Llano Estacado Regional Water Planning Area

Regional Water Plan

Prepared for

Texas Water Development Board

Prepared by

Llano Estacado Regional Water Planning Group

With administration by

High Plains Underground Water Conservation District No. 1

With technical assistance by

HDR Engineering, Inc.
Austin, Texas

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Llano Estacado Regional Water Plan

Executive Summary

Background

In 1997, Senate Bill 1 was enacted by the 75th Texas Legislature, which specified that near and long-term water plans be developed for regions of Texas. Senate Bill 1 also provided that future regulatory and financing decisions of the Texas Natural Resource Conservation Commission (TNRCC) and the Texas Water Development Board (TWDB) be consistent with approved regional plans. As stated in Senate Bill 1, the purpose of this regional planning effort is to:

> "Provide for the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of that particular region."

The TWDB is the state agency designated to coordinate the overall statewide planning effort. The TWDB divided the state into 16 planning regions. In the South Plains of Texas, a 21-county area was delineated by the TWDB as Planning Area O, which was subsequently named the Llano Estacado Regional Water Planning Region (herein referred to as the Llano Estacado Region). The counties of the region are:

1. Bailey
2. Briscoe
3. Castro
4. Cochran
5. Crosby
6. Dawson
7. Deaf Smith
8. Dickens
9. Floyd
10. Gaines
11. Garza
12. Hale
13. Hockley
14. Lamb
15. Lubbock
16. Lynn
17. Motley
18. Parmer
19. Swisher
20. Terry
21. Yoakum

The Llano Estacado Region 21 member Water Planning Group (LERWPG) was appointed by the TWDB to represent 11 stakeholder interests (Public, Counties, Municipalities, Industries, Agricultural, Environmental, Small Businesses, Electric Generating Utilities, River Authorities, Water Districts, and Water Utilities) and act as the steering and decision-making body of the regional planning effort. The planning group members and affiliations are listed below.

Voting Members

A. Wayne Wyatt, Chair, Deceased — High Plains Underground Water Conservation District

John Abernathy — Texas Tech University, Agricultural Science

H.P. Brown, Jr., Vice Chair — Attorney/Farmer/Rancher/Feedlot

Lee Arrington, Vice-Chair — Resigned

Delaine Baucum — Valley Irrigation and Pump

Bruce Blalack — City of Lubbock

Dallas Brewer — Yoakum County Judge

Ches Carthel — Sec/Tres & Engineer, City of Lubbock

Delmon Ellison, Jr. — Farmer

John Garland — Brazos River Authority

Bill Harbin — Golden Spread Co-op

Bob Josserand — Mayor of Hereford

Richard Leonard — Farmer

Don McElroy — Irrigation Pumps and Power

E.W. (Gene) Montgomery — Altura Energy Ltd.

Henry Rieff — Cotton Center WSC

Kent Satterwhite — Canadian River MWA

Jim Steiert — Quality Hunts

S.M. True, Jr. — Farmer

Lloyd Urban — Texas Tech University, WRI

Jerry Webster — City of Tahoka

Non-voting Members

Karen Leslie — Texas Parks and Wildlife Department

Ronald Bertrand — Texas Department of Agriculture

Joe Bragg — Texas Natural Resource Conservation Commission

Mickey Black — USDA, Natural Resource Conservation Service

Stefan Schuster — Texas Water Development Board

The LERWPG adopted the following Mission Statement:

> "Develop, promote, and implement water conservation, augmentation, and management strategies to provide adequate water supplies for the Llano Estacado Regional Water Planning Area of the High Plains of Texas and to stabilize or improve the economic and social viability and longevity of the region through these activities."

The Group designated the High Plains Underground Water Conservation District No. 1 as the political subdivision to act as principal contractor to apply for and administer a grant from the TWDB to develop the Water Plan. The prime planning and engineering consultant is HDR Engineering, Inc.

The planning horizon to be used is the 50-year period from 2000 to 2050. This planning period allows for a long-term forecast of the projected water supplies sufficiently in advance of needs to allow for appropriate management measures to be implemented to meet these needs. As required in Senate Bill 1, the TWDB specified planning rules and guidelines (31 TAC §357.7 and §357.12) to focus the efforts and to provide for general consistency among the regions so that the regional plans can then be aggregated into an overall State Water Plan by January 2002. Besides specifying overall report and data formats, the TWDB rules also require the maximum use of existing state water planning information, except where better information can be developed or provided. Where regions share common water issues, Senate Bill 1 and TWDB have provided for coordination mechanisms among the regions.

The LERWPG has developed a regional water plan to serve the needs of the region during all types of weather, but specifically to meet the water needs during drought. Since there is little opportunity to increase the region's water supplies through conventional water development, emphasis has been placed upon water management strategies to increase efficiency of water use in irrigation, and to augment regional supplies through precipitation enhancement and brush management. All of these strategies are aimed directly at sustaining the region's existing groundwater reserves as far into the future as possible.

With wholehearted support by the region's people and leaders, the water plan that follows can sustain the Llano Estacado Region into the future for an indefinite number of decades.

Description of the Region

The Llano Estacado Region is made up of 21 counties and contains 20,294 square miles (about 7.5 percent) of the state's land area. Although the region is located in the upstream parts of four major river basins (Canadian, Red, Brazos, and Colorado), almost no surface water leaves the region as runoff into these rivers. Of the 20,294 total square miles covered by the area, 94 square miles are located in the Canadian Basin, 6,681 square miles are located in the Red Basin, 8,732 square miles are located in the Brazos Basin, and 4,787 square miles are located in the Colorado Basin. The 21 counties in the planning region comprise about 8.3 percent of the 254 counties in Texas. The regional population of 447,781 represents about 2.3 percent of the state total population of about 19.6 million persons in 1998.[1]

Climate

The climate of the Llano Estacado Region is classified as a dry, steppe type. The region is characterized as semi-arid, with a wide range in temperatures. In an average year, about 80 percent of the annual rainfall occurs during the warm season (May through October). Monthly rainfall quantities ordinarily decline markedly in the colder months of the year, when frequent periods of cold, dry air from North American polar regions surge southward and cut off the supply of moisture from the Gulf of Mexico. The long-term average (1945 through 1997) precipitation received in the region is 18.4 inches. The average ranges from a high of 22 inches per year in a small area in Crosby County, to a low of about 16 inches in Cochran County in the southwestern portion of the region.

Land

Land elevations in the region generally range from about 1,900 feet-mean sea level (ft-msl) in the southeast to 4,300 ft-msl in the northwest. The plateau of the Southern High Plains contains many shallow depressions, or playa basins, a few of which hold water more or less permanently. There is broken terrain in the northwest corner of the planning region and on the eastern side of the planning region, which is a part of the Rolling Plains physiographic region, below the "caprock" escarpment. There are 15 general soil types in the region, 80 to 85 percent

[1] Texas State Data Center, Texas State Population Estimates and Projections, Texas A&M University, College Station, TX, March 1998.

of which are suitable for irrigation. About 57 percent of the 20,294 square miles of land area in the planning region is in cropland, approximately one-third of which is irrigated. The major irrigated crops are cotton, corn, grain sorghum, wheat, vegetables, peanuts, and soybeans.

Water

Riverine (fluvial) sand, clay, silts, and gravel sediments of the geologic Miocene/Pliocene age Ogallala Formation underlies the majority of the region. The Ogallala Formation of Pliocene age houses the principal aquifer in the Llano Estacado Region.[2] The Ogallala Formation rests upon the eroded surface of the underlying Triassic and Cretaceous rocks and consists of beds and lenses of clay, silt, sand, and gravel. In general, the Ogallala Formation is thicker in the northern part of the area, with the thickness ranging from 400 to 500 feet in central Parmer, west-central Castro, and southwestern Floyd Counties, to a knife edge where the formation wedges out against outcrops of older rocks. Erosion has almost completely isolated the formation so that the segment in southeastern New Mexico and the Southern High Plains of Texas is cut off in all directions from any underground connection with other water-bearing beds, except through the underlying older rocks, which contain highly mineralized water, unlike the fresh water in the Ogallala.

Generally, the water in the Ogallala occurs under water-table conditions, although locally it may be under slight artesian pressure. The water in the Ogallala occupies the pore spaces and voids in the unconsolidated sediments and occurs between the water-table and the underlying older rocks. The thickness of the zone of saturation varies throughout the region, chiefly because of the uneven nature of the bedrock surface. Within the region, the saturated thickness ranges from less than 1 foot to more than 200 feet.

The transmissivity of the Ogallala Formation ranges rather widely. Tests, both in the laboratory and in the field, indicate an average specific gravity yield of about 15 percent. The movement of water in the formation is generally from the northwest to the southeast. The rate of movement of water in the formation has been estimated to be about 150 feet per year on a gradient of 10 feet per mile.

Fluctuations of the water-table in the Ogallala Formation chiefly represent changes in the amount of water in storage. The long-term change in the water table throughout the region has

[2] High Plains Underground Water Conservation District No. 1, Lubbock, Texas, December 1998.

generally been a decline; however, in recent years the water table has stabilized or risen in some parts of the region. Water level rises in 11 of the 21 counties in the Llano Estacado Region from 1985 to 1995 indicate that more water was in storage in 1995 than in 1985 in these counties.

