canal system during distribution and is not available for use. Table 3-13 lists the actual water supply for each decade that will be used for the Region F plan. Table 3-14 lists the safe supply of the region's reservoirs, assuming safe yield analyses, water rights and operational limitations. Detailed discussions of the reservoir yield evaluations follow these summary tables.

Table 3-13
Firm Supply of Region F Reservoirs
(Values in Acre-Feet per Year)

Reservoir	Permitted Diversion (AF/Y)	2000 Firm Supply	2010 Firm Supply	2020 Firm Supply	2030 Firm Supply	2040 Firm Supply	2050 Firm Supply
Thomas	30,000	9,900	9,870	9,840	9,241	8,641	8,042
Spence	50,000	38,776	38,688	38,600	38,530	38,460	38,390
Ivie	113,000	96,169	95,174	94,180	93,397	92,613	91,830
Total CRMWD System Supply	193,000	144,845	143,732	142,620	141,168	139,714	138,262
Colorado City	5,500	750	750	750	750	750	750
Champion Creek	6,750	4,081	4,038	3,995	3,955	3,916	3,876
Additional System Supply		330	330	330	330	330	330
Total TXU System Supply	12,250	5,161	5,118	5,075	5,035	4,996	4,956
Mountain Creek	250	250	250	250	250	250	250
Oak Creek	10,000	5,684	5,534	5,383	5,251	5,119	4,987
Ballinger/Moonen	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Winters	1,755	1,407	1,397	1,387	1,370	1,352	1,335
Fisher	80,400	2,973	2,815	2,656	2,470	2,285	2,099
Twin Buttes	29,000	8,900	8,850	8,800	8,700	8,600	8,500
Nasworthy	25,000	7,900	7,800	7,700	7,650	7,600	7,550
Additional System Supply		2,127	2,110	2,092	2,064	2,035	2,007
Total San Angelo System Supply	134,400	21,900	21,575	21,248	20,884	20,520	20,156
Coleman	9,000	8,822	8,669	8,515	8,362	8,208	8,055
Hords Creek	2,260	1,425	1,412	1,400	1,389	1,379	1,368
Brownwood	29,712	29,712	29,712	29,712	29,712	29,712	29,712
Brady Creek	3,500	2,252	2,206	2,160	2,111	2,061	2,012
Red Bluff	292,500	16,000	16,000	16,000	16,000	16,000	16,000
Regional Total	***678,180***	***243,563***	***241,761***	***239,955***	***238,322***	***236,689***	***235,056***

Table 3-14
Safe Supply of Region F Reservoirs
(Values in Acre-Feet per Year)

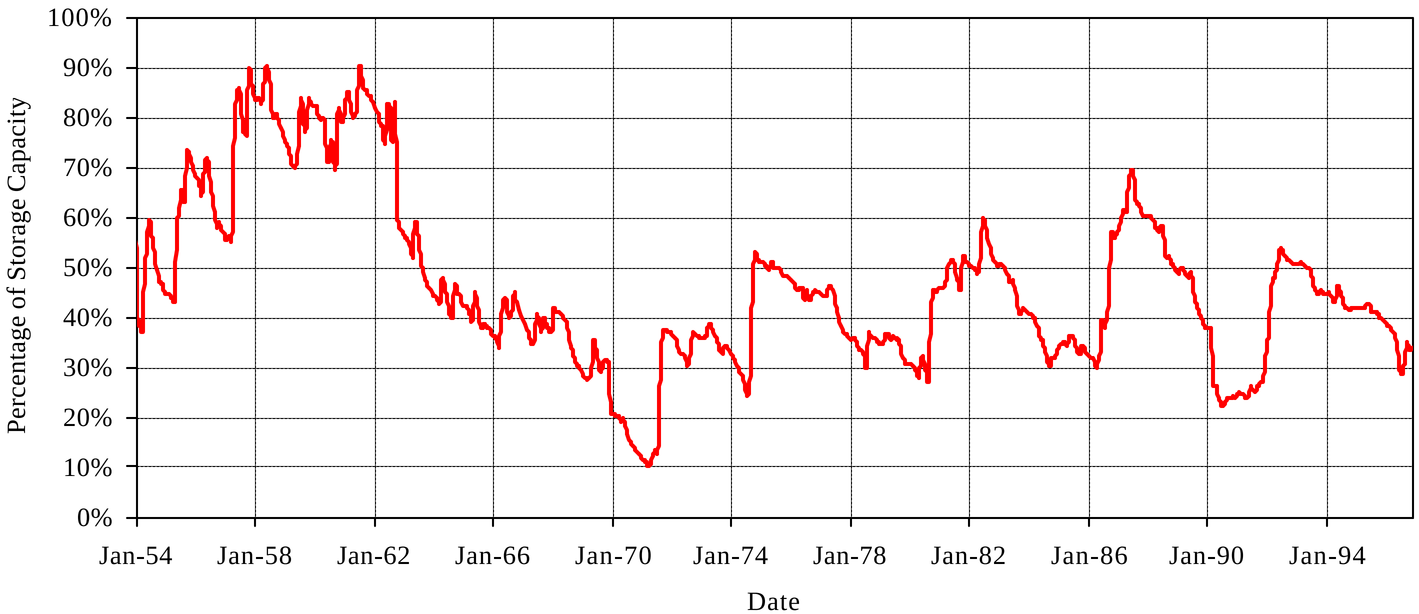
Reservoir	2000 Safe Supply	2010 Safe Supply	2020 Safe Supply	2030 Safe Supply	2040 Safe Supply	2050 Safe Supply
Thomas	8,150	8,125	8,100	8,081	8,061	8,042
Spence	34,450	34,385	34,320	34,258	34,196	34,134
Ivie	85,890	84,980	84,070	81,837	79,603	77,370
Colorado City	750	750	750	750	750	750
Champion Creek	3,473	3,433	3,394	3,358	3,321	3,285
Mountain Creek	197	186	174	162	149	137
Oak Creek	4,273	4,141	4,008	3,887	3,766	3,645
Ballinger/Moonen	1,000	1,000	1,000	1,000	1,000	1,000
Winters	997	985	973	959	945	931
Fisher	2,257	2,097	1,937	1,779	1,620	1,462
Twin Buttes	10,000	9,800	9,600	9,533	9,466	9,400
Nasworthy	3,500	3,400	3,300	3,250	3,200	3,150
Coleman	7,022	6,900	6,778	6,656	6,534	6,412
Hords Creek	1,176	1,165	1,153	1,141	1,130	1,118
Brownwood	29,000	28,400	27,800	27,200	26,700	26,200
Brady Creek	1,802	1,764	1,725	1,685	1,644	1,604
Red Bluff	NA	NA	NA	NA	NA	NA
Regional Total	**193,937**	**191,511**	**189,082**	**185,536**	**182,085**	**178,640**

3.2.2 Reservoir Yield Evaluation

In most of Texas, the most severe drought on record occurred in the 1950s, ending some time in 1957. Therefore yield studies done after about 1960 are adequate to evaluate supplies from reservoirs for most of the state. However, in West Texas there have also been many severe drought years in the 1980s and 1990s. Figure 3-22 compares the percentage of filled storage in Nasworthy, Brownwood, Fisher, Thomas, Twin Buttes, Spence and Ivie between 1954 and 1996. Although some of the troughs in the data are the result of construction of Spence in 1969 and Ivie in 1990, both of which have large capacities, this graph demonstrates that there have been significant droughts in the early 70s, the late 70s, mid 80s and late 90s. The yields of most reservoirs in Region F have not been re-evaluated in many years, and the older studies may be inadequate because they do not include drought-of-record conditions. Therefore, performing new yield studies was important to development of the Region F water supply plan.

Figure 3-22

Historical Percentage of Filled Reservoir Storage Capacity in Region F



Reservoir	**Construction Date**
Nasworthy	Jun-30
Brownwood	Jul-33
Fisher	May-51
Thomas	Sep-52
Twin Buttes	Feb-63
Spence	Nov-69
Ivie	Mar-90

3.2.3 Methodology

The yield of a reservoir is normally determined by a computer model. The input data for the reservoir simulation model are inflows into the reservoir, evaporation rates, precipitation and area-capacity relationships. Derivation of these data is a large part of the effort in a yield study. In Texas, comprehensive and accurate data on climate and hydrology are not generally available until about 1940, and reservoir evaporation data at the time of this analysis were only available through 1996. Therefore, most of the data used in this study cover the years from 1940 or 1941 through 1996.

3.2.3.1 Inflow Data

In general it is not possible to measure inflow into a reservoir directly. There are several methods employed by hydrologists to estimate inflow into a reservoir. The most common methods are the mass balance method, use of gaged flows above the reservoir, and use of gaged flows from adjacent watersheds.

When accurate and comprehensive records of reservoir elevations or contents, withdrawals from a reservoir, and spills and releases are available, a technique known as a mass balance can be employed. This method calculates the inflow based on the change in contents, losses and gains of the reservoir. However, for many reservoirs this information is not available. Therefore, stream flow gages and drainage areas are often used to estimate inflows.

It is unusual to have a significant portion of a reservoir's watershed measured by gage data, but inflows can be estimated based on upstream gages if they measure enough of the flow in the watershed. For example, between 1960 and 1995 the Christoval gage on the South Concho, the Tankersley gage on the Middle Concho, the Knickerbocker gage on Dove Creek and the Tankersley gage on Spring Creek measured flow from approximately 91 percent of Twin Buttes Reservoir drainage area. This method was used to calculate inflows into Twin Buttes when the gage records were available.

Where historical records for a reservoir are not available or are incomplete and upstream gage data are unavailable, inflows to a reservoir may be estimated using gage data from a nearby watershed. A commonly used method is the area ratio method. Inflows to the reservoir are calculated by multiplying the flows at the gage by the ratio of the reservoir's drainage area to the gage's drainage area. Assuming that the gage's watershed is of similar size and has similar flow characteristics to the reservoir's watershed, this method can give fairly accurate results. This method was used to calculate inflows for Lake Winters, Lake Ballinger, Lake Moonen, Lake Nasworthy, Oak Creek Reservoir, and Mountain Creek Reservoir.

In some cases, a combination of these techniques was used either to check the validity of the inflows or to extend the inflows into a period where records were not available. For example, inflows to Lake Coleman derived by the mass balance method were correlated to flows at the Ballinger gage on Elm Creek during the same period. The relationship between these flows was used to extend the Lake Coleman inflows to a period when records were not available for the reservoir or prior to the construction of the reservoir. In some cases it is not possible to establish this correlation. Elevation records for Brady Creek Reservoir are only available through 1983. The mass balance flows into Brady Reservoir do not correlate well to flows in the adjacent San Saba or Colorado River watersheds. The best correlation was with the Menard gage on the San Saba River, so it was used until the gage was cancelled in 1993. After that, no other gages were acceptable for use to develop inflows, so the analysis of Brady Creek Reservoir stops in 1993.

Yield studies generally cover as long a period as sufficient data are available, regardless of whether the reservoir existed during the entire period. Sometimes this is necessary to encompass the most severe drought in the historical record. It is also desirable to get a statistically significant sample of flow conditions to examine the reservoir's response. In most cases there are several years of stream measurements at or near a reservoir site that can be used to develop inflows to evaluate the proposed reservoir. This is often not the case for smaller or older reservoirs. In such cases, flow prior to the construction of the reservoir is usually based on a nearby gage using the area ratio method.

3.2.3.2 Evaporation and Precipitation Rates

Another important part of the data used in reservoir studies is evaporation and precipitation data. In Texas, evaporation accounts for significant losses in reservoir storage. As shown in Figure 1-7 of Chapter 1, average potential evaporation from a reservoir in Region F ranges from 5 to 6 acre-feet per surface acre per year. Precipitation directly on the reservoir's surface needs to be taken into account as well. For this analysis, statewide historical evaporation and precipitation data developed by TWDB for the state of Texas were used. These data are available in 1-degree quads covering the years 1940 to 1996. The availability of these data is the primary reason that the analyses stopped at the end of 1996 even though other types of information are readily available. The exception was Lake Thomas. Since Lake Thomas is currently in its critical drought period, the data were extended through the end of 1998, the last full year for which evaporation and precipitation data were available.

3.2.3.3 Area and Capacity Relationships

Area and capacity relationships are the last major component of the data required for a reservoir yield study. These tables relate elevation (the quantity directly measured in a reservoir) to surface area and the volume of water stored in the reservoir. Surface area is important because it determines the amount of water lost through evaporation or gained from precipitation on the lake surface. Area and capacity relationships change over time as a reservoir accumulates sediment. The reduction in storage volume reduces the yield of the reservoir. The impacts of sedimentation on yield can be visually observed in Figure 3-20.

For this planning effort, area-capacity relationships and sedimentation rates were developed from published reports and reservoir sedimentation surveys. New volumetric surveys were conducted for Lake J.B. Thomas and Lake Spence, which were used to update the area-capacity curves and sedimentation rates for these lakes. The data used in the yield analyses for each reservoir, including source references, is included in Appendix C.

3.2.4 Computer Analysis

The yield studies for this project were run using the OPERATE model, a proprietary reservoir operation model developed by Freese and Nichols. This model has been used in hundreds of similar studies. The model uses monthly reservoir inflow, net reservoir evaporation rates, and area-capacity relationships to simulate the behavior of a reservoir under various demand conditions. Yield studies were also evaluated for reservoir systems (i.e., several reservoirs that operated together to maximize the combined yields). System analysis was performed for the CRMWD system (Lakes Thomas, Spence and Ivie), San Angelo system (Fisher, Twin Buttes and Nasworthy), and the Colorado/Champion Creek system. Input data for the OPERATE model is included in Appendix C.

3.2.5 Results

Results of the firm yield analyses may be found in Table 3-11, and the safe yield results may be found in Table 3-12. For the system analyses, only firm yield was determined. Figure 3-20 graphically illustrates the difference between the firm and safe yields of the individual Region F reservoirs examined in this study. The total firm yield of these 16 reservoirs is almost 250,000 acre-feet per year and declines to approximately 230,000 acre-feet per year by 2050, a reduction of 20,000 acre-feet. The safe yields are approximately 50,000 acre-feet per year less than firm yields.

Figure 3-23 illustrates the critical period and drought of record for the 16 reservoirs. Note that three reservoirs, Thomas, Spence, and Fisher, were still in drought of record conditions at the end of the 1996 simulation period. The drought of record for Spence spans almost the entire simulation period. In the yield studies, Thomas had not yet begun to refill and continues a downward trend. (However, historically Thomas has rebounded somewhat from a low in February of 1999.) Since all of these reservoirs are still in drought of record conditions, it is possible that the yields of these reservoirs could be less than calculated in this analysis.

3.2.6 Run-of-the-River Supply

Water rights that are not backed up by reservoir storage are referred to as run-of-the-river rights. Reliability of these rights is difficult to estimate without basin-wide modeling such as the Senate Bill One sponsored water availability modeling studies (WAM). The WAMs for the Colorado and Rio Grande basins are not available for this planning cycle, and this type of analysis is beyond the scope of this study. In order to estimate the reliability of run-of-the-river demands, minimum flows were examined at several gages throughout the region. Results are tabulated in Table 3-15. Minimum daily and 7-day flows are indicators of short-term availability. Monthly and annual flows are more of an indicator of availability over long periods of time. May through September flows are indicative of availability in the growing season.

Figure 3-23

Critical Period and Drought of Record for Major Reservoirs

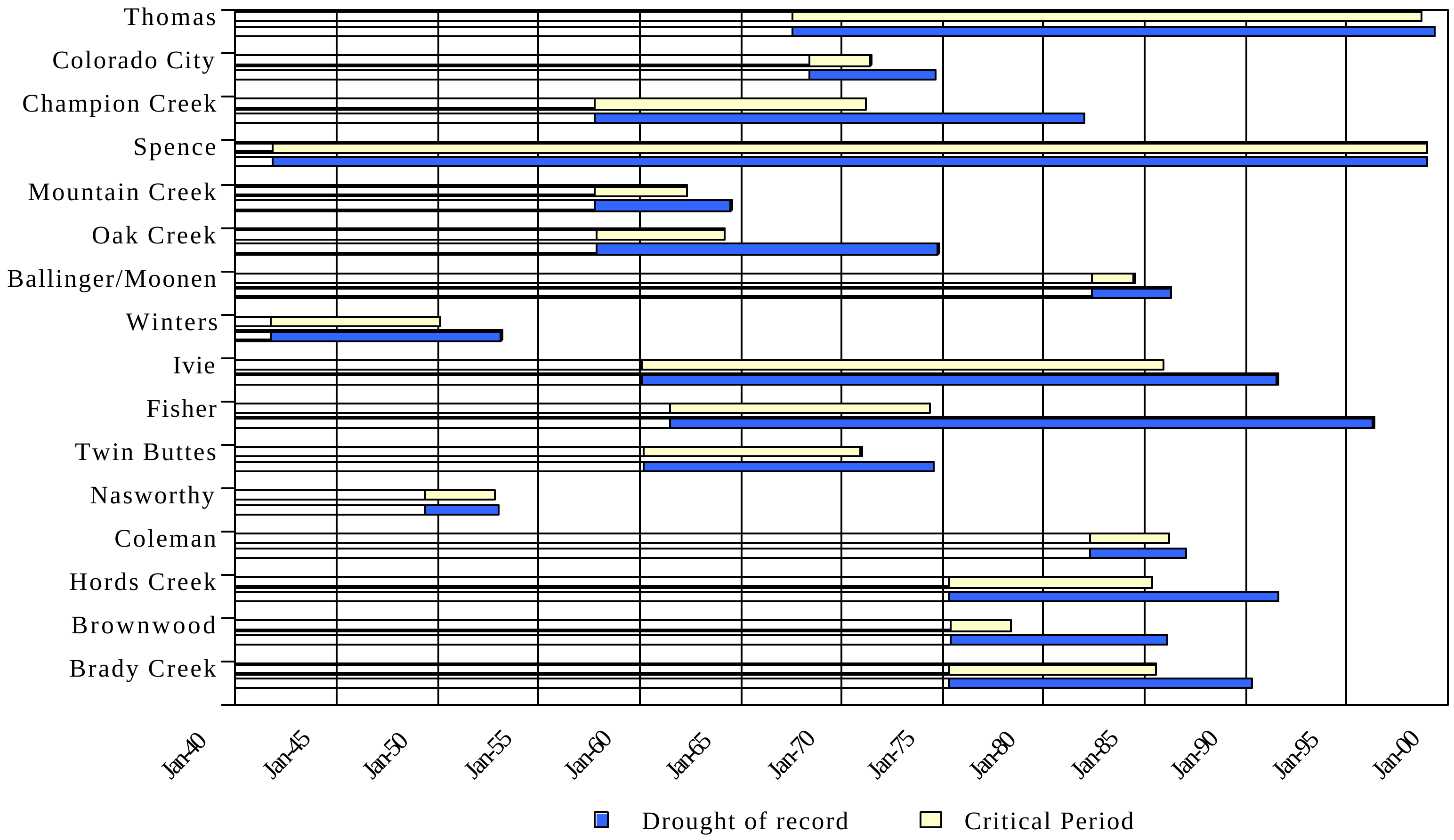


Table 3-15
Analysis of Flow at Selected Region F Gages
(Values in acre-feet)

Gage	Minimum Daily Flow	Minimum 7-Day Flow	Minimum Monthly Flow	Minimum May-Sept Flow	Minimum Annual Flows
Beals Creek at Westbrook	0	0	0	774	2,107
Middle Concho	0	0	0	0	0
North Concho	0	0	0	0	0
Elm Creek at Ballinger	0	0	0	401	2,263
Concho River at Paint Rock	0	0	0	954	9,914
Llano River near Junction	7	73	648	2,986	19,275
San Saba River at Menard	0	0	0	1,383	4,280
Pecos River near Girvin	4	32	169	2,133	12,221

These analyses indicate that run-of-the-river supplies are limited and there is more supply available in the eastern portions of Region F. Beals Creek near Westbrook and Elm Creek can only supply a very limited quantity of irrigation water. However, the quality of Beals Creek may prevent it from being useful. The Middle and North Concho have been dry for entire years and are not suitable for supply. The Llano River can probably supply some municipal demand reliably. The City of Junction relies on the Llano River for supplies, and the flows used in this analysis may have been affected by diversions upstream of the gage.

The City of Menard relies on wells on the banks of the San Saba, which are probably hydrologically connected to the river. Flows at the Menard gage are probably affected by these wells. However, since the river has been dry for extended periods during the 1950s Menard's wells may not be able to reliably supply sufficient water for the City during an extended drought. The Pecos can probably supply some irrigation water, but its quality may prevent it from being useful.

Although current water rights are not subject to instream flow criteria, future run-of-the-river water rights will probably be subject to these restrictions. *Instream flows* refer to water left in the stream for biological and other environmental purposes. As shown on Table 3-15, many streams in Region F have little to no flow at one time or another, and have limited flow during high demand periods. Additional restrictions on diversions will create extreme hardships in the agricultural economies of counties in which run-of-the-river rights predominate. In view of the region's regularly occurring severe shortages in the run-of-the-river supply to meet both human enterprise and environmental needs, it is inappropriate to uniformly apply instream flow criteria to all Region F streams. It is recommended that as part of the future planning process segment-by-segment stream studies be conducted to determine the minimum flows required to maintain environmental objectives. Determination of the amounts and locations of the minimal seasonal water flows required to maintain protected species will permit the "fine-tuning" of timing and location of diversions to avoid impairment of the rights of the surface water holders.

3.2.7 Probable Maximum Flood Studies

Probable maximum flood (PMF) analyses were updated for two reservoirs in Region F: Twin Buttes and Mountain Creek. The dams for both reservoirs are currently classified as "high hazard" by the TNRCC. This classification indicates that a failure of the dam would be expected to cause loss of human life and extensive damage to nearby facilities, utilities or highways. For "high hazard" dams, the spillway must be able to pass 100 percent of the PMF without breaching or overtopping the dam.

The PMF study for Mountain Creek found that the current spillway could pass approximately 46 percent of the PMF, making the structure inadequate in accordance with TNRCC safety standards. However, further review of the dam classification indicates that Mountain Creek could be considered for re-classification to "significant" hazard. This classification would require the spillway capacity to pass only 53 percent of the PMF. The size of the reservoir and utilization of the present Emergency Action Plan combined with other early warning systems may justify the re-classification of the dam. Further study of this option is needed.

The Twin Buttes Reservoir and dam, which is owned by the Bureau of Reclamation, is located approximately 6 miles upstream from San Angelo. The Bureau is considering selling the reservoir to San Angelo, and an updated PMF study was recommended. The results of the study found that the current capacity of the spillway and outlet works could discharge 57 percent of the PMF flows without overtopping the dam. Therefore, it is recommended that San Angelo not purchase the reservoir, pending modification of the dam to meet TNRCC safety standards.

3.3 Currently Available Supplies

As part of the Senate Bill One planning, the TWDB requires a distribution of the region's current supplies to water user groups based on existing conditions and limitations. This analysis presents a snapshot of how water is currently being used in Region F. All supplies that are currently available to a water user group are identified and quantified based on the most restraining limitation. For surface water supplies, the limitations may include water rights, contracts or reservoir yield. For ground water supplies, the available supply is based on developed well fields and aquifer availabilities. A more detailed description of the methodology for identifying currently available supplies follows.

3.3.1 Methodology

This section describes the process where currently available supplies are divided up among water users based on current ownership, contractual obligations, infrastructure and other factors. For example, a water provider may own a reservoir or a well field that has a certain yield. The water provider may not be able to deliver the full yield of the reservoir to its customers because it does not currently have the capacity to treat or deliver the full yield. Therefore, the supply from the source is limited to the capacity of the treatment or delivery system. If the demands for the water supplier exceed the current capacity of the plant or delivery system, it will require expansion at some time in the future. For Senate Bill One planning, this is considered a need. All needs for Region F will be identified and discussed in Chapter 4. This section only discusses the amount of water currently available to each user.

One purpose of this process is to identify the limits of current water supplies. Changes to the water supply of the Region will be included if the changes will be completed by 2001. This includes development of new sources (both ground water and surface water), expansion of existing water treatment plants, additional delivery capacity, and other system improvements.

Another purpose of this process is to reserve water supply for current legal obligations and uses. The distribution of supply takes into account water that is not currently used but is reserved for future uses through water rights, contracts, or other obligations. It also reserves ground water, which is often not regulated or subject to contractual obligations, for current uses. For water to be available for other uses, it must not be obligated for use elsewhere.

3.3.2 Surface Water Supplies

In accordance with Senate Bill One planning, surface water supplies can be limited by the following factors:

- *Yield* – The firm yield of the reservoir or the reliable run-of-the-river supply.
- *Water rights* – The amount of water that the owner of the water right can legally take from a source.
- *Contractual obligations* – A portion of the water right may be contracted to another water supplier or water user. This portion of the supply is not available for other uses even if the owner of the contract does not use all of the water.
- *Treatment and delivery capacity* – The current system may not be able to treat and deliver the full supply of the source.
- *Other limitations* – The supply from the source may be limited for other reasons.

Yields and Water Rights

The firm yields of major water supply reservoirs are shown on Table 3-11. There are also relatively small amounts of water used from small reservoirs and run-of-the-river supplies. For the most part, surface water supplies will be limited by water rights. However, reservoirs with less than 200 acre-feet of storage that are used for domestic or livestock needs do not require a water right. In Region F, this applies mostly to livestock ponds.

Generally, local surface water supplies are based on data from the TWDB or historical use. The historical use data provides information on water availability as well as delivery capacity. This was particularly useful in identifying water supplies by category, such as mining or livestock. For example, the historical surface water use reported to TWDB for livestock watering was assumed to be supplied by on-farm stock ponds unless there was a specific water right identified for domestic use. A summary of existing local surface water supplies is presented in Table 3-16.

3.3.2.1 Contracts

There are three basic types of contracts for water supply: (a) contracts with a specified annual maximum volume, (b) contracts that specify a peak delivery rate but no annual maximum volume and (c) contracts with no specified amount. The first specifies a maximum annual supply. This water is obligated to the customer regardless of whether the customer has a need for or uses the water. Quite frequently these contracts also include a 'take-or-pay' clause that specifies a minimum amount of water that the customer is obligated to pay for whether they use it or not. Take-or-pay clauses do not affect the amount of water available to a customer. The availability is always set to the annual maximum amount, because the owner is obligated to supply that amount of water if requested to do so by the customer.

Table 3-16
Local Surface Water Supplies by County

County	Local Supply (acre-feet/year)					
	2000	2010	2020	2030	2040	2050
Andrews	214	214	214	214	214	214
Borden	532	532	532	532	532	532
Brown	7,382	7,382	7,382	7,382	7,382	7,382
Coke	7,817	7,817	7,817	7,817	7,817	7,817
Coleman	3,905	3,905	3,905	3,905	3,905	3,905
Concho	898	898	898	898	898	898
Crane	1,443	1,443	1,443	1,443	1,443	1,443
Crockett	520	520	520	520	520	520
Ector	1,815	1,815	1,815	1,815	1,815	1,815
Glasscock	42	42	42	42	42	42
Howard	2097	2097	2097	2097	2097	2097
Irion	2,066	2,066	2,066	2,066	2,066	2,066
Kimble	3,600	3,600	3,600	3,600	3,600	3,600
Martin	79	79	79	79	79	79
Mason	1,178	1,178	1,178	1,178	1,178	1,178
McCulloch	755	755	755	755	755	755
Menard	3,905	3,905	3,905	3,905	3,905	3,905
Midland	1,582	1,582	1,582	1,582	1,582	1,582
Mitchell	690	690	690	690	690	690
Pecos	57	57	57	57	57	57
Reagan	45	45	45	45	45	45
Reeves	288	288	288	288	288	288
Runnels	7,279	7,279	7,279	7,279	7,279	7,279
Schleicher	135	135	135	135	135	135
Scurry	1,889	1,889	1,889	1,889	1,889	1,889
Sterling	99	99	99	99	99	99
Sutton	631	631	631	631	631	631
Tom Green	17,829	17,829	17,829	17,829	17,829	17,829
Upton	42	42	42	42	42	42
Ward	12	12	12	12	12	12
Winkler	8	8	8	8	8	8
Grand Total	*68,834*	*68,834*	*68,834*	*68,834*	*68,834*	*68,834*

A second type of contract specifies a maximum delivery rate, usually in million gallons per day (mgd), but does not specify a maximum annual amount. For identification of available supply, it was assumed that the specified rate is a ‘peak-day’ rate, which is the maximum amount of water that is delivered on the highest demand day of the year. Most days are less than this amount. Typically, peak-day delivery rates are 2.0 to 2.5 times greater than the average amount of water delivered in a year. As a preliminary assumption, the annual average is estimated to be half of the specified contract amount. For example, if a contract specifies a maximum delivery rate of 10 mgd, the annual average delivery rate is 5 mgd, or 5,600 acre-feet per year. This assumption was examined on a case-by-case basis to see if it is reasonable for these contracts.

A third type of contract obligates the owner to supply water to the customer but does not specify an amount. In most cases we have set these contractual limits to the maximum estimated demand for the customer and the customer’s customers. For some water users, such as irrigation demands or county other demands, the portion of the county-wide use from a particular source is not clear. In this case, the availability was set to the maximum historical use from the source in the last 10 years.

There are other variations in contracts that can affect defining currently available supplies. These limitations were examined on a case-by-case basis. For Senate Bill 1 planning purposes, it was assumed that contracts that expired during the planning period were renewed for the same supply amount, provided there was sufficient supply from the supplier and no other supply alternatives were identified.

3.3.2.2 Treatment and Delivery Limitations

The amount of water available from a source may be limited by the water supplier’s ability to treat and delivery the current water supply. In most cases, the capacity of a treatment plant or delivery system is defined as its peak-day delivery rate; the treatment plant and delivery facilities should be large enough to supply water on the highest demand days. Most of the time, the treatment plant and delivery facilities will be operating at less than maximum capacity. Typically, peak day delivery rates are 2.0 to 2.5 times greater than average delivery rates. Therefore, it was assumed that the annual average is half of the rated capacity of the system. This assumption was examined on a case-by-case basis to determine if it is reasonable. For example, treatment plant capacity may not a limiting factor for some water providers because they purchase treated water from a neighboring water supplier.

3.3.2.3 Other Limitations

There are other limitations that may affect the ability of a water supplier to meet needs under current conditions. For example, a steam-electric power plant is limited to less than the firm yield of the reservoir because once a reservoir drops below a certain level it no longer provides sufficient cooling for the plant to function efficiently. Other limitations may be structural. A pump station could be located in a portion of a reservoir where it cannot meet demands when the reservoir falls below a certain level. Another example is when water is released through a dam's outlet structure and diverted downstream. A portion of the storage in the reservoir may not be accessible because water cannot be released through the outlet structure below a certain level.

3.3.3 Ground Water Supplies

Limitations for ground water supplies are similar to surface water supplies except that the contractual and legal limitations do not apply in most cases. In Texas, ground water is a property right and is not limited by the state. In general, ground water supplies can be limited by the following factors:

- *Private Ownership* – Ground water is a property right and privately owned, and therefore can be controlled or limited by the property owner.
- *Yield* – The yield of an aquifer is limited to the retrievable storage in the aquifer and annual recharge to the aquifer.
- *Infrastructure capacity* – The current system may not be able to treat and deliver the full supply of the source, or the existing wells may not be capable of fully exploiting the supply from the source.
- *Other limitations* – The supply from the source may be limited by local regulations or other factors.

3.3.3.1 Private Ownership

Since ground water is privately owned, consent of the landowner is required to develop ground water supplies beneath private property. To account for this limitation, the historical use reported to TWDB was used as an estimate of developed supply. For agricultural use, it was assumed that individual farmers could develop on-farm ground water supplies, and the ground water availability estimate was used as the supply limit.

3.3.3.2 Yield

The yield of the aquifer is limited to the total retrievable storage in the aquifer plus the annual effective recharge to the aquifer. However, it may not be possible or desirable to completely use all the water in storage in an aquifer. In accordance with the region's guidance, the retrievable storage by county was limited as shown on Figure 3-1. The total annual availability by aquifer and county, which includes annual effective recharge plus an annual amount from storage, is summarized in Table 3-1.

In addition to the major and minor aquifers in Region F, there are other water-bearing formations that are often used for water supply. These deposits are collectively grouped as "other aquifer" by the TWDB. Historical water usage reported to the TWDB that cannot be assigned to a major or minor aquifer group is listed under "other aquifer". In some cases the other aquifer usage is significant and worth including in this planning effort. Since there are no ground water availability quantities determined for "other aquifer', the historical maximum use reported over the past ten years was used as an estimate of developed supply from these deposits. Minor aquifers that have insufficient data to calculate annual availability (Table 3-1) are also included as part of "other aquifers". These include Marble Falls, Rustler, Edwards-Trinity High Plains, and Capitan Reef Complex. A summary of the supply from "other aquifers" is presented on Table 3-17.

3.3.3.3 Infrastructure Capacity

The ability of a water supplier to deliver ground water may be limited by treatment facilities, delivery capacity, or well capacity. As with surface water treatment and delivery facilities, ground water infrastructure capacity is rated on peak-day delivery. For the identification of currently available supplies, it was assumed that the annual average delivery rate is half of the rated capacity. This assumption was examined on a case-by-case basis.

Table 3-17
Ground Water Supply from Other Aquifers in Region F

County	Ground Water Available (acre-feet/year)					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
Borden	1,163	1,077	1,077	1,077	1,077	1,077
Brown	213	392	392	392	392	392
Coke	873	789	789	789	789	789
Coleman	179	134	134	134	134	134
Concho	559	559	559	559	559	559
Irion	1,310	1,047	1,047	1,047	1,047	1,047
McCulloch	257	187	187	187	187	187
Menard	425	425	425	425	425	425
Mitchell	4	4	4	4	4	4
Pecos	1,493	15	15	15	15	15
Reeves	100					
Runnels	4,639	4,639	4,639	4,639	4,639	4,639
Scurry	678	678	678	678	678	678
Sterling	950	944	944	944	944	944
Tom Green	13,082	13,082	13,082	13,082	13,082	13,082

source: TWDB historical ground water pumping database.

For most cases, the infrastructure capacity was based on information provided by water suppliers, data from the TWDB, or historical maximum use. Information from the TWDB was verified by water providers whenever practical. For some water user groups it is difficult to identify these types of limitations. For example, many rural water users rely on their own wells for water supply, and most irrigation by ground water is from individual wells. In these cases, maximum historical use from recent years was used to allocate the supply. It is assumed that the same infrastructure that allowed the maximum usage is still in place.

3.3.3.4 Other Limitations

Possible limitations include local regulations imposed by ground water conservation districts, limited availability in some parts of counties, or other factors. In Region F, several ground water conservation districts (GCDs) have been created. Because of the diversity of aquifers located in the region and the recognition of GCDs as the preferred method of ground water management under Senate Bill One, it is the policy of the Region to support the creation and/or annexation of these local districts. These districts more clearly define and protect the rights of landowners and treats ground water as a property right while fostering good stewardship of ground water resources. Management of ground water within a GCD shall be consistent with its management plan, certified by the TWDB Executive Administrator under Texas Water Code §36.1072. In Region F, GCDs may have the authority to specify well spacing, limit pumping, restrict out-of-region transfers or impose other limitations. Such limitations, as specified by local GCDs, were considered in identifying currently available ground water supplies.

3.3.4 Water Quality and Currently Available Supplies

The assignment of available supply to a user does not take into account changes to drinking water standards that may limit the future use of a water supply for municipal purposes. The impact of drinking water standards on supply will be examined in Task 5.

3.3.5 Wastewater Reuse

Wastewater reuse was considered as available supply if an entity had a reuse program in place. If the water was used for municipal landscape irrigation, such as parks or golf courses, it was considered municipal supply. If the reuse was used for irrigation of crops or farmland, it was considered as irrigation supply. For example, the City of Midland has a developed reuse program that uses wastewater effluent for irrigation of a city-owned farm and sells effluent to other farmers. This water was included as irrigation supply for Midland County. For wastewater reuse projections, it was assumed that a similar percentage of the entity's future water use would continue to be utilized as wastewater reuse. A summary of the wastewater reuse currently used in Region F is presented in the following table.

Table 3-18

Reuse Supplies by County

County	Use Type	Reuse Amount (acre-feet/year)					
		2000	2010	2020	2030	2040	2050
Andrews	Mun	600	600	600	600	600	600
Coke	Mun	100	100	100	100	100	100
Crane	Mun	91	91	91	91	91	91
Ector	Irr	1,050	1,050	1,050	1,050	1,050	1,050
Ector	Man	2,481	2,481	2,481	2,481	2,481	2,481
Howard	Mun	53	53	53	53	53	53
Irion	Mun	41	41	41	41	41	41
Martin	Mun	61	61	61	61	61	61
Midland	Irr	15,773	17,400	18,778	20,666	22,864	25,667
Mitchell	Mun	450	450	450	450	450	450
Pecos	Irr	864	864	864	864	864	864
Reagan	Mun	40	40	40	40	40	40
Reeves	Irr	689	689	689	689	689	689
Runnels	Irr	298	298	298	298	298	298
Scurry	Mun	406	406	406	406	406	406
Sterling	Irr	65	67	68	68	67	66
Tom Green	Irr	11,530	11,530	11,530	11,530	11,530	11,530
Upton	Mun	87	87	87	87	87	87
Ward	Mun	1,200	1,200	1,200	1,200	1,200	1,200

3.3.6 Summary of Currently Available Supplies

Using the quantities estimated from the evaluation of current supplies, the region's existing water supply was distributed to water users based on the availability and limitations as discussed above. In accordance with Senate Bill One planning, water user groups are listed by county, river basin and use type (such as municipal, manufacturing, etc.). Available supplies are listed by source. Therefore, if a water user group receives water from CRMWD, who provides water from several sources, each of CRMWD's sources may be listed as supply for the user group. Local supplies are generally identified only by county and use type. The total amount of supply from a source that is assigned to different users cannot exceed the total amount that is available from the source. In many cases this limited the amount of supply that is available to some users. When a supply source had to be limited, demands, senior water rights, and use type were considered.

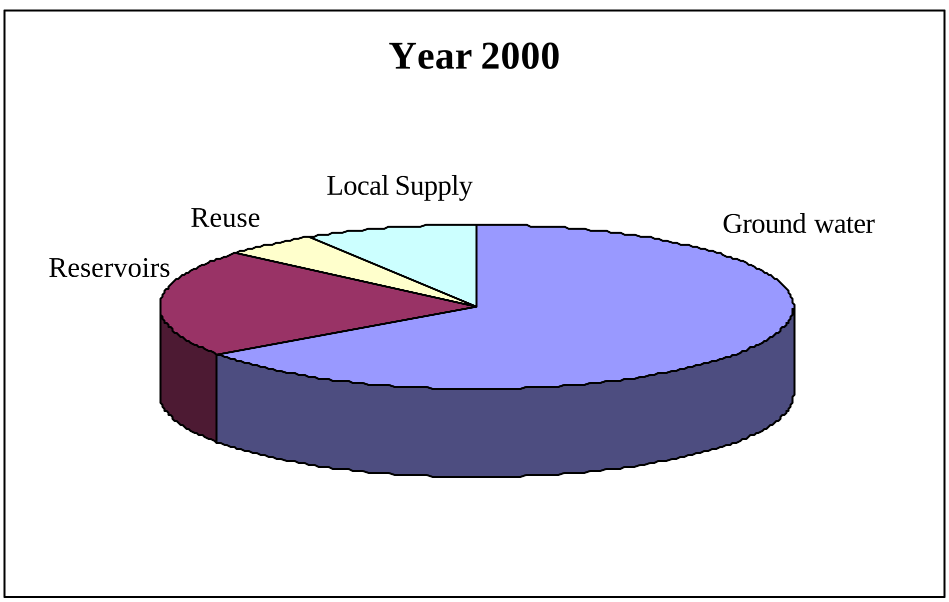
When appropriate, municipal and domestic uses were given priority over agricultural, manufacturing and mining. This preference scheme was examined on a case-by-case basis. A summary table of the currently available supplies to each water user group is presented in Appendix B, TWDB-required Exhibit B Table 5. The currently available supplies to major water providers are shown in Exhibit B Table 6 in Appendix B.

4.0 COMPARISON OF CURRENT SUPPLIES AND DEMANDS

4.1 Current Supply

The current supply in Region F consists of ground water, surface water from in-region reservoirs, local supplies and wastewater reuse. There is a small amount of ground water that comes from outside the region (Regions G and E). Based on the assessment of currently available supplies (Chapter 3), ground water is the largest source of water in Region F, accounting for 66 percent of the total supply. Reservoirs are the second largest source of water, with 21 percent of the supply, and local supplies and wastewater reuse generally provide the remainder of the region's supply. The total currently available water supply for Region F is estimated at approximately 713,000 acre-feet per year. The distribution of this supply by source type is shown on Figure 4-1.

Figure 4-1 Distribution of Current Supply



4.2 Regional Demands

Regional demands were developed by city, county and category, and are discussed in Chapter 2. In summary, the total demands for the region are projected to increase from 881,500 in 2000 to 900,200 acre-feet per year in 2050. The largest water demand category is irrigation, which accounts for nearly 75 percent of the total demand in the region. Municipal is the next largest water user in the Region F. Manufacturing, mining, steam electric power and livestock demands together account for only 10 percent of the total water demands. Over the planning period, irrigation and mining demands are expected to decrease, while municipal, manufacturing and steam electric are projected to increase. Livestock demands are projected to remain the same through 2050. The projected increases in demands are expected to occur near the larger municipalities and to a lesser extent in the rural areas. Recent trends indicate an increase in the southeast portion of the region due in part to the general expansion of the I-35 corridor.

4.3 Comparison of Demand to Currently Available Supplies

A comparison of supply to demand was performed based on the projected demands developed in Chapter 2 and the currently available supplies developed in Chapter 3. As discussed in Chapter 3, currently available supplies were based on the most restrictive of current water rights, contracts and available yields for surface water and historical use and/or ground water availability for ground water. There may be supplies available that can meet a need with changes to existing infrastructure or contractual agreements.

Figure 4-2 compares the supply allocation to demands for the entire region. The demand exceeds the available supply by over 170,000 acre-feet per year in the year 2000, increasing to 200,000 acre-feet per year by 2050. Figures 4-3 through 4-5 present the same information for the three largest water use categories: irrigation, municipal and steam-electric. Irrigation demand exceeds estimated supply by 192,000 acre-feet per year in the year 2000, decreasing to 159,000 acre-feet per year by the year 2050. Municipal supplies on a regional basis exceed the projected demands through 2020, with a need of about 33,000 acre-feet per year by 2050. Much of this need is attributed to contractual agreements or water quality limitations in municipal supply from the Hickory Aquifer. Steam-electric demand is expected to exceed allocations by 2010, with a need of about 15,600 acre-feet per year by 2050.

Figure 4-2 Region F Supplies and Demands

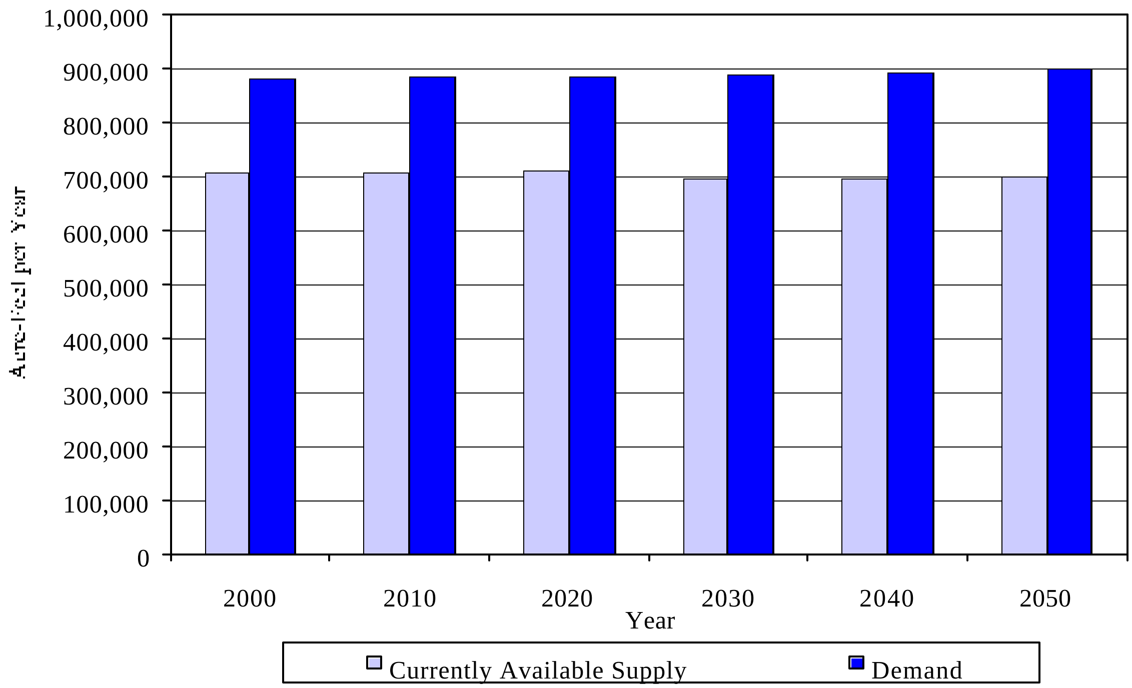


Figure 4-3 Irrigation Supplies and Demands

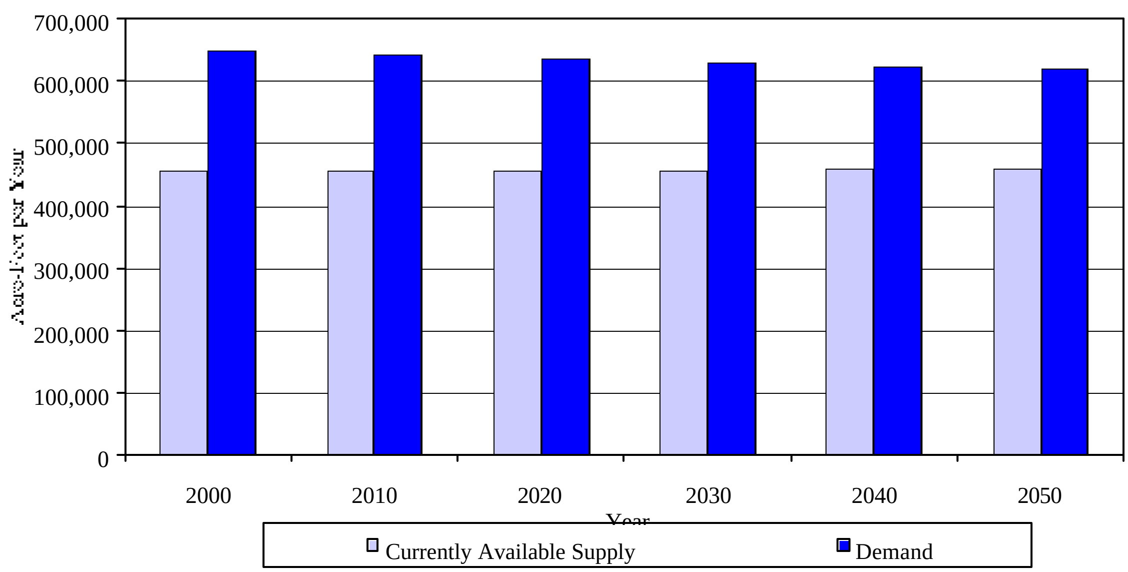


Figure 4-4 Municipal Supplies and Demands

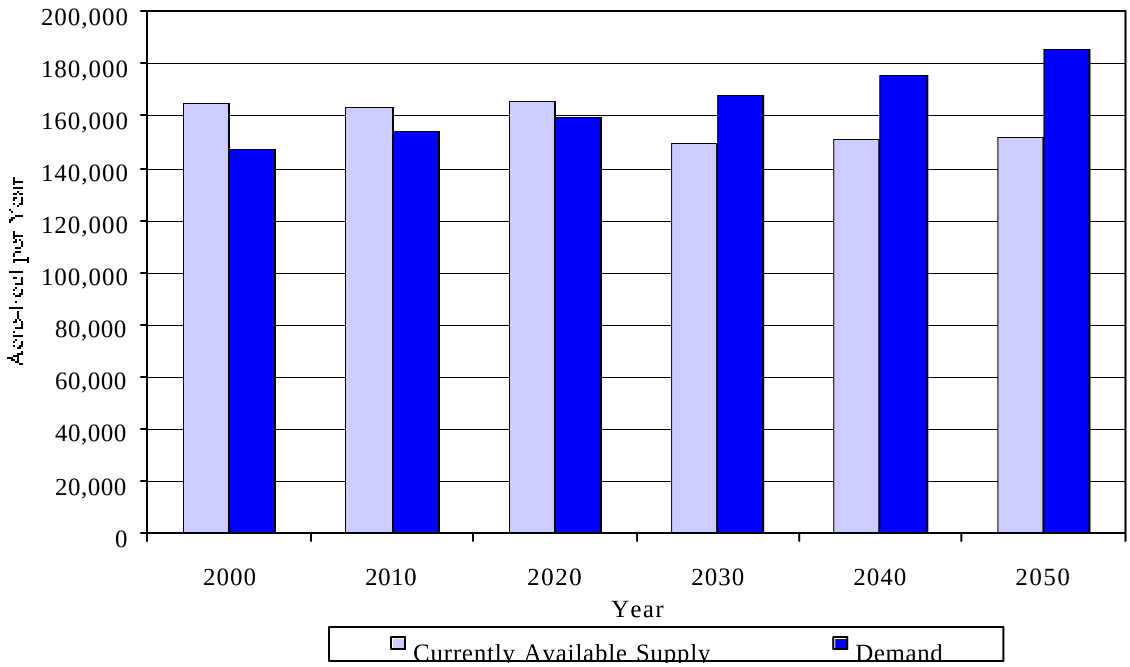


Figure 4-5 Steam Electric Supplies and Demands

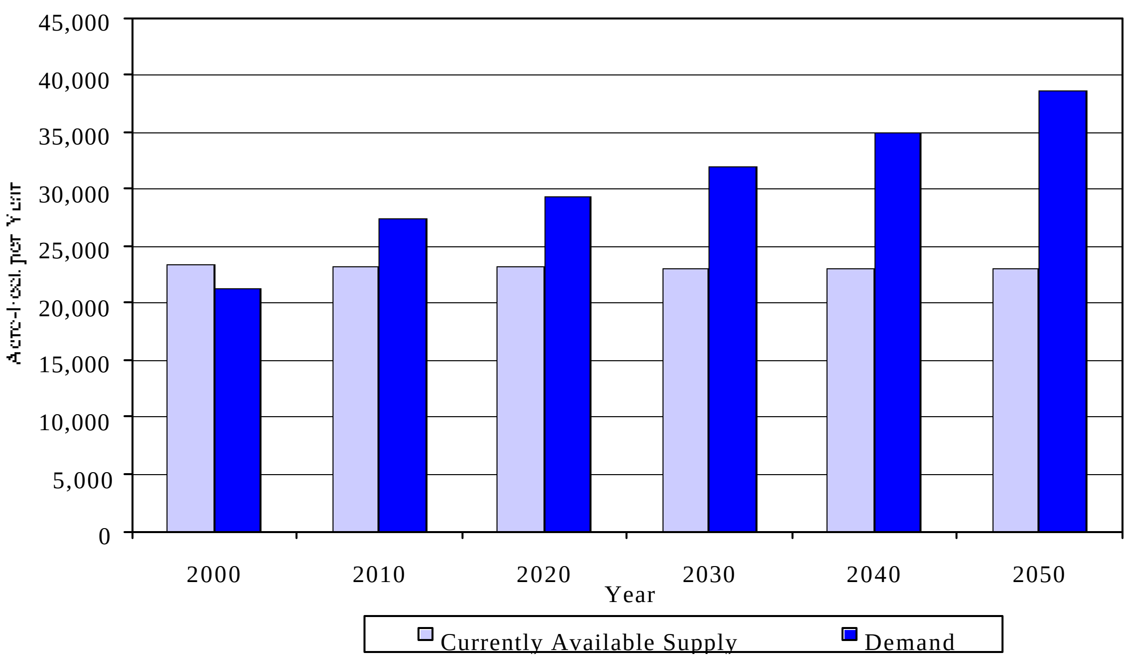


Table 4-1
Comparison of Water Currently Available* and Demand by County

	Year 2000		Year 2020		Year 2050	
County	**Currently Available Supply**	**Demand**	**Currently Available Supply**	**Demand**	**Currently Available Supply**	**Demand**
Andrews	25,717	27,273	25,724	24,461	25,705	23,500
Borden	2,596	11,042	2,596	10,780	2,596	10,711
Brown	24,156	20,687	24,045	20,766	24,005	20,692
Coke	5,219	3,290	5,202	3,144	5,170	3,041
Coleman	6,851	4,812	6,826	4,624	6,814	4,512
Concho	9,467	8,840	8,210	8,769	8,127	8,701
Crane	4,876	4,534	4,865	3,854	4,854	3,957
Crockett	6,288	5,622	6,287	7,821	6,307	7,818
Ector	50,508	52,196	53,338	54,607	59,670	60,901
Glasscock	21,117	68,970	21,117	67,890	21,117	66,262
Howard	19,855	17,984	19,795	18,068	20,005	18,351
Irion	4,208	4,044	4,190	3,890	4,176	3,666
Kimble	4,704	4,591	4,707	4,682	4,704	4,922
Loving	405	663	402	655	400	645
Martin	15,424	16,624	15,378	15,903	14,871	15,130
Mason	21,050	20,001	20,984	19,441	20,953	18,668
McCulloch	9,070	8,098	5,758	7,984	5,802	8,000
Menard	7,058	7,088	7,019	7,018	6,960	6,934
Midland	70,784	99,856	77,099	103,610	65,451	114,274
Mitchell	11,374	9,289	11,288	10,213	11,169	13,732
Pecos	91,151	88,291	88,689	85,970	84,924	82,184
Reagan	29,301	49,456	29,301	47,888	29,301	45,779
Reeves	73,064	112,274	73,394	110,698	73,394	108,198
Runnels	13,328	11,097	13,359	11,048	13,440	11,192
Schleicher	3,469	3,145	3,469	3,046	3,469	2,921
Scurry	14,465	11,951	14,860	11,330	14,991	11,125
Sterling	2,454	2,342	2,478	2,126	2,485	2,011
Sutton	4,770	4,457	4,855	4,459	4,915	4,303
Tom Green	118,990	151,209	118,338	157,144	117,246	163,384
Upton	16,521	23,343	16,544	22,229	16,552	21,392
Ward	17,170	21,813	17,181	22,951	17,192	27,238
Winkler	6,614	6,614	6,642	6,305	6,665	6,086
TOTAL	**712,024**	**881,496**	**713,940**	**883,374**	**703,980**	**900,230**

* Water currently available is referred to as "Currently Available Supply" in TWDB required tables. The county listed is where the available water is used. In some cases, supplies originate in other counties.

TABLE 4-2

TABLE 4-3

TABLE 4-4.

Table 4-1 presents current available supply versus demand by county. Figures 4-6 through 4-8 show the spatial distribution of needs in the region for years 2000, 2020 and 2050. Typically the counties with the largest needs are those with large irrigation demands and limited ground water resources. The needs by category and county for years 2000, 2020 and 2050 are summarized in Tables 4-2, 4-3 and 4-4, respectively. Based on this analysis, there are significant irrigation needs throughout the 50-year planning period. The municipal needs shown are typically attributed to growth or limitations in water supply contracts. Specific needs by user group are included on Table 7 in Appendix B. Needs identified on this table due to the expiration of an existing contract are not addressed in this chapter unless there was a possibility that the contract would not be renewed (i.e., alternative supply source or insufficient supplies from the water provider). If a contract is assumed renewed, this supply is reflected as being currently available in the text and associated tables in this chapter. A brief discussion of the needs in Region F is presented in the following section.

4.4 Identified Needs for Region F

A need occurs when currently available supplies are not sufficient to meet projected demands. When supplies were insufficient to meet demands, an allocation scheme based on a survey of the RWPG was used to distribute the projected demands. When supplies were limited municipal demands were met first, followed by livestock, steam electric, irrigation, manufacturing and mining categories. In some cases this allocation scheme was changed based on local considerations. For example, the Colorado City/Champion Creek reservoir system in Mitchell County is owned by TXU electric, so steam electric generation was given first priority with a small amount reserved for municipal needs. The remainder of this section discusses the needs of individual user groups.

4.4.1 Irrigation

4.4.1.1 Andrews County

Irrigation demands in Andrews County are projected to increase over 35 percent from 1996 to 2000. Nearly all of the irrigation supply is from the Ogallala Aquifer. This source is also used for most of the county's other demands and steam electric power in Ector County (contract with

Great Plains WSC). As a result, there are small irrigation needs in Andrews County through the planning period.

4.4.1.2 Borden County

Irrigation acreage and water use in Borden County increased substantially in the last ten years. Most irrigated acreage in Borden County is located over the Ogallala aquifer, which has a total estimated annual supply of 890 acre-feet per year. There were less than 1,000 irrigated acres in Borden County in 1994 with a reported water use from the Ogallala of 865 acre-feet. In 1996, there were more than 2,600 irrigated acres and a water use of 4,306 acre-feet. By 1997, there were more than 5,000 irrigated acres with a water use of 8,216 acre-feet from the Ogallala. After meeting small municipal and livestock demands from the Ogallala, there is an irrigation need of 8,709 acre-feet in 2000 declining to 8,617 by 2050.

According to representatives from Borden County, there has been a substantial increase in irrigated acreage in the county but the 1997 figures may be too high. Since projected irrigation demands were calculated using the 1997 acreage, they may also be high. However, even after reducing projected demands, there is still a significant need.

4.4.1.3 Glasscock County

Portions of Glasscock County are in a heavily irrigated area that also includes portions of Midland, Reagan and Upton Counties. The primary sources of ground water are the Edwards-Trinity Plateau and the Ogallala aquifers. The TWDB reports 45,307 acre-feet of irrigation use from the Edwards-Trinity and 7,437 acre-feet from the Ogallala in 1997. The estimated annual supplies from these sources are 16,772 acre-feet from the Edwards-Trinity and 3,896 acre-feet from the Ogallala. Projected demands indicate that there is a potential irrigation need of 47,853 acre-feet in 2000 and 45,145 acre-feet in 2050.

4.4.1.4 Loving County

According to the TWDB, all irrigation supply in Loving County comes from Red Bluff Reservoir. Water supply from this reservoir depends upon hydrologic conditions in New Mexico and the provisions of the Pecos River Compact. Water supply in some years may be curtailed or, in some cases, eliminated. There are also significant losses in delivery of water from Red Bluff to downstream users. It is likely that this supply will be limited under drought-of-record conditions.

4.4.1.5 Martin County

The primary source of water for irrigation in Martin County is the Ogallala Aquifer, which had a reported use of over 14,000 acre-feet for irrigation in 1997. The Ogallala is also used for municipal, manufacturing, livestock and mining demands. Due to competition for this supply, small irrigation needs are identified for Martin County in the beginning of the planning period. By 2020 the irrigation demands can be met with available supplies as expected conservation reduces demands.

4.4.1.6 Midland County

Portions of Midland County are in a heavily irrigated area that also includes portions of Glasscock, Reagan and Upton Counties. The primary sources of ground water are the Ogallala and Edwards-Trinity Plateau aquifers. There is competition for these sources among municipal, manufacturing, livestock, irrigation and mining demands. There is sufficient supply to meet municipal ground water demands, but not other demands. According to the TWDB, the total usage for irrigation in 1996 from the Ogallala was 24,215 acre-feet and 14,722 acre-feet from the Edwards-Trinity. The estimated year 2000 irrigation supplies from these sources are 3,400 acre-feet from the Ogallala and 11,360 acre-feet from the Edwards-Trinity. To supplement these supplies, there is an estimated 15,770 acre-feet of wastewater reuse from the City of Midland. This source is projected to increase to 25,670 acre-feet by 2050. Projected demands indicate a potential irrigation need of 34,640 acre-feet in 2000 and 21,752 acre-feet in 2050.

4.4.1.7 Reagan County

Portions of Reagan County are in a heavily irrigated area that also includes portions of Glasscock, Midland and Upton Counties. The primary sources of ground water are the Edwards-Trinity Plateau and the Dockum aquifers. Irrigation use in 1997 was 46,469 acre-feet from the Edwards-Trinity and 429 acre-feet from the Dockum. The estimated annual irrigation supplies from these sources are about 28,000 acre-feet from the Edwards-Trinity and 50 acre-feet from the Dockum. Projected demands indicate a potential irrigation need of 18,633 acre-feet in 2000 and 14,982 acre-feet in 2050.

4.4.1.8 Reeves County

The primary sources of irrigation supply in Reeves County are Red Bluff Reservoir and the Cenozoic Pecos Alluvium aquifer. Water supply from Red Bluff depends upon water deliveries from New Mexico governed by the Pecos River Compact. Water supply in some years may be curtailed or, in some cases, eliminated. There are also significant losses in delivery of water from Red Bluff to Reeves County. It is likely that this supply will be limited under drought-of-record conditions. In 1997 there was 99,428 acre-feet of irrigation use from the Cenozoic Pecos Alluvium. The estimated annual supply is 56,870 acre-feet. The estimated irrigation needs for Reeves County are 39,164 acre-feet in 2000 and 34,718 acre-feet in 2050.

4.4.1.9 Tom Green County

Irrigation supply in Tom Green County comes from the Twin Buttes/Nasworthy reservoir system, run-of-the-river supplies from the Concho and its tributaries, the Lipan aquifer and other aquifers that are not classified as a major or minor aquifer by the TWDB. New estimates of water availability from Twin Buttes, Nasworthy and the Lipan aquifer were made as part of this plan. Estimates of run-of-the-river supplies were provided by TWDB. Supplies for the unclassified aquifers are based upon recent historical use. There is competition for limited surface water supplies among municipal, steam-electric, manufacturing, irrigation and livestock water user groups. There also is competition for limited ground water supplies among municipal, irrigation and livestock water user groups. In 1997, 34,959 acre-feet of water from surface supplies and 73,413 acre-feet of water from ground water sources were used for irrigation. The total estimated supplies currently available for irrigation include 35,357 acre-feet of surface water (including reuse of San Angelo effluent) and 46,882 acre-feet of ground water. Projected demand exceeds supply by 37,863 acre-feet in 2000 and 36,753 acre-feet in 2050.

4.4.1.10 Upton County

Portions of Upton County are in a heavily irrigated area that also includes portions of Glasscock, Midland and Reagan Counties. The primary source of ground water for irrigation is the portion of the Edwards-Trinity Plateau aquifer in the Colorado Basin. Supplies are limited based upon the portion of supplies located in the Colorado Basin. On a countywide basis, supplies from the Edwards-Trinity are sufficient for all uses. Projected needs are 5,143 acre-feet in 2000 and 3,759 acre-feet in 2050.

4.4.1.11 Ward County

The primary source of irrigation supply in Ward County is Red Bluff Reservoir, with small supplies used from the Cenozoic Pecos Alluvium and Dockum aquifers. Water supply from Red

Bluff depends upon water deliveries from New Mexico governed by the Pecos River Compact. In some years water supply may be curtailed or, in some cases, eliminated. There are also significant losses in delivery of water from Red Bluff to downstream users. It is likely that this supply will be limited under drought-of-record conditions. Irrigation in Ward County has an estimated need of 5,430 acre-feet in the year 2000 and 4,264 acre-feet in 2050.

4.4.2 Municipal

4.4.2.1 Brown County

Lake Brownwood has sufficient supply to meet all of the municipal needs of Brown County. However, without additional infrastructure there may be municipal needs in some parts of the County. The City of Early may exceed the capacity of its current treatment facility between 2020 and 2030. Early may be able to purchase treated water from the BCWID plant, which should be able to meet needs throughout the planning period.

The County-Other user group shows needs throughout the planning period. Brown County is experiencing strong growth in unincorporated areas of the County and current infrastructure may not be adequate to meet future needs in this area. These needs imply that the BCWID and Early treatment facilities will need to supply a larger portion of the demand in unincorporated areas of Brown County. Growth that occurs in the Brookesmith and Zephyr service areas can probably be supplied from the BCWID treatment plant using current infrastructure. Growth that occurs in northern Brown County, which relies mostly on ground water, may exceed available supplies and may require additional infrastructure to obtain water from Lake Brownwood.

4.4.2.2 Concho County and McCulloch County

The cities of Eden, Mason and Brady and a large portion of the County-Other user groups in Concho, Mason and McCulloch Counties depend on the Hickory aquifer for municipal supplies. Water in this aquifer generally contains naturally occurring radioactive material that exceeds drinking water standards. However, some water located in the Hickory outcrop appears to meet the drinking water standards for these constituents. According to the TNRCC water quality records, the public water supply systems in Mason County do not exceed the radionuclide standards. For this analysis we have assumed that municipal supplies from the Hickory aquifer that have reported concentrations of radioactive materials above the drinking water standards are not available beginning in year 2010. Some municipalities that rely on the Hickory will either need to employ advanced treatment, switch to another source or blend with other sources of water to make this supply by 2010.

4.4.2.3 Kimble County

The City of Junction relies upon a run-of-the-river supply that may not be sufficiently reliable to meet needs under drought-of-record conditions. Junction takes its municipal diversions from a channel dam on the South Llano River. According to the TWDB, in 1996 the City was under water restrictions. The City reported 873 acre-feet of water diverted in that year. Using this value as an estimate of the water available from the Llano during drought conditions, the City has the potential to experience some small shortages throughout the planning period.

4.4.2.4 Menard County

The City of Menard has several wells near the banks of the San Saba River that are hydraulically connected to the river. Reduced flows in the San Saba River due to a severe drought have the potential to reduce the City's available supply. Using 1996 reported usage as an estimate of availability from the current source, Menard would experience small shortages throughout the planning period under drought-of-record conditions.

4.4.2.5 Midland County

The projected needs for the City of Midland are the result of the expiration of the City's 1966 contract with CRMWD between 2020 and 2030. The City will either need to renegotiate this contract or locate a new source of water. Without a renewed contract or additional supplies the City of Midland is projected to have a need of 17,861 acre-feet in 2030 and 26,967 acre-feet in 2050.

4.4.2.6 Reeves County

Reeves County-Other may experience small shortages beginning in 2010, and increasing through the planning period. County-other is currently supplied through sales from the cities of Balmorhea and Pecos, and ground water from the Cenozoic Pecos Alluvium and Edwards-Trinity Aquifers. Most likely these needs can be met through increased sales from the two cities.

4.4.2.7 Tom Green County

The City of San Angelo and its customers have the potential for water supply needs beginning in 2030 due to competition for water from the Nasworthy/Twin Buttes system among municipal, manufacturing, steam-electric and irrigation user groups. The estimated need for San

Angelo in 2030 is 887 acre-feet, increasing to 6,288 acre-feet by 2050. The County-Other category may begin experiencing shortages as soon as 2010, primarily due to competition for limited ground water supplies between municipal and irrigation users. The potential need for the County Other user group is 141 acre-feet in 2010, increasing to 946 acre-feet by 2050.

4.4.3 Steam-Electric

4.4.3.1 Crockett County

There is a potential need in Crockett County for additional steam-electric supplies when West Texas Utilities expands the Rio Pecos plant between 2000 and 2010. Demands are expected to increase from 1,914 to 4,280 acre-feet per year. The projections exceed the maximum reported historical use at the plant by 1,889 acre-feet. Using maximum historical use as an estimate of the capacity of the plant's currently developed ground water supply, additional capacity may be needed when the plant expands. Water for the Rio Pecos plant is currently supplied by wells located in the Edwards-Trinity Aquifer in Pecos County. Ground water supplies from this source are not a limiting factor. Alternatively, additional ground water supply is available from the Edwards-Trinity in Crockett County.

4.4.3.2 Mitchell County

As previously discussed, TXU Electric owns the Lake Colorado City/Champion Creek system. These reservoirs also provide municipal supply to Colorado City. The generation facility is located on Lake Colorado City with additional makeup water pumped into the lake from Champion Creek Reservoir. According to TXU officials, the minimum level in Lake Colorado City is 2,054.5 feet msl. Below this level, there is insufficient lake surface area for proper cooling. Therefore, the yield of Lake Colorado City reservoir is reduced by this operational limitation. The available supply from these reservoirs was set at the remaining supply less an amount reserved for municipal use based on recent historical use. Using this criterion, there are small steam electric needs in the near term increasing to 5,263 acre-feet by 2050.

4.4.3.3 Tom Green County

West Texas Utilities plans to expand its Tom Green County steam-electric plant by 2010. This plant uses water from the Nasworthy/Twin Buttes system. There is competition for limited supplies from this source among municipal, steam-electric, manufacturing and irrigation user groups. Using the allocation scheme adopted by the RWPG, additional supplies for the expansion may not be available unless an alternative source is found for some of these user groups. The projected needs for steam electric range from 2,156 acre-feet in 2010 to 2,470 acre-feet in 2050.

4.4.3.4 Ward County

TXU operates a steam-electric plant in Ward County that uses water from the Cenozoic Pecos Alluvium. There is competition for this limited supply between municipal, mining and steam-electric user groups that may limit expansion of this facility. The need for steam electric water in Ward County is projected to be 6,782 acre-feet by 2050.

4.4.4 Mining

4.4.4.1 Ector County

The Edwards-Trinity Plateau and Ogallala aquifers have been historically used for municipal, manufacturing, livestock, irrigation and mining supplies in Ector County. According to the TWDB, there were a total of 10,648 acre-feet pumped from the Edwards-Trinity and 7,208 acre-feet were used out of the Ogallala in 1997. These supplies are limited to 6,377 and 5,849 acre-feet, respectively. Supplies from these sources are sufficient to meet municipal, livestock, manufacturing and irrigation demands, but are not sufficient to meet mining demands. Some of the mining needs may be offset by the reuse of Odessa wastewater for manufacturing purposes, thereby reducing some of the competition for ground water resources. Potential mining needs in Ector County are 5,711 acre-feet in 2000, decreasing to 4,663 acre-feet by 2050.

4.4.4.2 Martin County

Martin County has sufficient supplies from the Ogallala to meet municipal and livestock demands. However, there is competition for limited supplies among manufacturing, irrigation and mining needs. Using the allocation scheme adopted by the RWPG, mining may experience needs in the beginning of the planning period. Potential needs are 928 acre-feet in the year 2000, with no needs by year 2040.

4.4.4.3 Midland County

The main source of mining supplies in Midland County is the Edwards-Trinity Plateau aquifer. There is competition for this limited source among municipal, livestock, irrigation and mining demands. Assuming the other demands from this source take precedence there is no supply remaining for mining use. Potential needs are 669 acre-feet in the year 2000, reducing to no needs in the year 2050.

4.4.4.4 Reagan County

The main source of mining supplies in Reagan County is the Edwards-Trinity Plateau aquifer. There is competition for this limited source among municipal, livestock, irrigation and mining demands. According to the allocation scheme adopted by the RWPG, the other demands from this source take precedence and there is no supply remaining for mining use. Potential needs are 1,589 acre-feet in the year 2000 and 1,481 acre-feet in the year 2050.

4.4.4.5 Reeves County

The main source of water for mining purposes in Reeves County is the Cenozoic Pecos Alluvium aquifer. There is competition for this limited source among irrigation, municipal, livestock and mining user groups. Using the allocation scheme adopted by the RWPG, there is no supply available from this source for mining purposes. Potential needs are 175 acre-feet in the year 2000 and 115 acre-feet in the year 2050.

4.4.4.6 Upton County

Most of the mining activities in Upton County occur in the Colorado basin. The main source of water is the Edwards-Trinity Plateau aquifer. There is competition for this limited source among irrigation, municipal, livestock and mining user groups. As a result, there is no supply available from this source for mining purposes. Potential mining needs in the Colorado basin are 1,787 acre-feet in the year 2000 and 1,195 acre-feet in the year 2050.

4.4.4.7 Ward County

In recent years the primary source of water for mining purposes in Ward County has been the Cenozoic Pecos Alluvium. There is competition for this limited source among municipal, steam-electric and mining user groups. Using the allocation scheme adopted by the RWPG, there are no supplies from this source remaining for mining purposes. Potential needs are 635 acre-feet in the year 2000 and 194 acre-feet in the year 2050.

4.4.5 Manufacturing

4.4.5.1 Kimble County

According to local representatives, Kimble County has three of the largest cedar processing operations in the world. At least some of these mills use surface water supplies that may not be reliable during drought-of-record conditions. Using 1995 surface water use as an estimate of availability, Kimble County could experience a shortage of about 1,000 to 1,500 acre-feet over the planning period.

4.4.5.2 McCulloch County

There is the potential for manufacturing needs in McCulloch County as demand increases over time. Projected demands exceed the historical portion of manufacturing supply that has been provided by the City of Brady and other local sources. There should be sufficient supply from Brady Creek Reservoir or the Hickory aquifer to meet these additional demands.

4.4.5.3 Midland County

There is the potential for small manufacturing needs in Midland County throughout the planning period due to competition for limited ground water supplies from the Ogallala among municipal, manufacturing, irrigation and mining demands. Potential needs are 37 acre-feet in the year 2000 and 104 acre-feet in the year 2050.

4.5 Ground Water Supplies

In Region F ground water is heavily used for many purposes, and in several counties it appears that some of the aquifers are being mined at rates than cannot be sustained over a long period of time. This is particularly true for those counties with high irrigation demands, although in some counties municipal and steam-electric generation have large demands as well. A list of these aquifers, the annual availability, and average historical use between 1993 and 1997 are shown in Table 4-5. As shown on this table, if these counties continue to use ground water at their historical rates, many will exhaust their resources before 2050. The two most critical aquifers are the Edwards-Trinity in Glasscock County and the Ogallala in Midland County. With continued historical use, the recoverable storage will be completely depleted by 2007. Other counties with limited ground water supplies include Reagan, Reeves and Tom Green Counties. In each of these counties demands are concentrated in only a portion of the county. Since the assessment of aquifer availability is determined on a countywide basis, the actual depletion of storage in the irrigation areas may be at a faster rate than shown in Table 4-5.

4.6 Surface Water Supplies

In general, the currently available supply from the regional reservoirs is based on the firm yield analyses of the reservoirs. Firm yield analysis determines the amount of water that is available on an annual basis during a repeat of the historical drought of record condition assuming all the water in the reservoir is available for use. Some reservoirs in Region F are still in their historical drought of record, and the available supply may be less than estimated in Chapter 3. The assessment of regional needs did not account for this potential reduction in supply (e.g., Spence, Thomas and Fisher Reservoirs).

To account for the uncertainties associated with Texas weather and firm yield analyses, many reservoirs are operated and contracts are based on a safe yield analysis. The safe yield analysis utilizes the same historical hydrology as the firm yield analysis, but assumes that a one-year supply of water is reserved in the reservoir at all times. Safe yields were determined for all regional reservoirs and are discussed in Chapter 3. For several of the smaller reservoirs in the region, the ability of the users to meet their needs may be affected using the safe yield analysis. This appears to be true for Lake Winters Reservoir. Further assessment of the reliability of Region F reservoir supplies using safe yield analyses is discussed in Chapter 5.

4.7 Socio-Economic Impacts of Not Meeting Water Needs

The TWDB performed a study of the socio-economic impacts of not meeting the water needs of a region. The complete report is presented in Appendix D. The economic variables chosen by the TWDB for the analysis include gross economic output, employment, and personal income. Social variables consisted of shortages in population and school enrollment. The TWDB calculated the direct economic impacts of unmet water needs, defined as the dollar value of final demand (production for sale to final consumers) that could not be produced because of the absence of water, and the indirect impacts, which result from changes in output from those directly impacted. It is important to note that for this analysis the TWDB assumed no applied management strategies. In the event that the entirety of the region's projected needs is not met with any strategy, by 2050 the following consequences are predicted by the TWDB: water

Table 4-5 Aquifers with Historical Use Near or Greater than Annual Availability

County	Aquifer	Annual Available (acre-feet)	Initial Recoverable Storage (acre-feet)	5-Year Average Historical Use (acre-feet)	Number of Years of Supply[1]	Remaining Storage after 50 Years[1] (acre-feet)	% Recoverable Storage Remaining[1]
Borden	Ogallala	890	39,300	3,099	14	0	0%
Brown	Trinity	2,026	38,500	2,243	>50	27,650	72%
Crane	Pecos Alluvium	3,000	243,000	1,986	>50	243,000	100%
Ector	Edwards-Trinity	6,377	82,500	9,352	20	0	0%
Ector	Ogallala	5,849	66,600	9,424	15	0	0%
Glasscock	Edwards-Trinity	17,147	234,500	48,301	7	0	0%
Glasscock	Ogallala	3,928	199,200	6,771	34	0	0%
Martin	Ogallala	19,402	776,100	13,394	>50	494,380	64%
Midland	Edwards-Trinity	13,632	175,000	15,598	>50	11,030	6%
Midland	Ogallala	4,667	186,300	27,007	7	0	0%
Pecos	Pecos Alluvium	20,408	1,137,000	25,784	>50	439,756	39%
Reagan	Edwards-Trinity	31,528	624,250	40,221	31	0	0%
Reeves	Pecos Alluvium	58,221	1,361,400	97,299	23	0	0%
Tom Green	Lipan	37,486	838,000	56,505	27	0	0%
Upton	Edwards-Trinity	32,897	173,750	20,721	24	0	0%
Ward	Pecos Alluvium	18,304	733,600	17,668	>50	196,552	27%

1. Assuming use continues at average historical pumpage between 1993 and 1997. Pumpage data are from the TWDB.

shortages of 236,000 acre-feet, a population decrease of 40,000, a loss of 68,000 jobs, and 15 percent less income than is currently projected assuming no water restrictions. However, these consequences are highly unlikely because most of the projected needs in the region can be met. Chapter 5 discusses the water management strategies that may be used to meet these needs.

4.8 Conclusions

On a regional basis, the demands in Region F exceed the currently available supplies beginning in 2000. Most of these needs are attributed to large irrigation demands that cannot be met with available ground water sources. Other needs are due to limitations of contractual agreements, infrastructure, water quality and/or growth. There are supplies in the region that are not fully utilized, such as Lake Brownwood and Lake Coleman, that could possibly be used for some of the identified needs. There are also several aquifers that potentially could be further developed. However, for some of these sources, the needed infrastructure is not developed or the potential source is not located near a water supply need. Further review of the region's existing supplies and other options and strategies to meet needs is explored in more detail in Chapter 5.

Table 1
Region F Currently Available* Supply Versus Demand

	Year 2000		Year 2020		Year 2050	
County	**Currently Available Supply**	**Demand**	**Currently Available Supply**	**Demand**	**Currently Available Supply**	**Demand**
Andrews	25,717	27,273	25,724	24,461	25,705	23,500
Borden	2,596	11,042	2,596	10,780	2,596	10,711
Brown	24,156	20,687	24,045	20,766	24,005	20,692
Coke	5,219	3,290	5,202	3,144	5,170	3,041
Coleman	6,851	4,812	6,826	4,624	6,814	4,512
Concho	9,467	8,840	8,210	8,769	8,127	8,701
Crane	4,876	4,534	4,865	3,854	4,854	3,957
Crockett	6,288	5,622	6,287	7,821	6,307	7,818
Ector	50,508	52,196	53,338	54,607	59,670	60,901
Glasscock	21,117	68,970	21,117	67,890	21,117	66,262
Howard	19,855	17,984	19,795	18,068	20,005	18,351
Irion	4,208	4,044	4,190	3,890	4,176	3,666
Kimble	4,704	4,591	4,707	4,682	4,704	4,922
Loving	405	663	402	655	400	645
Martin	15,424	16,624	15,378	15,903	15,421	15,130
Mason	21,050	20,001	20,984	19,441	20,953	18,668
McCulloch	9,070	8,098	5,758	7,984	5,802	8,000
Menard	7,058	7,088	7,019	7,018	6,960	6,934
Midland	70,784	99,856	77,099	103,610	65,451	114,274
Mitchell	11,374	9,289	11,288	10,213	11,169	13,732
Pecos	91,151	88,291	88,689	85,970	84,924	82,184
Reagan	29,301	49,456	29,301	47,888	29,301	45,779
Reeves	73,064	112,274	73,394	110,698	73,394	108,198
Runnels	13,328	11,097	13,359	11,048	13,440	11,192
Schleicher	3,469	3,145	3,469	3,046	3,469	2,921
Scurry	14,465	11,951	14,860	11,330	14,991	11,125
Sterling	2,454	2,342	2,478	2,126	2,485	2,011
Sutton	4,770	4,457	4,855	4,459	4,915	4,303
Tom Green	118,990	151,209	118,338	157,144	117,246	163,384
Upton	16,521	23,343	16,544	22,229	16,552	21,392
Ward	17,170	21,813	17,181	22,951	17,192	27,238
Winkler	6,614	6,614	6,642	6,305	6,665	6,086
Grand Total	712,024	881,496	713,940	883,374	703,980	900,230

* County shown is the county where the supply is used. The actual supply may come from a different

Table 4-2
Year 2000 Comparison of Currently Available Supply to Projected Demands by County and Category
(Values in Acre-Feet per Year)

County*	Irrigation			Manufacturing			Mining			Municipal			S. E. Power			Livestock			Total		
	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference
Andrews	16,543	18,931	-2,388	193	36	157	4,476	4,364	112	4,019	3,508	511	0	0	0	486	434	52	25,717	27,273	-1,556
Borden	953	9,662	-8,709	89	48	41	1,014	934	80	136	123	13	0	0	0	404	275	129	2,596	11,042	-8,446
Brown	11,508	10,526	982	494	485	9	2,388	300	2,088	7,766	7,778	-12	0	0	0	2,000	1,598	402	24,156	20,687	3,469
Coke	809	667	142	0	0	0	1,248	261	987	1,440	805	635	1,000	835	165	722	722	0	5,219	3,290	1,929
Coleman	2,310	1,376	934	1	1	0	17	15	2	2,766	2,059	707	0	0	0	1,757	1,361	396	6,851	4,812	2,039
Concho	7,082	7,082	0	0	0	0	0	0	0	1,426	799	627	0	0	0	959	959	0	9,467	8,840	627
Crane	337	337	0	0	0	0	2,723	2,726	-3	1,660	1,326	334	0	0	0	156	145	11	4,876	4,534	342
Crockett	500	439	61	18	6	12	434	402	32	1,948	1,873	75	2,391	1,914	477	997	988	9	6,288	5,622	666
Ector	9,095	8,602	493	4,886	2,152	2,734	1,902	7,613	-5,711	27,692	26,911	781	6,700	6,700	0	233	218	15	50,508	52,196	-1,688
Glasscock	20,668	68,521	-47,853	0	0	0	5	5	0	203	203	0	0	0	0	241	241	0	21,117	68,970	-47,853
Howard	4,724	4,724	0	2,491	2,344	147	1,385	452	933	8,835	8,688	147	2,024	1,380	644	396	396	0	19,855	17,984	1,871
Irion	3,296	3,296	0	0	0	0	129	6	123	296	255	41	0	0	0	487	487	0	4,208	4,044	164
Kimble	2,276	1,128	1,148	680	1,637	-957	105	105	0	1,079	1,157	-78	0	0	0	564	564	0	4,704	4,591	113
Loving	324	582	-258	0	0	0	3	3	0	13	13	0	0	0	0	65	65	0	405	663	-258
Martin	13,888	14,221	-333	32	32	0	300	1,228	-928	768	707	61	0	0	0	436	436	0	15,424	16,624	-1,200
Mason	18,550	17,501	1,049	0	0	0	12	12	0	981	981	0	0	0	0	1,507	1,507	0	21,050	20,001	1,049
McCulloch	3,406	2,964	442	831	844	-13	146	146	0	3,458	2,915	543	0	0	0	1,229	1,229	0	9,070	8,098	972
Menard	6,080	6,080	0	0	0	0	0	0	0	392	422	-30	0	0	0	586	586	0	7,058	7,088	-30
Midland	31,934	66,574	-34,640	111	148	-37	0	669	-669	37,995	31,721	6,274	0	0	0	744	744	0	70,784	99,856	-29,072
Mitchell	2,435	2,238	197	0	0	0	1,000	223	777	3,439	2,298	1,141	3,970	4,000	-30	530	530	0	11,374	9,289	2,085
Pecos	82,464	82,458	6	8	7	1	289	322	-33	7,027	4,147	2,880	6	6	0	1,357	1,351	6	91,151	88,291	2,860
Reagan	28,064	46,697	-18,633	0	0	0	0	1,589	-1,589	1,078	996	82	0	0	0	159	174	-15	29,301	49,456	-20,155
Reeves	66,667	105,831	-39,164	13	12	1	0	175	-175	4,138	4,002	136	0	0	0	2,246	2,254	-8	73,064	112,274	-39,210
Runnels	9,193	7,250	1,943	47	47	0	40	35	5	2,071	2,049	22	0	0	0	1,977	1,716	261	13,328	11,097	2,231
Schleicher	2,000	1,807	193	0	0	0	150	147	3	644	597	47	0	0	0	675	594	81	3,469	3,145	324
Scurry	3,742	3,325	417	112	112	0	5,800	3,694	2,106	3,862	3,861	1	0	0	0	949	959	-10	14,465	11,951	2,514
Sterling	980	886	94	0	0	0	585	570	15	318	315	3	0	0	0	571	571	0	2,454	2,342	112
Sutton	2,461	2,248	213	0	0	0	81	81	0	1,449	1,438	11	0	0	0	779	690	89	4,770	4,457	313
Tom Green	82,239	120,102	-37,863	790	718	72	192	79	113	31,843	27,166	4,677	1,602	1,020	582	2,324	2,124	200	118,990	151,209	-32,219
Upton	14,681	19,824	-5,143	0	0	0	618	2,405	-1,787	1,056	1,008	48	0	0	0	166	106	60	16,521	23,343	-6,822
Ward	5,843	11,273	-5,430	4	4	0	0	635	-635	5,308	4,108	1,200	5,728	5,500	228	287	293	-6	17,170	21,813	-4,643
Winkler	1,500	1,500	0	8	8	0	2,040	2,040	0	2,877	2,874	3	0	0	0	189	192	-3	6,614	6,614	0
Grand Total	456,552	648,652	-192,100	10,808	8,641	2,167	27,082	31,236	-4,154	167,983	147,103	20,880	23,421	21,355	2,066	26,178	24,509	1,669	712,024	881,496	-169,472

Note: (-) indicates shortage, (+) indicates supply greater than demand

* County shown is the county where the supply is used. The actual supply may come from a different county.