The principal source of recharge to the Ogallala Formation in the Llano Estacado Region is precipitation on the land surface. The amount of recharge depends on many factors, including the amount, distribution, and intensity of precipitation and the type of soil and vegetative cover. The amount of recharge has been estimated at from less than .5 inch annually to about 3 inches annually. One-half inch of recharge on the 12,988,160 acres of the region would equal 541,173 acre-feet (acft) of water, while 3 inches of recharge would equal about 3,247,040 acft of water. The water in the Ogallala Formation in the Llano Estacado Region is of good chemical quality, except that it is "hard", due to high levels of calcium and magnesium.

Precipitation is the only naturally reoccurring/renewable water supply for the Llano Estacado Region. The average annual precipitation received in the region is 18.4 inches (1945 through 1997), which would be 19,915,179 acft of water over the 12,988,160-acre region. Precipitation meets about 60 percent of urban landscape water and irrigated crop demands. It provides all the water for surface reservoirs and all the water for rangeland and dryland crop production. Precipitation also provides water for wildlife and natural recharge to the region's aquifers.

There are an estimated 20,000 playa basins on the entire High Plains of Texas, of which approximately 14,000 are located within the Llano Estacado Region.[3] Playas comprise approximately 2 percent of the total land surface. The majority of playa basins are ephemeral, holding water only during and for a short period of time after rains. Some of the dry playas are planted to crops, some are left fallow, and some are grazed. Approximately 70 percent of playas are modified with pits to recover rainfall runoff for irrigation or to create a water reserve for grazing livestock or wildlife when the bulk of the water collected in the basin from rainfall runoff has soaked into the soil or evaporated.

Vegetation

The original vegetation of the High Plains was classified as mixed prairie, shortgrass prairie, and, in some locations on deep, sandy soils, tallgrass prairie. Blue grama, buffalograss,

[3] Guthery, F.S., F.C. Bryant, B. Kramer, A. Stoecker, and M. Dvoracek, "Playa Assessment Study," U.S. Water and Power Resources Service, Southwest Region, Amarillo, Texas, 1981.

and galleta were the principal natural vegetation on the clay and clay loam soils. Characteristic grasses that were on sandy loam soils are little bluestem, western wheatgrass, sideoats grama, and sand dropseed.

The High Plains area was characteristically free from brush, but sand sagebrush, along with pricklypear and yucca, have invaded the ranchland that has sandy and sandy loam soils. Honey mesquite has invaded the ranchland on most soils in the region. Several grass species of dropseeds are abundant on land containing coarse sandy soils. The playa depressions, which can contain several feet of water after heavy rains, support unique patterns of vegetation within their confines. Various aquatic species, such as curltop smartweed, are associated with the playa basins.

Wildlife

Virtually all wildlife habitats in the High Plains are on privately owned farms and ranchland. Quail and mourning dove are abundant, and whitetail deer, mule deer, turkey, and exotic aoudad sheep provide hunting along the breaks and canyons of the caprock. Many playa basins and feedyard lagoons provide migratory waterfowl habitat, with as many as 2 million waterfowl and 350,000 to 400,000 sandhill cranes using playa lakes as wintering areas or as rest stops during annual migrations.[4] Pheasants are an economically important gamebird in irrigated areas, but their numbers tend to fluctuate widely with weather and habitat conditions.

In the region, approximately 25 wildlife species are listed by the Texas Parks and Wildlife Department as endangered, threatened, or just rare with no official listing. The list includes the Arkansas River Shiner and the Texas Horned Lizard.

Population

Since 1900, the area's population has grown from 11,418 to approximately 447,781 in 1998. In 1990, the age distribution across the region was fairly uniform from county to county.[5] The two age groups that include the highest percentage of the population in 1990 are from 5 to 14 years of age (18.2 percent of the population) and age 60 and above (19.3 percent).

[4] Ibid.
[5] 1990 U.S. Census of Population and Housing, U.S. Department of Commerce, Washington, D.C., 1991.

Economy

The region's economic base is agricultural crop and livestock production, with significant contributions from manufacturing, oil and gas, and trades and services, such as wholesale and retail trade, and finance, insurance, legal, advertising, medical, personnel, research, entertainment, repair services, and higher education. Agricultural processing, oilfield equipment, and electronics form the core of the region's manufacturing base. Beef cattle and cotton are the dominant agricultural enterprises, although peanuts, wheat, grain sorghum, vegetables, and oilseed crops are significant contributors to the region's economy. Cotton is the leading crop produced in the Llano Estacado Region, with an annual value of about $871 million, which is about 60 percent of the annual value of cotton grown in Texas annually.[6]

The region produces 16 percent of the state's grain sorghum, or approximately 29.3 million bushels per year. In 1997, value of grain sorghum production in the area was approximately $73 million.[7]

Approximately 25 percent of the state's corn crop (approximately 60 million bushels) is grown in the Llano Estacado Region.[8] Corn contributes approximately $169 million annually to the region's economy, second only to cotton.

In 1997, 2.2 million bushels of soybeans with a value of $15.1 million were grown in the Llano Estacado Region. Soybeans are frequently planted in the region as an alternative cash crop if hail destroys cotton; however, soybeans are not a dryland crop.

Peanut production is relatively new to the Llano Estacado Region, with peanut production having become a valuable crop for the region during the past 20 years. The Western Peanut Growers Association reports that the area now produces about 75 percent of the state's peanut crop. According to data provided by the Western Peanut Growers Association, value of production in 1997 was $107.8 million.

[6] 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997."
[7] Ibid.
[8] Ibid.

The 1997 Census of Agriculture indicates that while irrigated lands comprise about 2.7 million acres (37 percent) of the cropland in the region, irrigation is responsible for $915 million in value of farm sales, or about 75 percent of the value of major crop production. All crops (irrigated plus dryland) grown in the Llano Estacado Region had a market value of over $1.2 billion in 1997. With a multiplier of 2.87, the total business effect of crop production in the Llano Estacado Region is estimated at $3.44 billion.

During the last 25 to 30 years, the South Plains of Texas observed the development of confined feeding of cattle to finish weights before slaughter. Fed cattle marketing in Texas in 1960 was 477,000 head and by 1998 had increased to 6.06 million head. Of the 142 cattle feedlots in the state, 69, or 49 percent, are located in the Llano Estacado Region. In 1998, these 69 Llano Estacado Region feedlots marketed over 3.39 million head, or about $2.2 billion (1999 prices) of fed cattle. With a multiplier of 2.49, this primary production has an economy-wide business effect of over $6.27 billion annually. Feedyards of the Llano Estacado Region employ about 2,000 people, with an economy-wide effect of an additional 3,600 jobs, or a total employment effect of 5,600.

The first oil discoveries made in the High Plains Region occurred during the early 1920s, and by 1926 the High Plains was a major oil- and gas-producing region. In the late 1990s, the production of oil and gas in the Llano Estacado Region contributed over $2 billion per year (1999 prices) to the economy.

In 1992, the region's 480 manufacturing establishments contributed over $1.3 billion to the region's economy in value of shipments and provided over 8,800 jobs with an annual payroll of over $200 million. The leading types of manufacturing in the region are food and kindred products, agricultural and industrial machinery and equipment, printing and publishing, and fabricated metal products.

Wholesale trade, retail trade, services, finance, insurance, and real estate sectors have gross value of sales and billings of about $1.8 billion annually and employ about 70,000.

Water Agencies

There are two federal water agencies, three state water agencies, three water supply authorities and districts, and six underground water conservation districts in operation in the Llano Estacado Region at the present time. The federal and state agencies perform regulatory and development functions, while the underground water conservation districts were organized to conserve, preserve, protect, recharge, and prevent waste of the underground water.

Projections of Population and Water Demands

Population Projections

The population of the Llano Estacado Region was estimated at 447,781 in 1998 and is projected to be 586,156 in 2050. Nearly 80 percent of the population of the region is projected to reside in the Brazos River Basin. The population projections for 53 individual cities, rural areas of each county, and parts of a county in each river basin area of the region were tabulated for use in developing the regional water plan.

Water Demand Projections

For planning purposes, municipal water demand includes residential and commercial water uses. Commercial water use includes business establishments and public offices and institutions. Residential and commercial uses are categorized together because they are similar types of uses (i.e., they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering). Although per capita water use, in gallons per person per day, is projected to decline over the planning period, the projected increase in population is expected to cause municipal water demand to increase by 13.4 percent over the planning period. Total municipal water use in the Llano Estacado Region in 1990 was 81,608 acft/yr. Projected municipal water demand for the region is projected to be 92,529 acft/yr in 2050.

The Llano Estacado Region's major water using manufacturing sectors are food processing, industrial machinery and equipment, and fabricated metals. These industries used 8,494 acft of water in 1990 and are projected to have a demand of 15,697 acft/yr in 2050. Only three counties (Lamb, Lubbock, and Yoakum) of the Llano Estacado Region currently use or are projected to use water in steam-electric power production during the planning period. In 1990, 14,302 acft of water was used for steam-electric power generation; and by the year 2050, it is estimated that 37,200 acft of water will be needed for the production of steam-electric power.

In the Llano Estacado Region, the principal uses of water for mining are for recovery of crude petroleum and for sand and gravel washing. In the region, mining water demand is projected to reach a peak of 30,384 acft in 2000, followed by a decline to 11,824 acft in 2050. Overall, water use in this sector is expected to decline by 61 percent by 2050, due to the fact that the present "water flood" technology will no longer be used, since many of the oil fields of the region will have reached their economic limit, suspended operations, and plugged wells. The continuation of the industry in the region will hinge on new technologies to recover the oil remaining in the reservoirs.

The Texas Water Development Board (TWDB) irrigation water use data show annual use for irrigation in the Llano Estacado Region in 1990 of 3,657,740 acft, or 37 percent of the total irrigation water use in Texas in 1990. Projected irrigation water demands for the region in 2050 are 2,562,079 acft, or 30 percent less than in 1990. The projected decrease is based upon increased irrigation efficiency, declining well yields due to the thinning of the aquifer in some areas, economic factors, and reduced government programs affecting the profitability of irrigated agriculture.

Total livestock water demand projections for the Llano Estacado Region are the sum of water demand projections for beef cattle feedlots, swine feedlots, dairies, horses, range beef cows/bulls, range beef stocker cattle, sheep, and poultry. Total livestock water use in 1990 was estimated to be 36,492 acft. Total livestock water demand for the region is projected to be 73,671 acft/yr in 2050.

Total water use in the Llano Estacado Region was 3,813,487 acft in 1990, with projected 2050 water demands of 2,793,000 acft. The quantity of projected water demands in 2050 are 117 acft/yr for the Canadian River Basin, 611,129 acft/yr for the Red River Basin, 1,690,102 acft/yr for the Brazos River Basin, and 491,652 acft/yr for the Colorado River Basin.

Major Water Providers

The TWDB's definition of a Major Water Provider (MWP) is as follows:

> "A MWP 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."

At its meeting on April 22, 1999 the LERWPG identified the MWPs for the Llano Estacado Region. The list of MWPs for the Llano Estacado Region and the cities within the region to which they provide water is as follows:

Canadian River Municipal Water Authority (CRMWA)

1) City of Brownfield
2) City of Lamesa
3) City of Levelland
4) City of Lubbock
5) City of O'Donnell
6) City of Plainview
7) City of Slaton
8) City of Tahoka

White River Municipal Water District (WRMWD)

1) City of Crosbyton
2) City of Post
3) City of Ralls
4) City of Spur

Mackenzie Municipal Water Authority (MMWA)

1) City of Floydada
2) City of Lockney
3) City of Silverton
4) City of Tulia

Water supply and demand comparisons for CRMWA and WRMWD show that each has a surplus, thus no plan is needed. The water supply data for Lake Mackenzie indicates that the lake has a firm yield of 5,200 acft/yr, but Mackenzie Municipal Water Authority indicates it can supply only about 40 percent of this, or 2,080 acft/yr. Based upon this information, the quantity that was actually supplied to customers during the past 5 years (only 869 acft/yr), is included in this plan as supply from Lake Mackenzie for MMWA members. The remainder of each respective member's demands is to be met from each city's own groundwater sources and facilities.

Water Supplies and Water Needs

Water Supplies Available During the Drought of Record

Two major and two minor aquifers supply water to the area. The two major aquifers are the Ogallala and Seymour Aquifers. The two minor aquifers are the Edwards-Trinity (High

Plains) and the Dockum. In addition, four reservoirs located within or near the region supply water for municipal and industrial uses within the region. These four reservoirs are Lake Meredith, located in the Canadian River Basin to the north of the Llano Estacado Region, Mackenzie Reservoir located in the Red River Basin in Swisher and Briscoe Counties, White River Reservoir located in the Brazos River Basin in the southeast corner of Crosby County, and Alan Henry Reservoir located on the Double Mountain Fork of the Brazos River in Garza and Kent Counties.

For purposes of this regional planning project, and in accordance with TWDB Rules, water supply projections and needs projections were calculated by river basin, county or part of county located within the river basin, and city and rural areas of each county or part of county. Estimates were made of the quantities of water available within each county at each decadal planning date. The supplies are the quantifier available during the drought of record (firm yield for reservoirs and quantity that can be obtained from groundwater). These projected water supplies were then compared to projected water demands, and if demands exceeded supplies available, then the differences were shown as the measure of "water needs for that county, river basin and water user group." The user groups listed in Table ES-1 were projected to have needs (shortages) during the year 2000 to 2050 planning period.

Section 357.7(4) of the rules for implementing Senate Bill 1 require that the social and economic impact of not meeting regional water supply needs be evaluated by the Regional Water Planning Groups (RWPG). At the request of the Llano Estacado Regional Water Planning Group, the TWDB performed the required analyses.

The purpose of this element of Senate Bill 1 planning is to provide an estimate of the social and economic importance of meeting projected water needs, or conversely, provides estimates of potential costs of not meeting projected needs of each water user group. The social and economic effects of not meeting a projected water need can be viewed as the potential benefit to be gained from implementing a strategy to meet the particular need. The summation of all the impacts gives a view of the ultimate magnitude of the impacts caused by not meeting all of the projected needs.

The projected total water demands for the Llano Estacado Region decrease from 3.26 million acre-feet in 2000 to 2.96 million acre-feet in 2030, and 2.79 million acre-feet in 2050. The main reason for the projected decrease in water demand is the effect of reduced government programs and increased irrigation water conservation. Under historic drought of record water supply conditions, and with no water management strategies in place, water shortages would amount to 172 thousand acft/yr in 2000, increasing to 195 thousand acft/yr in 2030 and to 202 thousand acft/yr by 2050.

The water needs (shortages) of the region amount to about 6 percent of the projected demand by 2020, increasing to 7 percent of demand in 2040 and 2050. This means that by 2050 the region would be able to supply only 93 percent of the projected water demands unless supply development or other water management strategies are implemented.

The Llano Estacado Regional Water Planning Group identified 38 individual water user groups which showed an unmet need during drought-of-record supply conditions for each decade from 2000 to 2050. Of the 21 counties of the Llano Estacado Region, 17 have water user groups with projected water needs (shortages).

The estimated effect of water shortages projected for the Llano Estacado Region upon gross value of business, which includes the direct and indirect effects, are $140.7 million/yr in 2010, $1.4 billion/yr in 2030, and $1.6 billion/yr in 2050. The largest percentage of the economic and social impacts of unmet water needs in the Llano Estacado Region result from municipal water shortages. In 2030, municipalities have unmet needs of 13,261 thousand acre-feet, 6.8 percent of the total unmet needs. The economic impacts of this shortage (19 thousand jobs, $1.36 billion in output, and $501.9 million of income) represent approximately 60 to 70 percent of the total impacts. By 2050, unmet municipal needs total 14,599 thousand acre-feet (7.2 percent of the total) resulting in 21 thousand jobs not created, and reductions of $1.5 billion in potential output and $550.7 million in potential income.

Unmet irrigation needs represent the largest category of need through 2050, but, due to the relatively small value of economic output added per acre-foot, the impacts of not meeting irrigation needs are considerably less. In 2010, irrigation has unmet needs of 173 thousand acre-feet, 99 percent of the total. The economic impacts of the shortage (645 direct and indirect jobs, $58.5 million in output, and $11.8 million in income) represent 30 to 40 percent of the total economic impact. If the water needs are left entirely unmet, the level of shortage in 2010 results in 1,788 fewer jobs than would be expected if the water needs of 2010 are fully met. The gap in job growth due to water shortages grows to 20 thousand by 2030, and to 22 thousand by 2050.

Table ES-1. Water User Groups with Projected Shortages
Llano Estacado Region

City (County)	Year Shortage Develops	Shortage in 2050 (acft/yr)
Dimmitt (Castro)	2030	1,270
Hart (Castro)	2040	310
Morton (Cochran)	2020	653
Whiteface (Cochran)	2030	74
Hereford (Deaf Smith)	2030	2,717
Lockney (Floyd)	2030	140
Seagraves (Gaines)	2010	533
Abernathy (Hale)	2020	405
Cotton Center (Hale)	2006	71
Hale Center (Hale)	2040	384
Anton (Hockley)	2010	237
Sundown (Hockley)	2020	473
Amherst (Lamb)	2030	102
Earth (Lamb)	2030	343
Olton (Lamb)	2020	617
Sudan (Lamb)	2020	319
Abernathy (Lubbock)	2020	195
Idalou (Lubbock)	2020	543
New Deal (Lubbock)	2020	110
Shallowater (Lubbock)	2020	281
Wolfforth (Lubbock)	2020	494
Wilson (Lynn)	2030	42
Friona (Parmer)	2030	1,137
Bovina (Parmer)	2020	441
Farwell (Parmer)	2020	562
Kress (Swisher)	2010	59
Denver City (Yoakum)	2030	1,657
Plains (Yoakum)	2020	501
Total		**14,670**

County	Year Shortage Develops	Shortage in 2050 (acft/yr)
Irrigation Shortages		
Bailey	2000	925
Castro	2000	33,528
Cochran	2000	7,129
Crosby	2000	0
Floyd	2000	23,060
Garza	2000	0
Hale	2000	12,995
Hockley	2000	0
Parmer	2000	64,700
Swisher	2000	43,862
Terry	2000	1,406
Total		**187,605**

In the analyses summarized above, the emphasis is upon the effects of not meeting projected water shortages. More importantly, however, is knowledge about the value of a full and dependable water supply for the Llano Estacado 21-county region, since irrigation in the region accounts for 60 percent of the state's cotton production, 16 percent of the state's grain sorghum production, 25 percent of the state's corn production, 75 percent of the state's peanut production, and 50 percent of the state's fed cattle. Livestock require more water during periods of drought, which generally occur during summer months when temperatures are above normal with very low relative humidity. A shortage of water available to livestock would result in death of livestock, sickness, loss of body weight, and reduced volumes of beef for local, state, and national markets. In addition to the value of food and fiber produced in the region, irrigation farming is big business. The average size farm in the region is about 2,000 acres, with production costs ranging from $250 to $350 per acre, or $500,000 to $700,000 per farm per year. A water shortage to an irrigated farm of the region would be severely detrimental to the regional, state, and national economies.