Table 4-3
Year 2020 Comparison of Currently Available Supply to Projected Demands by County and Category
(Values in Acre-Feet per Year)

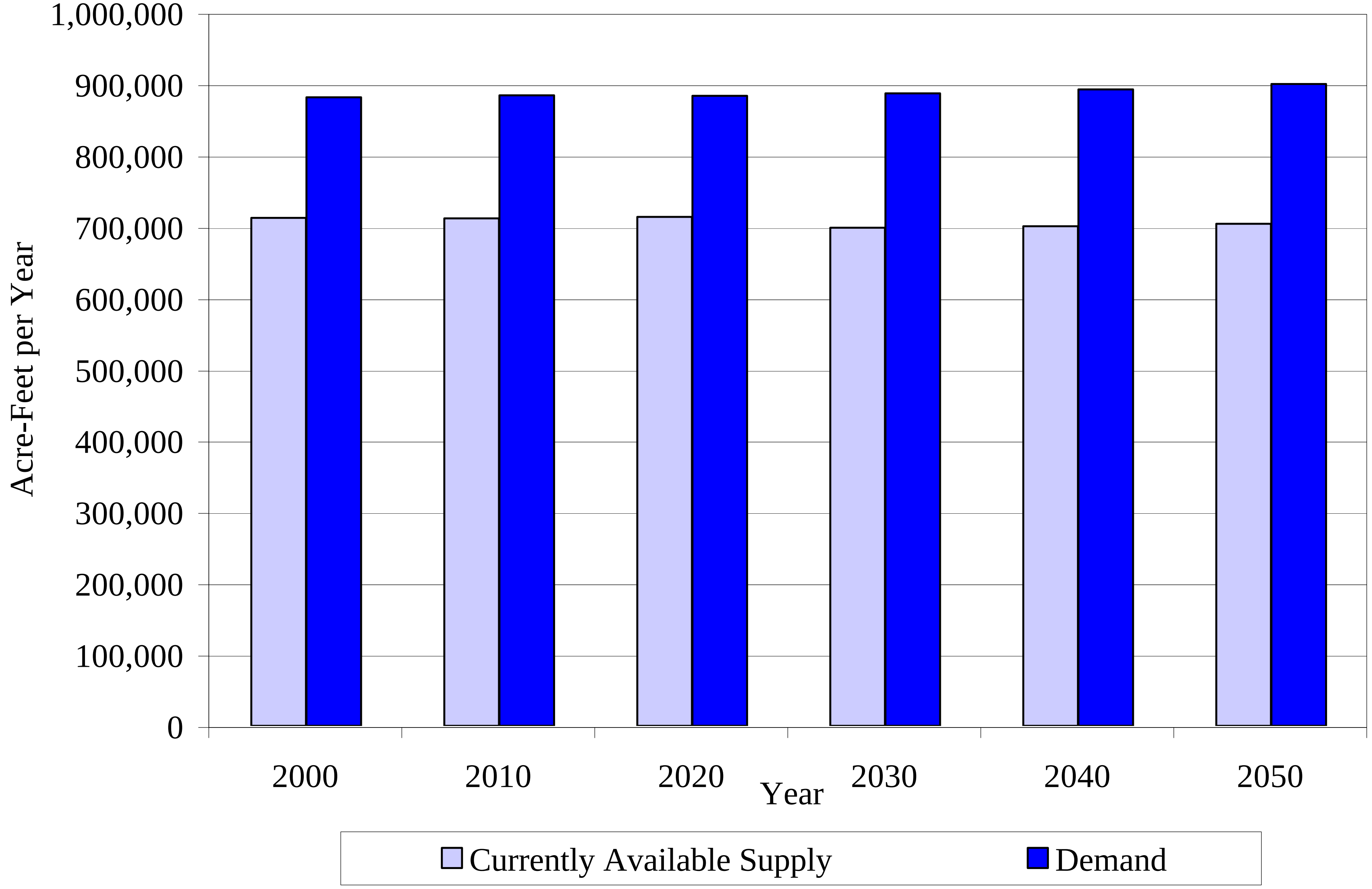
County	Irrigation			Manufacturing			Mining			Municipal			S. E. Power			Livestock			Total		
	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference
Andrews	17,570	18,616	-1,046	193	39	154	3,456	1,654	1,802	4,019	3,718	301	0	0	0	486	434	52	25,724	24,461	1,263
Borden	963	9,636	-8,673	89	68	21	1,014	701	313	126	100	26	0	0	0	404	275	129	2,596	10,780	-8,184
Brown	11,508	10,455	1,053	574	567	7	2,388	196	2,192	7,575	7,950	-375	0	0	0	2,000	1,598	402	24,045	20,766	3,279
Coke	809	666	143	0	0	0	1,248	159	1,089	1,423	762	661	1,000	835	165	722	722	0	5,202	3,144	2,058
Coleman	2,310	1,353	957	2	2	0	17	16	1	2,740	1,892	848	0	0	0	1,757	1,361	396	6,826	4,624	2,202
Concho	7,026	7,026	0	0	0	0	0	0	0	225	784	-559	0	0	0	959	959	0	8,210	8,769	-559
Crane	337	337	0	0	0	0	2,670	1,859	811	1,702	1,513	189	0	0	0	156	145	11	4,865	3,854	1,011
Crockett	500	424	76	18	10	8	434	226	208	1,947	1,893	54	2,391	4,280	-1,889	997	988	9	6,287	7,821	-1,534
Ector	9,104	8,399	705	4,980	2,413	2,567	1,902	6,892	-4,990	30,419	29,985	434	6,700	6,700	0	233	218	15	53,338	54,607	-1,269
Glasscock	20,664	67,437	-46,773	0	0	0	1	1	0	211	211	0	0	0	0	241	241	0	21,117	67,890	-46,773
Howard	4,620	4,618	2	2,741	2,677	64	1,385	421	964	8,629	8,576	53	2,024	1,380	644	396	396	0	19,795	18,068	1,727
Irion	3,290	3,157	133	0	0	0	129	3	126	284	243	41	0	0	0	487	487	0	4,190	3,890	300
Kimble	2,276	1,049	1,227	680	1,849	-1,169	99	99	0	1,088	1,121	-33	0	0	0	564	564	0	4,707	4,682	25
Loving	324	578	-254	0	0	0	3	3	0	10	9	1	0	0	0	65	65	0	402	655	-253
Martin	13,731	13,731	0	36	36	0	404	990	-586	771	710	61	0	0	0	436	436	0	15,378	15,903	-525
Mason	18,550	17,009	1,541	0	0	0	6	4	2	921	921	0	0	0	0	1,507	1,507	0	20,984	19,441	1,543
McCulloch	3,406	2,891	515	848	963	-115	158	158	0	117	2,743	-2,626	0	0	0	1,229	1,229	0	5,758	7,984	-2,226
Menard	6,041	6,041	0	0	0	0	0	0	0	392	391	1	0	0	0	586	586	0	7,019	7,018	1
Midland	35,143	65,548	-30,405	112	174	-62	0	159	-159	41,100	36,985	4,115	0	0	0	744	744	0	77,099	103,610	-26,511
Mitchell	2,435	2,215	220	0	0	0	1,000	53	947	3,407	2,135	1,272	3,916	5,280	-1,364	530	530	0	11,288	10,213	1,075
Pecos	79,927	79,921	6	8	10	-2	289	263	26	7,102	4,419	2,683	6	6	0	1,357	1,351	6	88,689	85,970	2,719
Reagan	28,059	45,177	-17,118	0	0	0	0	1,474	-1,474	1,083	1,063	20	0	0	0	159	174	-15	29,301	47,888	-18,587
Reeves	66,667	104,053	-37,386	13	13	0	0	116	-116	4,468	4,262	206	0	0	0	2,246	2,254	-8	73,394	110,698	-37,304
Runnels	9,193	7,191	2,002	68	68	0	40	26	14	2,081	2,047	34	0	0	0	1,977	1,716	261	13,359	11,048	2,311
Schleicher	2,000	1,737	263	0	0	0	150	107	43	644	608	36	0	0	0	675	594	81	3,469	3,046	423
Scurry	3,742	3,113	629	392	392	0	5,800	2,920	2,880	3,977	3,946	31	0	0	0	949	959	-10	14,860	11,330	3,530
Sterling	983	817	166	0	0	0	585	405	180	339	333	6	0	0	0	571	571	0	2,478	2,126	352
Sutton	2,461	2,164	297	0	0	0	81	81	0	1,534	1,524	10	0	0	0	779	690	89	4,855	4,459	396
Tom Green	82,145	119,515	-37,370	887	832	55	192	84	108	31,341	30,909	432	1,449	3,680	-2,231	2,324	2,124	200	118,338	157,144	-38,806
Upton	14,681	19,270	-4,589	0	0	0	618	1,792	-1,174	1,079	1,061	18	0	0	0	166	106	60	16,544	22,229	-5,685
Ward	5,933	10,999	-5,066	5	5	0	0	318	-318	5,276	4,076	1,200	5,680	7,260	-1,580	287	293	-6	17,181	22,951	-5,770
Winkler	1,500	1,500	0	11	11	0	1,940	1,605	335	3,002	2,997	5	0	0	0	189	192	-3	6,642	6,305	337
Grand Total	457,898	636,643	-178,745	11,657	10,129	1,528	26,009	22,785	3,224	169,032	159,887	9,145	23,166	29,421	-6,255	26,178	24,509	1,669	713,940	883,374	-169,434

Note: (-) indicates shortage, (+) indicates supply greater than demand
* County shown is the county where the supply is used. The actual supply may come from a different county.

Table 4-4
Year 2050 Comparison of Currently Available Supply to Projected Demands by County and Category
(Values in Acre-Feet per Year)

County	Irrigation			Manufacturing			Mining			Municipal			S. E. Power			Livestock			Total		
	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference
Andrews	17,551	18,144	-593	193	51	142	3,456	1,103	2,353	4,019	3,768	251	0	0	0	486	434	52	25,705	23,500	2,205
Borden	980	9,597	-8,617	89	109	-20	1,014	672	342	109	58	51	0	0	0	404	275	129	2,596	10,711	-8,115
Brown	11,508	10,348	1,160	717	714	3	2,388	134	2,254	7,392	7,898	-506	0	0	0	2,000	1,598	402	24,005	20,692	3,313
Coke	809	664	145	0	0	0	1,248	74	1,174	1,391	746	645	1,000	835	165	722	722	0	5,170	3,041	2,129
Coleman	2,310	1,319	991	3	3	0	17	17	0	2,727	1,812	915	0	0	0	1,757	1,361	396	6,814	4,512	2,302
Concho	6,943	6,943	0	0	0	0	0	0	0	225	799	-574	0	0	0	959	959	0	8,127	8,701	-574
Crane	337	337	0	0	0	0	2,616	1,759	857	1,745	1,716	29	0	0	0	156	145	11	4,854	3,957	897
Crockett	500	403	97	18	17	1	434	190	244	1,967	1,940	27	2,391	4,280	-1,889	997	988	9	6,307	7,818	-1,511
Ector	9,114	8,096	1,018	5,092	2,725	2,367	1,902	6,565	-4,663	36,629	36,597	32	6,700	6,700	0	233	218	15	59,670	60,901	-1,231
Glasscock	20,665	65,810	-45,145	0	0	0	0	0	0	211	211	0	0	0	0	241	241	0	21,117	66,262	-45,145
Howard	4,459	4,459	0	3,243	3,244	-1	1,385	440	945	8,498	8,432	66	2,024	1,380	644	396	396	0	20,005	18,351	1,654
Irion	3,290	2,948	342	0	0	0	129	2	127	270	229	41	0	0	0	487	487	0	4,176	3,666	510
Kimble	2,276	930	1,346	680	2,229	-1,549	103	103	0	1,081	1,096	-15	0	0	0	564	564	0	4,704	4,922	-218
Loving	324	572	-248	0	0	0	3	3	0	8	5	3	0	0	0	65	65	0	400	645	-245
Martin	12,997	12,997	0	40	40	0	1,236	1,006	230	712	651	61	0	0	0	436	436	0	15,421	15,130	291
Mason	18,550	16,271	2,279	0	0	0	6	0	6	890	890	0	0	0	0	1,507	1,507	0	20,953	18,668	2,285
McCulloch	3,406	2,782	624	874	1,153	-279	176	176	0	117	2,660	-2,543	0	0	0	1,229	1,229	0	5,802	8,000	-2,198
Menard	5,982	5,982	0	0	0	0	0	0	0	392	366	26	0	0	0	586	586	0	6,960	6,934	26
Midland	42,256	64,008	-21,752	112	216	-104	0	0	0	22,339	49,306	-26,967	0	0	0	744	744	0	65,451	114,274	-48,823
Mitchell	2,435	2,182	253	0	0	0	1,000	0	1,000	3,343	1,896	1,447	3,861	9,124	-5,263	530	530	0	11,169	13,732	-2,563
Pecos	76,120	76,114	6	8	15	-7	289	277	12	7,144	4,421	2,723	6	6	0	1,357	1,351	6	84,924	82,184	2,740
Reagan	27,915	42,897	-14,982	0	0	0	0	1,481	-1,481	1,227	1,227	0	0	0	0	159	174	-15	29,301	45,779	-16,478
Reeves	66,667	101,385	-34,718	13	15	-2	0	115	-115	4,468	4,429	39	0	0	0	2,246	2,254	-8	73,394	108,198	-34,804
Runnels	9,116	7,102	2,014	90	112	-22	40	25	15	2,217	2,237	-20	0	0	0	1,977	1,716	261	13,440	11,192	2,248
Schleicher	2,000	1,630	370	0	0	0	150	105	45	644	592	52	0	0	0	675	594	81	3,469	2,921	548
Scurry	3,742	2,796	946	392	392	0	5,800	2,934	2,866	4,108	4,044	64	0	0	0	949	959	-10	14,991	11,125	3,866
Sterling	981	714	267	0	0	0	585	396	189	348	330	18	0	0	0	571	571	0	2,485	2,011	474
Sutton	2,461	2,038	423	0	0	0	86	86	0	1,589	1,489	100	0	0	0	779	690	89	4,915	4,303	612
Tom Green	81,881	118,634	-36,753	1,084	1,064	20	192	93	99	30,555	37,789	-7,234	1,210	3,680	-2,470	2,324	2,124	200	117,246	163,384	-46,138
Upton	14,681	18,440	-3,759	0	0	0	618	1,813	-1,195	1,087	1,033	54	0	0	0	166	106	60	16,552	21,392	-4,840
Ward	6,324	10,588	-4,264	7	7	0	0	194	-194	4,811	3,611	1,200	5,763	12,545	-6,782	287	293	-6	17,192	27,238	-10,046
Winkler	1,500	1,500	0	17	17	0	1,940	1,398	542	3,019	2,979	40	0	0	0	189	192	-3	6,665	6,086	579
Grand Total	460,080	618,630	-158,550	12,672	12,123	549	26,813	21,161	5,652	155,282	185,257	-29,975	22,955	38,550	-15,595	26,178	24,509	1,669	703,980	900,230	-196,250

Note: (-) indicates shortage, (+) indicates supply greater than demand
* County shown is the county where the supply is used. The actual supply may come from a different county.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900,000
800,000
700,000
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500,000
400,000
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Acre-Feet per Year
2000
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2030
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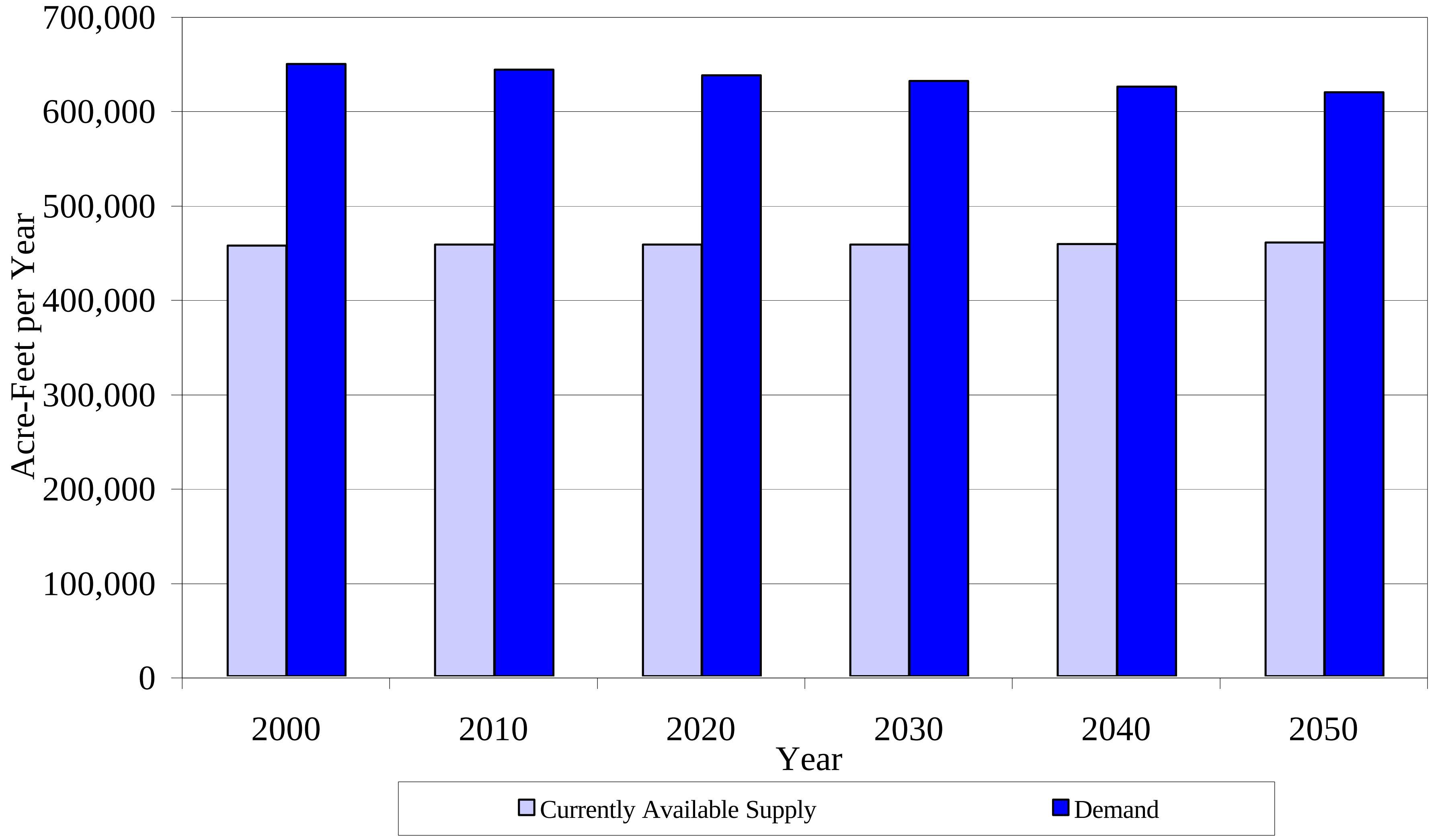
2050
Year
Currently Available Supply
Demand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600,000
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Acre-Feet per Year
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2010
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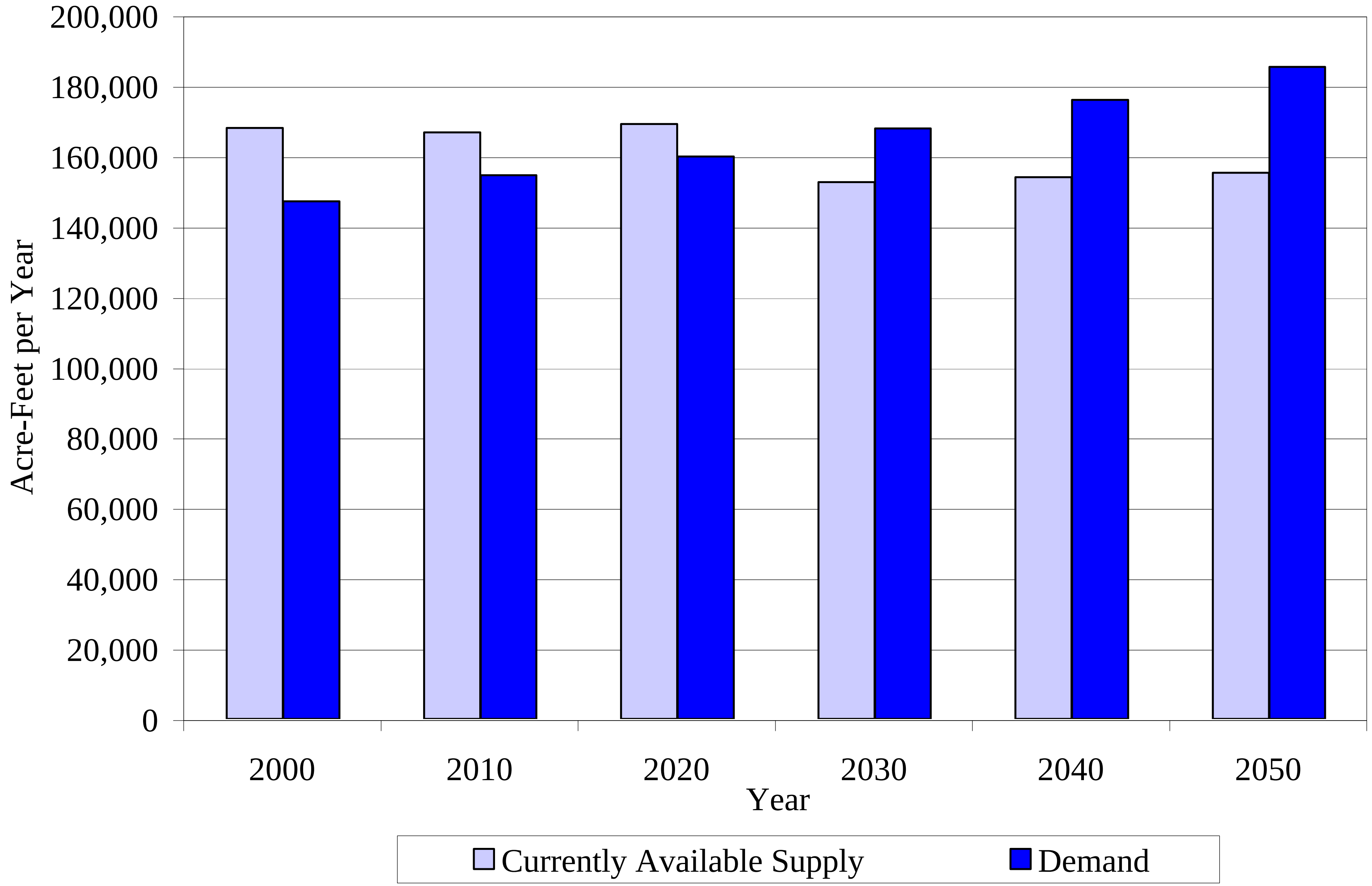
Year
Currently Available Supply
Demand



200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
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0
Acre-Feet per Year
2000
2010
2020
2030
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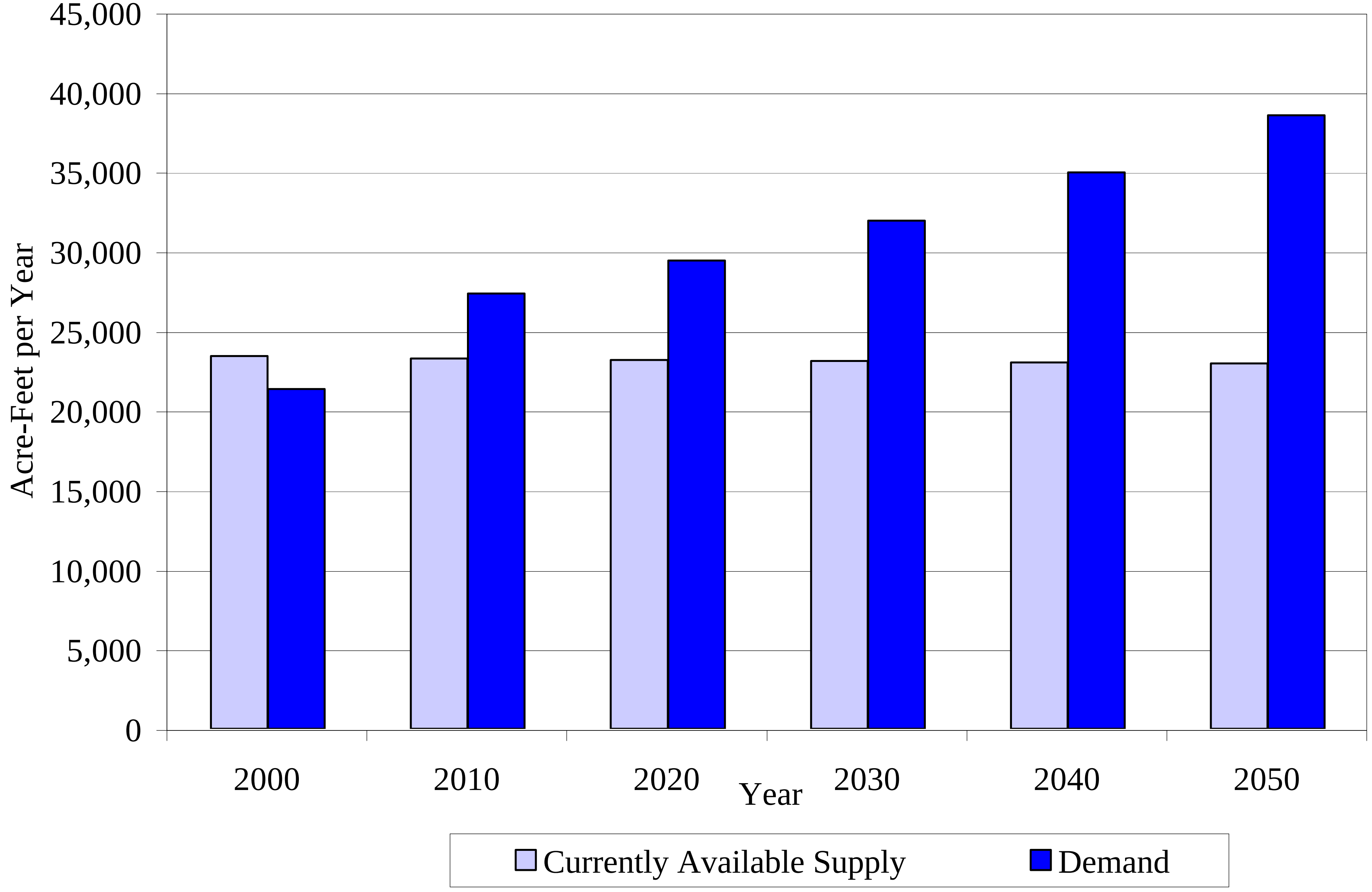
2050
Year
Currently Available Supply
Demand


45,000
40,000
35,000
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25,000
20,000
15,000
10,000
5,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
Year
Currently Available Supply
Demand

COUNTY	PROJECTED IRRIGATION NEED (acre-feet per year)								
	2000	2010	2020	2030	2040	2050	2000	2020	
ANDREWS	2,388	1,206	1,046	911	752	593	-2388.16	-1046	
BORDEN	8,709	8,692	8,673	8,653	8,635	8,617	-8709	-8673	
GLASSCO	47,853	47,316	46,773	46,231	45,686	45,145	-47853	-46773	
LOVING	258	256	254	252	250	248	-258	-254	
MIDLAND	34,640	32,371	30,405	28,042	25,414	21,752	-34640	-30405	
REAGAN	18,633	17,877	17,118	16,357	15,676	14,982	-18633	-17118	
REEVES	39,164	38,275	37,386	36,497	35,607	34,718	-39164	-37386	
TOM GRE	37,863	37,616	37,370	37,164	36,959	36,753	-37863	-37370	
UPTON	5,343	5,066	4,789	4,513	4,236	3,959	-5143	-4589	surplus of 200 ac-ft in Upton, Rio Grande basin
WARD	5,430	5,287	5,066	4,806	4,508	4,264	-5430	-5066	
TOTAL	200,281	193,962	188,880	183,426	177,723	171,031			

County/Sa	2000PROJ	2010PROJ	2020PROJ	2030PROJ	2050PROJ	2050PROJ	Savings		
Andrews	0	2054	4107	4107	4107	4107	2388	86%	172%
Borden	0	599	1197	1197	1197	1197	8709	7%	14%
Brown	0	76	152	152	152	152			
Coke	0	67	133	133	133	133			
Coleman	0	65	130	130	130	130			
Concho	0	622	1244	1244	1244	1244			
Crane	0	51	103	103	103	103			
Crockett	0	13	25	25	25	25			
Ector	0	757	1513	1513	1513	1513			
Glasscock	0	9159	18318	18318	18318	18318	47853	19%	38%
Howard	0	431	861	861	861	861			
Irion	0	121	242	242	242	242			
Kimble	0	2	3	3	3	3			
Loving	0	0	0	0	0	0	258	0%	0%
McCulloch	0	224	448	448	448	448			
Martin	0	1121	2243	2243	2243	2243			
Mason	0	1215	2430	2430	2430	2430			
Menard	0	75	149	149	149	149			
Midland	0	3872	7744	7744	7744	7744	34640	11%	22%
Mitchell	0	353	707	707	707	707			
Pecos	0	4771	9541	9541	9541	9541			
Reagan	0	8087	16174	16174	16174	16174	18633	43%	87%
Reeves	0	4963	9923	9923	9923	9923	39164	13%	25%
Runnels	0	586	1173	1173	1173	1173			
Schleicher	0	167	333	333	333	333			
Scurry	0	437	874	874	874	874			
Sterling	0	65	130	130	130	130			
Sutton	0	257	514	514	514	514			
Tom Greer	0	12723	25441	25441	25441	25441	37863	34%	67%
Upton	0	2817	5633	5633	5633	5633	5343	53%	105%
Ward	0	127	254	254	254	254	5430	2%	5%

Winkler	0	0	0	0	0	0			
Water Sav	0	55877	111739	111739	111739	111739	200281	28%	56%

5.0 IDENTIFICATION, EVALUATION, AND SELECTION OF WATER MANAGEMENT STRATEGIES

5.1 Identified Regional Needs and Evaluation Procedures

5.1.1 Regional Needs

The comparison of current water supplies to demands presented in Chapter 4 identified 39 different water user groups with needs greater than 10 acre-feet per year. The largest needs are associated with irrigation in Glasscock, Midland, Tom Green, Reagan and Reeves Counties. Other significant needs include the cities of Midland and San Angelo, municipal users of the Hickory aquifer, and several steam electric and mining needs. A list of these users and their respective needs are presented in the following table.

Table 5-1
Identified Needs in Region F

WATER USER GROUP	COUNTY	PROJECTED NEED (acre-feet per year)					
		2000	2010	2020	2030	2040	2050
BRADY	MCCULLOCH	0	1,871	1,827	1,803	1,779	1,775
EDEN	CONCHO	0	531	529	531	533	545
JUNCTION	KIMBLE	78	63	33	22	16	15
MENARD	MENARD	39	26	18	10	2	1
MIDLAND	MIDLAND	0	0	0	17,861	21,862	26,967
SAN ANGELO	TOM GREEN	0	0	0	887	3,420	6,288
COUNTY-OTHER	BROWN	135	321	447	570	581	525
COUNTY-OTHER	CONCHO	0	36	30	27	13	29
COUNTY-OTHER	MCCULLOCH	0	833	799	784	771	768
COUNTY - OTHER	REEVES	0	21	48	71	86	72
COUNTY-OTHER	RUNNELS	0	0	0	0	0	51
COUNTY-OTHER	TOM GREEN	0	141	175	728	931	946
IRRIGATION	ANDREWS	2,388	1,206	1,046	911	752	593
IRRIGATION	BORDEN	8,709	8,692	8,673	8,653	8,635	8,617
IRRIGATION	GLASSCOCK	47,853	47,316	46,773	46,231	45,686	45,145
IRRIGATION	LOVING	258	256	254	252	250	248
IRRIGATION	MARTIN	333	125	0	0	0	0
IRRIGATION	MIDLAND	34,640	32,371	30,405	28,042	25,414	21,752

Table 5-1 (continued)

WATER USER GROUP	COUNTY	PROJECTED NEED (acre-feet per year)					
		2000	**2010**	**2020**	**2030**	**2040**	**2050**
IRRIGATION	REAGAN	18,633	17,877	17,118	16,357	15,676	14,982
IRRIGATION	REEVES	39,164	38,275	37,386	36,497	35,607	34,718
IRRIGATION	TOM GREEN	37,863	37,616	37,370	37,164	36,959	36,753
IRRIGATION	UPTON	5,343	5,066	4,789	4,513	4,236	3,959
IRRIGATION	WARD	5,430	5,287	5,066	4,806	4,508	4,264
MANUFACTURING	BORDEN	0	0	0	0	5	20
MANUFACTURING	KIMBLE	957	1,097	1,169	1,229	1,387	1,549
MANUFACTURING	MCCULLOCH	13	64	115	170	224	279
MANUFACTURING	MIDLAND	37	49	62	76	90	104
MANUFACTURING	RUNNELS	0	0	0	0	5	22
MINING	ECTOR	6,268	5,949	5,546	5,350	5,256	5,216
MINING	MARTIN	928	712	586	184	0	0
MINING	MIDLAND	669	318	159	80	26	0
MINING	REAGAN	1,589	1,524	1,474	1,427	1,439	1,481
MINING	REEVES	175	136	116	113	112	115
MINING	UPTON	1,817	1,362	1,282	1,266	1,281	1,319
MINING	WARD	635	495	318	231	190	194
STEAM ELECTRIC POWER	CROCKETT	0	1,889	1,889	1,889	1,889	1,889
STEAM ELECTRIC POWER	MITCHELL	30	457	1,364	2,439	3,721	5,263
STEAM ELECTRIC POWER	TOM GREEN	0	2,156	2,231	2,294	2,382	2,470
STEAM ELECTRIC POWER	WARD	0	367	1,580	3,023	4,730	6,782

In addition to these users groups, there are several users whose supplies may not be reliable or may have infrastructure limitations such as limited treatment capacity. The users do not indicate a need based on the supply and demand comparison, but strategies were developed to increase the reliability of their supply during drought of record conditions. These users include the cities of Ballinger, Early, Eldorado, Miles, Bronte, Robert Lee and Winters.

5.1.2 Evaluation Procedures

Water supply strategies were developed for municipal and manufacturing needs. Most of these strategies are based on discussions with the municipalities and previous planning efforts.

General strategies were developed for mining, steam electric and irrigation. For large irrigation needs, conservation and demand reductions were examined as appropriate strategies.

In accordance with Senate Bill 1 guidance, the potentially feasible strategies were then evaluated with respect to:

- Quantity, reliability and cost;
- Environmental factors;
- Impacts on water resources and other water management strategies
- Impacts on agriculture and natural resources; and
- Other relevant factors.

The other considerations listed in TAC 357.7(a), such as interbasin transfers and third party impacts due to re-distribution of water rights, were reviewed on a case-by-case basis because they generally were not applicable to strategies identified for Region F needs.

The definition of “quantity” is the amount of water the strategy would provide to the respective user group in acre-feet per year. This amount is considered with respect to the user’s short-term and long-term needs. “Reliability” is an assessment of the availability of the specified water quantity to the user over time. If the quantity of water is available to the user all the time, then the strategy has a high reliability. If the quantity of water is contingent on other factors, such as infrastructure limitations, hydrologic conditions or calls by senior water rights, then reliability will be lower. Reliability may also be considered lower if the amount of available water is not well known. The assessment of cost for each strategy is expressed in dollars per acre-foot per year for water delivered and treated for the end user requirements. Calculations of these costs follow SB1 guidelines for cost considerations, and identify capital and annual costs by decade. Project capital costs are based on 1999 price levels, and include construction costs, engineering, land acquisition, mitigation, right-of-way, contingencies and other project costs. Annual costs include power costs associated with transmission, water treatment costs, water purchase (if applicable), operation and maintenance, and other project-specific costs. Debt service for capital improvements was calculated over 30 years at a 6 percent interest rate, with the exception of new reservoirs, which were calculated over 40 years.

Potential impacts to sensitive environmental factors were considered for each strategy. Sensitive environmental factors may include wetlands, threatened and endangered species, unique wildlife habitats, and cultural resources. In-stream flow requirements were also considered for strategies that would require new or amended water rights. The environmental review identified potential environmental factors based on existing reports and cursory surveys of the region. However, available data is limited for most identified strategies. If a strategy is selected for implementation, a more detailed environmental evaluation will be required.

The impact on water resources considers the effects of the strategy on water quantity, quality, and use of the water resource. A water management strategy may have a positive or negative effect on a water resource. An example of a positive impact would be increased stream flows or ground water supplies due to brush control. An example of a negative impact is reduced water supply for future needs due to overdrafting an aquifer. This review also evaluated whether the strategy would impact the water quantity and quality of other water management strategies identified. An example of a positive impact is improved water quality due to a chloride control project. An example of a negative impact is reduced water availability for downstream needs due to construction of a reservoir.

A water management strategy could potentially impact agricultural production or local natural resources. Impacts to agriculture may include reduction in agricultural acreage, reduced water supply for irrigation, or impact to water quality as it affects crop production. Some strategies may actually improve water quality, while others may have a negative impact. For example, increased irrigation efficiency may have a positive impact on water quality by reducing the amount of poor quality tail-water that enters a stream. The impacts to natural resources may consider reduction of habitats, impacts to exploitable natural resources (such as mining), recreational use of a natural resource, and other strategy-specific factors.

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

A summary of the evaluations for all feasible strategies identified to meet needs in Region F is presented in the Strategies Matrix in Appendix E. The associated costs for each strategy are also summarized in Appendix E.

5.1.3 Strategy Development

Strategies were developed for water user groups to meet projected needs in the context of their current supply sources, previous supply studies and available supply within the region. Much of the water supply in Region F is from ground water, and for several of the identified needs the potentially feasible strategies include development of new ground water supplies. Where site-specific data were available, this information was used. When specific well fields could not be identified, assumptions regarding well capacity, depth of well and associated costs were developed based on county and aquifer.

Water transmission lines were assumed to take the shortest route, following existing highways or roads where possible. Profiles were developed using USGS topographic maps. Pipes were sized to deliver peak-day flows within reasonable pressure and velocity ranges. More information regarding the development of conceptual project designs may be found in the development of costs included in Appendix E.

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

In addition to the development of specific strategies to meet needs, there are other water management strategies that are general and could potentially increase water for all user groups. These include:

- Water conservation and drought response,
- Reuse of wastewater,
- Weather modification,
- Brush control,
- Water quality improvement,
- Ground water recharge enhancement, and
- Aquifer storage and recovery.

A brief discussion of each of these general strategies and its applicability to Region F is included in Section 5.8 of this chapter.