Groundwater Modeling for the Southern High Plains – Texas Tech University Water Resources Center

A MODFLOW computer model was developed for the Llano Estacado Water Planning Region. The model has a grid of one cell per square mile, and is calibrated to water level contour maps constructed by the High Plains Underground Water Conservation District Number 1 for the District Counties for 1985 and 1995, and similar maps for other counties of the Region prepared by HDR Engineering, Inc. The purpose of the modeling study was to develop a tool that can be used to project changes in aquifer storage caused by withdrawal and recharge to the aquifer, compute volume of water in storage for each county, and construct detailed maps of saturated thickness of the Ogallala formation.

A summary of the baseline simulation is included as Appendix E. The baseline simulation illustrates the potential effects of groundwater pumpage using TWDB water demand projections for the Llano Estacado Water Planning Region. The simulated results are shown for each county and for each decade from year 2000 to year 2050. Simulation for other water demand scenarios are in progress and will be included in the final groundwater modeling report.

Llano Estacado Regional Water Plan

In Section 1 of the Llano Estacado Regional Water Plan, the Llano Estacado Region is described. In Section 2 projections of population and water demand are presented. In Section 3, existing water supplies are tabulated, and in Section 4, the projected water demands of Section 2 are compared with the existing water supplies of Section 3, and shortages or needs for additional supplies are calculated. Section 5 provides water management strategies and Section 6 provides legislative recommendations.

The Llano Estacado Regional Water Planning Group identified the following 17 water management strategies as potential strategies to meet the projected needs of the region:

Short-term Water Management Strategies (2000 to 2030)

- Water Supply from Nearby Groundwater Sources for Cities Projected to Need Additional Municipal Water Supply
- Interconnect Cities and Feedlots (Source of Groundwater to Include Hartley and Roberts Counties – Maximum Delivery Rate of 52,000 acft/yr)
- Precipitation Enhancement/Weather Modification
- Brush Control
- Desalt Brackish Groundwater
- Reuse of Municipal Effluent
- Municipal Water Conservation
- Irrigation Water Conservation
- Agricultural Water Conservation Practices of Farms
- Recovery of Capillary Water
- Cistern Well Construction
- Post Reservoir – Raw Water at the Reservoir
- Research and Development of Drought Tolerant Crops and New Technology

Long-term Water Management Strategies (2031 to 2050)

- Interconnect Cities and Industries (Sources of Water to Include Lake Alan Henry and Post Reservoir)
- Import Water
- Reuse of Municipal Effluent for Potable Supply
- Stormwater Capture, Treatment, and Use

Water management strategies selected to be included in the plan to meet the needs of specific water user groups include local groundwater development for municipalities and irrigation water conservation for irrigators, while strategies that are not specific to a particular water user group, but instead are region-wide strategies include precipitation enhancement and brush control.

The proposed plan to meet the specific short-term needs of cities located within the region is to develop additional groundwater supplies located as near as possible to each respective city. Each city with a projected need should gradually increase the number of existing wells and/or expand their well fields. Some cities will need to purchase land or groundwater rights for new well fields.

The proposed plan includes the irrigation water conservation strategy to meet as much as possible of the projected irrigation needs of the region. Irrigation water users who do not now have efficient irrigation systems will need to install center pivot Low Energy Precision Application (LEPA), Low Pressure Spray Application (LESA), or other efficient irrigation systems, which will result in water savings.

Also included in the proposed plan are non-specific strategies. These strategies would contribute to increasing the region's water supplies on a widespread scale for use by all water user groups, as opposed to being specifically applicable to an individual user group. They include precipitation enhancement and brush control. Both precipitation enhancement and brush control have been and should continue to be carried out by underground water conservation districts or other appropriate agencies.

Water Supply for Cities Having Projected Water Needs

Of the 41 cities in the Llano Estacado Region for which the Texas Water Development Board has made water use projections and which are projected to obtain all or part of their water supply from the Ogallala Aquifer, 27 were projected to need additional water supplies during the planning period. In Section 5 a selected strategy is presented for each city that is estimated to need additional water supplies. The tables show the approximate dates at which new wells will be needed by each city, the distance to potentially available supply, the capacity needed, and the estimated costs for land, wells and equipment, and pipelines. In addition, the costs are expressed as total capital costs, annual debt service, annual power costs, and cost per acre-foot and per 1,000 gallons of water. The cost estimates range from $40 per acft ($0.12 per 1,000 gallons) to $342 per acft ($1.05 per 1,000 gallons).

Although water supplies are included as firm yields from surface sources and dependable quantities from ground sources, cities are expected to follow their respective Demand Management and Drought Contingency Plans, plus implement additional water conservation, if needed, during drought.

Water Supply for Irrigation Having Projected Water Needs

The goal of this selected strategy is to bring the number of acres irrigated by center pivot systems or other highly efficient irrigation application methods to 95 percent of the total irrigated acres for each county within the Llano Estacado Region by the year 2020. In 1998, six counties (Cochran, Dawson, Gaines, Motley, Terry, and Yoakum) had center pivot irrigation systems on 95 percent or more of the irrigated acreages of the county. If irrigators in each county in the Llano Estacado Region increased their use of center pivot systems to cover 95 percent of the total irrigated acreage, an additional 716,925 acres could be irrigated with these systems, resulting in approximately 355,451 acft/yr of irrigation water savings. This water conservation could meet a part of the projected irrigation needs in Bailey, Castro, Cochran, Crosby, Floyd, Garza, Hale, Hockley, Parmer, Swisher, and Terry Counties.

Region-Wide Water Management Strategies Included in the Llano Estacado Water Plan

Interconnect Cities and Feedlots (Water from Region A)

Near the end of this planning effort, an alternative conceptual region-wide type of water supply alternative was identified in which groundwater would be obtained from counties of Region A to the north and piped to cities and feedlots within a large area of the Llano Estacado Region. This option includes the construction of a regional pipeline that could potentially serve many cities in the western part of the Llano Estacado Region that are currently projected to have short- and long-term water needs during the 50-year planning period. Interconnecting cities and feedlots with water supplied from Region A could provide a quantity of water of 52,000 acft/yr at an average cost of $681 per acft or $2.09 per 1,000 gallons.

Precipitation Enhancement

Precipitation enhancement has the potential to increase the quantity of water that would be available to many water user groups in the Llano Estacado Region, as well as reduce pumpage requirements from the Ogallala Aquifer.

Annual precipitation in the area served by the High Plains UWCD's project was estimated to have produced 1.47 to 1.97 inches more in 1997 and 1999, respectively, than the 1945 through 1997 long-term naturally occurring average of 18.29 inches. Although available data and cloud seeding experience are not adequate to give reliable estimates of long term increases in precipitation, the present information indicates that precipitation can be increased by cloud seeding. For example, for the 20,294 square mile (12,988,160-acre) Llano Estacado Planning Region, an increase in precipitation of 1.5 inch would result in an increase of about 1,623,520 acft of water per year to the land surface. At a cost of 7.2 cents per acre, the cost per acft of water is $0.57.

Additional precipitation during the growing season, which is the period during which the present cloud seeding project is operated, would directly and immediately benefit dryland and irrigated agriculture. Crop and grazing yields could be increased, irrigation water pumped from the Ogallala Aquifer could be reduced, and lawn irrigation could be reduced. The latter effect would contribute to meeting projected municipal water needs by reducing the quantities used per year from present supplies. Additional rainfall runoff would be collected in public water supply surface water reservoirs and in playa lakes, which could increase recharge to the aquifer, as well as provide water for wildlife.

Brush Control

Brush control could increase the water supply in the Llano Estacado Region by increasing quantities of water for recharge to the aquifers and increasing runoff into lakes and reservoirs. The areas of the region where significant concentrations of brush occur are in the east "caprock counties" and in the western counties.

Of the 21 counties in the region, 13 counties have 50,000 or more acres of mesquite and shinnery oak combined. The counties located on the eastern side of the planning area below the caprock have the highest acreages of mesquite and shinnery oak and would primarily be the locations where brush control can be applied to increase water supplies. As has been demonstrated in Crosby County on the White River Reservoir watershed, brush control can contribute to increased inflows to a reservoir. The existing Alan Henry Reservoir and the proposed Post Reservoir are located in Garza County, which has over 185,000 acres of mesquite and shinnery oak. Brush control projects on the watersheds of these two reservoirs could result in increased firm yields and thereby contribute to the region's water supply.

The capital outlay to implement brush control on 50 percent of the mesquite and shinnery oak infested acres in counties having more than 50,000 acres of these two species of brush is estimated at $39.2 million, with an annual follow-up cost of $2.55 million. For example, if brush control were to be implemented on the Alan Henry Reservoir contributing watershed, the annual cost would be approximately $300,625. If the yield of the reservoir were increased by 10 percent, or 2,900 acft/yr, the cost per acft of raw water yield at the reservoir would be $104, or $0.31 per thousand gallons. The owners of Alan Henry Reservoir and the proposed Post Reservoir should cooperate with the landowners of the watersheds and the Texas State Soil and Water Conservation Board to implement brush control on these watersheds (the same would be the case elsewhere).

Desalt Brackish Groundwater

The potential source of water for this option is the Santa Rosa Aquifer of the Dockum Formation, which underlies the entire area of the Llano Estacado Water Planning Region. Data currently available indicate that the quality of water in the Santa Rosa in the majority of the planning region is unsuitable for most uses without treatment. Water treatment costs are estimated at $281 to $342 per acft, depending upon brine concentration of the feedwater. Individual cities that need water could consider this source.

Use of Reclaimed Water

Examples of the use of reclaimed water are the use of treated municipal effluent for irrigation of golf courses, parks, cemeteries, and other public lands and irrigation of agricultural land near to or adjacent to the town or city from which the effluent is obtained. In the Llano Estacado Region, the primary use of reclaimed municipal and feedlot wastewater is to irrigate farmland. Approximately 95 percent of all the water obtained from the Ogallala Aquifer is used for irrigation purposes. By substituting water pumped from the Ogallala Aquifer with reclaimed water, the amount of groundwater withdrawal can be decreased.

Municipal Water Conservation

Municipal water is freshwater that meets drinking water standards. Such water is supplied by both public and private utilities. In areas not served by water utilities private wells supply individual households. The objective of the municipal water conservation option is to reduce per capita water use without adversely affecting the quality of life of the people involved. The potentials for additional municipal water conservation in the Region are about 2,000 acft/yr or 2.2 percent of the projected 2050 municipal demand. Although the potentials are modest, it is very important that municipal water conservation continue to be emphasized through active public information and education programs in the public schools, through the media, and at the individual water utility levels. With respect to the latter, it is suggested that each water utility of the region measure its water distribution system leaks and unaccounted for water, and set goals to bring this parameter into the 12 to 15 percent range.

Agricultural Water Conservation Practices on Farms

Dryland and irrigation farmers in the Llano Estacado Region attempt to obtain maximum benefit from the use of the precipitation they receive on their farms. Precipitation will support dryland cotton, dryland grain sorghum, and dryland wheat, resulting in yields adequate to return a profit in about six of ten years. With increased precipitation or supplemental irrigation, yields of these crops can be increased by 30 percent to more than 300 percent and other crops can be produced, i.e., cotton requires about 5 inches of water to grow the plant, then for each additional inch of water will produce from 30 to 50 pounds of lint per acre. Grain sorghum and wheat require a similar amount of water to grow the plant, and the yields produced have a direct relationship to the total amount of water available during the growing season. The water supply can be a combination of stored soil moisture and precipitation or irrigation water received during the growing season.

Irrigation application methods have been the subject of research and development since irrigation became possible in the Llano Estacado Region in the 1930s, and in recent decades there have been significant improvements in irrigation application methods. For example, during the 1940s, 1950s, 1960s, 1970s, and into the 1980s, the method of “furrow irrigation” was used to apply water to row crops, such as cotton, corn, grain sorghum, and vegetables. However, this is the least efficient irrigation method, since the method usually results in tailwater escaping the furrows, and deep percolation is quite high.

The following irrigation practices are currently being used in the planning region; (1) Subsurface Drip Irrigation—SDI, (2) Low Energy Precision Application—LEPA pivot, (3) Low Elevation Spray Applicator/Low Pressure in Canopy—LESA/LPIC, (4) Surge Valves, (5) Pipelines, (6) Lay Flat Tubing, (7) Furrow Diking, (8) Soil Moisture Monitoring, and (9) Irrigation Scheduling. These methods and practices improve water use efficiencies and sustain present water supplies from the region's aquifers.

Subsurface Drip Irrigation (SDI) delivers water to plants by means of buried, small diameter, plastic tubes. This method has the potential for irrigation efficiencies of 90 to 98 percent, since it ensures a minimum loss of water through evaporation or deep percolation into the ground. Yields have been increased from 500 to 1,500 pounds of lint cotton per acre on some drip irrigation tracts. The method is adaptable to most soils, but has limited acceptance because installation costs are high--$700 to $1,400 per acre.

Low-Energy Precision Application (LEPA) systems deliver water through drop lines to the land surface between crop rows. LEPA systems have application efficiency potentials of 90 to 95 percent. More uniform and timely applications of irrigation water results in higher yields (uniform production over the entire field). Less water is pumped, which reduces energy cost, and labor cost is lowered as compared to furrow irrigation. Cost to convert from older, high pressure types of sprinkler systems to LEPA are in the range of $25 to $50 per acre, and installation of new LEPA systems costs approximately $300 per acre.

Low Elevation Spray Applicator/Low Pressure in Canopy (LESA/LPIC) application systems are alternate row sprays with low drift nozzles placed one to four feet above the ground. Once the crop canopy is established, evaporation losses due to wind drift and heat are reduced. These systems are applicable to slopes greater than 1 percent and have application efficiency potentials of 80 to 90 percent. Cost of LESA/LPIC conversions from older, high-pressure systems is about $100 per acre, and a new system costs about $250 per acre.

Surge Valves are a variation of furrow irrigation in which gated pipes are used to release irrigation water into the furrows being irrigated. The surge method uses a time-controlled valve placed between two sets of pipe. The system alternately waters two sets of furrows in a series of timed "surges," with each cycle supplying only enough water to flow a part of the length of the field. During the off period of the cycle, the water in the furrow infiltrates into the soil and creates a surface sealing effect that reduces infiltration in that section of furrow when the valve recycles to the set. During the next surge, water flows down the previously wetted section of the furrow more rapidly, reducing deep percolation at the top end of the field. Surge irrigation improves irrigation efficiency in comparison to the standard furrow method by 10 to about 40 percent and is low cost in terms of capital investment. Surge valves cost between $1,000 and $1,500 each and can be moved from field to field during the irrigation season.

Pipelines that replace open ditches to convey water from the irrigation wells to the crops to be irrigated reduce water losses from 10 to 30 percent per 1,000 feet depending on soil type. Plastic pipelines costing from $1.00 to $5.00 per foot (depending on size) are suitable for most areas of the Llano Estacado Region.

Lay Flat Tubing, a thin wall polyethylene tube, is a usable temporary replacement for open ditches and can be used to transport irrigation water for furrow irrigation systems. Lay Flat Tubing can reduce water losses from 10 to 30 percent per 1,000 feet, depending on soil type, when used instead of open ditches. It is disposable and usually lasts for 1 or 2 years.

Furrow Dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve as much as 100 percent of rainfall, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. Capturing and holding precipitation that would have drained from the fields replaces required irrigation water on irrigated fields; and on dryland cropland it maximizes the benefits of precipitation for use by dryland crops. In addition, furrow diking may help increase recharge to the Ogallala Aquifer during periods when rainfall is in excess of the plant root zone soil water holding capacity. Furrow diking requires special tillage equipment and costs $3.00 to $5.00 per acre to install.

Soil Moisture Monitoring is the periodic measurement of soil moisture content. Its purpose is to indicate when and how much irrigation water needs to be applied to meet crop needs. Soil moisture information is used by irrigators to schedule application of the correct amount of water at the correct time. Soil Moisture Monitoring is most effective when used with an irrigation-scheduling program. The cost of Soil Moisture Monitoring is initially high because of the cost of the instruments; but annual costs are then usually low.

Irrigation Scheduling is the practice of applying irrigation water to crops in quantities that the crop can efficiently use, when the crop needs it, and in amounts that are not in excess of the soil water holding capacity. Proper Irrigation Scheduling also maintains a storage deficit in the soil profile to make room available for rainfall when it occurs, thus maximizing the utilization of rainfall as well as irrigation water. Irrigation Scheduling requires additional and higher levels of management from the irrigator than is the case without Irrigation Scheduling. Costs associated with Irrigation Scheduling are generally labor costs related to the time spent scheduling, subscriber costs to a PET network, or consultant fees.

Well-planned and managed agricultural practices, such as those described above, can significantly benefit the region through ensuring that playa basins can function both as wildlife habitat and aquifer recharge features.

Recovery of Capillary Water

Capillary water is the water that is retained in the formation by capillary forces following gravity drainage. Capillary forces are the result of the molecular attraction between formation particles and water. The method of recovery is air injection into the dewatered layers of the aquifer through specially designed wells. The injected air breaks the capillary bond and the released water will move by gravity to the water table and become available to wells.

Cistern Well Construction

A cistern well is a well that can store a small quantity of water for domestic and/or range livestock use in areas where the saturated thickness of the Ogallala Formation or alluvium are thin, or the formation will not yield large enough quantities of water to support a pump and/or a windmill. The well is drilled and a water holding reservoir (cistern) is constructed below the water bearing section to collect water. Water from the saturated layers of the formation drain into the cistern and can be pumped out as needed. The cost varies with the size and depth of the well.

Post Reservoir

The proposed Post Reservoir Project is located on the North Fork of the Double Mountain Fork of the Brazos River northeast of Post, Texas in Garza County. The Post Reservoir could serve as a future water supply source to cities and industries in the planning area. The firm yield of Post Reservoir is 9,500 acft/yr. The cost of raw water at the reservoir is $214 per acft.

Research and Development of Drought Tolerant Crops and New Technology

Both public and private agricultural research organizations are presently engaged in research on plant crop breeding, plant nutritional needs, and cultural practices to improve the productivity, quality, and other characteristics of crops that can be produced in the Llano Estacado and other regions of Texas, the United States, and other countries of the world. The Llano Estacado Regional Water Planning Group recommends that funding be continued in adequate levels for research and development of new and improved technology in the fields of drought tolerant strains of crops, new or alternative crops for arid and semiarid regions, plant nutritional needs, irrigation application methods, brush control, weather modification, aquifer recharge, and development of better information about the aquifers and other water resources of the region.