5.2 Municipal Needs

As shown on Table 5-1, there are six cities and six county-other municipal users with needs during the planning period. The cities of Ballinger, Early, Miles, Bronte, Robert Lee, Winters and Eldorado do not have reported needs in Chapter 4, but do have potential water supply limitations due to the reliability and operation of their water systems or water quality. The limitations for Ballinger and Winters are discussed with Runnels County-Other in Section 5.2.8, Early is presented in Section 5.2.6, Bronte and Robert Lee are discussed in Section 5.2.7, Miles is included with the Hickory users in Section 5.2.9 and Eldorado is discussed in Section 5.2.10.

Several of the county-other needs are discussed with strategies identified for nearby cities. Others are addressed separately. For Reeves County-Other, the recommended strategy is to increase sales from the cities of Balmorhea and Pecos. Since no additional infrastructure is needed and there is adequate supply from these cities, this strategy is not addressed separately.

Over the planning period there may be additional water users that will need to upgrade their water supply systems or develop new supplies, but are not identified in this plan because they are included in the "county-other" category or their water needs change. It is the intent of this plan to include all water systems that may demonstrate a need for water supply. This includes established water providers and new water supply corporations formed by individual users that may need to band together to provide a reliable water supply. In addition, water supply projects that do not involve the development of or connection to a new water source, but are needed to meet demands are consistent with the regional plan even though not specifically recommended in the plan.

5.2.1 City of Midland

The city of Midland currently obtains water from the Colorado River Municipal Water District (CRMWD) and the Paul Davis Well Field in Martin and Andrews Counties. The City provides water to its municipal customers and a small amount of water to industrial customers. According to the supply and demand comparison Midland will begin to experience a need starting in 2029 with the expiration of one of the City's two contracts with CRMWD. In addition, Midland County manufacturing is expected to experience small needs throughout the planning period, primarily due to limitations on local ground water supplies. It is assumed that the near-term needs will be met by sales from the city of Midland.

Two strategies were identified to meet these needs: renewal of the 1966 contract, and development of the T-Bar Well Field in Winkler and Loving Counties. Both of these strategies will be needed to meet the City's long-term needs. The proposed scenario is for the City to renew its contract with CRMWD before 2029, and the T-Bar Well Field will be developed as demand reaches the limits of the CRMWD contract. It is possible that the T-Bar Well Field may need to be developed sooner if supplies from the Paul Davis Well Field in Martin County are depleted faster than expected.

Table 5-2 is a detailed summary of the sources of supply for the city of Midland and Midland County Manufacturing. Figure 5-1 illustrates the comparison of the supply sources to the projected demands for the City and its customers.

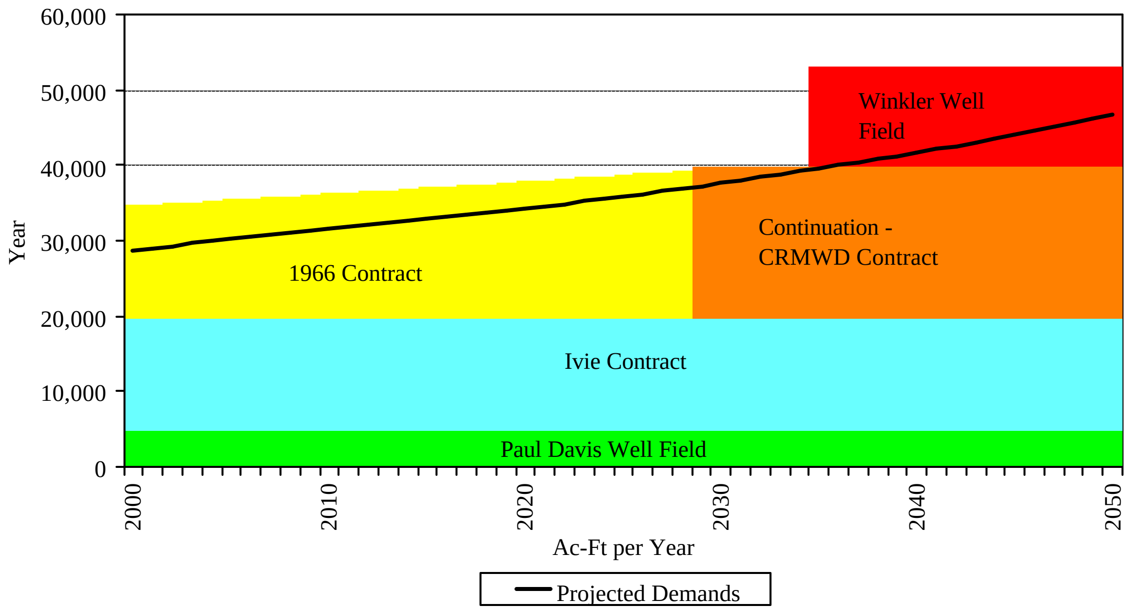
Table 5-2 Supply and Demand Comparison for the City of Midland

Water User Group	Year 2000	Year 2010	Year 2020	Year 2030	Year 2040	Year 2050
Demands:						
Midland	28,679	31,637	34,142	37,574	41,571	46,667
Midland County Other	20	20	20	20	20	20
Manufacturing	46	46	46	46	46	46
Increased Manufacturing Sales	*37*	*50*	*62*	*76*	*89*	*105*
Total Demand	**28,782**	**31,753**	**34,270**	**37,716**	**41,726**	**46,838**
Supplies:						
Ivie Contract	15,000	15,000	15,000	15,000	15,000	15,000
1966 Contract	14,991	16,624	18,257	0	0	0
Paul Davis Well Field	4,722	4,707	4,693	4,779	4,775	4,766
Renewed Contract				*20,000*	*20,000*	*20,000*
T-Bar Well Field					*13,400*	*13,400*
Total Supply	**34,713**	**36,331**	**37,950**	**39,779**	**53,175**	**53,166**
Supply Less Demands	**5,931**	**4,578**	**3,680**	**2,063**	**11,449**	**6,328**
Manufacturing Demands	**148**	**161**	**174**	**188**	**201**	**216**
Supplies						
Ogallala (Midland County)	5	5	6	6	6	5
Ogallala (Martin County)	60	60	60	60	60	60
Current Midland Sales	46	46	46	46	46	46
Increased Midland Sales	*37*	*50*	*62*	*76*	*89*	*105*
Total Supply	**148**	**161**	**174**	**188**	**201**	**216**
Supply Less Demands	**0**	**0**	**0**	**0**	**0**	**0**

Items in italics indicate new supplies or demands

Figure 5-1

Comparison of Supply and Demand
City of Midland



5.2.1.1 T-Bar Well Field

In 1965 the city of Midland purchased the T-Bar Well Field, which consists of approximately 20,230 acres in northwestern Winkler County and northeastern Loving County. The city of Midland estimates that there are approximately 650,000 acre-feet of available storage in the Cenozoic Pecos Alluvium from this field, and the field has a life of approximately 60 years (personal communication, Kay Snyder, city of Midland). The annual recharge is estimated at approximately 6,600 acre-feet per year.

The City is planning to use this well field during high demand periods (e.g., summer). The proposed design capacity is 20 MGD, with an annual use of 13,400 acre-feet per year. To develop this well field, it is assumed that 20 wells will be installed and a 70-mile transmission line will be constructed. As shown on Figure 5-1, this supply will need to be available between 2030 and 2040 to meet the projected demands.

Quantity, Reliability and Cost

The quantity of water could provide for almost half of the City's needs in 2050. When combined with the CRMWD contract extension, these supplies are more than adequate. The reliability is high, since there is available supply in the Pecos Alluvium in Winkler County and annual recharge is approximately half of the proposed annual supply. The cost of the water is $485 per acre-foot ($1.49/1,000 gallons).

Environmental Factors

The environmental impacts from ground water development would be low. It is assumed that the 70-mile pipeline can be routed to minimize impact on potentially sensitive areas if needed. Species of special concern listed in Table 1-17 for Ector and Winkler counties include the American and Artic Peregrine Falcons and the Jones Pocket Gopher. Once the route has been chosen, the potential for environmental impacts will need further investigation.

Impacts on Water Resources and Other Management Strategies

There is adequate supply in the Pecos Alluvium in Winkler County to support the proposed well field. Since the proposed well field is located in a geological trough, pumping of ground water should have minimal impacts on the aquifer outside of the well field. There are no other identified management strategies that will be affected.

Impacts on Agriculture and Natural Resources

This strategy should have minimal affects on agriculture since the water rights are already owned and there is little agriculture in the area. The right of way for the transmission line may temporarily affect a small amount of agricultural acreage.

Other Relevant Factors

There are no other identified relevant factors.

5.2.1.2 CRMWD Contract

The city of Midland has two contracts with CRMWD and contracts with others. The first CRMWD contract, signed in 1966, is a take-or-pay contract that increases by 163.3 acre-feet each year. This contract expires in 2029. The second contract is for 15,000 acre-feet per year of water from the Ivie Reservoir. This contract will not expire during the planning period.

It is assumed that the 1966 contract will be renewed at a constant value of 20,000 acre-feet per year. However, the amount of the renewed contract will depend on the safe yield of the CRMWD system and negotiations with the city of Midland.

Quantity, Reliability and Cost

The quantity of water would provide for all of Midland's needs up to 2040. Between 2040 and 2050, this supply would provide approximately 85 percent of the City's needs. The difference would be met with supply from the T-Bar Ranch well field. The reliability would be high due to the multiple sources in the CRMWD system. The cost of the water will be determined during contract negotiations with CRMWD. For SB-1 purposes, the cost of water is assumed at the assumed raw water costs of $386 per acre-foot/year ($1.25/1,000 gallons).

Environmental Factors

Adverse impacts to the environment are not expected since there will be no significant changes in water use from this existing source.

Impacts on Water Resources and Other Management Strategies

The current 1966 CRMWD contract has a built-in acceleration of the maximum annual use over time. It is assumed that the 1966 contract will be renewed to deliver a constant amount of water at the 2029 level, removing the increasing demand provision. Even though this demand on CRMWD reservoirs and transmission capacity will be frozen at 2029 levels, the increased demand from other CRMWD customers, combined with the renewal of the Midland contract, will limit the amount of additional water available from the CRMWD system.

Impacts on Agriculture and Natural Resources

There should be no impacts to agriculture since these supplies are not used for irrigation.

Other Relevant Factors

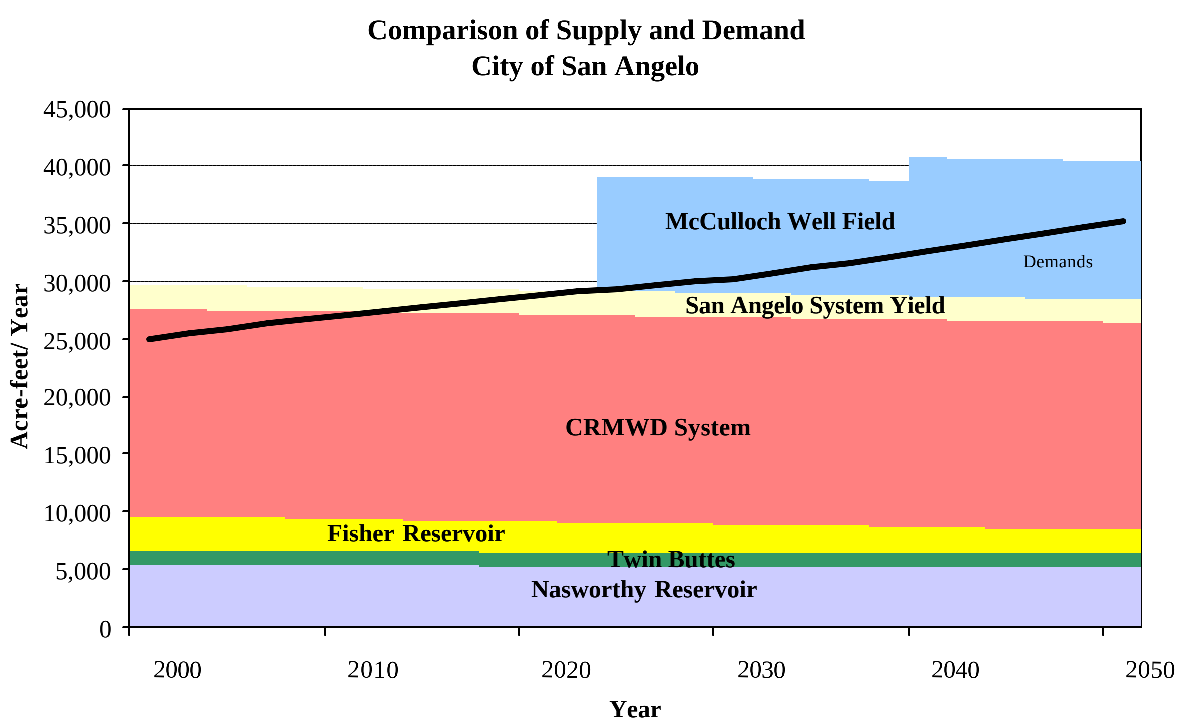
There may be some impacts to recreation on CRMWD reservoirs with increased use of water from this system.

5.2.2 City of San Angelo and Tom Green County Other

The city of San Angelo is located in Tom Green County and currently provides water to its in-city customers, county-other, and manufacturing. The City and its customers have the potential for water supply needs beginning in 2030 due to competition for water from the Nasworthy/Twin Buttes system among municipal, manufacturing, steam-electric and irrigation user groups. The estimated need for San Angelo in 2030 is 887 acre-feet, increasing to 6,288 acre-feet by 2050. The County-Other category may begin experiencing shortages as soon as 2010, primarily due to competition for limited ground water supplies between municipal and irrigation users. The potential need for the County Other user group is 141 acre-feet in 2010, increasing to 946 acre-feet by 2050. The primary strategy to meet County Other needs is increased sales from the city of San Angelo to nearby rural water supply providers. If available, additional supplies from a proposed treatment plant on Ivie Reservoir may be used as well (see Section 5.2.9.3). An alternative strategy to meet County Other needs is based on a proposed amendment to San Angelo's contract with the Upper Colorado River Authority, making approximately 1,000 acre-feet of water from O.C. Fisher Reservoir available for other uses. This proposed contract amendment includes provisions for storing treated effluent from the city of San Angelo in Fisher Reservoir for direct reuse. For planning purposes it is assumed that San Angelo will provide for approximately half of the county-other needs with the remainder coming from the proposed Ivie treatment plant. Therefore, the annual quantity of water needed for San Angelo to meet short-term municipal needs (2030) is approximately 1,250 acre-feet and 6,800 acre-feet to meet long-term needs.

To meet these needs two strategies were developed: 1) reservoir system operation enhancements, including Fisher Reservoir contractual amendments, and 2) a new well field in McCulloch County. The additional supply from reservoir system operation was included in the assessment of current supplies in Chapter 3. This supply source is discussed in the strategy section because the City does not currently operate their system in accordance with the modeled assumptions, and there are current infrastructure limitations. The Fisher water contract amendment was included as part of the revised system operation, however, this requires legal action to implement. A proposed new well field in the Hickory aquifer provides the primary source of additional supply. Figure 5-2 compares the projected municipal demands to San Angelo's water supply sources. As shown on this figure the new supply will be needed between 2020 and 2030.

Figure 5-2



5.2.2.1 Reservoir System Operation

The city of San Angelo receives water from six sources: Lake Nasworthy, Twin Buttes Reservoir, O.C. Fisher Reservoir, the Concho River, Lake Ivie, and Lake Spence. With multiple sources it is possible to operate the sources in a coordinated way to enhance yield and reduce cost. During normal to wet periods, the City can rely primarily on local supplies (Nasworthy, Twin Buttes, Fisher and the Concho River), which are the least expensive sources of water. The local supplies can be overdrafted, meaning that more water is taken from these supplies than their firm yields. During drought conditions, local supplies are used at less than their firm yields and more distant supplies from Lakes Ivie and Spence are used. However, the current infrastructure from Lakes Ivie and Spence limits the ability of the City to use these sources simultaneously. Therefore, in addition to implementation of refinements to the system operations, it is recommended that an additional pump station be built on the Spence/Ivie line to allow full delivery from both sources.

O.C. Fisher Contract Amendment

Although San Angelo's supplies are currently operated in a coordinated way, they are somewhat limited by restrictions on use of water from the sediment pool of Fisher Reservoir. Water from the Fisher sediment pool is only available during drought conditions. In recent years Fisher Reservoir has been in its sediment pool most of the time, restricting the ability of the City to access this supply during normal hydrologic conditions. It is recommended that the City's contracts for Fisher water be amended to allow access to water from the sediment pool at all times. For the assessment of additional system yield, it was assumed that this amendment would be granted.

Quantity, Reliability and Cost

Enhanced system operations of San Angelo's reservoirs could provide an additional 2,100 acre-feet per year of supply above the individual firm yields of the reservoirs. This supply has already been accounted for during the evaluation of currently available supplies. If the Fisher contractual amendment is not granted, the additional supply will be less. The reliability of the supply would be moderate, depending on reservoir conditions. The costs associated with the Ivie pump station improvements that would allow San Angelo to better utilize CRMWD's sources are $64/acre-foot ($0.20/ 1,000 gallons).

Environmental Factors

No significant environmental impacts were identified because the recommended system operation will reduce the current use from San Angelo's reservoirs. For Fisher Reservoir where water levels remain low most of the time, use of the water from the reservoir sediment pool may improve water quality and environmental conditions.

Impacts on Water Resources and Other Management Strategies

No impacts to water resources or other management strategies were identified.

Impacts on Agriculture and Natural Resources

No threats to agriculture or natural resources were identified.

Other Relevant Factors

This strategy will provide a positive impact on recreation for local reservoirs, but may reduce water levels in CRMWD's reservoirs because of additional demands on these reservoirs during droughts.

5.2.2.2 McCulloch Well Field

To help meet San Angelo's long-term needs, the City has an undeveloped well field on the border of McCulloch and Concho Counties. This well field produces from the Hickory aquifer. Water from this well field does not meet current drinking water standards for radium. It is assumed that water from the McCulloch well field will be sufficiently diluted by water from other sources to meet drinking water standards and will not require special treatment. There are two alternatives delivering water from the McCulloch well field to San Angelo:

- *A direct pipeline from the well field to San Angelo*. This alternative was considered in 1979 and preliminary plans were developed.
- *A pipeline from the well field to Ivie Reservoir*. Water from the well field would be delivered to Ivie Reservoir and pumped to San Angelo using the CRMWD Ivie pipeline.

Quantity, Reliability and Cost

The quantity of water available from the McCulloch well field is limited by agreement with the Hickory Underground Water Conservation District to 5,000 acre-feet per year when the well field is brought on line in about 2024, increasing to 10,000 acre-feet in 2026. By 2036, the maximum amount of water available will be 12,000 acre-feet per year. The reliability of water from the well field is high, but the ability to make full use of the well field through the Ivie pipeline may be limited. Most likely the city of San Angelo will be limited to their contractual amount of 25 MGD from the Ivie pipeline regardless of the source of water, thereby limiting use during peak periods. The direct pipeline option would be able to provide the full peak pumpage capacity from the well field, and San Angelo would still maintain a capacity of 25 MGD from the Ivie pipeline, substantially increasing peak demand supplies. The costs associated with the well field and direct pipeline are $495 per acre-foot ($1.52/1,000 gallons). The costs for the well field, utilizing the existing Ivie pipeline are $359 per acre-foot ($1.10/1,000 gallons).

Environmental Factors

The environmental impacts from ground water development would be low. If well water is pumped to Lake Ivie, the quantity as compared to lake volume should so low that adverse impacts to the environment are not expected. The transmission line may cause temporary disturbances during construction, but it is assumed that the pipeline can be routed to minimize impact on potentially sensitive areas if needed. Species of special concern for Concho County are listed in Table 1-17. Once the route has been chosen, the potential for environmental impacts will need to be further investigated.

Impacts on Water Resources and Other Management Strategies

There is adequate supply in the Hickory aquifer in McCulloch County to support the proposed well field. However, there is concern that other users of the Hickory aquifer, particularly the city of Eden, will be affected by lowering of the water table caused by pumping for San Angelo. It is recommended that additional investigations be performed prior to implementation of this strategy to assess the impacts on other users.

Impacts on Agriculture and Natural Resources

This strategy should have minimal effects on agriculture since most of the irrigated acreage is located upgradient of the well field in the recharge zone or shallower areas of the aquifer. San Angelo's holdings are in the deeper portion of the aquifer. The right of way for the transmission line may affect a small amount of agricultural acreage.

Other Relevant Factors

This water source has radium levels above the maximum contaminant level (MCL). Proper mixing ratios are necessary to ensure the water supply for San Angelo meets safe drinking water standards. If the McCulloch well field water is mixed with Ivie water, this will increase radium concentrations for other CRMWD users, but the mixed water should be well below the MCL.

5.2.3 City of Menard

The city of Menard has several wells near the banks of the San Saba River that are hydraulically connected to the river. Reduced flows in the San Saba River during a severe drought have the potential to reduce the City's available supply. Under drought-of-record conditions Menard may experience small shortages. The projected need for Menard is 39 acre-feet per year beginning in 2000, decreasing to less than 10 acre-feet/year by 2040. The City has recently adopted a five-stage emergency water management plan to reduce municipal water use as a strategy during drought conditions. However, it is recommended that Menard consider developing one or two wells in the Edwards-Trinity aquifer to increase the long-term reliability of its existing supplies. For costing purposes, it was assumed that the wells would be located within three miles of the City.

Quantity, Reliability and Cost

There is available supply in the Edwards-Trinity aquifer in Menard County. However, the well yields tend to be low (less than 35 gpm). The reliability is moderate to high, depending on local drawdown. The estimated cost is $850 per acre-foot/year ($2.61/1,000 gallons), assuming minimal treatment.

Environmental Factors

There is a possibility that development of water wells could affect local spring flows. Otherwise, the environmental impacts should be low. The transmission line could be routed to minimize impacts on environmentally sensitive areas, if needed. Once the well field and transmission route are chosen, a more detailed environmental review should be conducted.

Impacts on Water Resources and Other Management Strategies

There are minimal impacts to ground water resources, since there is adequate supply from this aquifer. Additional study will be needed to determine the potential impacts on springs and surface water. There are no other identified strategies that would be affected.

Impacts on Agriculture and Natural Resources

Other than possible impacts to springs, there are no known impacts to agriculture or natural resources.

Other Relevant Factors

The water quality of the Edwards-Trinity wells is unknown. If additional treatment is needed, cost per acre-foot will increase.

5.2.4 City of Junction

The city of Junction is located in central Kimble County and relies upon municipal diversions from a channel dam on the South Llano River. During drought conditions, the City has the potential to experience some small shortages throughout the planning period. The projected need for Junction is 78 acre-feet/year in year 2000, which decreases to 15 acre-feet/year by 2050. To increase the reliability of their supply, Junction could develop ground water supply from the Edwards-Trinity aquifer in Kimble or Menard Counties. For this plan it is assumed that Junction will install two wells within three miles from the City to supplement their existing supplies. As an alternative strategy, the City may lease existing water rights on the South Llano River upstream of the City for additional surface water supply.

Quantity, Reliability and Cost

There is available supply in the Edwards-Trinity aquifer in Kimble County. However, the average well yields tend to be low (less than 35 gpm). The reliability of the Edwards-Trinity is moderate to high depending on local drawdown. The estimated costs for the two local wells are $696 per acre-foot ($2.14/1,000 gallons).

Environmental Factors

There is the possibility that the development of water wells could affect local spring flows. Otherwise, the environmental impacts should be low. The transmission line could be routed around environmentally sensitive areas, if needed. Once the well field and transmission route are chosen, a more detailed environmental review should be conducted.

Impacts on Water Resources and Other Management Strategies

There are no known impacts to ground water resources since there is adequate supply from this aquifer. However, there is the possibility that ground water use could affect area spring flows. There are no other known strategies that would be affected.

Impacts on Agriculture and Natural Resources

There are no known impacts to agriculture and natural resources.

Other Relevant Factors

The water quality of the Edwards-Trinity is unknown. There is the possibility that ground water will need to be treated at Junction's water treatment plant. A combination of surface water and ground water would provide the highest reliability of supply for Junction.

5.2.5 City of Early

The city of Early, in Brown County, currently receives raw water from Lake Brownwood and treats it at the City's water treatment plant. In addition to supplying their city customers, Early provides approximately 300 acre-feet/year of treated water to Zephyr Water Supply Corporation for rural municipal use. There are no projected needs for Early. However, if Early continues to provide County-Other demands as it did in 1996, the total demands for treated water may exceed the capacity of its existing treatment facility sometime between 2020 and 2030. The existing plant capacity is 2 MGD. The estimated peak demands for Early and its customers are expected to be slightly greater than 2 MGD by 2030. To meet the increased demands, the City may be able to purchase treated water from the Brown County Water Improvement District (BCWID) plant via the city of Brownwood, which should be sufficient to meet needs throughout the planning period. This would require a new 2-mile transmission line. Alternatively, the City could expand and upgrade its existing treatment facility to 3 MGD to meet increased demands and provide increased reliability of its system.

Quantity, Reliability and Cost

The estimated amount of treated water that Early needs is approximately 0.5 MGD. This is available from BCWID, and the reliability would be high because there is sufficient capacity at BCWID's treatment plant. If the City chooses to increase its treatment capacity, there is sufficient supply from its existing contract with BCWID for raw water. The reliability would be high because there is sufficient supply in Lake Brownwood, and the plant improvements would also increase the reliability of existing supply that is treated by the City. The costs to receive treated water via Brownwood (with infrastructure improvements) would be $837 per acre-foot ($2.57/1,000 gallons). The costs to expand the treatment plant would be $1,065 per acre-foot ($3.27/1,000 gallons).

Environmental Factors

Potential impacts on environmentally sensitive areas from the pipeline can be minimized if existing right-of-ways are used. The crossing of Pecan Bayou may require a detailed environmental study. The impacts should be minimal for a treatment plant expansion if there is sufficient space for the expansion. If a new site is needed, then a more detailed environmental review will be required.

Impacts on Water Resources and Other Management Strategies

There are no impacts to water resources since Early is not increasing the projected demand from Lake Brownwood. Purchasing treated water from BCWID may impact other strategies that rely on treated water from BCWID. However, at this time BCWID has sufficient treatment capacity to provide for identified strategies in Region F.

Impacts on Agriculture and Natural Resources

There are no identified impacts on agriculture or natural resources.

Other Relevant Factors

There are no identified other relevant factors.

5.2.6 Brown County Other

Water supply corporations (WSCs) provide much of the rural municipal water supply in Brown County from Lake Brownwood. However, most of the northern portion of the county relies exclusively on ground water. Based on current ground water supplies for County-Other, this user group shows needs of 135 acre-feet/year in year 2000, with a maximum need of 581 acre-feet/year in 2040. At least a part of this need will probably occur within the service areas of local WSCs, but a large portion of it could occur within the area that exclusively relies on the ground water. There is available supply in Lake Brownwood that can be used to meet these needs. For the Brookesmith and Zephyr service areas, it is assumed that the projected needs will be supplied from the BCWID treatment plant, using current infrastructure. Other needs may be met by the Thunderbird Bay treatment plant. For northern Brown County, which relies mostly on ground water, additional infrastructure will be needed to supply water to the unincorporated areas. For conceptual purposes, a transmission line that would deliver treated water from BCWID plant to the community of May was evaluated as an estimate of the cost to provide water to the northern part of the county.

Quantity, Reliability and Cost

Approximately 580 acre-feet/year will need to be provided to Brown County Other. BCWID's water treatment has sufficient capacity to meet these needs, and there is available supply from Lake Brownwood. The reliability of this source is high. The cost is estimated at $1,727 per acre-foot ($5.30/1,000 gallons).

Environmental Factors

Environmental impacts should be low. The only major infrastructure expansion is limited to the northern portion of the county. The distribution lines can be routed to minimize impacts on environmentally sensitive areas if needed. Other improvements to existing WSC distribution systems are considered part of the normal operation of these entities and are not appropriate for inclusion in the Region F plan.

Impacts on Water Resources and Other Management Strategies

The quantity of water provided by this strategy should have minimal impacts to water resources since there is available supply from Lake Brownwood. It may impact other strategies that rely on treated water from BCWID. However, at this time BCWID has sufficient treatment capacity to provide for identified strategies in Region F.

Impacts on Agriculture and Natural Resources

There are no negative impacts on agriculture and natural resources. There may be positive impacts as more ground water becomes available for irrigation as municipal users decrease their reliance on ground water supplies.

Other Relevant Factors

Increased use of Lake Brownwood may impact recreation by lowering lake levels more frequently.

5.2.7 Coke County

The Cities of Bronte and Robert Lee in Coke County have water supply needs related to reliability, infrastructure and water quality. Bronte has a contract with the City of Sweetwater for 504 acre-feet per year from Oak Creek Reservoir. This contract amount is sufficient to meet the City's maximum projected demands of approximately 300 acre-feet per year (including sales). However, the City has concerns about the reliability of supplies from this source due to current drought conditions. The City estimates that if the reservoir continues to drop at current rates they will have difficulties obtaining water from the reservoir in about a year. As of August 30, 2000 the reservoir was at elevation 1,977.7 feet (source: USGS website), representing approximately 5,000 acre-feet of storage remaining in the reservoir. It is recommended that the City investigate structural modifications to their current intake structure that would allow the City to withdraw water from the lower parts of the reservoir. Possibilities include lowering pumps, dredging, construction of temporary levy system around the City's intakes, and other improvements.

The City of Robert Lee is expected to have a maximum projected demand of about 420 acre-feet per year (in-city use plus municipal sales). The City has two sources of water: Mountain Creek Reservoir and Lake E.V. Spence. Mountain Creek Reservoir is a small lake just east of the City owned by the Upper Colorado River Authority and operated by the City. It has not had sufficient water in it in recent years to be used as a water supply, so the City has been using water solely from Spence Reservoir. There is adequate supply in Spence, but the water is high in chlorides, dissolved solids and sulfates. Because of the water quality of Spence Reservoir, Mountain Creek remains an important supply source for Robert Lee when supplies are available.

The City of Robert Lee currently relies upon a floating pump in Spence that may not be able to divert water at low reservoir levels. The City may want to consider improvements to their current intake system. The estimated cost of a new intake structure is approximately $500,000.

A regional approach to the water quality and reliability problems in Coke County involves construction of a reverse osmosis facility at Robert Lee and a pipeline from Robert Lee to Bronte. This would provide both cities with sufficient water of good quality.

Quantity, Reliability and Cost

The quantity of water would provide for all of the cities' demands. The reliability of this alternative is moderate to high, depending on the availability of water from Spence Reservoir. However, the availability of water from Mountain Creek increases the reliability of this alternative. The estimated annual cost is $ 892 per ac-ft or $2.74 per 1000 gallons for Robert Lee and $1,422 per ac-ft ($4.37 per 1000 gallons) for Bronte.

Environmental Factors

The proposed Robert Lee WTP would have a low to moderate environmental impact. The primary environmental issue is disposal of brine reject from the RO treatment. The volume of reject brine will depend on the salinity of the raw water, but could approach 25 percent of the raw water volume. Disposal options for brine reject water include mixing with effluent from the city's wastewater treatment plant and discharging to the Colorado River, or discharge directly to evaporation ponds. Discharge to the Colorado would have minimal impacts if the blended salinity levels were lower than current river conditions. Further review of the disposal options and environmental impacts is needed.

The specific locations for the proposed structures have not been identified for this analysis. Wetlands, endangered species, and archeological assessments will need to be performed for the raw water intake structure, raw water pipeline and water treatment plant.

Impacts on Water Resources and Other Management Strategies

Due to the large capacity of Spence Reservoir, withdrawal of water for this strategy should generally have minimal effect on the lake or on downstream water resources.

Impacts on Agriculture and Natural Resources

There are no known impacts to agriculture or natural resources.

Other Relevant Factors

There are no other relevant factors.

5.2.8 Runnels County

Runnels County has small needs for additional water supplies to meet municipal and manufacturing demands, including the city of Ballinger, city of Winters, and a large portion of the County Other water user groups. The magnitude of these needs is relatively small, which makes it difficult to develop economical new supplies to meet the needs. The total need in 2050 for municipal use in Runnels County is 51 acre-feet and the manufacturing need is 22 acre-feet. However, the reliability of the existing water sources is low to moderate.

There are three primary sources of municipal and manufacturing supply in Runnels County: Lake Moonen, Lake Winters and ground water from an unclassified aquifer. Lake Moonen supplies the city of Ballinger, Rowena Water Supply Corporation, about 45 percent of the demand for the North Runnels Water Supply Corporation, other rural customers, and a small amount of the manufacturing demand. Lake Winters supplies the city of Winters, about 55 percent of the demand for the North Runnels Water Supply Corporation, other rural customers, and most of the county's manufacturing demand. Other municipal demands in the vicinity of the city of Miles are met from an unclassified aquifer, referred to in the regional plans as 'Other aquifer'. Figure 5-3 presents a comparison of currently available supplies and projected water demand for the county.

During 1999 and the first part of 2000 water supplies were very low in both Lake Moonen and Lake Winters, requiring restrictions on water use. If recent rains had not brought water levels up in both reservoirs, it is likely that some shortages would have occurred during the summer of 2000. Ballinger was in the process of negotiating a temporary contract with CRMWD for water from Lake Spence. This water would be delivered using the bed and banks of the Colorado River and pumped into Lake Moonen using temporary diversion facilities. Ballinger used this procedure in 1984. Winters has no other developed surface water options, and was investigating or had already purchased ground water sources.

To increase the reliability of the county's water sources, two near-term strategies and six long-term strategies have been identified. The recommended near-term strategies are:

- Purchase of Spence water from CRMWD during drought periods, and expand the Ballinger water treatment plant to 3 mgd

- Improvements to the North Runnels WSC system to increase delivery of treated water from Ballinger to Winters using the North Runnels distribution system

Surplus water may be available from Lake Spence to meet near-term needs through 2020. It is assumed that CRMWD would be willing to sell this water on an as-needed basis during drought conditions. Approximately 25 percent of the water released from Spence is assumed to be lost in transmission.

The city of Ballinger's treatment plant currently has a capacity of approximately 2 MGD and does not have any excess capacity. For planning purposes, it is assumed that during drought-of-record conditions the Ballinger plant will be supplying all of the North Runnels WSC demand as well as part of the city of Winters demands. Ballinger is currently investigating expansion of its plant to 3.0 or 3.5 MGD. To meet near-term needs, it is recommended that the current plant be expanded to 3.0 MGD. A summary of the evaluation of the near-term strategies for Runnels County is presented in Table 5-3.

Both the city of Ballinger and the city of Winters supply treated water to the North Runnels Water Supply Corporation. Currently it is possible for North Runnels to supply 20 gpm of water from Ballinger to Winters in the existing system. With some improvements, it would be possible to supply up to 188 gpm to Winters [Jacob and Martin, letter to Lanny England of North Runnels WSC, May 8, 2000]. These improvements will greatly increase the reliability of supply to a large portion of Runnels County. Supplying additional water will require expansion of the existing Ballinger treatment plant.

Figure 5-3

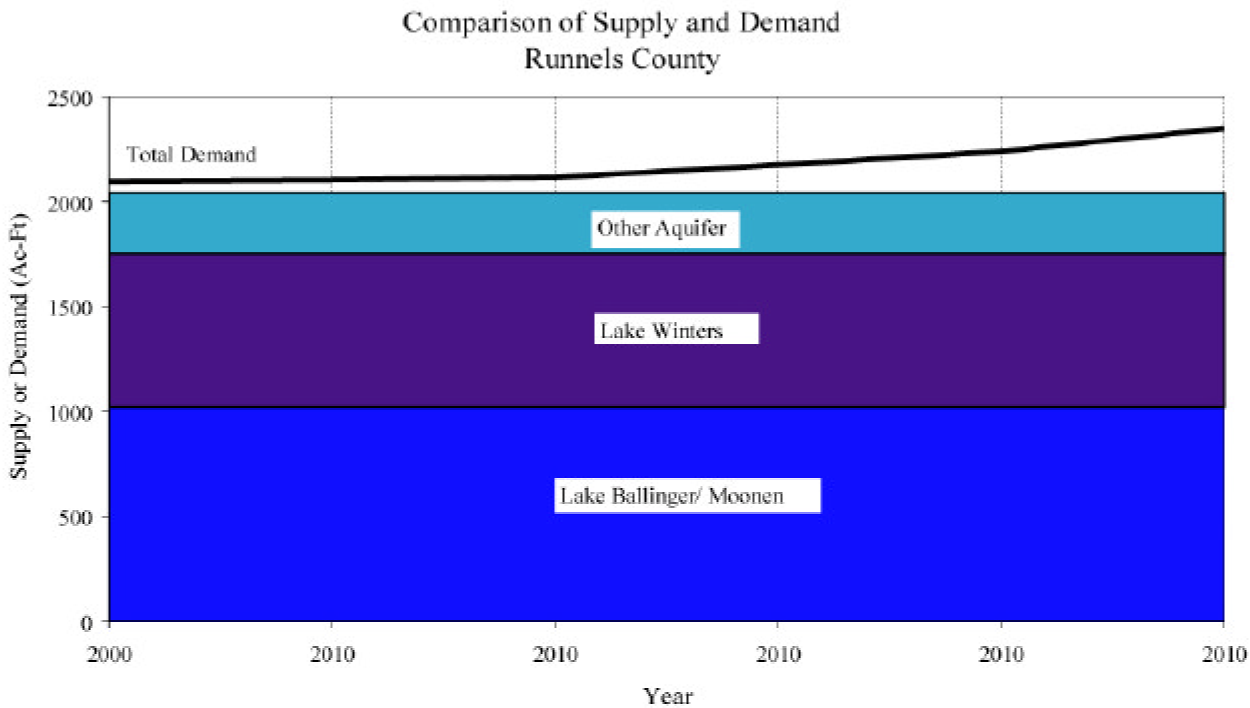

Comparison of Supply and Demand
Runnels County
Total Demand
Other Aquifer
Lake Winters
Lake Ballinger/ Moonen
Supply or Demand (Ac-Ft)
2500
2000
1500
1000
500
0
2000
2010
2010
2010
2010
2010
Year

Table 5-3 Near-term Strategies for Municipal and Manufacturing Needs in Runnels County

Water User Group(s)	Strategy Description	Quantity	Reliability	Cost (ac-ft/yr)	Environmental Factors	Impact on Water Resources and Other Proposed Strategies	Impact on Agricultural Resources	Recreational Impacts	Other Impacts
Ballinger County-Other Manufacturing	Temporary Contract with CRMWD	80 to 400 acre-feet per year	Depends upon availability of surplus Spence water. Assumed reliable for short-term needs	$554	Positive impact due to increased flows in Colorado River between Spence and Ballinger	Increased supply available for other users in Runnels County	None identified, CRMWD supplies are not used for agriculture	Increased potential for recreation in the Colorado River. Minimal impact on recreation at Spence Reservoir.	Increased salinity of raw water may impact third parties using treated water from Ballinger
	Expand Water Treatment Plant (1 MGD)	550 acre-feet per year	Very reliable	$483	None identified	Increased supply available for other users in Runnels County	None identified	None identified	Improved quality of treated water
Winters County-Other Manufacturing	Increase delivery capacity from Ballinger to Winters via North Runnels WSC	375 gpm capacity, estimated 100 to 200 acre-feet per year	Reliable if supplies available for Ballinger	$1,150	None identified	Requires additional supply for city of Ballinger. Increases reliability of surface water supplies	None identified	None identified	Increased salinity of raw water may impact third parties using treated water from Ballinger

Long-term Strategies

The improvements to the North Runnels system and expansion of the Ballinger treatment plant will greatly improve the reliability of treatment and distribution for a large portion of the demand in Runnels County. However, long-term raw water supply will remain an issue as long as the system relies upon temporary purchase of surplus water from CRMWD during drought conditions. There are several options available to meet the long-term needs of the County, including:

- Enhancement of the yield of Lake Moonen using diversions from the Colorado River or Elm Creek
- Purchase of treated Ivie water from Millersview-Doole
- Purchase of water from the proposed pipeline between Lake Ivie and the city of Abilene
- Purchase of treated water from Lake Coleman
- Development of ground water supplies
- Reuse of treated wastewater

The yield of Lake Moonen could be enhanced by construction of permanent diversion facilities on either the Colorado River or Elm Creek. Rather than diverting from the river only when in critical drought conditions, water would be pumped at other times as well, thereby increasing the yield of Lake Moonen. Water could either be pumped directly to Ballinger's water treatment plant or stored in Lake Moonen. It would be difficult to obtain a new water right from either the Colorado River or Elm Creek. However, the City could either enter a permanent contract with CRMWD or purchase existing irrigation water rights. Although this is a feasible method to increase supplies, the water in both the Colorado River and Elm Creek is frequently high in chlorides, sulfates and TDS and would increase treatment costs. The permanent diversion facilities would be costly to construct and operate as well. The high cost of this project and the poor quality of the water make it less attractive than other options.

A strategy that is being examined to meet needs elsewhere in Region F is the construction of a small treatment plant on Ivie Reservoir (see Section 5.2.9.3). Water from this plant would be used primarily to blend with water from the Hickory aquifer to meet current drinking water standards for radionuclides. The main distributor of water from this new treatment facility would be the Millersview-Doole Water Supply Corporation, which already supplies portions of southern Runnels County. It would be possible to construct a connection between Millersview-

Doole and the Ballinger treatment facility, possibly using at least part of the existing infrastructure of the Rowena WSC. The demands for Ballinger are also included in the strategy assessments for the Hickory users in Section 5.2.9.

There is a proposed pipeline from Ivie Reservoir to Abilene that passes through eastern Runnels County, very near Lake Winters. This pipeline is currently in the design phase and may be built as early as May of 2002. It is possible that some of the water from this pipeline could be purchased and delivered to Lake Winters. A cost effective method of delivering water to Lake Winters would be the construction of an outlet structure where the pipeline crosses one of the tributaries of Lake Winters, using the channel of that tributary to deliver water to the reservoir. An alternative is the construction of a pipeline from the Abilene pipeline to Lake Winters, reducing the channel losses associated with delivering water using an existing watercourse. Concerns with this strategy include the quality of water from Ivie Reservoir, uncertainties regarding the operation of the Abilene pipeline, and the availability of excess supply from the pipeline.

Lake Coleman has additional supplies that are not currently allocated to meet a particular need. Given the relatively small amount of water required to meet needs in Runnels County, it is unlikely that construction of a raw water delivery system would be cost-effective. However, it may be possible to transport treated water from the city of Coleman, possibly via improvements to the Coleman County WSC system in Coleman County and the North Runnels WSC system in Runnels County. The additional supplies may require expansion of the Coleman water treatment plant as well.

The city of Winters has a few ground water wells to supplement its supply from Lake Winters and is currently investigating additional ground water supplies. Most water wells in the area have a low yield, but some well locations may produce sufficient volume for municipal use. There may be water quality concerns as well. Historically, some wells in Runnels County have had high nitrate levels and high salinity.

Both the city of Winters and the city of Ballinger have permits to reuse treated wastewater effluent. Currently, the city of Winters' effluent is used for agricultural irrigation. A portion of Winters' need could be reduced by using treated effluent for manufacturing purposes as long as the type of manufacturing process is appropriate. If not already implemented, part of the municipal demand could be reduced in both cities by using treated effluent for municipal irrigation such as golf courses, cemeteries, or municipal properties

Table 5-4 presents a comparison of these strategies using applicable TWDB criteria. Based upon this evaluation, the most feasible options to meet long-term needs are:

- Water from Lake Ivie delivered to the city of Ballinger via the Millersview-Doole distribution system
- Water from Lake Coleman delivered to the city of Winters via the Coleman County and North Runnels WSC system.

5.2.9 Hickory Aquifer Users

An analysis of potentially viable alternatives for meeting water demand in McCulloch and Concho Counties and portions of Runnels and Tom Green Counties is included in this section. The area of Region F that this analysis involves is depicted in Figure 5-4. The majority of the identified water supply need for these counties is based on the assumed enforcement of drinking water standards for radionuclides by 2010, effectively eliminating the use of the Hickory aquifer as a primary drinking water source. As a result, a review of alternatives was conducted to identify an effective regional response. A lack of alternative water supply sources, the relatively small quantity of water needed to supply the needs, and the large geographic area involved make the radionuclide issue a significant challenge. If the radionuclide water standard is not enforced in the assumed time frame, the implementation of the proposed strategies may be delayed.

In the course of the review, several local entities that do not rely exclusively on the Hickory Aquifer were identified with reliability or water quality problems. These entities include the cities of Ballinger, Paint Rock, and Miles, Eola WSC, and Lakeland Services, Inc. Most of the water quality problems are exceedances of secondary drinking water standards such as chlorides, sulfates, and total dissolved solids (TDS). While water systems have not generally been required to meet secondary standards, the Texas Natural Resource Conservation Commission (TNRCC) has begun to base approval of proposed major improvements to water systems on compliance with secondary standards. Because of these and other water supply issues, these entities are included in this discussion.

Table 5-4 Long-Term Strategies for Municipal and Manufacturing Needs in Runnels County

Water User Group(s)	Strategy Description	Quantity	Reliability	Cost	Environmental Factors	Impact on Water Sources & Other Proposed Strategies	Impact on Agricultural Resources	Recreational Impacts	Other Impacts
Ballinger County-Other Manufacturing	Permanent diversion and pipeline to Lake Moonen	Sufficient	Depends upon source of makeup water. Assumed to be relatively reliable	High	None identified Further environmental review needed.	Possible increased supply available for other users in Runnels County	May require purchase of irrigation rights	Positive impact on Lake Moonen water levels	Poor water quality of diversions will increase treatment costs and may impact third party users.
	Water from Millersview-Doole	Sufficient	Very reliable	Moderate	None identified Further environmental review needed	Possible increased supply available for other users in Runnels County	None identified	None identified, quantity of water diverted from Lake Ivie insufficient to significantly affect lake levels	Increased salinity of raw water may impact third parties using treated water from Ballinger
Winters County-Other Manufacturing	Tap into proposed pipeline between Ivie and city of Abilene	Sufficient	Unknown, operation of proposed pipeline not defined	High	None identified	May make expansion of North Runnels capacity unnecessary	None identified	Total water diversions by city of Abilene will probably affect lake levels	Increased salinity of raw water may impact third parties using treated water from Winters
	Treated water from city of Coleman via Coleman County WSC	Sufficient	Reliable	Moderate	None identified	May make expansion of North Runnels capacity unnecessary	None identified	Possible impacts on recreation in Lake Coleman	May require expansion of city of Coleman facilities
	Develop well field	Unknown, may not be sufficient to totally meet needs	Unknown, shallow aquifers may not be reliable during drought	Low	None identified Further environmental review needed	May make expansion of North Runnels capacity unnecessary	Possible impacts on irrigation or livestock supplies	None identified	None identified
Manufacturing Winters	Reuse of Winters effluent for manufacturing needs	Sufficient, but treated effluent may not be appropriate depending upon manufacturing process	Reliable	Unknown, assumed moderate	None identified, effluent currently used for irrigated agriculture	Makes a small amount of water available for municipal use	Effluent currently used for irrigated agriculture	None identified	None identified

Figure 5-4

At least 13 public water systems in the area of evaluation are considered to be in need of additional water. Table 5-5 lists these water systems and the expected water demands. The annual demand for each system is based on the highest water-use projections between the years 2000 and 2030. Water-use projections for individual systems are based on available records of current water use. Some of these water systems may desire to use their Hickory supply to blend with new water sources developed, but there is generally insufficient data to provide a precise determination of the potential mixing ratio for each community. For purposes of development of strategies, the projected demand was used. The issue of blending was considered, however, in the evaluation of water management strategies.

TABLE 5-5
WATER DEMANDS FOR MANAGEMENT STRATEGY ANALYSIS

PUBLIC WATER SYSTEM	AVERAGE DEMAND (AC-FT/YR)	MAXIMUM DAILY DEMAND (MGD)
City of Brady	2,103* [I]	3.0
Millersview-Doole WSC	849	1.5
City of Eden	545*	1.0
City of Ballinger	200**	0.18
Richland SUD	177	0.3
City of Miles	129*	0.25
Rochelle WSC	66	0.10
City of Paint Rock	59	0.10
City of Melvin	28	0.05
Eola WSC	26	0.05
Live Oak Hills Subdivision	16	0.03
Lohn WSC	10	0.02
Lakeland Services, Inc.	10	0.02
AREA TOTALS	4,218	6.6

* TWDB municipal water demand forecast, the higher of the projections for 2000 and 2030.

[I] Also includes 175 ac-ft/yr in manufacturing demand, which is approximately 15 percent of the TWDB projection for McCulloch County manufacturing demand.

** Estimated water needed to supplement existing supply

Table 5-5 also provides the expected maximum daily demand in million gallons per day (MGD) for each water system. This parameter was taken from historical information on system usage, where available, or was based on twice the average demand, where information was not otherwise available. The total projected demands for the area of study are 4,218 acre-feet per year with a peak day demand of 6.6 MGD.

To meet this demand, a number of alternatives were considered. These included new sources of surface water for either replacement or blending purposes, purchase of treated water from a source outside the immediate area, and new ground water sources.

A number of other alternatives were considered as well but were eliminated as impractical for one or more reasons, including treatment to remove radionuclides, aquifer storage and recovery (ASR), and reuse of treated effluent. Treatment of the Hickory water to remove radionuclides is a viable strategy but has been eliminated because of uncertainties regarding disposal of treatment residuals. Cost-effective disposal of treatment residuals is not possible in Texas at this time because State regulations do not adequately address disposal of water treatment residuals with elevated radionuclides. A general discussion of removal of radionuclides is provided in Section 5.9, Water Quality Issues.

Aquifer Storage and Recovery (ASR) was initially considered as a means to supplement existing water supplies and other proposed alternatives. The city of Eden has a number of shallow wells taking water from the Fort Tarrant Limestone (part of the Edwards-Trinity Plateau). This shallow aquifer supplies a reasonably good quality of water but of very limited quantity during dry periods of the year. ASR was considered as a means of increasing available water during dry periods but was determined not to be feasible at this time. First, there does not appear to be a reliable alternative source of water in the Eden area to use for storage in the aquifer. The hydrogeology of the aquifer is such that if water is introduced into the formation when it is available, it may not still be in the area later when it is needed. Finally, any surface water introduced for ASR would need to be treated first, making this an expensive alternative, even if it is possible. For these reasons, ASR was not further considered for the city of Eden.

ASR was also briefly considered for an area of southeast McCulloch County, near the San Saba River. The storage aquifer would have been the Hickory, and the source of water would have been the San Saba River. The water would have to be treated prior to injection into the aquifer. In this case, the heavily faulted nature of the Hickory formation in this area would require substantial investigation to determine if it could adequately store water introduced in this manner. The primary drawback to this alternative was that treated potable water would be introduced into a formation with possibly unacceptable levels of radionuclides. Unless the storage time was very short, there would be a significant potential that the water recovered could have become contaminated in the interim. For these reasons, this alternative was not further considered.

Reclaimed wastewater effluent was also considered for supplementing the yield of Brady Creek Reservoir. This alternative would involve advanced treatment of Brady's wastewater treatment plant effluent using deep-bed filtration. The treated effluent would then be transmitted to the upper end of Brady Creek Reservoir, where it would eventually flow back to the proposed surface water treatment plant. As a supplement to Brady Creek Reservoir, this alternative could be considered of moderately high reliability. However, it is possible that during extended dry periods, the amount of wastewater effluent diverted into the lake would be reduced to maintain appropriate detention time and blending ratio. The costs for wastewater reuse would be high for a relatively small increase in reservoir yield. Given the limited reliability and high cost, this alternative was considered not feasible at this time.

The alternatives selected for detailed analysis are summarized in Table 5-6. This table includes a brief description and the projected yield of each alternative. Sections 5.2.9.1 through 5.2.9.6 provide a discussion of each alternative, including an estimate of cost, as required by SB1. Figure 5-5 depicts the general location of each alternative in the area.

As indicated in the table, no single alternative can effectively serve the needs of the entire area. Therefore, the strategies selected as viable for the area will be various appropriate combinations of the individual alternatives. Section 5.2.9.7 presents an overview of the evaluations of each strategy and recommends the most feasible strategies that could be combined. It should be noted that the total costs for combined strategies may differ from the sum of the individual strategy costs due to possible additional infrastructure needed to deliver water to the recipients. A preliminary assessment of combined strategies indicates that the unit cost of the water could increase by as much as 40 percent due to additional infrastructure.

Table 5-6
Summary of Water Management Strategies for McCulloch, Concho, Runnels, and Tom Green Counties

ALTERNATIVE NUMBER	DESCRIPTION OF STRATEGY	DESIGN YIELD (AF/YR)	DESIGN PEAK (MGD)
H-1	Brady Creek Reservoir Water Treatment Plant (BCRWTP), Conventional Treatment with RO for TDS removal. Also, includes unused capacity of existing City wells, used for specific landscaping purposes to reduce the amount of treated water used. Capacity includes 1520 ac-ft/yr Brady Creek Reservoir (treated water available after RO treatment) plus 0.5 MGD of ground water for about six months in Spring and Summer seasons (annual volume of about 300 ac-ft). Also included is limited blending with treated lake water, and water from two existing Hickory wells operated by the City at the lake. The expected yield from the lake wells is 380 ac-ft/yr.	2,200	3.0
H-2	San Saba Off-Channel Reservoir. Includes the reservoir and a pump station/transmission line to the BCRWTP. Also includes an expansion of the BCRWTP. There are two potential configurations for this alternative (3a and 3b) that provide different yields, with different associated water treatment plant expansions.	2a: 2,600 2b: 1,500	2a: 3.0 2b: 2.0
H-3	Lake Ivie Water Treatment Plant. Includes conventional treatment of Lake Ivie water plus RO treatment for TDS removal.	1,000	2.0
H-4	New Ellenburger well field. Includes construction of sufficient number of wells in the Ellenburger formation in San Saba County. Would also include pump station/transmission line from the well field to the Richland SUD pump station and standpipe located north of Brady. Also includes line to connect Rochelle WSC to the Ellenburger transmission line.	800	1.44
H-5	Treated surface water purchased from Brown County WID. Would include a new transmission line from the BCWID WTP to a point at intersection of Hwy 377 and FM 765 in McCulloch County. Storage and pumping facilities will be located at this intersection but will be sized according to the planned strategies using this alternative.	1,000	2.0
H-6	New Hickory well field with low radionuclides. Includes the required well field and transmission lines to gather water at a single distribution point that will have ground storage for the pumped water. Pump stations will be sized according to the planned strategies using this component. For purposes of the evaluation, assume the distribution point is located in McCulloch County on Hwy 377 at the San Saba River (Camp San Saba).	2,600	4.0

Figure 5-5

5.2.9.1 Brady Creek Reservoir with Supplemental Ground water

This alternative includes development of a new water treatment plant for potable water to blend with the existing Hickory water source. In addition, this alternative provides for limited distribution of Hickory Aquifer water (previously used for drinking water) to various landscaping projects in the City. Although not specifically identified, this ground water resource could also be used for various manufacturing purposes.

The Brady Creek Reservoir Water Treatment Plant (BCRWTP) is proposed as a 3.0 MGD facility. Because of expected high salinity of the reservoir water, conventional treatment will be followed by reverse osmosis (RO). The annual production capacity of the plant will be 1,520 acre-feet (ac-ft). Other primary components of the BCRWTP include the following:

- raw water line from the reservoir outlet works to the treatment plant
- clearwell for treated water
- piping to enable blending of Hickory aquifer water from two existing City wells near the plant with treated water.
- pump station and transmission line to deliver treated water to the City
- pump station and ground storage facilities at the high point between the plant and the City.

The two wells currently have a maximum pumping capacity of 700 gpm or about 1 MGD. For this analysis, it was assumed that the maximum blend ratio would be 1 to 4 (ground-water to surface water). If the radionuclide levels in the City's lake wells could be shown to be sufficiently low, the blend ratio may be less. The total expected yield from the lake wells is 380 ac-ft/yr. The pumping capacity of the lake wells is sufficient to enable an increase in ground water use.

The landscape irrigation component of this alternative involves primarily the installation of transmission lines and pumping facilities to deliver water from operating Hickory wells in the city of Brady to various public properties, such as city parks, public buildings, cemeteries, and golf courses. The assumed minimum volume of water delivered annually for landscaping is 300 ac-ft. It is assumed that most of this volume will be used during the six-month period from April through September.

Quantity, Reliability and Cost

The combination of the water treatment plant and the landscape irrigation systems produces a water management alternative capable of producing 2,200 ac-ft/yr. The supply from this alternative is considered highly reliable. The quantity from the reservoir was estimated based on the firm yield. However, even the safe yield indicates that there should generally be sufficient water available, if limited blending with Hickory water can be accomplished. If Hickory water is used for manufacturing, the potential volume of ground water could be higher, which would increase the reliability of this strategy. The estimated cost of Alternative H-1 is $800 per ac-ft, or $2.46 per 1,000 gallons.

Environmental Factors

This alternative has a low to moderate adverse impact on the environment. The primary environmental factor associated with this alternative is the disposal of the brine reject associated with advanced treatment of the water by RO. The volume of reject will depend on the salinity of raw water, but could approach 25 percent of the raw water volume. Disposal options include discharge to a receiving stream, evaporation in ponds, and an injection well.

Discharge to Brady Creek would be the simplest option, but requires a discharge permit from the TNRCC. It may be difficult to obtain permission for discharge of highly saline water into Brady Creek. The City could consider mixing wastewater treatment plant effluent and brine reject water prior to discharge into Brady Creek. This option would require construction of a pipeline from the water treatment plant to the wastewater treatment plant to transport brine reject water. An amendment to the existing wastewater discharge permit would also be required.

Other options for disposal of brine reject water are more expensive to implement and may be very difficult to manage. Evaporation would require a significant investment in land for evaporation ponds. Care must be taken to minimize storm water runoff into such ponds. Disposal of sediment from such ponds may eventually be necessary and will be further difficult to implement. Disposal of brines by injection well would require drilling an injection well nearby, or having access to one within a reasonable distance. No existing injection wells capable of accepting the potential volume of brine reject water have been identified near the proposed plant location.

The only other potentially significant environmental factors associated with this alternative are those related to wetlands, endangered species, or archeological impacts by construction of either the water treatment plant or pipelines necessary for the alternative. Since the plant location is not precisely identified and pipeline routes are not known, it is not possible to directly assess such impacts at this time. It should be possible to minimize impacts by avoiding environmentally sensitive areas. The environmental impacts associated with the use of Hickory well water for landscape irrigation in Brady should be considered low. The water used for landscaping could be human contact. However, the radionuclides in the well water are not generally considered to be significant health hazards through simple contact with skin. As long as the water is not provided as a drinking water source, it is unlikely that adverse health effects would be seen.

Impacts on Water Resources and Other Management Strategies

This alternative would result in the development of a new water resource for municipal purposes and may be considered as a positive impact from the point-of-view of development. However, the withdrawal of water from Brady Creek Reservoir for treatment and distribution will result in a depletion of the available water in the reservoir, which may affect recreation on the lake during dry periods. The preliminary assessment of this alternative is based on the firm yield of the reservoir, indicating that during periods of drought, lake levels could potentially drop to very low levels. Because of this potential effect on Brady Creek Reservoir, the adverse impacts on water resources should be considered moderately high. It should be noted that the Brady Creek Reservoir was originally developed specifically for use as a drinking water supply source. As such, its use for a drinking water source may be considered of higher importance than other uses.

Impacts on Agriculture and Natural Resources

The impacts of this alternative to agriculture and on natural resources should be considered low. Brady Creek Reservoir is not used for irrigation, so diversion of water for municipal use will not limit agriculture in the area. There are no known natural resources that would be adversely impacted by this alternative.

Other Relevant Factors

The city of Brady is currently pursuing the development of Brady Creek Reservoir as a drinking water source. Preliminary engineering studies have been completed on a proposal similar to this alternative for a 3.0 MGD water treatment plant. It is understood that the TWDB has given at least preliminary approval of funds to support the City's plan. Given the likelihood that the City will implement their plan, preferred strategies for water management for the overall area of McCulloch, Concho, Runnels, and Tom Green Counties will probably need to include Brady Creek Reservoir.

This alternative includes a component of using well capacity no longer needed for drinking water purposes for landscape irrigation. This is an important aspect of managing the dependence on Brady Creek Reservoir and preserving its availability for drinking water.

5.2.9.2 San Saba Off-Channel Reservoir and Expansion of BCRWTP

This alternative involves the construction of an off-channel reservoir (OCR) and transmission facilities near the San Saba River. A preliminary location based on topographic characteristics has been selected on Hudson Branch, as shown in Figure 5-5. Hudsons Branch has a very small drainage area and natural topography can be used to minimize the size of the embankment. This site was picked for conceptual purposes only. Until field investigations have been performed, it is unknown if this site should would be suitable for an off-channel reservoir. Water would be diverted from the San Saba River during periods of excess flow and stored in the off-channel reservoir. The stored water would then be transmitted, as needed, to BCRWTP by pipeline where it would be treated at the surface water treatment plant described in the discussion of Alternative H-1. The water would be diverted under LCRA's Highland Lakes water rights and requires a contractual agreement with LCRA. For this analysis, two configurations of the OCR were considered, each with a different capacity and yield.

To treat the additional supply from the OCR, the originally proposed BCRWTP (3 MGD) would need to be expanded. Since the water quality in the San Saba River is anticipated to be sufficiently low in chlorides, sulfates, and TDS, the expansion of the BCRWTP will be only for conventional treatment. The amount of expansion is dependent upon the OCR capacity. Capital improvements required by this alternative are:

- Channel dam, raw water intake facilities and pump station on the San Saba River
- Embankment, outlets and emergency spillway for the off-channel reservoir
- Intake structures and pumps at the off-channel reservoir
- Transmission pipeline to BCRWTP
- Conventional treatment expansion of BCRWTP.

Quantity, Reliability and Cost

The larger configuration of the OCR and its associated expansion of the water treatment plant (Alternative H-2a) would yield 2,600 ac-ft/yr of raw water to BCRWTP. This would require the plant to be expanded by 3.0 MGD. The smaller configuration, Alternative H-2b, would divert only 1,500 ac-ft per year from the San Saba River, thereby requiring smaller facilities for storage, transmission, and treatment of the diversion water. The required conventional expansion of BCRWTP would be 2.0 MGD. Based on historical records, water should be available for diversion even during drought conditions. However, depending upon the contract with LCRA, during extended extreme drought conditions access to flows may be restricted. The estimated cost for water delivered for the off-channel reservoir is as follows:

- Large OCR — $1,665- per ac-ft or $5.11 per 1,000 gallons
- Small OCR — $1,861- per ac-ft or $5.71 per 1,000 gallons

Environmental Factors

Environmental considerations will play a significant role in the viability of this alternative. The development of an off-channel reservoir will require a detailed assessment of potential wetlands, endangered species, and archeological impacts. Consensus-based instream requirements were used to develop the conceptual design, but instream flow requirements must be assessed. Such assessments would be included as part of the project costs associated with development of the reservoir.

The development of an off-channel reservoir in this location will create wildlife and aquatic habitat. The addition of stored water may also create limited wetlands habitat at the fringes of the lake and will provide a source of water for wildlife as well.

Impacts on Water Resources and Other Management Strategies

This alternative may impact stream flows in the San Saba River and downstream reservoirs. Since the water would be diverted under existing unallocated water rights, this alternative should not have significant impacts on downstream water resources.

Impacts on Agriculture and Natural Resources

The development of an off-channel reservoir in this location is not expected to have significant impacts on threats to agriculture. Likewise, impacts on natural resources should be minimal. Depending on the final location of the reservoir, it is possible that property currently used for agriculture could be removed by development of this alternative. However, the relatively small capacity of the proposed OCR does not require inundation of a large area.

Other Relevant Factors

The development of this alternative would put the city of Brady in the position of being a water provider to a significantly larger part of the area. This alternative, therefore, depends in part on the willingness of the city of Brady to accept that role.

5.2.9.3 Alternative H-3 – Lake O.H. Ivie Surface Water Treatment Plant

Alternative H-3 includes conventional treatment of Lake Ivie surface water followed by RO treatment for TDS removal. A specific location of this proposed Lake Ivie Water Treatment Plant (Ivie WTP) has not been established, but a site on the south shore has been assumed for purposes of this analysis (see Figure 5-5). The capacity of the plant would be 2.0 MGD, with an annual volume of 1,000 ac-ft of treated water. In addition to the treatment facility itself, this alternative requires the following:

- Raw water intake and line from Lake Ivie to the plant
- Clearwell storage for treated water

- High service pump stations and pipelines to deliver water to potential customers

It is assumed that Millersville-Doole WSC will distribute the supply from this strategy. Improvements to the distribution system will depend on the recipients of the water and the quantity of the required supply. Therefore, costs were not developed for pumping and transmission capacities beyond the clearwell storage.

Quantity, Reliability and Cost

The quantity of water would provide for approximately 20 percent of the demands. The reliability of this alternative shall be considered high. In discussions with the Colorado River Municipal Water District (CRMWD), the annual quantity limit was determined to be a safe volume given other commitments for Lake Ivie water. The estimated total cost is $ 1,648 per ac-ft or $5.06 per 1000 gallons.

Environmental Factors

The proposed Ivie WTP would have a low to moderate environmental impact. The primary environmental issue is disposal of brine reject from the RO treatment. The volume of reject brine will depend on the salinity of the raw water, but could approach 25 percent of the raw water volume. Disposal options for brine reject water were previously discussed in the BCRWTP alternative (see 5.2.9.1). In the case of the proposed Ivie WTP, however, there are no nearby wastewater treatment facilities so that effluent could be mixed with brine reject.

The specific locations for the proposed structures have not been identified for this analysis. Wetlands, endangered species, and archeological assessments will need to be performed for the raw water intake structure, raw water pipeline and water treatment plant.

Impacts on Water Resources and Other Management Strategies

This alternative would develop a new drinking water supply from an existing water source. Due to the large capacity of Lake Ivie, withdrawal of water for this plant should generally have minimal effect on the lake or on downstream water resources.

Impacts on Agriculture and Natural Resources

There are no known impacts to agriculture or natural resources.

Other Relevant Factors

There are no other identified relevant concerns.

5.2.9.4 Alternative H-4 – New Ellenburger Well Field

This alternative is based on a study prepared for Richland Special Utility Division (SUD) to identify potential raw water resources to off set its high radionuclide well. The recommendations of that study were that Richland SUD should drill a new well (or wells) in the Ellenburger-San Saba or Marble Falls formations near the town of Richland Springs in San Saba County. Water from these formations is considerably lower in radionuclides than the Hickory. The new well would be transmitted to Richland's current well location north of Brady and blended with water from Hickory aquifer wells in an existing 100,000-gallon standpipe.

The components of the new Ellenburger well field are as follows:

- Five wells and well pumps
- Required piping to combine well flows
- A well field ground storage tank prior to transmission of the water to Richland SUD
- Pumps and transmission line to transmit well water from the well field ground storage tank to Richland SUD's existing standpipe north of Brady

Quantity, Reliability and Cost

The quantity of water supplied by this alternative is designed to be 800 ac-ft/yr. This alternative should be considered a reliable source of acceptable water, provided necessary test wells and preliminary studies agree. The estimated total cost of the proposed new Ellenburger well field is $ 1,203 per ac-ft, or $3.69 per 1,000 gallons.

Environmental Factors

In general, this alternative should have minimal environmental impacts. The transmission line will follow existing rights-of-way for most of the route. Investigation for potential environmental impacts could be needed at creek or drainage way crossings.

Impacts on Water Resources and Other Management Strategies

The new Ellenburger well field will tap a water resource that is not currently in use. It is expected that impacts on other resources will be very low.

Impacts on Agriculture and Natural Resource

There are no known impacts to natural resources. Withdrawal of water from the Ellenburger could potentially impact agriculture on a localized basis. The anticipated rate of withdrawal is small, so impacts should be minimal.

Other Relevant Factors

It should be noted that the yield of the new Ellenburger well field could potentially be increased, if necessary, to improve the viability of the alternative. However, a detailed hydrogeologic study of the proposed location of the well field has not yet been accomplished. Therefore, projecting an increased yield would be speculative at this time.

5.2.9.5 Alternative H-5 – Purchase Treated Water from Brown County WID

In this alternative, supply from Lake Brownwood could be utilized to supplement supplies in the target area. These facilities would transport treated water from the Brown County Water Improvement District (WID) water treatment plant to a proposed pump station located near Winchell in the northeast portion of McCulloch County. Alternative H-5 requires the following components:

- Transmission line from the BCWID treatment plant located south of Brownwood to the existing Richland SUD standpipe north of Brady (approximately 35 miles)
- Three booster pump stations located along the transmission line as appropriate
- Ground storage facilities at each booster station
- Pump stations at the Richland SUD standpipe will be designated and sized as part of the strategies that use Alternative H-5. In developing the cost estimate for this alternative, the purchase cost of treated water is included.

Quantity, Reliability and Cost

As designated by Brown County WID, the total amount of water available for this alternative is 1,000 ac-ft/year. It is assumed that this source is highly reliable, given the yield of Lake Brownwood and the available capacity of the water treatment plant. The estimated cost of water for this alternative is $ 1,756 per acre-foot, or $5.39 per 1,000 gallons.

Environmental Factors

Environmental impacts associated with this alternative should be minimal. The transmission line will be placed in existing road rights-of-way for most of the route. Investigation of potential environmental impacts should be undertaken as necessary at creek crossings. The water line will also cross the Colorado River at one point. Potential environmental impacts should be investigated at that crossing, as well.

Impacts on Water Resources and Other Management Strategies

The allowable yield of 1,000 ac-ft/yr was established by Brown County WID. It is assumed that this volume will not critically affect water levels in Lake Brownwood, although some impact would be expected during extended periods of drought.

Impacts on Agriculture and Natural Resource

There are no known impacts to agriculture or natural resources.

Other Relevant Factors

This strategy could improve water service to southern Brown County by providing a new larger transmission line through the area.

5.2.9.6 Alternative H-6 – New Hickory Low Radionuclide Well Field.

An area south of Brady has been located that could prove to be the source of a large supply of acceptable quality ground water. Substantial study will need to be performed to confirm the location and characteristics of such a well field. Assuming this can be done, this alternative would require the following components

- A well field of ten wells completed in the Hickory aquifer
- Transmission lines from the wells to a central ground storage facility at Camp San Saba (Hwy 87 at the San Saba River)
- Ground storage facilities at Camp San Saba
- Pump stations at the Camp San Saba ground storage facility will be designated and sized according to the needs of the strategies using Alternative H-6.

Quantity, Reliability and Cost

The proposed quantity provided by this alternative is 2,600 ac-ft/yr, with a maximum short-term capacity of 3.0 MGD. A well field of this capacity is necessary to take advantage of a limited area in which there is an expectation of low radionuclides. The reliability of this alternative should be considered only moderate, given the uncertainty that exists in locating the required number of wells in the appropriate areas of the Hickory. The estimated cost for water delivered for this alternative is $ 547 per ac-ft, or $ 1.68 per 1,000 gallons.

Environmental Factors

Environmental impacts associated with the new Hickory well field should be relatively low. The transmission lines should generally follow existing road rights-of-way. It is possible, however, that some well locations will require new easements over previously undisturbed property. The transmission lines will also cross a number of drainage ways, including the San Saba River. Therefore, an investigation of potential environmental impacts will be necessary.

Impacts on Water Resources and Other Management Strategies

There should be minimal impacts to water resources since there is available supply in the Hickory aquifer. However, a new well field may produce localized drawdowns that may affect other nearby users.

Impacts on Agriculture and Natural Resource

The new Hickory well field could potentially pose a threat to agricultural interests if there are nearby farms that use the Hickory for irrigation. However, a preliminary review of existing data indicates that this yield should have a minimal impact on water levels in this part of the Hickory. The hydrogeological study for the well field will need to address this issue.

<u>Other Relevant Factors</u>

This alternative appears to provide the least costly delivery of water among the various alternatives evaluated. The reason is primarily related to the assumption that the water produced by this well field will be of acceptable quality, requiring only disinfection as treatment. If hydrogeologic studies find this well field capable of producing more than 2,600 acre-feet per year, then this potential source of water may be available for other needs within the surrounding counties, if needed.

5.2.9.7 Recommended Potential Water Management Strategies.

Numerous potential combinations of the six alternatives were examined to identify an appropriate set of strategies that could meet the area's demands. The potential water management strategies selected are not the only combinations that could work, but they do represent the most feasible strategies to serve the area. Based on the evaluations, the recommended potentially feasible strategies are:

- Alternative H-1: Brady Creek Reservoir Water Treatment Plant
- Alternative H-3: Lake Ivie Water Treatment Plant
- Alternative H-4: New Ellenburger Well Field
- Alternative H-6: New Hickory Well Field

The Brady Creek Reservoir was originally constructed for municipal water supply, and utilization of this water source has been in the city of Brady's water supply plan for years. The water quality issues with the Hickory aquifer have brought the use of this reservoir to the forefront. The reservoir can provide a large portion of City's demands and the reliable is considered high. The costs are moderate, and as the reservoir is used over time, the salinity levels may decrease, reducing the treatment costs associated with RO.

The Ivie WTP provides supply to the western portion of the demand area, which has limited supply options. This strategy also provides Millersview Doole WSC with additional supply that can be used throughout their distribution area. The only other alternative to provide water to this area is via a long transmission line from one of the other identified strategy sources. When a regional strategy is developed the costs for this alternative versus the distribution requirements will need to be examined. The Ivie WTP helps to fully utilize an existing water supply source, but the costs are relatively high.

The new Ellenburger well field can supplement existing ground water supplies, but the mixing ratio may be high and the quantity of supply from this formation is unknown. The costs for this strategy are moderate and further review of the feasibility is needed.

The new Hickory well field provides the least costly alternative for low radionuclide water. This supply can easily be incorporated into many of the cities infrastructure with minimal capital improvements. Preliminary data indicates there is sufficient supply to support a well field capacity of 3 MGD, however, the life expectancy of this source is unknown. Based on the potential supply amount and low costs, it is recommended that this strategy be retained as a feasible water management strategy, but further testing of the hydrogeology is needed to confirm this well field as a viable source.

The off-channel reservoir is a more costly alternative to the new Ellenburger well field; therefore it is not included as a preferred strategy. However, if the Ellenburger well field is found to have insufficient quantity or quality of water, the off-channel reservoir would provide a reliable surface water supply to the area. The proposed transmission line from BCWID to Brady is an alternative that utilizes existing supplies in the region, but is one of the most costly. Since there are other strategies that provide the needed supply, this alternative is also not considered a preferred strategy.

In order for multiple strategies to be successful it will require that several of the water supply entities work together to jointly execute the strategies. Additional infrastructure most likely will be needed to distribute new water supplies within the area of identified need. A regional system can provide adequate, reliable water supply, but it requires regional participation.

5.2.9.8 Alternative Short-term Strategy for the City of Eden

In June 1999, the Mayor of Eden, with concurrence of the City Council, appointed a Water Resource Task Force of local Eden citizens. The Task Force completed its report on the status of the water needs in September 2000. Part of the Task Force's charge was to investigate current water supplies, present population and future growth, and present and future water usage. Because of the work of the Task Force and the more immediate water demand needs identified, an alternative strategy for the city of Eden is described in this section.

The Task Force concluded that Eden needs additional water sources and should develop a conservation program. Additional water need is based, in part, on the impending restriction on the use of the Hickory aquifer due to radionuclide levels. It is anticipated that additional sources will be needed to blend with the Hickory water. In addition to the Region F strategies previously identified, the Eden Task Force recommended that the City search for additional shallow water from the Edwards-Trinity aquifer. This recommendation comes from a review of available production records of the three shallow wells currently used by the City. Production reports from other shallow wells in the Eden vicinity were also reviewed. Based on the review, it was determined that additional water may be available, even in drought conditions. If additional water of adequate quantity and quality can be found, it will provide an interim water supply for blending. A regional solution, such as one proposed in Section 5.2.9, may still be necessary for long-term water needs. However, the development of a local short-term strategy as described here could help reduce the eventual cost of a regional system

The City of Eden obtains it water from three wells in the Edwards-Trinity aquifer and two wells in the Hickory aquifer. Two of the three wells in the Edwards-Trinity are sensitive to drought conditions. To meet water demands during drought, additional pumping is required from the Hickory. It is anticipated that any additional pumping from the Hickory will result in Eden's water system exceeding MCL's for radionuclides imposed by USEPA. To maintain an acceptable level of radioactivity, an additional water source is needed under drought conditions. It is proposed that Eden explore for additional Edwards-Trinity water and, if adequate sources are discovered, develop a new well field.

Quantity, Reliability and Cost

Local studies indicate that additional Edwards-Trinity water may be found south of the city of Eden, near Brady Creek and Hardin Creek. The quantity of water needed, based on the Task Force report, is 259 ac-ft/year. However, it is possible that more can be found, depending on factors such as the characteristics of the formation and accessibility to drilling locations. If found to be available, as much as 545 ac-ft/year could be developed. This amount would correspond to the maximum anticipated demand for the city of Eden during the planning period. The process of identifying well numbers and locations, and ultimately the available quantity of water from the well field, will require some time to complete. The City must first perform an investigation to identify potential well sites. This investigation will be based on limited geologic information and land ownership. Access to property must be obtained to allow drilling rigs onto the sites. Test borings/wells are then drilled. For test wells that appear to be promising, pumping tests must be accomplished to establish an expected pumping rate for each potential well.

Several wells in the area are known to produce between 50 and 60 gpm during dry periods, while others have gone dry. Eden's drought-resistant shallow well produces at a rate of 75 gpm, even during the current dry period. The reliability of locating a sufficient number of wells to produce 259 ac-ft/year is considered to be moderate to high. However, it cannot be determined at this time whether 545 ac-ft/year can be produced from the field during extended dry periods. The reliability of producing 545 ac-ft/year is moderate to low.

The unit cost for this strategy will depend on the amount of water that can be produced from the eventual well field that is developed. At 545 ac-ft/year, the estimated cost is $637 per ac-ft per year ($1.95 per 1000 gallons). If less water can be developed, the unit cost could be higher. Transmission of the water is the major cost. Development of the well field and its operation and maintenance will be relatively low costs.

Environmental Factors

Brady and Hardin Creeks are intermittent streams, which typically flow during the dormant season of wetter than normal rainfall years. It is anticipated, at this time, that a well field will have minimal impact on the overall stream flow. However, pumping tests performed on potential wells during the initial investigation phase should help determine the potential impacts on stream flow, if any. Otherwise, the environmental impacts should be low. The pipeline, access roads, and other utilities should be routed to minimize impacts on environmentally sensitive areas. Once the well field and transmission route are chosen, a more detailed environmental review should be conducted.

Impacts on Water Resources and Other Management Strategies

Because ground water comes from cracks and voids that are highly variable in size and widely dispersed throughout the limestone formation, wells with the capacities needed by Eden typically have little or no impact on other widely scattered, low volume, domestic wells. Therefore, there should be minimal impacts to water resources. There are no other identified strategies that would be affected.

Impacts on Agriculture and Natural Resources

Local agricultural is predominantly livestock operations on range and pastureland with interspersed dry-land cropland. Wheat, oats, and hay are the predominant crops. No confined feeding operations or irrigated cropland exist in the area. Dependable livestock and domestic water is provided by shallow wells in the Edwards-Trinity formation. Ground water comes from cracks and voids that are highly variable in size and widely dispersed throughout the limestone formation. Evidence indicates that well production, even at a 50 gpm rate, has minimal impact on the production of other wells in the same area. Other potential impacts on agriculture or natural resources are considered to be unlikely.

Other Relevant Factors

The quality of shallow water in the Edwards-Trinity aquifer is generally good. As with any shallow aquifer in cavernous limestone, contamination is always a potential. The proposed well field will be predominantly in rangeland with interspersed, dry-land cropland, minimizing the potential for contamination from agriculture. A dependable Edwards-Trinity well field will not only reduce reliance on the Hickory aquifer and the need to solve the immediate radionuclide problems, but it will save energy and reduce pumping costs

5.2.10 City of Eldorado

The city of Eldorado is located in Schleicher County, and currently receives water from six wells in the Edwards-Trinity Aquifer. Historical supply from this system has ranged from 400 to 500 acre-feet per year. With recent drought conditions, the water levels in the wells have declined as much as 40 feet, and all six wells are pumping at capacity. The supply and demand comparison indicated Eldorado has sufficient supplies, provided the well system can continue to provide nearly 500 acre-feet per year. Based on current conditions, it appears that the City's existing well field will not support this quantity long-term, and Eldorado will need to develop additional ground water supplies. The City is planning on developing one to three new wells in the Edwards-Trinity. The estimated quantity of water from three wells is 225 acre-feet per year. This quantity in conjunction with their existing well field should provide adequate supply for the City through the planning period. Assuming no costs for transportation from the existing well field to Eldorado, the estimated cost of additional supply is $182 ac-ft per year ($0.52 /1,000 gallons).

5.3 Manufacturing Needs

There are five counties showing manufacturing needs over the planning period: Borden, Kimble, McCulloch, Midland and Runnels Counties. Many of these needs can be met with strategies identified for cities or county-other needs in Section 5.2. This includes the manufacturing needs in McCulloch, Midland and Runnels Counties. Therefore, no other strategies will be identified for manufacturing needs in these counties. Strategies for Borden and Kimble Counties are presented in the following sections.

5.3.1 Borden County

The only manufacturing reported in Borden County is for stone, clay, glass or concrete products. The source of water is a local surface water supply. The demands for manufacturing in Borden County are projected to increase from 48 acre-feet/year to 109 acre-feet/year over the planning period. As a result there is a projected long-term need of 20 acre-feet in 2050. It is assumed that the local surface water supply can be increased to meet this need. Historical data reported to the TWDB indicates that 164 acre-feet of water were available for manufacturing use in 1981. It is assumed that this amount of supply will be available to meet demands in 2050.

5.3.2 Kimble County

According to local representatives, Kimble County has three of the largest cedar processing operations in the world. At least some of these mills use surface water supplies that may not be reliable during drought-of-record conditions. Using 1995 surface water use as an estimate of availability, Kimble County could experience a shortage of about 1,000 to 1,500 acre-feet over the planning period. There are available ground water supplies in the Edwards-Trinity in Kimble County, but generally these supplies are not used for manufacturing (historical use ranges from 3 acre-feet in 1997 to 72 acre-feet in 1984). This may be due in part to the low well yields from the Edwards-Trinity. There are some areas within the county that indicate higher well yields that could be used to meet these needs. Therefore, for SB1 planning, it is assumed that additional supply for manufacturing in Kimble County will be obtained from the Edwards-Trinity aquifer. Assuming 200 gpm well capacities, a minimum of 7 new wells will need to be installed with an average transmission distance of 15 miles. Alternatively, the cedar industry could implement industrial wastewater reuse (reuse of process water). It appears that this strategy has been implemented at some facilities.

Quantity, Reliability and Cost

The quantity of water would be sufficient since there is available supply in the aquifer. Reliability would be moderate to high, depending on well capacity. The cost of water would be approximately $456 per acre-foot/year ($1.40 / 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be minimal impacts to water resources since there is available supply from recharge to the aquifer. The strategy for Junction that relies solely on ground water may compete for supply from the portion of the aquifer with higher than average well yields.

Impact on Agriculture and Natural Resources

This strategy may reduce the irrigated acreage for farming as additional land is purchased for ground water rights. However, this should be minimal since only a portion of the county is considered prime farmland.

Other Relevant Factors

There are no other identified relevant factors.