Interconnect Cities, Industries, and Feedlots - Lake Alan Henry and Post Reservoir

Interconnecting cities and industries to provide water supplies from Lake Alan Henry and the proposed Post Reservoir would include the construction of a pipeline from Lake Alan Henry, which has a firm yield of 29,900 acft/yr, to the City of Lubbock. A second pipeline to tie a pipeline to Lubbock from the proposed Post Reservoir, which would have a firm yield of approximately 9,500 acft/yr, is included in the study. The treated water could be utilized by the City of Lubbock as an additional water supply source, or the city could sell this water to its existing customers or new customers. The cost per acft of this option, including cost for the water, is $594 per acft, or $1.82 per 1,000 gallons. Should the regional water distribution network be developed as described in Section 5.1.2, the water from these reservoirs could be made available to cities south and east of the Llano Estacado Regional Planning Area. Certainly the holders of the water rights and owners of the dam would need to be fairly compensated.

Reuse of Municipal Effluent for Potable Water Supply

Of the total quantities of water used for municipal purposes, 45 percent to 65 percent is returned to the respective municipal wastewater treatment plants for treatment and disposal. In the Llano Estacado Region a large percentage of this treated effluent, or reclaimed water, is used for irrigation of open spaces, golf courses, and neighboring farmland. This water could become a significant source of municipal water in the future if treatment levels were increased to the extent that the use of this water does not pose a health risk. The Llano Estacado Regional Water

Planning Group recommends that funding be made available to universities, water districts, and the cities to further study the quantity of water available from this option and to study treatment technologies to make this option feasible.

Stormwater Capture, Treatment, and Use

In some cities of the Llano Estacado Region, disposal of stormwater has become a serious problem. Lubbock is one of the cities having this problem. Therefore, in this water-short region, it has become desirable to evaluate the possibility to capture, treat, and use this water as a source of supply for non-potable as well as potable uses. The Llano Estacado Regional Water Planning Group recommends that funding be made available to the cities and water districts to further study the quantity of water available from this option and to study ways to successfully integrate flood protection, store this stormwater, and treat this water for useful purposes.

Protecting and Enhancing Playas and Playa Watersheds

Protecting uplands surrounding playas can significantly slow their siltation. Maintaining the integrity of these basins ensures that they serve as catchments that provide valuable wildlife habitat and provide recharge to the Ogallala Aquifer. Measures to protect playa drainages include planting of native grass buffer strips and fencing to control grazing. The Llano Estacado Regional Water Planning Group recommends best management practices on playa watersheds that enhance their function as wildlife habitat and as a recharge source for the Ogallala Aquifer.

Public Education

Underground water conservation districts, cities, universities, the Texas Agricultural Extension Service, and other water agencies will continue existing education and information dissemination programs. In addition, Llano Estacado Region water suppliers and agencies will build a strong cooperative relationship with formal and informal educators including the region's Educational Service Centers and Independent School Districts.

Section 1
Description of the Planning Region

1.1 Introduction

The rapid growth of the State, increasing pressure on its water resources, recent experiences of drought, and the special needs of utilities and water management entities has resulted in growing concerns at local, regional, and state levels. In 1997, Senate Bill 1 was enacted by the 75th Texas Legislature to address these issues. A cornerstone of the new law was an emphasis on the development of meaningful near- and long-term water plans conducted at the regional level with greater local acceptance and commitment. Besides requiring the best information possible to guide future water resource decisions, Senate Bill 1 also provided that future regulatory and financing decisions of the Texas Natural Resource Conservation Commission and the Texas Water Development Board (TWDB) be consistent with approved regional plans. As stated in Senate Bill 1, the purpose of this regional planning effort is to:

> "Provide for the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of that particular region."

The TWDB is the state agency designated to coordinate the overall statewide planning effort. After seeking public input, the TWDB divided the state into 16 distinct planning regions. In the South Plains of Texas, a 21-county area was delineated by the TWDB as Planning Area O, which was subsequently named the Llano Estacado Regional Water Planning Region (herein referred to as the Llano Estacado Region). The counties of the region are:

1. Bailey
2. Briscoe
3. Castro
4. Cochran
5. Crosby
6. Dawson
7. Deaf Smith
8. Dickens
9. Floyd
10. Gaines
11. Garza
12. Hale
13. Hockley
14. Lamb
15. Lubbock
16. Lynn
17. Motley
18. Parmer
19. Swisher
20. Terry
21. Yoakum

The Llano Estacado Regional Water Planning Group (LERWPG) was appointed by the TWDB to represent a wide range of stakeholder interests and act as the steering and decision-making body of the regional planning effort. The LERWPG members are listed in Table 1-1. Non-voting members include representatives of state agencies and adjoining regions.

Table 1-1.
Current Members and Representation of the
Llano Estacado Regional Water Planning Group

Voting Members

A. Wayne Wyatt, Chair, Deceased — High Plains Underground Water Conservation District

John Abernathy — Texas Tech University, Agricultural Science

H.P. Brown, Jr., Vice Chair — Attorney/Farmer/Rancher/Feedlot

Lee Arrington, Vice-Chair — Resigned

Delaine Baucum — Valley Irrigation and Pump

Bruce Blalack — City of Lubbock

Dallas Brewer — Yoakum County Judge

Ches Carthel — Sec/Tres & Engineer, City of Lubbock

Delmon Ellison, Jr. — Farmer

John Garland — Brazos River Authority

Bill Harbin — Golden Spread Co-op

Bob Josserand — Mayor of Hereford

Richard Leonard — Farmer

Don McElroy — Irrigation Pumps and Power

E.W. (Gene) Montgomery — Altura Energy Ltd.

Henry Rieff — Cotton Center WSC

Kent Satterwhite — Canadian River MWA

Jim Steiert — Quality Hunts

S.M. True, Jr. — Farmer

Lloyd Urban — Texas Tech University, WRI

Jerry Webster — City of Tahoka

Non-voting Members

Karen Leslie — Texas Parks and Wildlife Department

Ronald Bertrand — Texas Department of Agriculture

Joe Bragg — Texas Natural Resource Conservation Commission

Mickey Black — USDA, Natural Resource Conservation Service

Stefan Schuster — Texas Water Development Board

After considerable discussion, the LERWPG adopted a Mission Statement, dated April 16, 1998, which reads:

> "Develop, promote, and implement water conservation, augmentation, and management strategies to provide adequate water supplies for the Llano Estacado Regional Water Planning Area of the High Plains of Texas and to stabilize or improve the economic and social viability and longevity of the region through these activities."

This Mission Statement is meant to keep the LERWPG focused on the fact that the economy of the region is mostly dependent on agribusiness, which is totally dependent on a dependable water supply.

The LERWPG designated the High Plains Underground Water Conservation District No. 1 as the political subdivision to act on behalf of LERWPG as principal contractor to apply for and administer a grant from the TWDB to develop the Water Plan. The prime planning and engineering consultant is HDR Engineering, Inc.

The planning horizon, or study period, to be used by the LERWPG and all other water planning groups is the 50-year period from 2000 to 2050. This planning period allows for a long-term forecast of the prospective water situation, sufficiently in advance of needs, to allow for appropriate management measures to be implemented. As required in Senate Bill 1, the TWDB specified planning rules and guidelines (31 TAC §357.7 and §357.12) to focus the efforts and to provide for general consistency among the regions so that the regional plans can then be aggregated into an overall State Water Plan by January 2002. Besides specifying overall report and data formats, the TWDB rules also require the maximum use of existing state water planning information, except where better information can be developed or provided. Where regions share common water issues, Senate Bill 1 and TWDB have provided for coordination mechanisms among the regions.

1.2 Physical Description of the Region, including the Economy, Water Use, Water Supplies, Water Quality, and Major Entities with Water Resources Management Responsibilities

1.2.1 Description of the Region

The Llano Estacado Region is made up of 21 counties, as shown in Figure 1-1. The Llano Estacado Region encompasses 20,294 square miles (about 7.5 percent) of the state's land area. Although the region is located in the upstream parts of four major river basins (Canadian,