5.4 Steam Electric Power Needs

Needs for steam electric power were identified for four counties: Crockett, Mitchell, Tom Green and Ward Counties. Some of these needs are associated with specific power plant expansions. Other needs are the result of general increases for water supply to meet growing demands for power. For these needs (i.e., not directly associated with a plant), the steam electric demands (i.e., plant) can be moved to an area with available water supply. However, with the deregulation of the power industry, there are many factors that affect the siting of proposed power plants. These include other entrants into the power generation business, changes in technology, location of fuel supplies, and transmission line construction or constraints, in addition to water availability. The strategies for meeting power generation water demands identified in this plan were chosen as possible options based on proximity to available water supplies. The actual location of new generation facilities will be based on all factors considered.

5.4.1 Crockett County

There is a potential need in Crockett County for additional steam-electric supplies when West Texas Utilities expands the Rio Pecos plant between 2000 and 2010. Demands are expected to increase from 1,914 to 4,280 acre-feet per year. Water for the Rio Pecos plant is currently supplied by wells located in the Edwards-Trinity aquifer in Pecos County. According to WTU personnel, previous hydrologic studies indicate the existing well field can supply between 4,000 and 5,000 acre-feet per year. The water gathering system is sized to transport this amount, and the current generation system could use up to 3,700 acre-feet per year. There appears to be sufficient supply from the existing well field to meet future needs, but the existing system may not be able to meet peak future demands. To meet peak demands it is assumed that six new wells will be needed over the planning period and a new 12-inch transmission line installed. Alternatively, additional ground water supply is available from the Edwards-Trinity in Crockett County.

Quantity, Reliability and Cost

The quantity of water would be sufficient since there is available supply in the aquifer. Reliability would be moderate to high, depending on well capacity. The cost of water would be approximately $178 per acre-foot/year ($0.55/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

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

There should be minimal impacts to water resources since there is available supply in the aquifer.

<u>Impact on Agriculture and Natural Resources</u>

There are no identified impacts on natural resources. Irrigated acreage could be impacted in areas near the new wells due to localized drawdown of the aquifer. This could be minimized by purchase or lease of sufficient land to extend beyond significant drawdown.

<u>Other Relevant Factors</u>

There are no other identified relevant factors.

5.4.2 Mitchell County

The current demands for steam electric power (SEP) in Mitchell County are associated with the TXU generation facility located on Lake Colorado City. Water supply for this plant comes from Lake Colorado City with additional makeup water pumped into the lake from Champion Creek Reservoir. Based on the operational limitation for cooling, the available supply from these reservoirs is approximately 3,900 acre-feet/year, which is sufficient for the current power plant. Based on projections provided by TXU, the demands for SEP in Mitchell County are expected to increase from 4,000 to over 9,100 acre-feet/year by 2050. This increase is not necessarily associated with the TXU generation facility on Lake Colorado City. Therefore, it is possible to move the steam electric demands to nearby counties that have available supplies.

Based on information received from the Electric Reliability Council of Texas, a power transmission line is proposed from the city of San Angelo to the city of Dallas, crossing through the southern portions of Coleman and Brown counties (http://www.ercot.com). The availability of water and this proposed line make locating steam electric demands in Brown, Coleman or Coke counties potentially feasible options, using water from Lake Brownwood, Lake Coleman or Lake Spence. For SB1 planning purposes, it is assumed that projected steam electric power needs for Mitchell County will be split between these three locations. To supplement this supply, if needed, wastewater effluent from the cities of Brownwood or Coleman could also be used to meet future steam electric demands. The evaluations of each siting alternative will be similar and is presented below. Alternatively, the steam electric needs could be met with ground water supplies located in the western portion of the region.

Quantity, Reliability and Cost

The quantity of water would be sufficient since there is available supply in Lakes Brownwood, Coleman and Spence. Reliability would be moderate to high, depending on other demands on the lake. The cost of water would be approximately **$**482 per acre-foot/year **($**1.49 / 1,000 gallons).

Environmental Factors

Construction of a power plant will increase water temperatures in the lake. Based on the quantities involved this increase should be minimal, however, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There may be increased evaporation of water from the lake. It is assumed that a water efficient power plant will be constructed so there should be minimal requirements for cooling beyond the projected demands. There is available supply in Lakes Brownwood, Coleman and/or Spence to meet the power demands and other projected demands on the lake.

Impact on Agriculture and Natural Resources

There are no known impacts to agriculture or natural resources.

Other Relevant Factors

The increased use may impact recreational use of the respective lake.

5.4.3 Tom Green County

According to projections provided by West Texas Utilities, demands for the San Angelo power generation plant will increase by 2010. The projected needs for steam electric range from 2,156 acre-feet in 2010 to 2,470 acre-feet in 2050. Alternative strategies for meeting the increased demand include:

- Use of treated effluent from San Angelo,
- Purchase of irrigation rights from the Nasworthy/Twin Buttes system, and
- Use of water efficient technology for power generation

Purchase of irrigation rights is probably the most cost-effective method of obtaining additional supplies. However, given the magnitude of irrigation shortages and the lack of alternative supplies in Tom Green County this strategy is not recommended. New power generation facilities typically use water efficient technology. It is assumed that the projections, which were provided by West Texas Utilities, are indicative of the water needs of a water-efficient facility. Therefore, the only feasible strategy to meet steam electric power needs is use of treated effluent form San Angelo. However, during wet years water may be used from Lake Nasworthy if available.

5.4.3.1 Wastewater Reuse

The city of San Angelo currently sells approximately 11,500 acre-feet per year of treated effluent for irrigation. This represents 60 percent of their 1996 historical water use. If the available effluent remains at 60 percent of the City's demands over the planning period, there would be an additional 3,300 acre-feet of supply available in 2000, increasing to 9,100 acre-feet by 2050 that could be used for steam electric or irrigation during drought.

For the new generating facilities to be able to use San Angelo's treated effluent during drought conditions, a pipeline from San Angelo's wastewater treatment plant to the power plant would be needed. An alternative is to locate the new generation facilities near the effluent storage ponds, eliminating the need for a pipeline to transfer the water. However, new facilities at this location could not use supplies from Lake Nasworthy or take advantage of existing electrical transmission facilities. For SB1 planning, a new pipeline was considered.

Quantity, Reliability and Cost

The quantity would be sufficient to meet needs and the reliability would be high. The costs for wastewater reuse are estimated at $482 per acre-foot ($1.48/1,000 gallons).

Environmental Factors

There are no identified environmental impacts. San Angelo has a no discharge wastewater permit and does not discharge to a receiving stream.

Impacts on Water Resources and Other Management Strategies

There are no identified impacts to water resources, but this strategy may reduce supplies that could be available to meet some of the irrigation needs.

Impacts on Agriculture and Natural Resources

As discussed above, this strategy may reduce the future available supplies for irrigation. Depending on the technology, this strategy may increase the salinity of the treated effluent from the SEP plant. Since San Angelo has a no discharge permit, there would be minimal impacts on natural resources.

Other Relevant Factors

There are no other identified relevant factors.

5.4.4 Ward County

TXU operates a steam-electric plant in Ward County that uses water from the Cenozoic Pecos Alluvium. There is competition for this limited supply between municipal, mining and steam-electric user groups that may limit expansion of this facility. The projected need for steam electric water in Ward County is 6,782 acre-feet by 2050. To meet these needs, it is recommended that the steam electric power demands be moved to Winkler County. Winkler

County has approximately 50,000 acre-feet/year of currently unused supply in the Pecos Alluvium, which could easily meet the projected power needs.

To develop a new well field in Winkler County, approximately 10 new wells will be needed and a 30-inch transmission line constructed. It is assumed that the well field will be located within 10 miles of the power plant.

Quantity, Reliability and Cost

The quantity of water would be sufficient since there is available supply in the aquifer. Reliability would be high. The cost of water would be approximately $ 238 per acre-foot/year ($0.73/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be minimal impacts to water resources since there is available supply in the aquifer.

Impact on Agriculture and Natural Resources

There should be no impacts to agriculture since Winkler County has no irrigated acreage. No natural resources should be impacted by this strategy.

Other Relevant Factors

There are no other identified relevant factors.

5.5 Irrigation Needs

There are substantial irrigation needs identified in portions of Region F primarily due to limitations of the available ground water supplies within the region. Eleven counties were identified with irrigation needs over the planning period, ranging from a total need of 200,600 acre-feet per year in 2000 to 171,000 acre-feet per year in 2050. The reduction in need is due to the TWDB required expected conservation in irrigation practices (i.e., more water efficient technology). No readily available water supplies were identified that could be developed to fully meet all irrigation needs. However, one or more of the following strategies may reduce these needs:

- Making full use of available treated effluent
- Precipitation enhancement
- Brush control programs
- Using advanced water conservation technology

Precipitation enhancement, brush control programs and wastewater reuse are also general strategies to increase water supplies in the region, and are addressed separately in Section 5.8 of this chapter. This section will focus on irrigation demand reduction through advanced water conservation technologies. Where applicable, the use of wastewater effluent to meet specific irrigation needs is also discussed in this section. The counties with identified irrigation needs are listed in Table 5-7.

Table 5-7 Counties with Projected Irrigation Needs

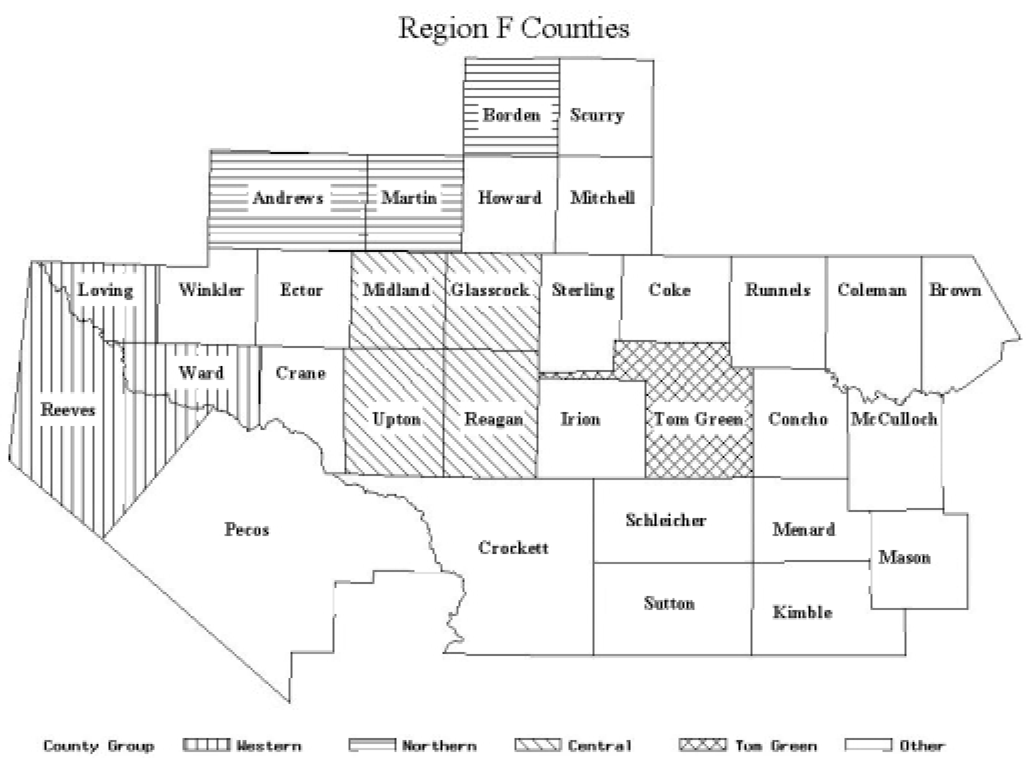
COUNTY	PROJECTED IRRIGATION NEED (acre-feet per year)					
	2000	2010	2020	2030	2040	2050
ANDREWS	2,388	1,206	1,046	911	752	593
BORDEN	8,709	8,692	8,673	8,653	8,635	8,617
GLASSCOCK	47,853	47,316	46,773	46,231	45,686	45,145
LOVING	258	256	254	252	250	248
MARTIN	333	125	0	0	0	0
MIDLAND	34,640	32,371	30,405	28,042	25,414	21,752
REAGAN	18,633	17,877	17,118	16,357	15,676	14,982
REEVES	39,164	38,275	37,386	36,497	35,607	34,718
TOM GREEN	37,863	37,616	37,370	37,164	36,959	36,753
UPTON	5,343	5,066	4,789	4,513	4,236	3,959
WARD	5,430	5,287	5,066	4,806	4,508	4,264
TOTAL	**200,614**	**194,088**	**188,880**	**183,426**	**177,723**	**171,031**

5.5.1 Advanced Water Conservation Technologies

Crop production in Region F is diverse across the region due to differing climatic conditions, soil types, water sources (ground water and surface), water quality and cropping mixes. To facilitate the analysis, four sub-regions were identified which grouped counties with similar crop production characteristics. These sub-regions are shown in Figure 5-6 and relate to those counties identified as having irrigation needs as indicated in Table 5-7. The sub-regions are: Western – Reeves, Ward, and Loving counties; Central – Glasscock, Midland, Upton, and Reagan counties; Northern – Andrews, Borden, and Martin counties; and Tom Green County.

The primary advanced water conservation strategy identified for Region F is irrigation equipment efficiency improvements. Changes in crop types or crop variety were not considered applicable because the types of crops currently grown in Region F are typically water efficient varieties. While only ten counties were identified with irrigation needs, the adoption of advanced conservation technologies throughout the region will help preserve existing water resources for continued agricultural use and provide for other demands. Therefore, this analysis presents water savings for all counties in Region F.

Figure 5-6 Irrigation Sub-Regions



Irrigation Equipment Changes

Six alternative irrigation systems were evaluated in this analysis. Irrigation systems were selected on the basis of current use in Region F or having the potential to improve water use efficiency. The alternative irrigation systems analyzed included furrow flood (FF), surge flow (SF), mid-elevation sprinkler application (MESA), low elevation spray application (LESA), low energy precision application (LEPA) and subsurface drip irrigation (DRIP). It was assumed an irrigation system was installed on a "square" quarter section of land (160 acres). Terrain and soil types were assumed to not limit the feasibility of adopting an irrigation system. Application efficiencies for the various irrigation technologies were assumed as follows: furrow irrigation – 60 percent, surge flow – 75 percent, MESA – 78 percent, LESA – 88 percent, LEPA – 95 percent, and drip irrigation – 97 percent (New, 1999). The system with the higher efficiency rating is considered more efficient because it leads to less water usage.

Irrigated acres within Region F in 1997 totaled 308,012 as shown in Table 5-8 (Texas Water Development Board, 1997). Cotton was the most significant irrigated crop with 55 percent of the acres followed by hay-pasture and forage crops at 8 percent and 7 percent, respectively. Six counties (Glasscock, Midland, Pecos, Reagan, Reeves, and Tom Green) account for 72 percent of the regions irrigated acres.

The current adoption of irrigation technologies is shown in Table 5-9. Conventional furrow irrigation practices are estimated to cover 56 percent of the region. When combined with surge, 67 percent of irrigated acres are under furrow or flood irrigation. Sprinkler systems are used on 21.6 percent of irrigated acres. Drip systems have been installed on 11.5 percent of irrigated acres. The adoption of advanced irrigation technologies varies significantly across counties.

It was estimated that 44 percent of the region's irrigated crop production is produced utilizing some form of advanced irrigation technology (surge, sprinkler or drip) in the base year of 2000 (Warrick et al, 2000). Accelerated adoption of advanced irrigation technologies, and in particular, adoption of the most feasible advanced technologies could potentially reduce irrigation demands while maintaining the highest level of irrigated production possible. In order to examine the impact of an aggressive rate of technology adoption, it was assumed that one half of the necessary adoption of advanced irrigation technologies would take place by the year 2010, with 100 percent adoption resulting by the year 2020.

Table 5-8 Irrigated Acres by Crop Type

County/Crop	Cotton	Grain Sorghum	Wheat	Alfalfa	Forage Crops	Hay Pasture	Veg Deep	Veg Shallow	Peanuts	Pecans	Vineyards	Corn	Other	County Total
Andrews	8,200					80			3,500	120				11,900
Borden	5,000									40				5,040
Brown					885	2,161			500	3,600				7,146
Coke	200		22			53				40				315
Coleman						871								871
Concho	300	1,000	900	100	230	490					10			3,030
Crane			260							2	2			264
Crockett			217			78								295
Ector	625	500	1,100	244	120	488	42	12		690	31		30	3,882
Glasscock	50,700	1,900	400	58	21		95			209			18	53,401
Howard	2,800			408		153				144				3,505
Irion		595	272	61	593	436	8			57	22		56	2,100
Kimble					295	787				311			59	1,452
Loving				140										140
McCulloch			406		500	454		8	216				420	2,004
Martin	6,000		1,112	278		260			1,800	44			304	9,798
Mason	310	425	1,300			490		175	2,600	8		350	245	5,903
Menard			49	300	520	1,687				138	35		820	3,549
Midland	10,300		948	440	4,050	12,000		160	60	500			40	28,498
Mitchell	1,100			217						17				1,334
Pecos	9,700	1,200	278	4,469	3,750	2,500	1,754	505		3,060	1,031		674	28,921
Reagan	27,500	680	218	50						80				28,528
Reeves	8,500	269	800	5,032	4,805	100	5,366	1,701		233			1,927	28,733
Runnels	2,800	1,043	300		498	352				260	180	150	150	5,733
Schleicher			49		688					201			125	1,063
Scurry	300		150	145	51	55		35		21			7	764
Sterling			42		539					41				622
Sutton			900		252	58				152				1,362
Tom Green	26,600	7,600	6,800	1,600	3,900	1,400				1,600	300	3,921	1,550	55,271
Upton	8,500	87	1,099		140	315				340		95	861	11,437
Ward	300			600	140	62				44	5			1,151
Winkler														0
Crop Totals	**169,735**	**15,299**	**17,622**	**14,142**	**21,977**	**25,330**	**7,265**	**2,596**	**8,676**	**11,952**	**1,616**	**4,516**	**7,286**	**308,012**

Irrigated crops as reported in 1997. Acreages and/or crop types may have changed since 1997, but these changes are not reflected in this table.

Table 5-9 Current Distribution of Irrigation Equipment

County	Irrigated Acres	Acres by Equipment Type						Percentage of Acreage		
		Furrow	Surge	MESA	LESA	LEPA	Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	11,900	5,114	0	0	5,000	1,750	36	43.0	56.7	0.3
Borden	5,040	1,040	0	2,000	2,000	0	0	20.6	79.4	0
Brown	7,146	5,528	0	1,121	497	0	0	77.4	22.6	0
Coke	315	140	0	161	14	0	0	44.4	55.6	0
Coleman	871	87	0	740	44	0	0	10.0	90.0	0
Concho	3,030	2,400	0	460	160	0	10	79.2	20.5	0.3
Crane	264	262	0	0	0	0	2	99.2	0	0.8
Crockett	295	11	0	102	182	0	0	3.7	96.3	0
Ector	3,882	2,731	0	0	602	0	549	70.4	15.5	14.1
Glasscock	53,401	33,021	0	0	0	2,535	17,845	61.8	4.7	33.5
Howard	3,505	1,655	0	0	281	1,400	169	47.2	48.0	4.8
Irion	2,100	1,649	0	429	0	0	22	78.6	20.4	1.0
Kimble	1,452	985	0	54	413	0	0	67.8	32.2	0
Loving	140	140	0	0	0	0	0	100.0	0	0
McCulloch	2,004	594	0	1,336	74	0	0	29.6	70.4	0
Martin	9,798	2,881	0	1,731	1,877	3,000	309	29.4	67.4	3.2
Mason	5,903	550	0	4,967	386	0	0	9.3	90.7	0
Menard	3,549	2,867	0	647	0	0	35	81.3	17.7	1.0
Midland	28,498	8,969	0	6,230	12,374	0	925	31.5	65.3	3.2
Mitchell	1,334	995	55	163	121	0	0	78.7	21.3	0
Pecos	28,921	9,141	14,277	0	2,367	97	3,039	81.0	8.5	10.5
Reagan	28,528	24,953	0	0	0	275	3,300	87.4	1.0	11.6
Reeves	28,733	5,544	14,478	0	2,750	85	5,876	69.6	9.9	20.5
Runnels	5,733	5,031	232	0	290	0	180	91.8	5.1	3.1
Schleicher	1,063	977	0	86	0	0	0	91.9	8.1	0
Scurry	764	562	15	30	157	0	0	75.5	24.5	0
Sterling	622	157	0	465	0	0	0	25.2	74.8	0
Sutton	1,362	1,255	0	15	92	0	0	92.1	7.9	0
Tom Green	55,271	44,109	3,275	349	6,671	0	867	85.7	12.7	1.6
Upton	11,437	9,142	0	0	0	0	2,295	79.9	0	20.1
Ward	1,151	856	220	0	70	0	5	93.5	6.1	0.4
Winkler	0									
System Totals	**308,012**	**173,346**	**32,552**	**21,086**	**36,422**	**9,142**	**35,464**	**66.9**	**21.6**	**11.5**

Irrigated crops as reported in 1997. Acreages and/or equipment types may have changed since 1997.

The selection of the most feasible advanced irrigation technology for each crop within a county was based on several assumptions and constraints relating to crop type, water source, and water quality considerations. The following guidelines were used:

- Furrow and surge acres were moved to drip or sprinkler whenever feasible.
- Existing sprinkler acres were moved to the most efficient sprinkler technology whenever feasible.
- Surface water supplies were assumed to remain as furrow or flood due to problems associated with the use of sprinkler or drip technologies with surface supplies. While there may be ways to make more efficient use of surface water supplies, this would involve a county by county assessment, which was beyond the scope of this analysis.
- The shift of furrow to drip was considered feasible for cotton and grain sorghum.
- Other crops such as wheat, alfalfa, peanuts, forage crops, hay-pasture, etc were shifted from furrow to the most feasible sprinkler technology.
- Orchard and vineyard crops currently under flood irrigation were not changed to alternative technologies.
- The application efficiency of drip and LEPA in Reeves, Ward, Loving, and Pecos counties was reduced to 93 percent and 91 percent, respectively, to allow for a flood irrigation at least once every 3 years to leach any buildup of salts in the upper soil profile.
- No additional sprinkler acreage was included in Glasscock, Midland, Upton, and Reagan counties due to the low well yields in those counties. This would involve using multiple wells per system and was deemed unlikely.

Utilizing these assumptions, the projected use percentages for different irrigation equipment are shown in Table 5-10.

Table 5-10 Projected Adoption of Advanced Irrigation Technology in Region F

County	Irrigated Acres	2000 (current)			2010			2020 - 2050		
		% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	11,900	43.0	56.7	0.3	21.8	64.1	14.1	0.7	71.4	27.9
Borden	5,040	20.6	79.4	0	17.7	79.3	3.0	14.7	79.3	6.0
Brown	7,146	77.4	22.6	0	77.4	22.6	0.0	77.4	22.6	0.0
Coke	315	44.4	55.6	0	30.1	55.6	14.3	15.8	55.6	28.6
Coleman	871	10.0	90.0	0	10.0	90.0	0.0	10.0	90.0	0.0
Concho	3,030	79.2	20.5	0.3	57.9	33.2	8.9	36.5	46.0	17.5
Crane	264	99.2	0	0.8	50.0	49.2	0.8	0.8	98.4	0.8
Crockett	295	3.7	96.3	0	1.8	98.2	0.0	0.0	100.0	0.0
Ector	3,882	70.4	15.5	14.1	39.0	40.1	20.9	7.7	64.7	27.6
Glasscock	53,401	61.8	4.7	33.5	31.5	4.8	63.7	1.2	4.8	94.0
Howard	3,505	47.2	48.0	4.8	25.3	51.9	22.8	3.3	55.9	40.8
Irion	2,100	78.6	20.4	1.0	71.3	25.3	3.4	64.1	30.2	5.7
Kimble	1,452	67.8	32.2	0	67.8	32.2	0.0	67.8	32.2	0.0
Loving	140	100.0	0	0	100.0	0.0	0.0	100.0	0.0	0.0
McCulloch	2,004	29.6	70.4	0	17.5	82.5	0.0	5.4	94.6	0.0
Martin	9,798	29.4	67.4	3.2	14.9	68.2	16.9	0.4	68.9	30.7
Mason	5,903	9.3	90.7	0	5.1	94.6	0.4	0.8	98.4	0.8
Menard	3,549	81.3	17.7	1.0	80.8	18.2	1.0	80.8	18.2	1.0
Midland	28,498	31.5	65.3	3.2	21.1	65.7	13.2	10.7	66.2	23.1
Mitchell	1,334	78.7	21.3	0	40.0	22.9	37.1	1.3	24.5	74.2
Pecos	28,921	81.0	8.5	10.5	61.8	8.5	29.7	10.5	40.7	48.8
Reagan	28,528	87.4	1.0	11.6	43.9	1.4	54.7	0.3	1.9	97.8
Reeves	28,733	69.6	9.9	20.5	54.7	9.9	35.4	5.5	44.1	50.4
Runnels	5,733	91.8	5.1	3.1	68.9	11.2	19.9	46.1	17.2	36.7
Schleicher	1,063	91.9	8.1	0	55.4	44.6	0.0	18.9	81.1	0.0
Scurry	764	75.5	24.5	0	39.1	41.9	19.0	2.7	59.3	38.0
Sterling	622	25.2	74.8	0	15.9	84.1	0.0	6.6	93.4	0.0
Sutton	1,362	92.1	7.9	0	54.9	45.1	0.0	17.8	82.2	0.0
Tom Green	55,271	85.7	12.7	1.6	56.4	27.6	16.0	27.0	42.5	30.5
Upton	11,437	79.9	0	20.1	41.5	10.9	47.6	3.0	21.9	75.1
Ward	1,151	93.5	6.1	0.4	89.6	6.1	4.3	85.7	6.0	8.3
Winkler	0									
System Totals	**308,012**	**66.9**	**21.6**	**11.5**	**43.2**	**26.3**	**30.5**	**13.4**	**37.2**	**49.4**

Irrigated crops as reported in 1997. Acreages may have changed since 1997.

The methodology for calculating water savings in acre-feet was to shift acreages of furrow irrigated crops to surge flow, MESA, LESA, LEPA, or drip when an advanced technology was considered feasible. The gross irrigation application rate per acre for each crop in a given county using a furrow system was used as the base water application rate. This base rate was then compared to the required equivalent irrigation application rate with an advanced irrigation technology. The difference in application rates was the assumed water savings. For example, in Glasscock County the total per acre applied irrigation water for cotton using a furrow system was 16 acre-inches. Using the 60 percent application efficiency for furrow gave an effective application rate of 9.6 acre-inches. If a drip system were used with an application efficiency of 97 percent, the resulting application rate would be 9.9 acre-inches. Therefore, the potential water savings for a shift from furrow to drip would be 6.1 acre-inches per acre.

Table 5-11 presents the estimates of water savings (acre-feet) by decade from accelerated adoption technology in Region F for all counties. With partial adoption (50%) completed by 2010, the annual water savings for the region is 55,877 acre-feet. Following full adoption in 2020, these annual water savings increase to 111,739 acre-feet. For only the counties with irrigation needs, 22 percent of the initial deficit was recovered by 2010 and 44 percent recovered by 2020. As shown on Table 5-11, all of the projected irrigation need can be met by advanced conservation for Andrews and Upton Counties. For the large irrigation counties, such as Glasscock, Midland, Reeves and Tom Green, there still are considerable unmet irrigation demands. For Tom Green County, there is available wastewater effluent that could be used to further reduce the projected irrigation need. No specific alternative strategies were identified for the other counties. It is anticipated that in the counties with unmet irrigation demands, some portion of the irrigated acres will shift to non-irrigated crop production or to other uses. While it is difficult to predict what crops will likely go out of production, the crops with the lower relative value of water will most likely exit first. Table 5-12 presents the revised projected irrigation needs after accounting for advanced irrigation technologies. Also shown are estimates of the number of irrigated acres lost as a result of insufficient irrigation water.

Table 5-11 Projected Water Savings with Advanced Irrigation Technologies

County	Irrigation Need	Projected Water Savings (acre-feet/year)		% Reduction of 2000 Need	
	2000	**2010**	**2020-2050**	**2010**	**2020-2050**
Andrews	2,388	2,054	4,107	86%	100%
Borden	8,709	599	1,197	7%	14%
Brown		76	152		
Coke		67	133		
Coleman		65	130		
Concho		622	1,244		
Crane		51	103		
Crockett		13	25		
Ector		757	1,513		
Glasscock	47,853	9,159	18,318	19%	38%
Howard		431	861		
Irion		121	242		
Kimble		2	3		
Loving	258	0	0	0%	0%
McCulloch		224	448		
Martin	333	1,121	2,243	100%	100%
Mason		1,215	2,430		
Menard		75	149		
Midland	34,640	3,872	7,744	11%	22%
Mitchell		353	707		
Pecos		4,771	9541		
Reagan	18,633	8,087	1,6174	43%	87%
Reeves	39,164	4,963	9,923	13%	25%
Runnels		586	1,173		
Schleicher		167	333		
Scurry		437	874		
Sterling		65	130		
Sutton		257	514		
Tom Green	37,863	12,723	25,441	34%	67%
Upton	5,343	2,817	5,633	53%	100%
Ward	5,430	127	254	2%	5%
Winkler		0	0		
Water Savings Totals	**200,614**	**55,877**	**111,739**		

.

Table 5-12 Revised Irrigation Needs Incorporating Advanced Irrigation Technologies

County	Projected Irrigation Need (ac-ft/yr)							Projected Irrigated Acres Lost					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**		**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Andrews	2,388	334	0	0	0	0		1,502	209				
Borden	8,709	8,106	7,502	7,495	7,490	7,485		4,536	4,503	4,465	4,461	4,458	4,455
Glasscock	47,853	38,699	29,539	29,539	29,536	29,538		37,358	34,864	31,424	31,424	31,421	31,423
Loving	258	258	258	258	258	258		62	62	62	62	62	62
Martin	333	0	0	0	0	0		200					
Midland	34,640	29,012	23,687	21,838	19,723	16,574		14,803	13,187	11,499	10,601	9,574	8,046
Reagan	18,633	10,550	2,464	2,463	2,542	3,608		11,362	7,815	2,303	2,302	2,376	3,372
Reeves	39,164	34,202	29,241	29,241	29,241	29,241		10,642	9,744	8,755	8,755	8,755	8,755
Tom Green	37,863	25,187	12,517	12,605	12,693	12,781		17,448	12,983	7,320	7,371	7,423	7,474
Upton	5,343	2,526	0	0	0	0		3,089	1,561				
Ward	5,430	5,297	5,086	4,963	4,802	4,695		555	547	531	518	502	491
Totals	**200,614**	**154,171**	**110,294**	**108,402**	**106,285**	**104,180**		**101,557**	**85,475**	**66,359**	**65,494**	**64,571**	**64,078**

Summary of Costs for Advanced Irrigation Technologies

The costs of implementing advanced irrigation technologies in Region F are presented in Table 5-13. The additional investment for converting a furrow irrigation system to surge flow, MESA, LESA, EPA, and drip is $20.00, $267.10, $303.98, $317.28, and $666.92 per acre, respectively. These cost are based on alternative irrigation system costs for a 350-foot pumping lift. The corresponding annualized cost per acre for each strategy amortized over 25 years at 6 percent interest is $1.56, $20.89, $23.78, $24.82, and $52.17, respectively.

The estimated per acre water savings achieved with shifts from furrow to alternative irrigation technologies varies by sub-region. Therefore, the costs to adopt alternative irrigation systems are given by sub-region. In addition to showing the cost per acre-foot of shifts from furrow to alternative systems, the cost of upgrading a MESA sprinkler system to a LEPA system was also analyzed. The Western Sub-Region has the greatest potential water savings per acre because of the high irrigation application rates in this sub-region. This sub-region also has the lowest per acre-foot cost due to the higher water savings. In general, the highest cost per acre-foot of water savings is for shifts from furrow to drip with the lowest cost associated with a shift from furrow to surge. However, this represents only capital costs associated with equipment changes. Cost savings associated with reduced labor requirements for the more advanced irrigation technologies (sprinkler and drip) are not included in this analysis. To fully assess the economic feasibility of a strategy, a more complete economic evaluation is required.

Table 5-13 Summary of Costs for Advanced Irrigation Technologies

Strategy	Capital Costs ($/acre)	Annual Cost ($/acre)	Water Savings (ac-ft/yr/acre)	Cost/ ac-ft/yr/acre
Western Sub-Region				
Furrow to Surge	$20.00	$1.56	0.72	$2.17
Furrow to MESA	$267.10	$20.89	0.83	$25.17
Furrow to LESA	$303.98	$23.78	1.14	$20.86
Furrow to LEPA	$317.28	$24.82	1.22	$20.34
Furrow to DRIP	$666.92	$52.17	1.27	$41.08
MESA to LEPA	$50.18	$3.92	0.49	$8.00

Table 5-13 (continued)

Strategy	Capital Costs ($/acre)	Annual Cost ($/acre)	Water Savings (ac-ft/yr/acre)	Cost/ ac-ft/yr/acre
Central Sub-Region				
Furrow to Surge	$20.00	$1.56	0.28	$5.57
Furrow to MESA	$267.10	$20.89	0.33	$63.30
Furrow to LESA	$303.98	$23.78	0.45	$52.84
Furrow to LEPA	$317.28	$24.82	0.52	$47.73
Furrow to DRIP	$666.92	$52.17	0.54	$96.61
MESA to LEPA	$50.18	$3.92	0.20	$19.60
Northern Sub-Region				
Furrow to Surge	$20.00	$1.56	0.32	$4.88
Furrow to MESA	$267.10	$20.89	0.37	$56.46
Furrow to LESA	$303.98	$23.78	0.51	$46.63
Furrow to LEPA	$317.28	$24.82	0.59	$42.07
Furrow to DRIP	$666.92	$52.17	0.61	$85.52
MESA to LEPA	$50.18	$3.92	0.22	$17.82
Tom Green Sub-Region				
Furrow to Surge	$20.00	$1.56	0.39	$4.00
Furrow to MESA	$267.10	$20.89	0.45	$46.42
Furrow to LESA	$303.98	$23.78	0.62	$38.35
Furrow to LEPA	$317.28	$24.82	0.72	$34.47
Furrow to DRIP	$666.92	$52.17	0.74	$70.50
MESA to LEPA	$50.18	$3.92	0.27	$14.52

5.5.2 Wastewater Effluent for Irrigation Needs

Tom Green County

The city of San Angelo has historically used treated effluent on a City farm and has contracts in place to sell treated effluent to irrigators. Treated effluent is more reliable than water from Twin Buttes and Nasworthy. Water from the reservoirs is subject to contract limitations during dry conditions, while treated effluent is available at all times. The City currently contracts approximately 11,500 acre-feet of treated effluent for irrigation use. This amount is assumed available during the planning period. As previously discussed in Section 5.4.3, if the available treated effluent remains at 60 percent of the City's water use, then there would be an additional 3,300 acre-feet of supply currently available, increasing to 9,100 acre-feet by 2050. Some of this supply is identified for steam electric use during drought (see Section 5.4.3). The remainder could be used for irrigation.

The City has approximately 3,200 acre-feet of storage for treated effluent. The storage facilities were built in 1993 at a cost of approximately $7 million [reference – conversation with Will Wilde, Utility Director, San Angelo]. The City is considering increasing its treated effluent storage facilities so that more supplies would be available for irrigation or other uses. It will be assumed that a facility similar to the existing storage ponds would be constructed at a cost of about $8 million, approximately doubling the storage capacity.

5.6 Mining Needs

Mining needs were identified for seven counties: Ector, Martin, Midland, Reagan, Reeves, Upton and Ward. Most of these needs are attributed to competition for supply with other users and a hierarchy scheme of assigning water supplies to municipal and manufacturing needs before mining. It is assumed that all of this demand is for production of oil and gas. Because the oil industry is required by law to use non-potable supplies whenever possible (reference section 27.0511 Texas Water Code), mining demands in these counties may not actually be competing for the same supplies as other use categories. Therefore, the actual amount of mining needs may be considerably less than indicated. The cost estimates developed for these strategies are presented for conceptual purposes only and, for the most part, assume that the mining needs will be met by saline ground water or water from chloride control projects.

5.6.1 Ector County

The Edwards-Trinity Plateau and Ogallala aquifers have been used historically for municipal, manufacturing, livestock, irrigation and mining supplies in Ector County. Supplies from these sources are sufficient to meet municipal, livestock, manufacturing and irrigation demands, but are not sufficient to meet mining demands. As a result, potential mining needs in Ector County are 5,711 acre-feet in 2000 decreasing to 4,663 acre-feet by 2050. Some of the mining needs may be offset by the reuse of Odessa wastewater for manufacturing purposes, thereby reducing some of the competition for ground water resources. The remainder of the need could possibly be met with supply from the Dockum aquifer. There is approximately 2,450 acre-feet/year of supply from the Dockum aquifer in the Colorado basin that is not currently being used. In addition, there is approximately 2,700 acre-feet/year available from the Dockum in the Rio Grande basin, and 2,000 acre-feet/year from the Pecos Alluvium that could be used to meet mining needs.

To develop these aquifers, approximately 30 new wells will be needed in the Dockum and 12 wells in the Pecos Alluvium, provided the well capacities are a minimum of 100 gpm. Generally, these formations are not used extensively for mining because of limited well capacity. Further review of hydrogeology of the potential well fields is needed to confirm their potential as viable water sources. Since the exact locations of the well fields relative to the demand area is not known, an average connection cost of $150,000 per well was assumed.

Quantity, Reliability and Cost

The quantity of water would be sufficient since there is available supply in the aquifers. Reliability would be low to moderate, depending on the well capacities. The cost of water would be approximately $213 per acre-foot/year ($0.65/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be low impacts to water resources since there is available supply in the aquifer. Excessive localized pumping could lower the water levels in these formations and affect other users. Currently, there are only small amounts of water used from the Dockum and Pecos Alluvium in Ector County.

Impact on Agriculture and Natural Resources

This strategy should have minimal effects on agriculture, but may reduce the irrigated acreage for farming as additional water right acreage is purchased.

Other Relevant Factors

There are no other identified relevant factors.

5.6.2 Martin County

Mining in Martin County may experience needs during the planning period due to competition for limited supplies from the Ogallala. Some additional supplies may become available beginning in 2030 as irrigation demand decreases due to conservation. Potential needs are 928 acre-feet in the year 2000 decreasing to 0 acre-feet in the year 2040. There are no other known ground water sources that may be used for mining needs, with the possible exception of non-potable supplies (water with TDS levels greater than 3,000 mg/l). There is available supply from the CRMWD chloride control project at Sulphur Draw or from Natural Dam Lake. For this plan, it is assumed that mining will meet its needs using water from Sulphur Draw. If needed, additional water could be obtained from Natural Dam Lake.

Quantity, Reliability and Cost

The quantity of water is should be sufficient. Reliability would be moderate to high, depending on the amount of diverted water. The cost of water would be approximately $393 per acre-foot/year ($1.20/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be positive impacts to water resources since use of this supply may reduce the potential for saline spills that would impact other water resources.

Impact on Agriculture and Natural Resources

This strategy should have no impacts on agriculture because this water is not suitable for irrigation.

Other Relevant Factors

There are no other identified relevant factors.

5.6.3 Midland County

Most of the mining activities in Midland County is associated with the oil and gas industry, and the main source of water is the Edwards-Trinity Plateau Aquifer. There is competition for this limited source among irrigation, municipal, livestock and mining user groups. Using the allocation scheme adopted by the RWPG, there are potential mining needs of 669 acre-feet in the year 2000, decreasing to zero over the planning period due to no projected demands in 2050. There appears to be no other source of water available for mining, with the possible exception of non-potable supplies. This may be a need that cannot be met. No strategies were identified.

5.6.4 Reagan County

The main source of mining supplies in Reagan County is the Edwards-Trinity Plateau aquifer. Due to competition for this limited source there are potential mining needs of 1,589 acre-feet in the year 2000 and 1,481 acre-feet in the year 2050. There are no other known sources that may be used for mining needs, with the possible exception of non-potable supplies. In the central western part of the county there is a small area in the Edwards-Trinity with high TDS levels that may be available for mining needs, but the quantity may be limited. For this plan, it is assumed that mining will meet its needs using non-potable ground water.

Quantity, Reliability and Cost

The quantity of water is unknown. Reliability would be low to moderate, depending on the well capacities. The cost of water would be approximately $290 per acre-foot/year ($0.89/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be low impacts to water resources since this supply is not used.

Impact on Agriculture and Natural Resources

This strategy should have no impacts on agriculture because this water is not suitable for irrigation.

Other Relevant Factors

There are no other relevant factors identified.

5.6.5 Reeves County

The main source of water for mining purposes in Reeves County is the Cenozoic Pecos Alluvium aquifer. There is competition for this limited source among irrigation, municipal, livestock and mining user groups. As a result there are small mining needs of 175 acre-feet beginning in the year 2000 and decreasing to 115 acre-feet by the year 2050. These small needs can be met with non-potable supplies from the Cenozoic Pecos Alluvium. Ground water with TDS levels greater than 3,000 mg/l is available over a large area in the northeastern portion of the county. This supply could easily meet the projected mining needs for Reeves County.

Since the demand centers are not known, it is assumed that two new wells will be needed to provide 175 acre-feet/year, and there will be a general connection cost of $150,000 per well.

Quantity, Reliability and Cost

The quantity of water should be sufficient. Reliability would be moderate to high, depending on the well capacities. The cost of water would be approximately $337 per acre-foot/year ($1.03/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be low impacts to water resources since this supply is not used.

Impact on Agriculture and Natural Resources

This strategy should have no impacts on agriculture because this water is not suitable for irrigation.

Other Relevant Factors

There are no other relevant factors identified.

5.6.6 Upton County

Most of the mining activities in Upton County occur in the Colorado basin, and the main source of water is the Edwards-Trinity Plateau aquifer. There is competition for this limited source among irrigation, municipal, livestock and mining user groups. Using the allocation scheme adopted by the RWPG, there are potential mining needs in the Colorado basin of 1,787 acre-feet in the year 2000 and 1,195 acre-feet in the year 2050. Ground water supply from excess water savings from implementing advanced irrigation technologies in the county could be used to meet a portion of Upton's mining need. Through conservation, Upton's mining needs can be completely met from 2030 through 2050. There remain unmet needs in years 2000 – 2020, with no other apparent source of water available for mining.

5.6.7 Ward County

In recent years the primary source of water for mining purposes in Ward County has been the Cenozoic Pecos Alluvium. The supplies from this aquifer with TDS levels less than 3,000 mg/l are limited due to competition among municipal, steam-electric and mining user groups. After meeting municipal demands, there are potential mining needs of 635 acre-feet in the year 2000 decreasing to 194 acre-feet by 2050.

There are supplies from the Cenozoic Pecos Alluvium in Ward County with higher TDS levels that were not included in the ground water availability assessment. It is assumed that this non-potable supply will be used to meet mining needs. Since the demand centers are not known, it is assumed that four new wells will be needed to provide 635 acre-feet/year, and there will be a general connection cost of $150,000 per well.

Quantity, Reliability and Cost

The quantity of water should be sufficient. Reliability would be moderate to high, depending on the well capacities. The cost of water would be approximately $206 per acre-foot/year ($0.63/ 1,000 gallons).

Environmental Factors

No significant environmental impacts are anticipated as a result of the installation of the wells; and the transmission line can be routed to minimize impacts on environmentally sensitive areas, if needed. However, a detailed environmental review should be performed prior to installation of any new infrastructure.

Impact on Water Resources and Other Management Strategies

There should be low impacts to water resources since this supply is not used.

Impact on Agriculture and Natural Resources

This strategy should have no impacts on agriculture because this water is not suitable for irrigation.

Other Relevant Factors

There are no other relevant factors identified.

5.7 Recommended Strategies for Major Water Providers

The comparison of supply and demands by major water provider found no supply needs through the planning period for CRMWD and BCWID. However, studies of the CRMWD system conducted as part of the Region F plan indicate that there may be infrastructure limitations of the existing system. The infrastructure is sufficient to meet current demands, but may be limited to meet peak future demands as proposed in this regional plan. To fully utilize CRMWD's existing supplies, the existing transmission/distribution system will need to be upgraded. In addition, CRMWD is pursuing additional water resources to improve both the quantity and quality of the water supplies. One strategy CRMWD is exploring is the development of a well field in Winkler County. CRMWD owns water rights in Winkler County and preliminary studies indicate this potential well field could produce 6,000 acre-feet per year of water. The water would be used to blend with existing supplies. Discussions of both strategies are presented in the following sections.

In addition to these identified strategies, CRMWD plans to:

- Look at additional water supply options of both surface and ground water supplies within 200 miles of the District's system, recognizing that development of these supplies will require coordination with the appropriate local, state and federal agencies;

- Continue to evaluate the conjunctive use of both surface and ground water supplies;
- Evaluate coordinated reservoir operations of Lakes Thomas, Spence and Ivie, and assess the ability of CRMWD's raw water transmission system to move water from the source to where it is needed, taking into account water quantity, quality, system capacity and the operations and power costs to move water;
- Look at additional diversion facilities of low-flow, poor quality water on the Colorado River, Beals Creek, and other tributaries above Spence Reservoir for water quality enhancement. This includes the timely releases of water from Spence downstream to blend or pass through Ivie Reservoir to enhance water quality in this reservoir as well;
- Consider possible amendments to its water appropriations permits with the TNRCC to use bed and banks of the Colorado River to transport stored water from Spence to Ivie, and include multiple uses for existing permits. This will give CRMWD the ability to use its allocated water to beneficially meet the needs of the region, either through municipal, industrial, agricultural, irrigation, mining, steam electric power or other uses. The permits may also be amended to allow withdrawal points at any location around the edges of CRMWD's reservoirs.
- CRMWD will also continue its efforts to evaluate reuse of wastewater, use of lesser quality water, advanced conservation practices, demineralization, and blending sources of water for beneficial purposes.

5.7.1 Upgrade Infrastructure

The CRMWD distribution system has six major components for delivering water to their customers:

- Ivie Reservoir to a terminal storage reservoir between Midland and Odessa
- Spence Reservoir to Big Spring
- Lake Thomas to Big Spring
- Lake Thomas to Snyder

- Ward County to Odessa
- Big Spring to Odessa

The Lake Thomas to Snyder line serves only the city of Snyder and its customers. Although Snyder is primarily served by water from Lake Thomas, water from other CRMWD sources can be used as well if the water is passed through Lake Thomas. The Big Spring to Odessa leg links together the other customers and sources of water.

Table 5-14 lists the current and future needed capacities of the delivery system. To achieve future capacities, two new pumps at each existing Ivie pump station will be needed, as well as a new pump station on the Ivie pipeline in Glasscock County and additional terminal storage facilities. Using SB-1 demands the increased capacity will be necessary by 2010. However, the SB-1 projections for the year 2000 are about 20 percent higher than actual demands experienced by CRMWD in 1999 (CRMWD 1999 Annual Report), so the expansion may be delayed until demands reach projected levels.

Table 5-14
Current and Future Peak Capacity of the CRMWD System

Component	**Current Peak Capacity** (mgd)	**Future Peak Capacity** (mgd)
Ivie to San Angelo	62	90
San Angelo to Terminal Storage	42	65
Spence to Big Spring	30	30
Thomas to Snyder	9	9
Thomas to Big Spring*	10	10
Ward County to Odessa	23	23
Big Spring to Odessa	29	29

*Actual capacity is 20 mgd. However, peak day supply is limited by yield of Lake Thomas.

5.7.2 Winkler Well Field

To further increase the reliability of their system and improve water quality, CRMWD is pursuing the development of ground water from the Cenozoic Pecos Alluvium in Winkler County. Water quality considerations often prevent CRMWD from operating its system at full capacity. The dissolved solids concentration (TDS) of water varies among CRMWD's sources of water, ranging from less than 500 mg/l in Lake Thomas to up to 4,000 mg/l in Lake Spence.

The CRMWD system is operated so that all of its customers receive water of approximately the same quality. To fully utilize the yield of Lake Spence and maintain water quality, additional low TDS water is needed. It is anticipated that the new well field in southern Winkler County would provide an additional 6,000 acre-feet per year of water. This water would be pumped approximately 43 miles directly to the city of Odessa. From there it would be blended with other sources and distributed to CRMWD's customers.

5.8 Other Water Management Strategies Not Directly Associated with Needs

5.8.1 Water Conservation and Drought Response

Water conservation is a potentially feasible water savings strategy that can be used to preserve the supplies of existing water resources. The demand projections for SB1 planning have already incorporated a significant level of conservation to be implemented over the planning period. For municipal use, assumed reductions in per capita use is the result of implementation of the State Water-Efficiency Plumbing Act, water conservation programs promoted by state and federal regulations, and the increasing cost of water. The manufacturing projections assume that manufacturing use per unit of output will be reduced over time due to improvements in technology and other water conservation efforts, and irrigation use is expected to decrease approximately one percent per decade based on more efficient irrigation systems. If the expected conservation is not achieved, then the water needs identified in this plan may be greater than projected. In Region F, reductions in demands due to conservation were not considered for mining, steam electric power and livestock. To utilize conservation as a feasible strategy advanced conservation measures will be needed.

Such advanced measures are considered specifically for steam electric power and irrigation, where appropriate, and are discussed in those respective sections. For municipalities and manufacturers, advanced drought planning and conservation can be used to protect their water supplies and increase the reliability during drought conditions.

As required by SB1, each region's water plan must address drought management and conservation for each water supply source within the region. This includes both ground water and surface water sources. Where possible, existing drought management plans have been reviewed to develop consistent drought trigger conditions and management actions for each source. Trigger conditions and responses for ground water supplies are being discussed with the TWDB. A proposed regional approach is presented below.

For ground water resources, the monitoring of water levels on a regular basis provides critical data necessary to manage the water supply for municipal, industrial or irrigation demands. Historical water levels combined with water demand or pumping data allow management to establish different trigger water levels for the various stages of drought. For a regional approach, a percentage of the difference between the lowest historical water level and the average water level was used as the trigger conditions for drought management. Provided this difference was greater than 10 percent of the water column in the associated well, the drought trigger water level was set at 50 percent below the average water level. The corresponding drought response involves notification of drought conditions and coordination with respective entities' drought contingency plans. However, each user would ultimately determine the management of the water supply based on the level of drought.

In a few areas of Region F, the ground water is being mined, meaning that the water levels are expected to be lower than the previous year. In this case, the managing entity of the water resource needs to establish the maximum allowable drop of the water level in a year, also considering the long-term impact on the availability of the ground water source. For this plan, it was assumed that an increase of the average mining rate by 25 percent would trigger a drought response.

The proposed locations of wells to be monitored in Region F are illustrated on Figure F-1 in Appendix F. These wells were selected because of availability of historical data including water levels and chemistry, and regional representation by county and aquifer.

For surface water sources, a single drought trigger was identified based on reservoir content or stream flow. These trigger levels and associated management actions are outlined in Table F-1 in Appendix F.

5.8.2 Reuse of wastewater

Water reuse is the intentional use of treated wastewater effluent for a beneficial purpose that takes the place of potable and/or raw water that would otherwise be used. Common uses for wastewater effluent include irrigation, fire protection, and cooling tower make-up. Potable reuse is less common due to the treatment requirements and public perception. However, indirect potable reuse (where wastewater effluent supplements a raw water source) does occur in Texas and is a potentially feasible water supply strategy. Some of the benefits to reusing treated wastewater are:

- It is a drought-proof water source,
- The supply increases with economic and population growth, and
- Provides an alternate water source when high quality water is not needed.

The current and potential providers of wastewater effluent for reuse in Region F are listed in Table F-2 of Appendix F. This table identifies publicly-owned facilities and industrial wastewater treatment facilities that generate wastewater effluent. It also provides a summary of each permit with respect to the discharge status, permitted effluent volume and identified current methods of effluent management. Currently, a total of 76 wastewater permits exist in the region.

Based on the respective wastewater permit, an entity may be allowed to discharge the treated effluent into the waters of the state or has a "no-discharge" permit. Facilities with a no-discharge permit typically use land applications (may include irrigation) or evaporation ponds. Many of these facilities are practicing water reuse and are not potential new sources for reuse. The facilities that discharge their effluent are assumed to be potential providers. However, entities considering reuse projects should investigate the potential from all generators. It is possible that operations at some of the no-discharge facilities could be changed so that part or all of the effluent is made available for reuse.

For those facilities for which actual flow records are readily available (facilities permitted for discharges must report actual flows to the TNRCC), the average volume of wastewater currently being generated is about half of the permitted volume. If this average is true for all public domestic wastewater facilities in the region, then the total volume of treated effluent that is produced could approach 37 MGD (over 40,000 acre-feet/year). However, much of the effluent produced is already being managed by irrigation, or is otherwise being reused. Only eight public domestic wastewater facilities in the region have permits that allow only discharge at this time. The estimated effluent volume for these eight facilities totals 6 MGD. Thirteen other facilities have permits allowing both discharge and some form of reuse. Many of these permittees operate reuse projects.

The viability of a potential reuse project will rest largely on its cost, which is impacted primarily by the available quantity, the amount of additional treatment necessary for the intended use, and the distance between the wastewater treatment plant and the location of the intended use. The reuse of wastewater as a water management strategy can be cost effective, if the appropriate conditions exist. In evaluating potential wastewater reuse, the following issues should be considered:

- Whether there is a potential reuse project available within a reasonable distance of the wastewater treatment plant to receive the effluent.
- Whether there are water rights requirements specific to those waters that would limit the ability to provide part or all of the effluent for some, or all, types of reuse.
- Whether the quality of the effluent is suitable for specific potential reuse projects.
- Seasonal variations in the availability of water for reuse. Where there are existing irrigation reuse projects, additional irrigation reuse may not be possible unless significant storage is provided.

Development of potential reuse projects in Region F could be feasible water management strategies. Some reuse is already incorporated in the currently available supply. Other reuse projects have been evaluated to meet specific needs, such as the reuse of the city of Winter’s effluent for manufacturing in Runnels County and San Angelo’s effluent for irrigation in Tom Green County. Each of these projects was evaluated with respect to the TWDB’s criteria. As other projects are identified, they too will require consideration of these issues in order to determine the viability of the projects.

5.8.3 Weather Modification to Enhance Yields

Weather modification is defined as an attempt to increase the efficiency of a cloud to return more of the water drawn into the cloud as precipitation. Hail suppression and rainfall enhancement are common forms of weather modification. Early forms of weather modifications began in Texas in the 1880s by firing cannons to induce convective cloud formation. Efforts to enhance rainfall in Texas have continued to present day. Most efforts to increase rainfall take place in the spring and summer and are suspended during the winter months.

Silver iodide, AgI, emitted from flares located on the plane is a common agent used for cloud seeding. Silver iodide enhances ice crystal concentrations in clouds, encouraging larger drops to form increasing the chance that precipitation will reach the ground. Environmental concerns have been raised with regard to using a heavy metal as a seeding agent, but research conducted along the Oklahoma border indicated only trace amounts, much smaller than allowed by law, of silver in livestock grazing or in soil downwind.

To conduct weather modification activities a weather modification license application must be approved, and then a weather modification permit must be obtained. All applications for licenses and permits are subject to a technical review. Based on the findings of this review TNRCC may decide whether to grant the licenses or permit. TNRCC may revoke permits or licenses if the terms of the permit are violated, or if there is evidence to believe that the seeding is preventing the clouds from releasing their normal amount of precipitation.

There are several on-going weather modification programs in Region F. One conducted by CRMWD and the other by West Texas Weather Modification Association. CRMWD began weather modification efforts in 1970. The intent of the rainfall enhancement program is to increase runoff to reservoirs located in the District. CRMWD has a permit to operate in a 14-county area along the Colorado River as shown in Figure 5-7.

The West Texas Weather Modification Association (WTWMA) began weather modification efforts in 1996. The intent of the rainfall enhancement program was to increase ground water recharge, spring flow, and runoff resulting in increased agricultural productivity and reduction in ground water withdrawals. WTWMA operates in eight counties covering an area of 10 thousand square miles as shown in Figure 5-7. The city of San Angelo, Emerald UWCD, Glasscock

County UWCD, Irion County WCD, Plateau UWC & SD, Santa Rita UWCD, Sterling County UWCD and Sutton County UWCD are the current participants in the rainfall enhancement effort.

The effects of weather modification are difficult to measure. To precisely estimate the benefit of weather modification requires an estimate of how much precipitation would have occurred naturally without weather modification. Research has suggested increases of 15 percent or more of rainfall in areas participating in weather modification. Local experiences have shown increases of 27 percent in rainfall. Other methods of measuring the effects of rainfall enhancement have shown positive benefits of weather modification. Dryland farm production, a common measurement, has increased in regions participating in rainfall enhancement. The cost of operating the weather modification program is approximately 9 cents per acre.

5.8.4 Brush Control

The Texas Water Resources Institute estimates that one acre-foot of water is lost annually for every 10 acres of brush. Since the early 1900s the region has seen significant increases in brush. Much of the brush in Region F consists of mesquite, salt cedar and juniper. As these plants were introduced into the area, they spread from the riverbanks to the plains, replacing native grasslands. Some of the potential concerns associated with brush are increased erosion, competition for water with grasses, and reduced runoff and infiltration. Estimates of the amount of water used by different plant species in Region F are summarized in Table 5-15.

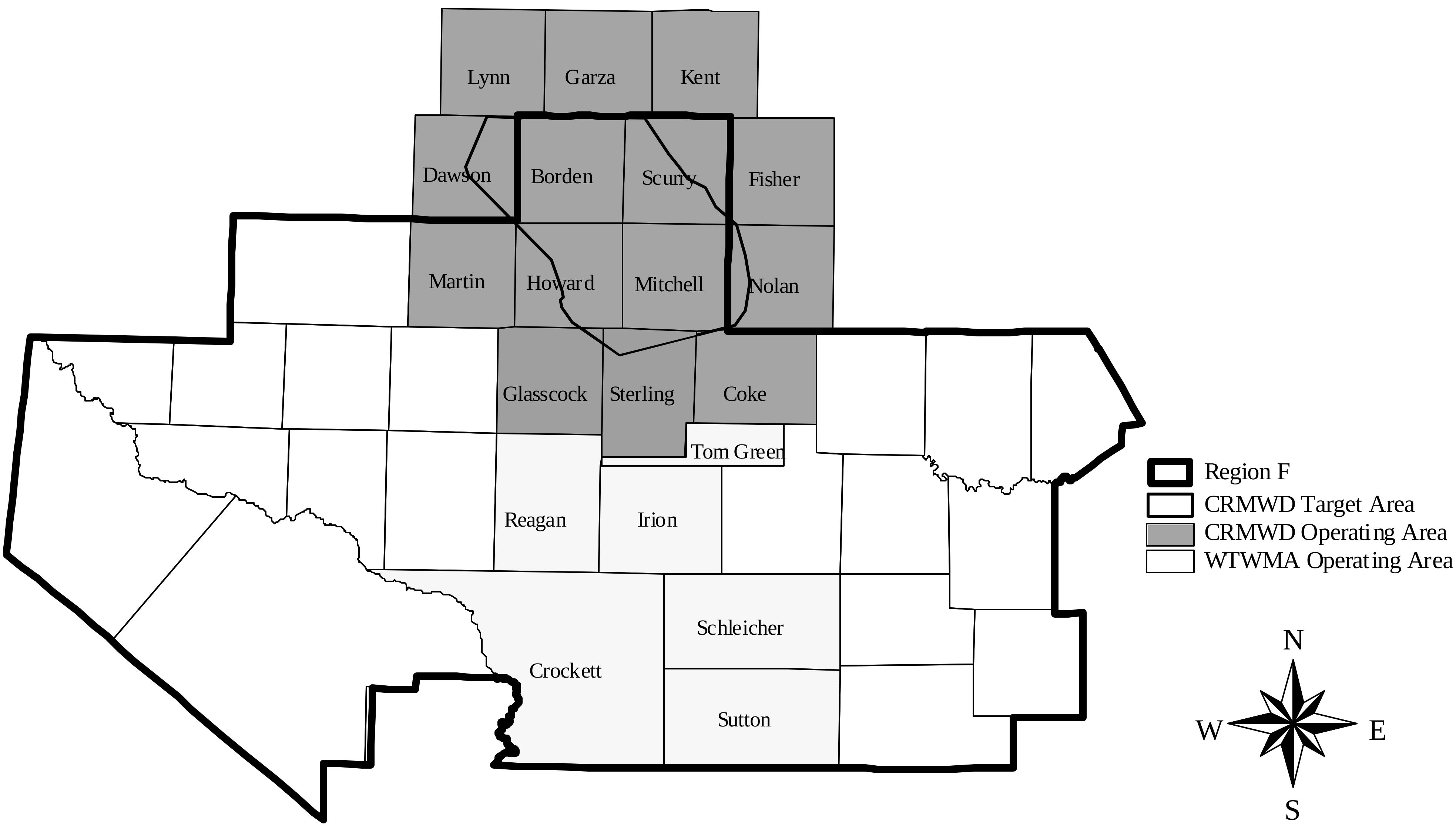
Table 5. 15 Plant Water Use Rates

Plant	Water Loss (in/yr)	Water Loss (ac-ft/ac/yr)	Sources
Cottonwood	43.5 – 64.5	3.63 – 5.38	Gatewood et al (1950) Mogg et al (1960)
Crops	30.8 – 37.0	2.57 – 3.08	Borrelli et al (1998)
Fourwing Saltbush	28.5 – 68.8	2.38 – 5.73	McDonald & Hughes (1968)
Grass	6.0	0.50	Hines (1992)
Honey Mesquite	13.7 – 25.4	1.14 – 2.12	Ansley et al (1998)
Juniper	23.3 – 25.0	1.94 – 2.08	Dugas & Hicks (1998)
Mesquite	19.2 – 26.3	1.60 – 2.19	Gatewood et al (1950)
Salt cedar	27.3 – 234	2.28 – 19.52	Van Hylckama (1970) Gatewood et al (1950) Sala et al (1996) Weeks et al (1987)
Salt grass	11.9 – 44.8	0.99 – 3.73	Duell (1990)

Predicting the amount of water that would be made available for ground water recharge or additional stream flow by implementing a brush control program is difficult. The Upper Colorado River Authority, Texas A&M University and the Texas Soil & Water Conservation Board are now conducting studies. Initial and preliminary results indicate that some areas within the region may benefit from successful and long-range brush control. A review of vegetative cover extent, type of brush and watershed hydrology indicates that Lake Ivie, Lake Spence and Twin Buttes Reservoir may be likely candidates for brush control programs.

There are several brush control studies currently being conducted in Region F. The North Concho River and O.C. Fisher program, probably the largest developed program, has experienced good landowner participation during the first year with over 500,000 acres contracted for review. An additional 400,000 acres are scheduled for treatment between 2000 and 2003. The North Concho program involves a 10-year contract period of treating brush initially and a minimum of two additional follow-up treatments in the remaining years of the contract. State participation costs of the program can reach as high as 75 percent with the landowner paying the remainder. The large-scale monitoring program for this study will provide the data necessary to assess the impacts of brush control on local water resources.

Figure 5-7
Current Areas of Weather Modification
Activities in Region F



In addition to the North Concho program there are on-going studies of the Middle Concho and the Upper Colorado Rivers. These studies contain similar features and requirements that were adopted for the North Concho project. When completed in the fall of 2000, the findings of these studies will provide data for other areas within Region F. If brush control is determined to be a viable strategy to enhance water supplies in Region F, there are several factors that could affect the quantity and/or quality of water available from brush control. These include:

- Landowner participation,
- Brush control follow-up programs,
- Surface water – ground water relationship,
- Impact of chemicals used to kill brush, and
- Potential increased sediment loads on reservoir yields and ecosystems.

As previously discussed, the number of landowners who participate is important to a successful program. This region has indicated considerable interest in such programs as evidenced by the North Concho participation. It is expected that there will be substantial participation in other brush control programs.

Evidenced by the persistence and increase of brush in Region F, the control of this vegetation will be an on-going process. A brush control strategy should include follow-up brush control, and these costs should be considered as part of the strategy. The frequency of these programs is dependent on the area and type of brush, but it is expected that follow-up brush control should be performed at least every ten years.

One of the unknowns with brush control is the reliable amount of water made available by this strategy. In addition, how this water is generated (either by increased recharge to ground water supplies or increased surface runoff) needs to be determined. Increased recharge to a near surface aquifer may not realize increases in water supply if the aquifer is not used for supply, or the increased recharge may recharge the aquifer outside the area of the brush control project. Increased surface runoff may provide additional supply to water rights holders downstream. However, since flood flows typically account for a large percentage of safe yields of surface reservoirs in Region F small increases in average daily flows may not substantial increase reservoir yields. More information is needed from the on-going brush control studies to assess the true enhancements of water supplies from this strategy.

There are typically three types of ways brush control can be implemented: physical removal, controlled burns and chemical kills. Table 5-16 gives the estimates of costs for different methods of brush control. Physical removal is labor intensive for large areas, so often burning or chemicals are used. There are some potential concerns regarding the environmental impact of such chemicals on water supplies and local ecosystems. In addition, there is the potential for increased sediment loads on streams if brush control is implemented without grass replacement. It may take several months before grass will grow on an area that has been cleared by chemicals. The increased sediment loads may affect water quality and reduce reservoir yields. Further study of these potential environmental impacts is needed.

Table 5-16 Costs for Various Brush Control Methods

Treatment	Cost per Treatment ($ per acre)	Treatment Interval
Chemical spray	$15 - $25	Retreat every 10-12 years
Chemical spray & chain	$25 - $40	Chain after 2 years, spray every 10-12 years
Roller chopping	$25 - $65	Retreat every 6-8 years
Root plowing & reseed	$80 - $90	Grub every 12 years
Fire	$2.5 - $5	Burn every 5-7 years
Grub	$10 - $75	Retreat every 10-15 years

Source –*Draft Report: Assessment of Brush Control as a Water Management Strategy*, Prepared for TWDB, Research & Planning Consultants and Espey, Padden Consultants, Inc., December 1999

Even with these unknowns and possible concerns regarding brush control, this strategy provides significant possible enhancements to water supplies in Region F. Therefore, the RWPG recommends:

- Brush control programs like the ones on the North Concho, Middle Concho and Upper Colorado should be accelerated.
- Brush control implementation programs should include monitoring and analysis of the impact on ground water and surface water supplies.
- Beneficial uses for the water supplies developed from brush control should be investigated as part of the 2005 Regional Water Plan.

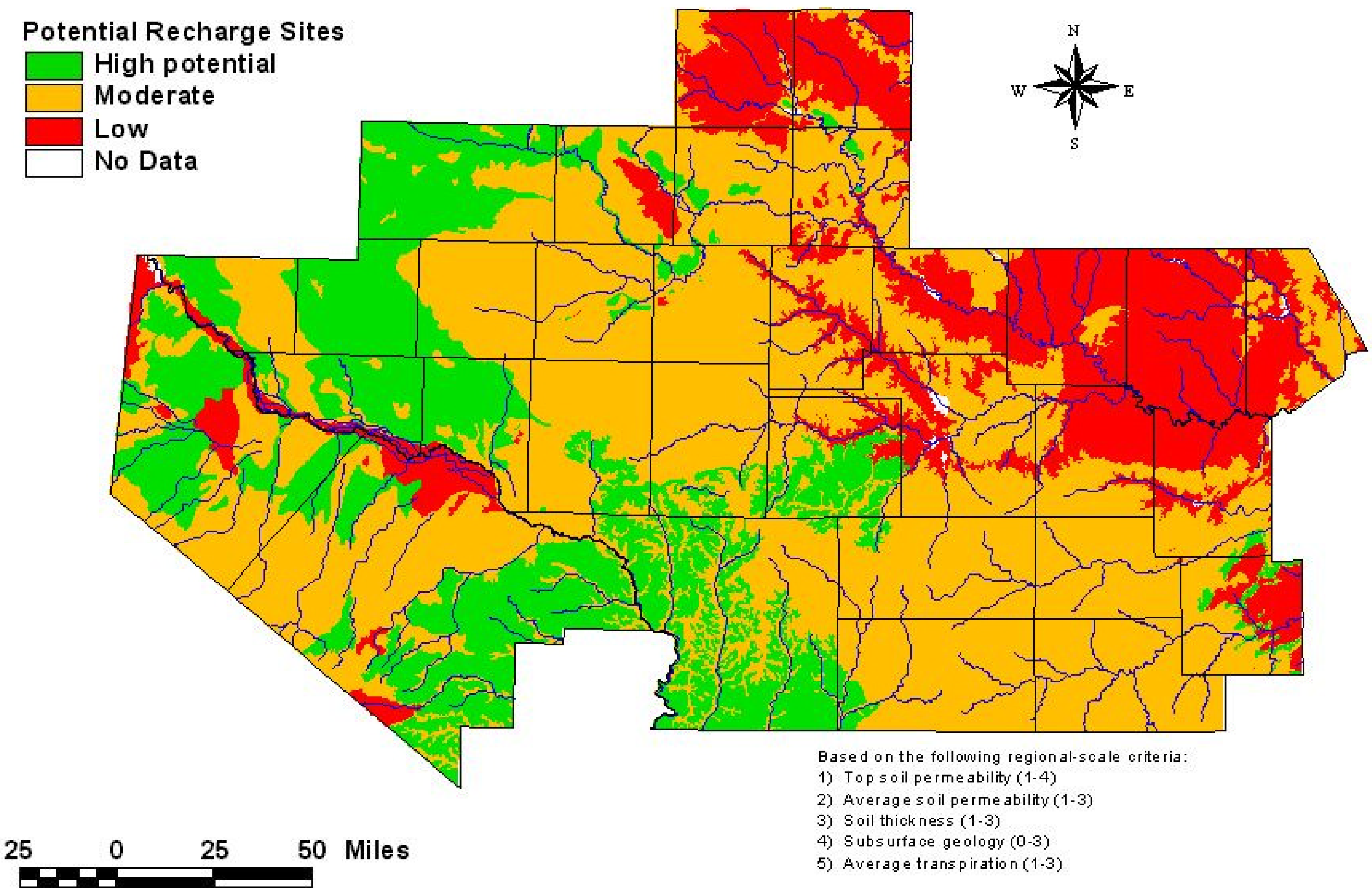
5.8.5 Recharge Enhancement

Recharge enhancement is the process in which surface water is purposefully directed to areas where permeable soils or fractured rock allow rapid infiltration of the surface water into the subsurface to increase localized ground water recharge. This would include any man-made structure that would slow down or hold surface water to increase the probability of ground water recharge. To evaluate potential locations for recharge enhancement in Region F, the geographic information system (GIS) mapping of the region was utilized.

Five different mapping layers were reviewed to identify the areas most favorable to recharge enhancement. Three layers are associated with soils (topsoil permeability rate, average permeability rate of total soil profile and soil thickness), one is vegetation (transpiration rates of local indigenous vegetation) and one is subsurface geology (average transmissivity and/or specific capacity of the underlying aquifer). The ranges of values within each of the five layers was then evaluated and rated on a scale from 1 to 4, with 4 being the most favorable. As shown in Figure 5-8, areas in green are the most favorable areas for recharge enhancement to the ground water, areas in yellow less so and areas in red have the lowest potential of surface recharge of the underlying aquifer. There may additional local sites that are conducive to recharge enhancement that are not shown on this figure. Topography, drainages, soil properties and the extent and hydraulic characteristics of aquifer outcrops on a local scale would need to be evaluated for the final selection of favorable sites. Consideration should also be given to the potential reduction of surface runoff and how that affects existing surface water reservoirs.

Further study is needed to determine the quantity of increased ground water supplies from enhanced recharge structures and the potential impacts to surface water rights.

Figure 5-8 Potential Recharge Enhancement Sites



5.8.6 New Supply Development

5.8.6.1 Potential Reservoir Sites

Three possible sites have been evaluated as potential reservoir projects to supplement the water supply in Region F: Mason County, Pecan Bayou and Mountain Creek. Of these three sites, the Texas Water Development Board has investigated Pecan Bayou and Mason County previously and listed them as potential alternative or long-term reservoir sites. Mountain Creek Reservoir is an alternative site to replace an existing reservoir.

The Mason County Reservoir and Dam project is sited in Mason County on the Llano River and the James River. The U. S. Army Corps of Engineers (USACE) first proposed the project in April 1966. The conservation pool elevation is 1,428 ft. msl and has a storage capacity of 650,000 acre-feet. With required environmental releases, the yield of the reservoir is approximately 31,000 acre-feet/year. Total capital cost of construction not including permitting, contingencies or environmental studies is $463,000,000 as of January 1998. This site is located on a stream segment that is designated by Texas Parks and Wildlife as "of highest importance for protection". The proposed site is also in a significant ground water recharge area, and a preliminary archeology review indicates the area has many historical cultural resources.

The Pecan Bayou Reservoir has been studied for both water supply and flood control purposes. The site is located on the Pecan Bayou just south of the northern border of Coleman County. In a 1965 hydrologic study of the Pecan Bayou Watershed, the proposed reservoir had a yield of 5,900 ac-ft/yr with a 102,000 ac-ft conservation capacity. The proposed project consisted of an earthfill dam 15,500 ft in length with a maximum height of 107 ft. Lack of funding delayed any further progress on the project. Since there are sufficient local surface water supplies already developed in the area, the most recent studies of the Pecan Bayou site have considered it only as a flood control reservoir.

The proposed Mountain Creek Reservoir site is located upstream of the existing reservoir north of Robert Lee. The Colorado River Municipal Water District briefly studied this site in 1990. According to their calculations, at an elevation of 1,880 feet msl, the volume of the reservoir would be 1,187 acre-feet. No further studies have been conducted.

The Mason County Reservoir site has the greatest potential for yield of these possible reservoir locations, yet it has significant environmental concerns. The Pecan Bayou site is located in part of the region with sufficient water supply. However, the reservoir could provide flood control and recreation. It could be operated as a system with Lake Brownwood, Lake Coleman, and possibly Lake Clyde to provide additional water supply. The proposed Mountain Creek Reservoir, if constructed, would serve as a replacement for the existing water supply reservoir for the city of Robert Lee.

Other reservoir sites that have been previously proposed in Region F included the Burkett and Camp Colorado sites in the Pecan Bayou watershed, the Winchell, Runnels County and Mitchell County sites on the Colorado, the Menard site on the San Saba, Paint Creek site in the Llano watershed, the Deep Creek site in Mitchell County, the Bluff Creek site in the Elm Creek watershed, and the Madera Canyon site in Jeff Davis County. Development of these sites is highly unlikely because there is no unappropriated water available to these reservoirs, and construction will impact existing water rights holders.

5.8.6.2 Potential Ground water Sites

Based on a comparison of available ground water supplies and the currently developed supply, there appear to be undeveloped ground water supplies in the Edwards-Trinity, Dockum and Hickory aquifers. However, in many of the counties with available ground water there are specific reasons why these supplies have not been fully developed. Parts of the Edwards-Trinity formation underlie the Ogallala or Cenozoic Pecos Alluvium, which are more economical sources of water. Where this occurs, these overlying aquifers will be fully developed rather than the Edwards-Trinity. The Edwards-Trinity also has limited well yields in many parts of the region that further limit its use. Often use of the Hickory aquifer is limited due to depth and/or water quality (radionuclides), and the Dockum aquifer has limited well yields that may preclude large scale development, but has the potential to meet small needs.

A review of available well information, including well densities and yields was conducted to assess the potential of new well field development in Region F. This data along with the assessment of undeveloped supplies indicates there are two potential well field sites. One is in the Hickory aquifer in the southwest corner of Mason County. This site has been identified in Section 5.2.9.6 for potential development to meet the needs of the city of Brady and surrounding communities. Another potential site is the Ellenburger-San Saba Aquifer in central McCulloch County. Presently this aquifer is used for livestock watering, but could be developed for other uses.

Most likely there are other localized sites in the region that may prove highly reliable. This includes local minor aquifers such as the Rustler and Marble Falls formations. Further review of the hydrogeology and ground water development potential should be conducted if a need is identified.

5.8.7 Aquifer Storage and Recovery

Aquifer storage and recovery, or ASR, is a water-supply management technology that optimizes conjunctive use of surface water and ground water. The concept involves placing water from one source, usually surface water, into a ground water reservoir (aquifer) from which it can be later recovered. Water for storage is usually secured during times when the source is available in excess of distribution needs and is generally treated to drinking water standards prior to being injected underground (Class V). The temporarily stored supply is later pumped back to the surface to meet peak demands. ASR is typically employed on an annual cycle with water being stored during the low demand (winter and spring) months and retrieved during the high demand (summer) months. This storage and recovery cycle is what differentiates ASR from simple aquifer recharge projects. ASR system advantages include:

- An ASR system typically costs a fraction of an equivalent surface impoundment.
- ASR does not increase total water supply availability but allows greater use of existing supplies.
- Environmental benefits are realized by reducing the need to divert surface water during high demand and low stream-flow periods.
- The use of ASR to meet peak demands can reduce the need to increase water treatment capacity.
- ASR recovery efficiency is appealing when compared to surface-water reservoir evaporation losses.

ASR may not be an acceptable alternative at all locations. There are several minimum requirements for insuring the feasibility of ASR projects.

- A suitable geologic strata or aquifer capable of receiving and holding in place a desired quantity of water is required.
- A supply of water must be available.
- Treatment and conveyance facilities must be convenient.
- Injected water chemistry must be compatible with the chemical makeup of the native ground water and the rock material of the storage zone.
- The project must represent the best economic management alternative available to the community.
- There must be some measure of protection against the unauthorized withdrawal of the stored water.

Although hydrogeologic formation conditions may be favorable, the applicability of ASR in Region F is generally limited by the lack of excess seasonal surface-water supplies that could be applied to an underground storage facility. Most likely ASR candidates occur in those counties primarily in the eastern and northern parts of the region where a higher probability of available surface water supplies exists. Both the Edwards-Trinity and Hickory formations potentially offer favorable underground reservoir characteristics; however, any potential site will require thorough feasibility characterization prior to initiating the construction of a facility.

5.9 Water Quality Issues

While water quality may not affect the quantity of water from an available source, it often affects the use of the water. There are different water quality criteria for different end uses. Potable water must meet established Drinking Water Standards, while water for manufacturing or mining does not. In Region F there are several significant water quality issues that affect the use of viable water sources. A brief discussion of these issues and identified technology to improve water quality is presented in the following sections.

5.9.1 Municipal Supplies

Some of the identified water supply shortages in Region F are a result of the poor water quality of the water supply itself. The natural occurrence of radionuclides in the Hickory formation, for example, may cause a number of water systems that depend on the Hickory aquifer to be in violation of primary drinking water standards when the new standards are adopted. Thus, for planning purposes, the Hickory aquifer has been assumed not to be available as a drinking water source after 2010 unless treatment or other measures to improve the quality are implemented. Following is a discussion of the types of water quality conditions that currently limit use of water supplies in Region F, or potentially could limit use, and the types of treatment processes that can be applied to improve water quality. Based on TNRCC records, the number of public water systems where water quality may restrict usage, and the parameters of concern are summarized in Table 5-17.

TABLE 5-17 Drinking Water Quality in Region F

CONTAMINANT	DRINKING WATER STANDARD			NUMBER 0F PUBLIC WATER SYSTEMS AFFECTED
	CURRENT		PROPOSED	
	PRIMARY	SECONDARY	PRIMARY	
Gross Alpha	15 pCi/L			7
Radium (226 + 228)	5 pCi/L*			5
Nitrate	10 mg/L			14
Fluoride	4 mg/L			2
		2 mg/L		9
Selenium	0.05 mg/L			1
Chloride		300 mg/L		6
Sulfate		250 mg/L		8
Total Dissolved Solids		1,000 mg/L		15
Arsenic			5 ug/L	37
Uranium			20 ug/L	3

Note: In 1991, the USEPA considered raising the MCL for radium to 20pCi/L for radium 226 and 20 pCi/L for radium 228. However, the current proposal is to maintain the existing combined radium MCL of 5 pCi/L. This proposal should be finalized by November 2000.

There are 57 public water systems in the region that appear to have significant water quality problems, based on available records of the TNRCC. Many water systems have more than one issue with water quality. Water supply strategies previously discussed in this chapter addressed water quality problems for a number of the systems. In all, 38 public water systems have primary drinking water standards problems for which water management strategies may eventually need to be addressed. The larger of these systems with reported exceedances for current or proposed primary standards are:

- City of Andrews (Andrews County) – exceeds current primary and secondary standards for fluoride. The system may also exceed the proposed primary standard for arsenic. Arsenic reduction will eventually be required, although it may be a number of years before the new standard is implemented.

- City of Robert Lee (Coke County) – may exceed the proposed primary standard for arsenic. The system also exceeds current secondary standards for chloride, sulfate, and total dissolved solids.

- City of Crane (Crane County) – may exceed the proposed primary standard for arsenic.

- City of Stanton (Martin County) - exceeds the current primary standard for nitrate, and may exceed the proposed primary standard for arsenic. The system also exceeds current secondary standards for fluoride, chloride, sulfate, and total dissolved solids.

- Colorado City (Mitchell County) – may exceed the proposed primary standard for arsenic. The system also exceeds current secondary standards for sulfate and total dissolved solids. As Colorado City converts to more ground water for supply, these water quality concerns may be resolved.

- City of Monahans (Ward County) – may exceed the proposed primary standard for arsenic.

How, and when, these water systems eventually resolve their water quality issues will be a function of TNRCC enforcement actions, the availability and cost of alternative water sources, and the availability and cost of treatment methodologies. The selection of treatment methods will need to consider the appropriateness of specific contaminant removal processes, treatment costs, impacts of the disposal of waste residuals from the treatment process, regulatory issues, and other factors.

Table 5-18 summarizes the primary methods of treatment available for removal of drinking water contaminants known in Region F. For most contaminants, several treatment options may be available. The most effective method of treatment must be determined through appropriate engineering design procedures and water quality study for the planned source.

Table 5-19 summarizes issues of importance to each potential treatment process. Issues related to cost, regulation, and waste disposal are addressed. For treatment methods for which applicable cost information could be found, ranges of expected cost have been included.

Table 5-18
Treatment Processes for Removal of Drinking Water Contaminants Found in Region F

Contaminant	APPLICABLE TREATMENT PROCESS					
	Ion Exchange	Reverse Osmosis or Electro-Dialysis/-Reversal	Softening (Lime or Lime Soda)	Point of Use – Ion Exchange	Activated Alumina-Adsorption	Coagulation Micro-filtration
Radium (226 / 228)	X	X	X	X		
Nitrate	X	X		X		
Fluoride		X			X	
Selenium	X	X		X	X	
Chloride	X	X		X		
Sulfate	X	X		X		
Total Dissolved Solids	X	X		X		
Arsenic	X	X		X	X	X
Uranium	X	X	X	X	X	

It should be noted that treatment to remove radionuclides could potentially be a viable alternative, either for individual water systems, or for a regional system serving multiple communities in the affected areas of McCulloch and Concho Counties. However, there are currently no provisions for the disposal of water treatment residuals with elevated levels of radioactivity. Without a regulatory framework for disposal of such waste residuals, it is unlikely that the recommendation of a treatment system to improve water quality could be justified.