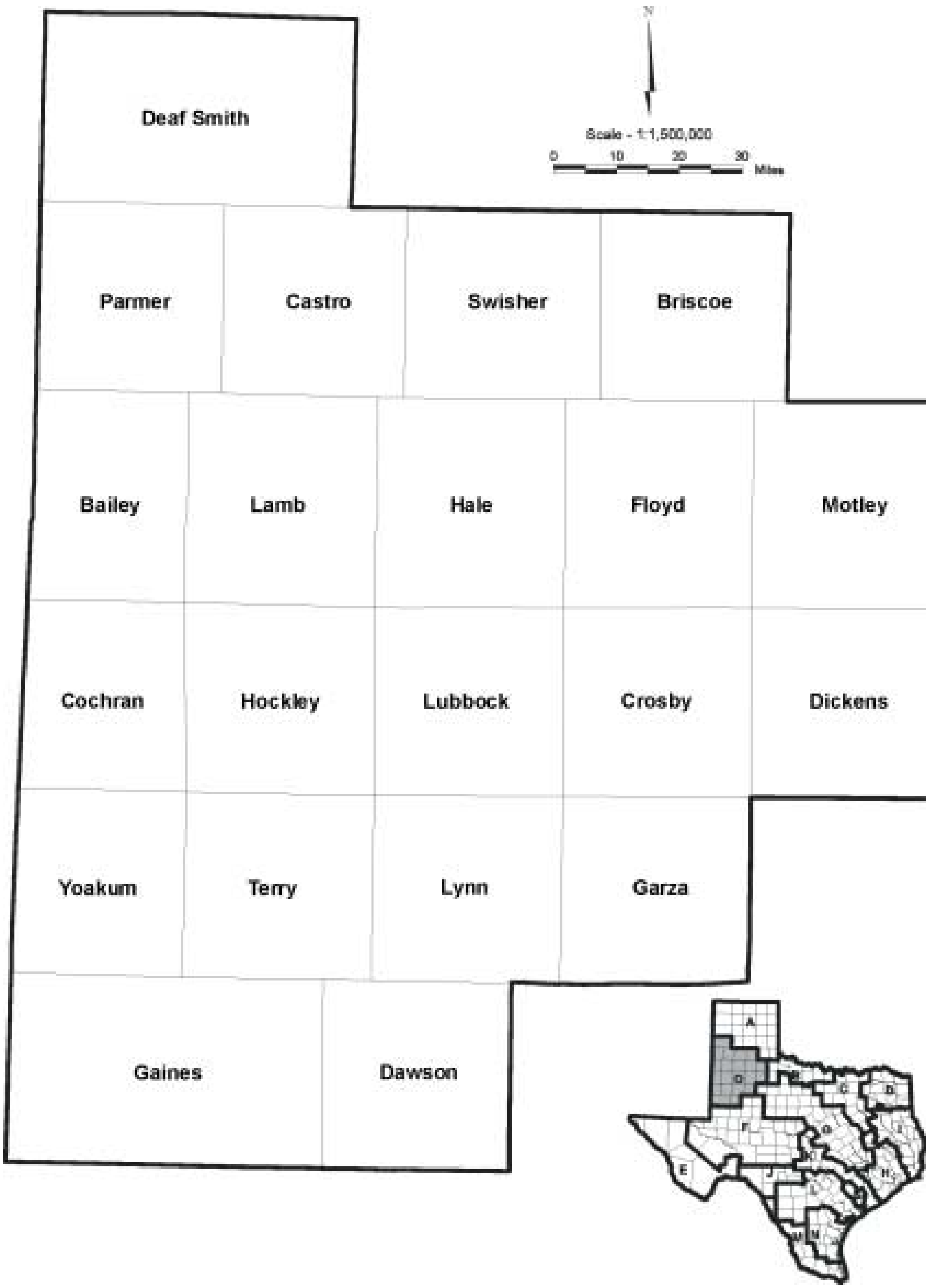

Figure 1-1. Map of Planning Region

Red, Brazos, and Colorado), almost no surface water exists within the region. Of the 20,294 total square miles covered by the area, 94 square miles are located in the Canadian Basin, 6,681 square miles are located in the Red Basin, 8,732 square miles are located in the Brazos Basin, and 4,787 square miles are located in the Colorado Basin. The region is bounded on the west by the Texas-New Mexico border, on the north by TWDB Planning Region A, on the south by TWDB Planning Region F, and on the east by the county lines of Deaf Smith, Briscoe, Motley, Dickens, Garza, and Dawson Counties. The region extends beyond the escarpment and the eastern extent of the Ogallala into the Rolling Plains. The 21 counties in the planning region comprise about 8.3 percent of the 254 counties in Texas, slightly more than the average planning region number of about 16 counties.

The regional population of 447,781 represents about 2.3 percent of the state total population of about 19.6 million persons in 1998.[1] Ten major cities with a population greater than 5,000 persons are located in the region, with these population centers relatively equally distributed within the 21 counties of the planning area. Lubbock County is the only county that contains more than one population center of this size, with the cities of Lubbock and Slaton. Twelve counties in the region (Bailey, Briscoe, Castro, Cochran, Crosby, Dickens, Floyd, Garza, Lynn, Motley, Parmer, and Swisher) do not contain a city of greater than 5,000 persons.

1.2.2 Climate[2]

The climate of the Llano Estacado Region is classified as a dry, steppe type. The region is characterized as semi-arid, with a wide range in temperatures. In spite of occasional periods of very low temperatures, the winters in the region are generally mild. Although afternoon temperatures in the summer are hot, the season is usually a pleasant one, with cool nights. Spring offers the greatest variety in weather. It is also the windiest season of the year, and occasionally strong southeasterly to northwesterly winds carry blowing dust.

In an average year, about 80 percent of the annual rainfall total occurs during the warm season (May through October). Monthly rainfall quantities ordinarily decline markedly in the colder months of the year, when frequent periods of cold, dry air from North American polar regions surge southward and cut off the supply of moisture from the Gulf of Mexico. Mean

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[1] Texas State Data Center, Texas State Population Estimates and Projections, Texas A&M University, College Station, TX, March 1998.

[2] TWDB, Op. Cit., May 1977.

annual precipitation in the region ranges from a high of 22 inches per year in Crosby County to a low of 16 inches per year in the southern areas of the region. Values for annual net lake surface evaporation range from a high of 65 inches per year for the southern portion of the region to a low of 53 inches per year in the north. A summary of the climatological conditions for the region is shown in Table 1-2.

Table 1-2.
Climatological Data for Llano Estacado Region

River Basin	Precipitation			Temperature					Annual Net Lake Surface Evaporation (inches)
					Mean Daily Minimum		Mean Daily Maximum		
	Mean Annual (inches)	Wettest Month(s)	Driest Month(s)	Mean Annual (°F)	January (°F)	July (°F)	January (°F)	July (°F)	
Canadian	23	July	Jan.	60	21	67	53	93	53
Red	19	May, June	Jan., Feb.	58	22	65	51	93	53
Brazos	18	May, June	Dec.	58	25	67	53	92	54
Colorado	16	May, Sept.	Feb.	62	26	67	56	95	65

Source: Texas Water Development Board.

1.2.3 Physiography, Geology, Soils, and Vegetation[3]

The Southern High Plains area of Texas, spanning much of the planning region, is the most southerly extent of the Southern Great Plains of the United States. Land elevations in the region generally range from about 1,900 feet-mean sea level (ft-msl) in the southeast to 4,300 ft-msl in the northwest. The relatively level plateau of the Southern High Plains contains many shallow depressions, or playa basins, a few of which hold water more or less permanently (Section 1.6.4). There is broken terrain in the northwest corner of the planning region and on the eastern side of the planning region, which is a part of the Rolling Plains physiographic region, below the "caprock" escarpment.

Riverine (fluvial) sand, clay, silts, and gravel sediments of the geologic Miocene/Pliocene age Ogallala Formation underlies the majority of the region. The uppermost portions of the formation are cemented by caliche, forming the resistant caprock that is overlain by windblown

[3] Texas Water Development Board (TWDB), "Continuing Water Resources Planning and Development for Texas," May 1977.

sand of the Quaternary age. Throughout the area, riverine (alluvial) sediment deposits of the current geologic period occur along major stream valleys and caps upland areas.

"The Ogallala Formation of Pliocene age houses the principal aquifer in the Llano Estacado Region.[4] The formation consists chiefly of sediments deposited by streams that had their headwaters in the mountainous regions to the west and northwest. The Ogallala Formation rests upon the eroded surface of the underlying Triassic and Cretaceous rocks. The Ogallala consists of beds and lenses of clay, silt, sand, and gravel. Caliche occurs as a secondary deposit in many places in the formation. In general, the Ogallala Formation is thicker in the northern part of the area, with the thickness ranging from 400 to 500 feet in central Parmer, west-central Castro, and southwestern Floyd Counties to a knife edge where the formation wedges out against outcrops of older rocks. The Ogallala Formation probably originally formed a continuous blanket of sediments extending from the Rocky Mountains on the west to well into Texas. However, erosion has almost completely isolated the formation so that the segment in southeastern New Mexico and the Southern High Plains of Texas is cut off in all directions from any underground connection with other water-bearing beds, except through the underlying older rocks, which contain highly mineralized water, unlike the fresh water in the Ogallala. This emphasizes the fact that in Texas and New Mexico, the source of the recharge to the Ogallala is precipitation falling on the surface of the plains.

"Thin deposits of Pleistocene and Recent age material overlie the Ogallala Formation in many places. These consist of lake or pond deposits, stream deposits, and sand-dune deposits. These unconsolidated sediments are important hydrologically only where they form recharge facilities, such as in the sand-dune areas, and occur in the draws that cross the region.

"Caliche deposits underlie much of the surface of the region. The caliche consists of beds, lenses, or nodules, chiefly of calcareous and siliceous material.

"Generally, the water in the Ogallala occurs under water-table conditions, although locally it may be under slight artesian pressure. The water in the Ogallala occupies the pore spaces and voids in the unconsolidated sediments and occurs between the water-table and the underlying older rocks. The thickness of the zone of saturation in the Ogallala varies throughout the Llano Estacado Region, chiefly because of the uneven nature of the bedrock surface. Within the region, the saturated thickness ranges from less than 1 foot to more than 200 feet.

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[4] High Plains Underground Water Conservation District No. 1, Lubbock, Texas, December 1998.

"The transmissivity of the Ogallala Formation ranges rather widely. Tests at Amarillo indicate a coefficient of 6,000 to 7,000 gallons per day (gpd) per foot and tests in the vicinity of Plainview indicate a transmissibility of about 34,000 gpd per foot. Numerous tests, both in the laboratory and in the field, indicate an average specific gravity yield of about 15 percent.

"The movement of water in the Ogallala Formation is generally from the northwest to the southeast. The water-table slopes roughly parallel to the slopes of both the bedrock and land surface, the average slope of the water-table being about 10 feet per mile. The rate of movement of water in the formation has been estimated to be about 150 feet per year, on a gradient of 10 feet per mile.