Table 5-19

Summary of Treatment Process Issues for Region F Water Quality

TREATMENT PROCESS	COST ISSUES	REGULATORY ISSUES	WASTE DISPOSAL ISSUES	OTHER ISSUES OR IMPACTS
ION EXCHANGE	• For very small systems: Capital Cost = $3-4 per gpd of capacity; O & M Cost = $0.05 - $0.10/year per gpd of capacity • Generally lower cost than RO for small systems • For 1 to 5 MGD systems: Capital Cost = $0.75 - $ 1.50 per gpd of capacity; O & M Cost = $0.20 - $1.00/yr per gpd of capacity	• For radionuclide treatment: Texas currently has no rules for disposal of waste residuals with elevated radioactivity; rules must be adopted to make treatment viable.	• Residuals are backwash brine and spent/fouled resins • Disposal of liquids to sewer or by injection well where available, if regulations permit • Disposal of liquids by discharge to receiving stream may be possible in certain cases • Disposal of solids by landfill, if regulations permit	• Treatment may completely remove some desirable constituents of water, requiring additional treatment to restore desired quality • Raw water sulfate level has been shown to have significant impact effectiveness for arsenic removal; could impact effectiveness for others as well.
REVERSE OSMOSIS or ELECTRO-DIALYSIS/-REVERSAL	• For 1 to 5 MGD systems: Capital Cost = $2 - $8 per gpd of capacity; O & M Cost = $0.20 - $0.75/yr per gpd of capacity • EDR may be lower cost than RO, depending on raw water quality	• For radionuclide treatment: see Ion Exchange.	• Waste residuals include reject brine; constant flow (could be 30% of inflow) • Disposal in sewer or by injection well, where available, and regulations permit • Disposal of liquids by discharge to receiving stream may be possible in certain cases	• Becoming more widely used, especially for larger systems • Pretreatment is necessary for surface water, and could be needed for some ground water sources
SOFTENING (LIME or LIME-SODA)	• Conventional treatment process costs	• For radionuclide treatment: see Ion Exchange.	• Waste residual is lime sludge; volume could be significant • Disposal of sludge by landfill or land spreading, where regulations permit	• None identified

Table 5-19 (continued)

TREATMENT PROCESS	COST ISSUES	REGULATORY ISSUES	WASTE DISPOSAL ISSUES	OTHER ISSUES OR IMPACTS
POINT-OF-USE ION EXCHANGE	• May be most cost effective for very small rural water systems or individual homes	• TNRCC will require the water system operator to have access to all treatment units for maintenance and monitoring purposes • For radionuclide treatment: see Ion Exchange.	• Residuals are backwash brine and spent/fouled resins • Collection of waste residuals by the water system operator from points-of-use (individual homes) could be difficult • Disposal of backwash brines possible in sewer, where regulations permit	• Issues of privacy (requiring the water system operator to have access to a point-of-use system located in a private household) may hinder the use of this treatment option in most public water systems • Could be more acceptable for school district systems or other non-community public water systems • Point-of-use devices are currently in use by individuals on some systems for water treatment
ACTIVATED ALUMINA ADSORPTION	• For 1 to 5 MGD systems: Capital Cost = $0.75 - $1.50 per gpd of capacity; O & M Cost up to $2.50/yr per gpd capacity	• For uranium treatment: see radionuclide note under Ion Exchange.	• Waste residuals are backwash brines • Disposal possible in sewer, where available and regulations permit	• Effectiveness varies with raw water arsenic level
COAGULATION/ MICROFIL-TRATION	• For 1 to 5 MGD: Capital Cost = $1.50 - $2.50 per gpd of capacity; O & M Cost = $ 0.10 - $0.20/yr per gpd of capacity	• None identified	• Waste residuals are primarily ferric hydroxide solids; volume could be relatively small • Disposal of residuals by landfill	• None identified

Development of cost-effective treatment for any water system requires an in-depth understanding of the chemistry of the system's water source and study of potential treatment options. Public water supplies considering water treatment should retain appropriate engineering expertise to assist with selection and design.

5.9.2 Salinity Concerns in Region F

Waters in the Colorado River Basin have historically exhibited high concentrations of dissolved solids, including chlorides and sulfates. These salt concentrations, if uncontrolled, can limit the use of the water for municipal, industrial and irrigation purposes. Contamination from oil industry activities and natural mineral deposits are commonly cited as the major sources of saline water in surface water bodies and shallow aquifers. There are two basic approaches to improving water quality of saline water for beneficial uses: 1) controlling the amount of salts entering a water resource, and 2) removing the salts before use (desalination). Both of these approaches are potentially feasible strategies to improve water quality in Region F.

5.9.2.1 Chloride Control Projects

In an attempt to control the amount of solids/salts discharged to the Colorado River, CRMWD has initiated several management practices in the E.V. Spence watershed. The most significant management practices used to improve water quality in E.V. Spence Reservoir are low-flow diversions located on Beals Creek and the Colorado River. Other control measures have included expanding the Natural Dam Lake and the construction of Sulphur Draw Reservoir to prevent large spills of highly saline water.

As part of a Total Maximum Daily Load (TMDL) evaluation recently completed for the Spence Reservoir watershed, water quality modeling was conducted to assess contaminant loading and the impacts of different management practices. This study found that as much as 390 tons per day of solids are discharged to the Colorado River upstream of Spence. Evaluations of the system with and without current management practices indicate that the existing low flow diversions are controlling approximately 40 percent of the potential contaminant loading. Further study found that implementation of additional management practices such as watershed modifications (e.g., oil well plugging, brush control, etc.) and modifications to the operation of the reservoir (e.g., release management) continued to improve the water quality in Spence Reservoir. However, the chloride, sulfate, and total dissolved solids stream standards set forth by the TNRCC were not achievable all of the time.

The findings of this study give additional support to the beneficial impacts of chloride control management practices. It is recommended that existing management practices continue and other best management practices identified during the TMDL study be considered for implementation. The improved water quality of Spence Reservoir will provide a more versatile water supply and reduce costs associated with more advanced treatment.

5.9.2.2 Desalination

Removal of salts from ground and surface water sources has the potential to improve existing water supplies and make new supplies available. In 1999 there were more than 100 desalination facilities in Texas, with 24 municipal systems using desalination for all or part of their supply, including a 3 mgd facility in Fort Stockton.

The most common technology for desalination is reverse osmosis. Reverse osmosis uses pressure to force dissolved material through a semi-permeable membrane into a reject brine. Reverse osmosis can be used to remove not only salts but also other undesirable constituents. An alternative technology is electrodialysis, which uses an electric current and semi-permeable membranes to remove ionic material from solution. Electrodialysis is generally used only to remove salts. Electrodialysis may be preferable when treating turbid waters or other waters that would tend to clog the membranes used in reverse osmosis and pre-treatment is not available (Allison, 1998).

There are several factors that need to be considered in desalination, including:

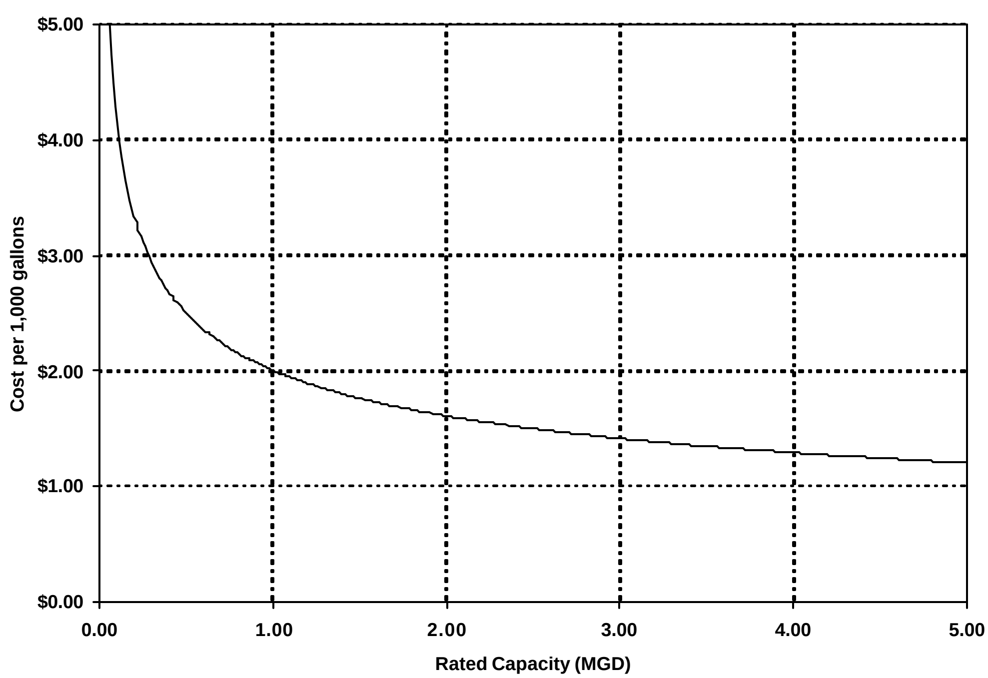
- *Salinity of source water.* In general, the more saline the source water the more expensive it is to remove the salts.
- *Disposal of reject material.* A large part of the cost of any desalination facility is the disposal of the large volume of brine containing the concentrated salts. In some cases

the brine may contain sufficient concentrations of undesirable materials to require special handling or disposal. Options for disposal include discharge to a surface water body, well injection or evaporation.

- *Efficiency of the process.* A typical reverse osmosis or electrodialysis system returns 75 percent of the volume of water input into the process as a usable product (conversation with J.D. Beffort, TWDB). The remaining 25 percent is returned as brine reject.
- *Final use of the water*. Water that is to be used for sensitive manufacturing processes or municipal purposes may require removal of more salt than water used for other purposes.
- *Other material in the source water.* In some cases turbidity or biological material may require pre-treatment to prevent fouling of membranes. In other cases it may be beneficial to remove other undesirable dissolved material such as nitrates, arsenic or radionuclides.

Figure 5-9 is a cost curve for reverse osmosis derived from a survey published by the Bureau of Reclamation in 1997. This cost curve is only an approximation since costs can vary greatly depending upon the amount of salt removed from the water, brine disposal and other factors.

Figure 5-9 Approximate Cost for Reverse Osmosis Treatment



5.10 Summary of Recommended Water Management Strategies for Region F

To assess the preferred strategy for each water group a rating system was established based on the evaluation criteria specified by TWDB. These rating values are not absolute numbers but rather relative ratings for different strategies for the user group. Comparisons of the rating value between users groups are not appropriate. Summaries of the evaluations and ratings are included in the Matrix Summary table in Appendix E.

A listing of each user group, the short-term and long-term needs and the preferred strategy by use type order (e.g., municipal, irrigation, etc.) is presented in Table 5-20. This list is also presented by county order in Table 5-21. For preferred strategies with developed transmission routes and known locations of the supply source, schematic layouts of the proposed improvements are shown on Figures G-1 through G-6 in Appendix G.

A total of 32 strategies (excluding strategies for irrigation and general strategies) were identified as preferred strategies in Region F. Costs associated with municipal and manufacturing strategies range from $366 to $2,175 per acre-foot. Costs for steam electric power and mining were estimated at $160 to $471 per acre-foot. However, the uncertainty with the mining and steam electric costs is high due to the unknowns associated with the locations of need and supply source.

The preferred general strategies (i.e., those not directly associated with a need) are listed in Table 5-22. These strategies, while not quantified at this time, are considered highly feasible water management alternatives that could be used to improve water supplies and/or reduce projected demands in the region.

A list of the needs that cannot be fully met with the identified strategies is presented in Table 5-23. This list includes the amount of need after the reliable supply from an associated strategy is applied, and the reason the need cannot be fully met. Needs of 10 acre-feet or less are not included.

Table 5-20

Preferred Strategies by Use Type

Water User Group	County	Short Term Need (2000-2030)	Long Term Need (2040-2050)	Preferred Strategy
Early	Brown	NA	NA	Purchase treated water from BCWID
Robert Lee	Coke	NA	NA	Construct intake structure on Lake Spence; construct RO system for Spence water
Bronte	Coke	NA	NA	Purchase water from Robert Lee, construct pipeline
Eden	Concho	531	545	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field; or new wells in the Edwards-Trinity
Junction	Kimble	78	16	Develop Edwards-Trinity aquifer wells
Brady	McCulloch	1,871	1,779	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Menard	Menard	39	2	Develop Edwards-Trinity aquifer wells
Midland	Midland	0	26,967	Renew contract with CRMWD and develop T-Bar Well Field
Eldorado	Schleicher	NA	NA	Develop new wells in Edwards-Trinity Aquifer
San Angelo	Tom Green	887	6,288	Enhance system operation (Pump addition on the Spence/Ivie line), McCulloch well field development
County-Other	Brown	447	581	Additional supplies from Lake Brownwood
County-Other	Concho	36	29	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
County-Other	McCulloch	833	771	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
County - Other	Reeves	71	86	Purchase additional supply from Pecos and Balmorhea
County-Other (Includes Ballinger And Winters)	Runnels	0	51	**Short-term** - Purchase Spence water; increase Ballinger's treatment capacity. Improve delivery of North Runnels WSC **Long-term** – Lake Ivie via Millersville-Doole, or water from Lake Coleman via North Runnels WSC
County-Other	Tom Green	175	946	Purchase water from San Angelo and Millersview Doole WSC
Irrigation	Andrews	2,388	752	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Borden	8,709	8,635	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Glasscock	47,853	45,686	Improve irrigation practices to maximize benefit of existing supplies

NA – Not Applicable, no needs were identified in supply-demand comparison

Table 5-20 (continued)

Water User Group	County	Short Term Need (2000-2030)	Long Term Need (2040-2050)	Preferred Strategy
Irrigation	Loving	258	250	No strategies identified
Irrigation	Martin	333	0	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Midland	34,640	25,414	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Reagan	18,633	15,676	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Reeves	39,164	35,607	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Tom Green	37,863	36,959	Improve irrigation practices to maximize benefit of existing supplies, plus enhanced use of treated effluent from San Angelo
Irrigation	Upton	5,343	4,236	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Ward	5,430	4,508	Improve irrigation practices to maximize benefit of existing supplies
Manufacturing	Borden	0	20	Increase use of current supply
Manufacturing	Kimble	1,169	1,549	Develop Edwards-Trinity aquifer wells
Manufacturing	McCulloch	115	279	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Manufacturing	Midland	62	104	Purchase water from Midland
Manufacturing	Runnels	0	22	See Runnels County-Other
Mining	Ector	6,268	5,256	Develop Dockum and Pecos Alluvium wells
Mining	Martin	928	0	Use non-potable water from the Sulphur Draw chloride control project
Mining	Midland	669	26	Purchase water from others, No identified strategies
Mining	Reagan	1,589	1,481	Use non-potable water from the Edwards-Trinity Plateau aquifer
Mining	Reeves	175	115	Use non-potable water from the Cenozoic Pecos Alluvium Aquifer
Mining	Upton	1,817	1,319	Use water savings from irrigation practices to meet portion of needs. No other identified strategies
Mining	Ward	635	194	Use non-potable water from the Cenozoic Pecos Alluvium aquifer
Steam Electric Power	Crockett	1,889	1,889	Expand existing well field in Edwards-Trinity in Pecos County
Steam Electric Power	Mitchell	1,364	5,263	Move demands to Brown, Coleman and/or Coke Counties, use water from Lakes Brownwood, Coleman and Spence
Steam Electric Power	Tom Green	2,231	2,470	Use treated effluent from San Angelo,
Steam Electric Power	Ward	1,580	6,782	Develop new well field in Winkler County

Table 5-21
Preferred Strategies by County

Water User Group	County	Maximum Short Term Need (2000-2030)	Maximum Long Term Need (2040-2050)	Preferred Strategy
Irrigation	Andrews	2,388	752	Improve irrigation practices to maximize benefit of existing supplies
Irrigation	Borden	8,709	8,635	Improve irrigation practices to maximize benefit of existing supplies
Manufacturing	Borden	0	20	Increase use of current supply
County-Other	Brown	447	581	Additional supplies from Lake Brownwood
Early	Brown	NA	NA	Purchase water from BCWID
Robert Lee	Coke	NA	NA	Construct intake structure on Lake Spence; construct RO system for Spence water
Bronte	Coke	NA	NA	Purchase water from Robert Lee, construct pipeline
County-Other	Concho	36	29	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Eden	Concho	531	545	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field; or new wells in the Edwards-Trinity
Steam Electric Power	Crockett	1,889	1,889	Expand existing well field in Edwards-Trinity in Pecos County
Mining	Ector	6,268	5,256	Develop Dockum and Pecos Alluvium wells
Irrigation	Glasscock	47,853	45,686	Improve irrigation practices to maximize benefit of existing supplies
Manufacturing	Kimble	1,169	1,549	Develop Edwards-Trinity aquifer wells
Junction	Kimble	78	16	Develop Edwards-Trinity aquifer wells
Irrigation	Loving	258	250	No strategies identified
Irrigation	Martin	333	0	Improve irrigation practices to maximize benefit of existing supplies
Mining	Martin	928	0	Use non-potable water from Sulphur Draw chloride control project
County-Other	McCulloch	833	771	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Manufacturing	McCulloch	115	279	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Brady	McCulloch	1,871	1,779	Regional system that uses a combination of Brady Creek Reservoir, Ivie WTP, Ellenburger well field, New Hickory well field
Menard	Menard	39	2	Develop Edwards-Trinity aquifer wells
Irrigation	Midland	34,640	25,414	Improve irrigation practices to maximize benefit of existing supplies

NA – Not Applicable, no needs were identified in supply-demand comparison

Table 5-21 (continued)

Water User Group	County	Maximum Short Term Need (2000-2030)	Maximum Long Term Need (2040-2050)	Preferred Strategy
Manufacturing	Midland	62	104	Purchase water from Midland
Midland	Midland	0	26,967	Renew contract with CRMWD and develop T-Bar Well Field
Mining	Midland	669	26	No strategies identified.
Steam Electric Power	Mitchell	1,364	5,263	Move demands to Brown, Coleman and/or Coke Counties, Use water from Lakes Brownwood, Coleman, and Spence
Irrigation	Reagan	18,633	15,676	Improve irrigation practices to maximize benefit of existing supplies
Mining	Reagan	1,589	1,481	Use non-potable water from the Edwards-Trinity Plateau aquifer
County-Other	Reeves	71	86	Purchase additional supply from Pecos and Balmorhea
Irrigation	Reeves	39,164	35,607	Improve irrigation practices to maximize benefit of existing supplies
Mining	Reeves	175	115	Use non-potable water from the Cenozoic Pecos Alluvium aquifer
County-Other (Includes Ballinger And Winters)	Runnels	0	51	**Short-term** - Purchase Spence water and increase treatment capacity system and improve delivery of North Runnels WSC **Long-term** – Lake Ivie via Millersville-Doole, or water from Lake Coleman via North Runnels WSC
Manufacturing	Runnels	0	22	See Runnels County-Other
Eldorado	Schleicher	NA	NA	Develop new wells in Edwards-Trinity Aquifer
County-Other	Tom Green	175	946	Purchase water from San Angelo and Early
Irrigation	Tom Green	37,863	36,959	Improve irrigation practices to maximize benefit of existing supplies, plus enhanced use of treated effluent from San Angelo
San Angelo	Tom Green	887	6,288	Enhance system operation (Pump addition on the Spence/Ivie line), McCulloch well field development
Steam Electric Power	Tom Green	2,231	2,470	Use treated effluent from San Angelo
Irrigation	Upton	5,343	4,236	Improve irrigation practices to maximize benefit of existing supplies
Mining	Upton	1,817	1,319	Use water savings from irrigation practices to meet portion of needs. No other identified strategies
Irrigation	Ward	5,430	4,508	Improve irrigation practices to maximize benefit of existing supplies
Mining	Ward	635	194	Use non-potable water from the Cenozoic Pecos Alluvium aquifer
Steam Electric Power	Ward	1,580	6,782	Develop new well field in Winkler County

NA – Not Applicable, no needs were identified in supply-demand comparison

Table 5-22 List of Preferred General Strategies

Brush Control
Weather Modification
Wastewater Reuse
Recharge Enhancement
Desalination and Chloride Control

Table 5-23 List of Needs that cannot be met with Identified Strategies

Water user group	County	Unmet Need						Reason for unmet Need
		2000	2010	2020	2030	2040	2050	
Irrigation	Andrews	2,388	334	0	0	0	0	No economical source of water identified. Conservation could meet only portion of need.
Irrigation	Borden	8,709	8,093	7,476	7,456	7,438	7,420	No economical source of water identified. Conservation could meet only portion of need.
Irrigation	Glasscock	47,853	38,157	28,455	27,913	27,368	26,827	No economical source of water identified. Conservation could meet only portion of need.
Manufacturing	Kimble	957	0	0	0	0	0	Strategy cannot be implemented immediately.
Irrigation	Loving	258	258	258	258	258	258	Type of crop does not support more efficient irrigation systems. No other economical source of water identified.
Irrigation	Martin	333	0	0	0	0	0	Strategy cannot be implemented immediately.
Mining	Martin	928	0	0	0	0	0	Strategy cannot be implemented immediately
Irrigation	Midland	34,640	28,499	22,661	20,298	17,670	14,008	No economical source of water identified. Conservation could meet only portion of need.
Mining	Midland	669	318	159	80	26	0	Water supplies limited by availability. May be non-potable supplies that were not identified.
Irrigation	Reagan	18,633	9,790	944	183	0	0	No economical source of water identified. Conservation could meet only portion of need.
Irrigation	Reeves	39,164	33,312	27,463	26,574	25,684	24,795	No economical source of water identified. Conservation could meet only portion of need.
Irrigation	Tom Green	34,577	22,659	8,795	7,883	6,408	4,721	No other economical source of water identified. Conservation and wastewater reuse could meet only portion of need.
Irrigation	Upton	5,143	2,049	0	0	0	0	No economical source of water identified. Conservation could meet only portion of need in 2010.
Mining	Upton	1,787	1,269	130	0	0	0	Water supplies limited by availability. May be non-potable supplies that were not identified.
Irrigation	Ward	5,430	5,160	4,812	4,552	4,254	4,010	No economical source of water identified. Conservation could meet only portion of need.

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6.0 REGULATORY, ADMINISTRATIVE OR LEGISLATIVE RECOMMENDATIONS

6.1 Introduction

As Regional Water Planning Group F, (RWPG F), has proceeded through the preparation of the regional water supply plan, several items have been identified that RWPG F recommends be considered before the next planning cycle. Title 31 of the Texas Administrative Code (TAC) §357.7(a)(9) states that the SB1-sponsored regional water plans will include: "regulatory, administrative, or legislative recommendations that the regional water planning group believes are needed and desirable to: facilitate the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the state and regional water planning area." Following is a list of recommendations for the TWDB to consider.

6.2 Regulatory Issues

- *Regulatory guidance regarding naturally occurring radioactive materials.* A major issue in Region F is water from the Hickory aquifer, which in many locations contains naturally occurring radioactive materials that exceed current and anticipated future drinking water standards.

    a. Meeting drinking water standards for radioactive materials in areas relying on the Hickory aquifer will be a financial burden on an area that is already experiencing economic difficulties. Health risk modeling conducted by the EPA over the past decade has produced a questionable basis for the current and proposed standards. A moratorium on enforcement of current radionuclide standards and on adoption of new standards is recommended pending more research on the health hazards associated with radionuclides. If research supports higher allowable levels, new standards should be proposed and adopted.

b. In the event that additional research indicates treatment is required, there is currently no regulatory guidance regarding disposal of the waste products from this type of treatment. The lack of guidance effectively prevents consideration of the treatment of water for radionuclides because the disposal issues are unknown. It is recommended that TNRCC give this matter immediate attention, especially if radionuclide standards are to be enforced on those communities that depend on the Hickory aquifer for drinking water.

- *Reduction of required releases from Spence and Ivie during drought periods.* The current permits for Spence and Ivie Reservoirs require constant releases from the reservoirs. These releases have a significant impact on the yield of these reservoirs and the water quality in Ivie Reservoir by requiring releases of high-chloride water from Spence Reservoir. Since the releases are made regardless of inflow into the reservoir, they do not serve the purpose of maintaining natural conditions in the Colorado River. It is recommended that releases from Spence and Ivie be limited to the inflow into the reservoirs. When there is no inflow into the reservoirs, there would be no releases.
- *Use of supplies that exceed the Secondary Drinking Water Standards.* In Region F there are water supplies that meet primary drinking water standards, but exceed one or more secondary standard. In some cases, treatment to meet secondary standards may be costly and has little to no health benefits. It is recommended that the state allow, without prejudice, the development and use of water supplies that exceed Secondary Drinking Water Standards without mandatory treatment to bring the water into compliance with the standard.

- *Oil and gas operations threat to water supplies.*

  a. Improperly plugged oil and gas wells offer a significant threat to ground water and surface water supplies throughout the region. It is recommended that the Railroad Commission of Texas request increased funding of existing programs to identify improperly plugged wells and operator-abandoned oil and gas wells to ensure the proper plugging of these wells.

  b. It is recommended that the Railroad Commission of Texas strengthen existing rules to plug loopholes in regulations on abandoned wells. If Legislative action or funding is needed, the Railroad Commission should work with the Legislature to provide the necessary protection.

  c. It is recommended that the Railroad Commission of Texas review existing regulations and policy procedures for drilling and completing new oil and gas wells that penetrate potential water supply aquifer(s) to ensure adequate protection of fresh water supply. It is recommended that the state provide sufficient funding for Railroad Commission field inspectors to oversee drilling and surface cementing of such wells.

  d. It is recommended that the Railroad Commission develop plans to clean-up saltwater disposal pits. The program envisioned by RWPG F would be similar to the program to correct improperly plugged or abandoned wells.

6.3 Legislative Issues

- *State-sponsored water availability modeling.* It is recommended that the State of Texas give high priority to funding water availability modeling projects, including the water availability modeling projects sponsored under SB1 and the ground water availability projects sponsored by TWDB. This information is vital to the preparation of regional water plans. Particular emphasis should be placed upon areas where regional water plans have identified new surface water projects, new well fields, or areas that have insufficient information.

- *Support retaining the junior priority date for interbasin transfers of water.* SB1 required the TNRCC to complete water availability models for all of the river basins in Texas. As of this date the studies have not been completed for basins in Region F. Until good scientific information is available on how much water might be available for transfer, the junior priority date of interbasin transfers should remain in place. Also the new State Water Plan (2002) should be completed before changes are considered to this provision, which protects water rights holders in the basin of origin.

- *Brush control.* RWPG F recommends that the state of Texas provide funding to implement more brush control programs like the ones underway on the North Concho and proposed for the Middle Concho, South Concho, Spring Creek, Dove Creek, and Pecan Creek basins upstream from Twin Buttes Reservoir and the upper Colorado River basin upstream from the Spence and Ivie reservoirs. The programs should include money for monitoring and analysis of the impact on ground water and surface water supplies.

- *Ground water recharge enhancement.* RWPG F recommends that the state of Texas provide funding to implement the development and maintenance of ground water recharge enhancement structures that convert more surface water to ground water. The programs should include money for monitoring and analysis of the impact on ground water and surface water supplies. Impacts on surface water rights should be considered when locating recharge structures.

- *Weather modification.* RWPG F recommends expanded funding to continue and increase weather modifications projects. Weather modification increases precipitation by an average of 15 percent with some areas reporting even a greater increase. The programs should include money for the actual cloud seeding as well as analysis of the impact. Also, a review is needed on limitations of cloud seeding during National Weather Service storm warnings.

- *Irrigation and Municipal Conservation.* RWPG F recommends that the state of Texas provide funding through low interest loans or monetary incentives to implement advanced conservation technologies. These technologies require individual participation to implement. Education and financial incentives would result in higher adoption rates of such technologies.

- *Support the position that the State's preferred method of managing ground water resources is through locally controlled ground water districts.* In areas where ground water management is needed, districts could be created taking into consideration hydrological units (aquifers), sociological conditions, and political boundaries. Legislation developed for managing the beneficial use and conservation of ground water must be fair for all users. Rules and regulations must respect property rights and protect the right of the landowners to capture and market water within or outside of district boundaries. In addition, RWPG F recommends that the Legislature fund staffing of TWDB ground water specialist(s) at field offices around the state to coordinate research and field testing to provide a better understanding of ground water supplies, which would be used to carry out the intent of SB1.
- *Interim funding for regional water planning.* RWPG F recommends that the state of Texas provide interim funding for the regional water planning process to continue between 5-year planning cycles. The funds are needed for administration, maintenance and amendment of the regional water supply plan and the RWPG. Funds are also needed for continued public participation and information distribution.
- *Funding for administrative duties of SB1 process*. Currently the administrative costs of the regional planning process are provided from monies collected from participating counties and cities. It is unlikely that these entities will continue to fund these costs at the same level for future planning efforts. It is recommended that the State provide funding for required administrative costs, such as notices, printing, mailouts, travel expenses for RWPG members, etc.
- *Funding for implementation of water supply strategies and regulatory standards changes.* Many water supply strategies and proposed changes in regulatory standards require funding. It is recommended that the State sponsor programs to provide funds to implement these strategies and changes in regulatory standards.

This funding should include new supply development as well as strategies based solely on water quality considerations.

- *Funding for local supply improvements.* Many of the local supplies identified in the plan assumed supplies were available based on historical use (e.g., stock tanks). While many of these sources are available, some have high losses due to leaks and infiltration. It is recommended that the State sponsor programs to provide funds to improve the reliability of local supplies, such as lining of stock tanks.
- *Funding for on-going research.* It is recommended that the State fund on-going research for drought-tolerant crops and other drought related research.

6.4 Recommendations for Future State Water Plans

- *Grass roots regional water planning.* RWPG F supports the grass roots regional water planning process enacted by SB1 and strongly encourage the process be continued with appropriate funding.
- *Clarification of the significance of designating unique reservoir sites and stream segments.* It is recommended that the purpose of designating a unique stream segment or reservoir site be defined before the next planning cycle. The implications of such a designation are unclear. No designation of unique reservoir sites or unique stream segments should be accepted until the Legislature better defines the terms.
- *Allow development of alternative near-term scenarios.* Current planning rules require a single scenario be developed for meeting near-term needs. Since future permits must be consistent with the regional plan, a single State-approved scenario may hamper the ability of a water provider to make choices among viable sources of additional water supply.
- *Alternative definitions of the reliable supply from a reservoir.* The current water plan requires the use of firm yield as the definition of water availability in a reservoir. It is recommended that in future water plans the definition of supply

from a reservoir match the owner's operational criteria or definition of supply. For example, a reservoir that is used for steam-electric power generation must maintain a minimum pool level in order to effectively dissipate heat. Another example is the case where the water rights of a reservoir are less than the firm yield of the reservoir. In addition, many owners of reservoirs prefer to use the more conservative safe yield as the definition of reliable supply from their reservoirs to allow for more severe droughts than those experienced in the past.

- *Definition of available ground water supply.* The TWDB rules give no guidance for the definition of available annual supply from ground water supplies. Region F has defined ground water availability as annual recharge plus a portion of retrievable storage. Some regions have chosen to define ground water supply as the total amount of water in storage in an aquifer at any given point in the planning period. RWPG F recommends that available ground water supply be defined as the amount of water that can be withdrawn from an aquifer per year rather than the total recoverable quantity of water. This definition is consistent with the definition of annual supply from surface water supplies.

- *Separate water conservation from demand projections so conservation can be evaluated as a strategy.* Water conservation should be the number one strategy in any water supply plan. However, in the current planning cycle water conservation was automatically included in the demand projections as a demand reduction. This makes it very difficult to evaluate demand reduction strategies, since it is not clear how conservation strategies were applied in developing the demand projections. It has also been confusing for the RWPG members and members of the public who are involved in the planning process. The public often asked why water conservation is not being recommended because they are not aware that conservation has been included in the projections. It is recommended that in future plans water conservation be explicitly addressed as a strategy.

- *Develop mining demands for potable water only.* Currently mining demands are based on historical use. However, much of the supply for mining is non-potable water. This supply is typically not included as part of the region's available supply. Therefore, there are potential needs identified for mining that may not exist. It is recommended that for future water plans the demands for mining be limited to potable water demands only.

- *Clarification of the goals of regional drought contingency planning.* Although local drought contingency planning is critical to water resource management, historically drought contingency planning has not been part of regional water supply planning. Under current state guidelines, it is not clear what role drought contingency planning has in the regional planning process. Also, since one of the goals of drought contingency planning is demand reduction, it is particularly difficult to analyze conservation strategies because conservation is already included in the demand projections.
- *Simplification of required tables and better guidance for populating the tables.* The required tables outlined in Attachment B of the TWDB regional contracts were not available at the time that scopes and budgets were developed for the regional plans. Guidance for these tables did not appear until well into the planning process and, when it was available, the guidance did not sufficiently define what information was required in the tables. The tables require considerable effort to populate and are not an effective tool for the planning process. It is recommended that (a) the tables be simplified, (b) the guidance for these tables be clarified and (c) the TWDB provide draft versions of these tables for future water supply plans.
- *Allow complete access to TWDB and TNRCC database files by consultants.* Although the State did an excellent job assembling information for the regional plans in a short period of time, there remained a large amount of information that was not readily accessible by the consultants, including databases of historical water use by water right, historical return flows, and complete TWDB water survey information. It is recommended that a method be developed that allows complete access to these databases by contracted consultants in future water plans.

- *Water quality should play a more important role in future planning efforts.* Although there are some provisions for assessing water quality and its impact on available water quantity, the planning process makes it difficult to assess the use of water for a specific water use category. For example, although the firm yield of a surface water supply source is to be used for determining the available supply, that water source may not be suitable for all uses without specialized treatment. Additionally, localized ground water contamination may have an equally detrimental impact on the available supply of ground water for drinking water without significant treatment.

- *Data on agricultural water use.* It is recommended that the State sponsor voluntary information gathering programs that accurately measure number of irrigated acres, types of crops, and water used for irrigated agriculture, as well as water used for livestock production. Current information on water use by agriculture may not be sufficiently accurate for water planning. Precautions should be included to keep this data confidential and prevents this data from being used for any purpose other than water planning.

7.0 PLAN ADOPTION AND PUBLIC PARTICIPATION

This section describes the plan approval process for the Region F Water Plan and the efforts made to encourage public participation in the planning process. During the development of the regional water plan special efforts were made to inform the general public, water suppliers, and others with special interest in the planning process and to seek their input.

7.1 Regional Water Planning Group

As part of Senate Bill 1 regional water planning groups were formed to guide the planning process. These groups were comprised of local representatives of eleven specific interests:

- General public
- Counties
- Municipalities
- Industrial
- Agricultural
- Environmental
- Small businesses
- Electric generating utilities
- River authorities
- Water districts
- Water utilities

Table 7-1 lists the voting members of the Region F Water Planning Group, the interests they represent, and their counties. The Region F Water Planning Group also has non-voting members to represent counties that are not otherwise represented by voting members. Table 7-2 lists the non-voting members. The Region F Water Planning Group held regular meetings during the development of the plan, receiving information from the region's consultants and making decisions on planning efforts. These meetings were open to the public, and proper notice was made under Senate Bill 1 guidelines.

Table 7-1
Voting Members of the Region F Water Planning Group

Member	Interest	County
Aubrey Edwards	Public	Tom Green
Judge Marilyn Egan	Counties	Runnels
Judge Jeffrey Sutton	Counties	Crockett
Will Wilde	Municipalities	Tom Green
Len Wilson	Municipalities	Andrews
John Gayle	Municipalities	Scurry
John W. Lasiter	Industries	Ector
Larry M. Sanders	Industries	Ector
Kenneth Dierschke	Agricultural	Tom Green
John W. Jones	Agricultural	McCulloch
Frances S. Mertz	Environmental	Tom Green
Stuart Coleman	Small Business	Brown
Alvin Goodman	Electric Generating Utilities	Mitchell
Stephen Brown	River Authorities	Tom Green
John Grant	Water Districts	Howard
Scott Holland	Water Districts	Irion
Cindy Cawley	Water Districts	Schleicher
Richard Gist	Water Utilities	Brown
Ray Stoker	Other(s)	Ector
Steven Hofer	Other(s)	Midland
D.A. Harral	Other(s)	Pecos

Table 7-2
Non-Voting Members of the Region F Water Planning Group

Member	Interest	County
Ken Hensley	Counties	Borden
Winton Miliff	Counties	Coke
Wendell Moody	Counties	Concho
Gordon Hooper	Counties	Crane
Rick Harston	Counties	Glasscock
Charles L. Hagood	Counties	Kimble
Billy Hopper	Counties	Loving
Jim Hurlbut	Counties	Mason
Caroline Runge	Counties	Menard
Eugene Vinson	Counties	Reagan
Skeete Foster	Counties	Sterling
Joe David Ross	Counties	Sutton
Mac Jones	Counties	Winkler

7.2 Outreach to Water Suppliers and Regional Planning Groups

The Region F Water Planning Group made special efforts to contact municipalities, water districts, and rural water supply corporations and others in the region and obtain their input in the planning process. Appendix H contains copies of the questionnaires sent to County Judges, selected cities, rural water supply corporations, regional water suppliers, underground water conservation districts, steam electric power providers, and industries. The questionnaires sought information on population and water use projections, drought planning, water quality issues, and other water supply issues as well as questionnaires handed out at public meetings. The response rate for all questionnaire recipients was 37 percent, excluding the 54 responses from the public meeting questionnaire. The responses to these questionnaires were recorded in a database.

7.3 Outreach to the Public

7.3.1 Public Awareness Presentations

Members of the Region F Planning Group held a series of workshops focusing on groundwater and surface water issues in the planning process. The locations and dates of these meetings are given in Table 7-3. At these workshops presentations were made on the status of the plan and issues relating to ground or surface water users. Opportunities were given for members of the public to provide input on these issues or any other aspects of the plan.

Table 7.3
Public Awareness Presentations Made During this Region F Planning Process

Date	Location	Topic
February 23, 1999	Fort Stockton	Groundwater Supply Technical Workshop
February 23, 1999	Menard	Groundwater Supply Technical Workshop
March 30, 1999	Brownwood	Surface Water Supply Technical Workshop
March 30, 1999	Odessa	Surface Water Supply Technical Workshop
June 27, 2000	San Angelo	Groundwater Workshop

7.3.2 Media Outreach

Media outreach during development of the Region F plan included using a number of communications vehicles to keep the media, and hence the public, informed of the progress and activities of the Region F Water Planning Group:

- **Public meetings –** The media were invited via a printed Public Meeting Notice to attend the initial public meetings on July 13 and 14, 1998. Media were invited to attend the groundwater and surface water supply technical workshops in February and March 1999 and the population and water use projections on December 14 and 15, 1998.
- **Press releases and media advisories –** A press release was issued on August 23, 2000 to inform the public of the public hearings held on September 5 and 6, 2000.

The Region F Water Planning Group and its efforts have resulted in a significant amount of press coverage since February 1999. Appendix I includes copies of the press clippings for Region F.

7.3.3 Publication on the Web

In order to make the adopted *Region F Regional Water Plan* more accessible to the public, it is available on the Freese and Nichols web page, at http://www.freese.com/senbill/regionf/index.htm. Freese and Nichols, the Colorado River Municipal Water District and the Texas Water Development have all maintained web sites with information on the Region F planning process as planning proceeded.

7.4 Public Meetings and Public Hearings

7.4.1 Public Meetings

As required by Senate Bill 1 rules, the Region F Water Planning Group held initial public meetings to discuss the planning process and the scope of work for the region on July 13, 1998 in Odessa and July 14, 1998 in San Angelo. Presentations were made on the planning process and input was solicited from participants.

In December of 1999, the water planning group held an additional set of public meetings to discuss the planning effort, present population and water use projections, and encourage public feedback. These meetings were held at the following locations:

- December 14, Brady
- December 15, Pecos.

Presentations were made on the planning effort to date and input was solicited from participants.

7.4.2 Public Hearing on the Draft Initially Prepared Plans

On July 31, 2000 copies of the draft *Initially Prepared Region F Water Plan* were mailed to Region F county courthouses and libraries for public review. Copies of the draft plan were also posted on the Region F website, and additional hard copies were made available to interested parties. Notices of the upcoming public meetings were sent to the Secretary of State, county clerks, county judges, regional legislators, groundwater and irrigation districts, and regional newspapers along with a description of how to obtain copies of the draft plan for review.

On September 5 and 6, 2000, the Region F Water Planning Group held public meetings in San Angelo and Odessa to present the draft *Initially Prepared Region F Water Plan* and seek public input. Oral comments were received following the presentation and written comments were accepted through September 11, 2000. All public comments received during the comment period are documented in Appendix J. Where appropriate, modifications to the plan were made and incorporated into the adopted *Regional Water Plan*.

7.5 Plan Implementation Issues

Implementation issues identified for the Region F *Regional Water Plan* include: 1) financial issues associated with paying for the proposed capital improvements, 2) identification of the governing authorities for general regional strategies such as brush control, recharge enhancement and weather modification, 3) cooperation between entities to implement regional strategies, 4) public acceptance of selected strategies, and 5) public participation in water conservation measures that were assumed in this plan.

7.5.1 Financial Issues

It is assumed that the entities for which strategies were developed will utilize existing financial resources, incur debt through bond sales and/or receive state-supported financial assistance. Most likely the funding of identified strategies will increase the cost of water to the customers. The economic feasibility to implement the strategies will depend on the cost increases the customer base can assume. Some strategies may not be able to be implemented without state assistance.

7.5.2 Governing Authorities

In Region F there are identified governing authorities for many of the preferred strategies discussed in Section 5.10. However, for general strategies, such as brush control or weather modification, no governing authority has been identified. As part of the feasibility of these strategies for Region F, a governing authority will need to be identified to implement such strategies.

7.5.3 Regional Cooperation

One of the major water issues for the region involves the potential loss of the Hickory Aquifer for municipal water supply. This will affect both cities and smaller communities in Concho and McCulloch Counties, and possibly surrounding counties. The strategies identified to replace and/or supplement existing supplies from the Hickory will require regional cooperation between the identified users to jointly execute them.

7.5.4 Public Acceptance

Some of the strategies identified for water supply include using water of possibly lesser quality than current supplies. While the overall quality of water meets drinking water standards, the public may object to mixing water of different qualities.

7.5.5 Water Conservation

The projected demands developed for this plan include a significant level of conservation to be implemented over the planning period. These assumed demand reductions were applied to municipal, manufacturing and agricultural water uses. Some of the demand reductions will occur simply through improvements in technology and installation of water-efficient plumbing fixtures as older, less efficient fixtures are replaced. However, a moderate level of public participation is required to fully realize the expected conservation. If the conservation is less than expected, then there may be additional shortages that were not identified in this plan.

Appendix H

Questionnaires

Appendix I

Press Clippings

Appendix J

Public Comments