"The fluctuations of the water-table in the Ogallala Formation chiefly represent changes in the amount of water in storage. The long-term trend of the fluctuations throughout the region has generally been a decline, reflecting the large quantities of water withdrawn for irrigation. Water level rises in 11 of the 21 counties in the Llano Estacado Region from 1985 to 1995 indicate that more water was in storage in 1995 than in 1985 in these counties.

"The depth to water below land surface in the Ogallala Formation is affected by the topography of the land surface, the proximity to areas of recharge or natural discharge, the proximity to areas of withdrawal of water, and the configuration of the bedrock surface. The depth to water in the formation within the region in 1998 ranged from less than 50 feet to more than 300 feet.

"The principal source of groundwater recharge to the Ogallala Formation in the Llano Estacado Region is precipitation on the land surface. The amount of recharge depends on many factors, including the amount, distribution, and intensity of precipitation and the type of soil and vegetative cover. The amount of recharge has been estimated at from less than one-half inch annually to about 3 inches annually. One-half inch of recharge on the 12,988,160 acres of the region would equal 541,173 acre-feet (acft) of water, whereas 3 inches of recharge would equal about 3,247,040 acft of water.

"The water in the Ogallala Formation in the Llano Estacado Region can generally be said to be of good chemical quality, except that it is "hard", due to high levels of calcium and magnesium. This causes the water to consume soap before it will lather. It may result in scale being formed in water heaters and pipes. It also contains a high silica content, which also can cause scale. Most of the water is suitable for irrigation and meets the U.S. Public Health Service recommendations for public supplies, although the water from some wells has an excessive fluoride content.

"Cretaceous formations directly underlie the Ogallala. They are the Trinity, Fredericksburg, and Washita groups. They consist of sandstone, shale, and limestone; the sandstone and limestone being the principal water-bearing units. In a few places where the Cretaceous rocks are in hydraulic connection with the overlying Ogallala Formation, moderate quantities of water can be obtained, particularly from the limestone. Locally, the Cretaceous rocks may be important aquifers where other water is not available; however, they generally do not constitute a large source of water for irrigation or municipal use.

"Triassic rocks underlie the Cretaceous in the Llano Estacado Region. They consist of three formations of the Dockum group: the Tecovas Formation, the Santa Rosa sandstone, and the Chinle Formation equivalent. The Tecovas Formation and Chinle Formation equivalent both consist chiefly of shale and sandy shale, while the Santa Rosa sandstone consists mainly of medium to coarse conglomeratic sandstone containing some shale. The formations of the Dockum group are capable of yielding small to moderate quantities of water in many parts of the region. However, in practically all places, the water is rather saline and probably unsuitable for most purposes.

"Below the Triassic, rocks of Permian age underlie the entire area and consist chiefly of red sandstone and shale containing numerous beds of gypsum and dolomite. The Permian rocks are not a significant source of water in the Llano Estacado Region. Water in these rocks contains gypsum and salts and is generally unsuitable for domestic use. However, it is used in the Rolling Plains area for livestock water."

The soils and the characteristics of the soils of the region are described in detail in a 1999 report, "Soils of the Llano Estacado Regional Water Planning Region" by Gerald Crenwelge, USDA, NRCS Soil Scientist. There are 15 general soil types in the region, 80 to 85 percent of which are suitable for irrigation.

The original vegetation of the High Plains was variously classified as mixed prairie, shortgrass prairie, and, in some locations on deep, sandy soils, as tallgrass prairie. Blue grama, buffalograss, and galleta were the principal natural vegetation on the clay and clay loam soils. Characteristic grasses that were on sandy loam soils are little bluestem, western wheatgrass, sideoats grama, and sand dropseed.

The High Plains area is characteristically free from brush, but sand sagebrush, along with pricklypear and yucca have invaded the ranchland that have sandy and sandy loam soils. Honey mesquite has invaded the ranchland on most soils in the region. Several grass species of dropseeds are abundant on land containing coarse sandy soils. The playa depressions, which can contain several feet of water after heavy rains, support unique patterns of vegetation within their confines. Various aquatic species, such as curltop smartweed, are associated with the playa basins.

1.2.4 Natural Resources

1.2.4.1 Water Resources

The Llano Estacado Region includes the upstream parts of four major river basins (Canadian, Red, Brazos, and Colorado) and overlies the southern part of the Ogallala Aquifer, a small area of the Seymour Aquifer, and two minor aquifers (Dockum and Edwards Trinity Aquifers), as shown in Figures 1-2 and 1-3. Details about these water resources are presented in Section 1.6. Within the Llano Estacado Planning Area, none of these carry much water, except briefly after a heavy precipitation event. Almost no water is carried by these rivers out of the region.

Precipitation is the only reoccurring/renewable water supply for the Llano Estacado Region. The average annual precipitation received in the region is 18.4 inches (1945 through 1997), which would be 19,915,179 acft of water over the 12,988,160 acre region. Precipitation meets about 60 percent of urban landscape water and irrigated crop demands. It provides all the water for surface reservoirs and all the water for rangeland and dryland crop production. Precipitation also provides water for wildlife and natural recharge to the region's aquifers. Figure 1-4 shows the average annual precipitation for the region. Less than 1 percent of the precipitation escapes from the area as runoff in streams or rivers. The remainder of the runoff is collected in playa basins.

There are an estimated 20,000 playa basins on the entire High Plains of Texas, of which approximately 14,000 are located within the Llano Estacado Region.[5] Playas comprise approximately 2 percent of the total land surface. The majority of playa basins are ephemeral,

[5] Guthery, F.S., F.C. Bryant, B. Kramer, A. Stoecker, and M. Dvoracek, "Playa Assessment Study," U.S. Water and Power Resources Service, Southwest Region, Amarillo, Texas, 1981.

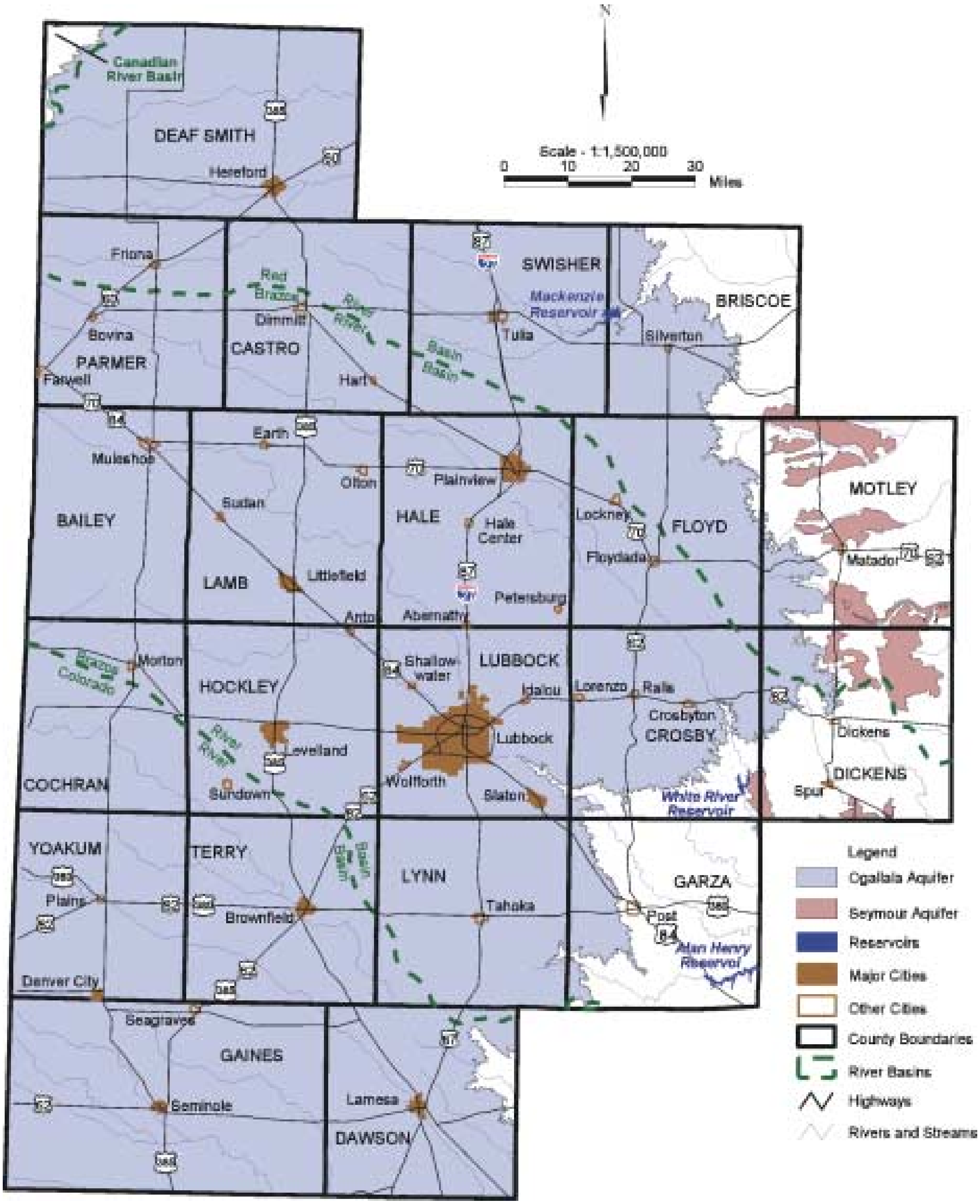

Figure 1-2. Map of Llano Estacado Region — Major Aquifers and River Basin Boundaries

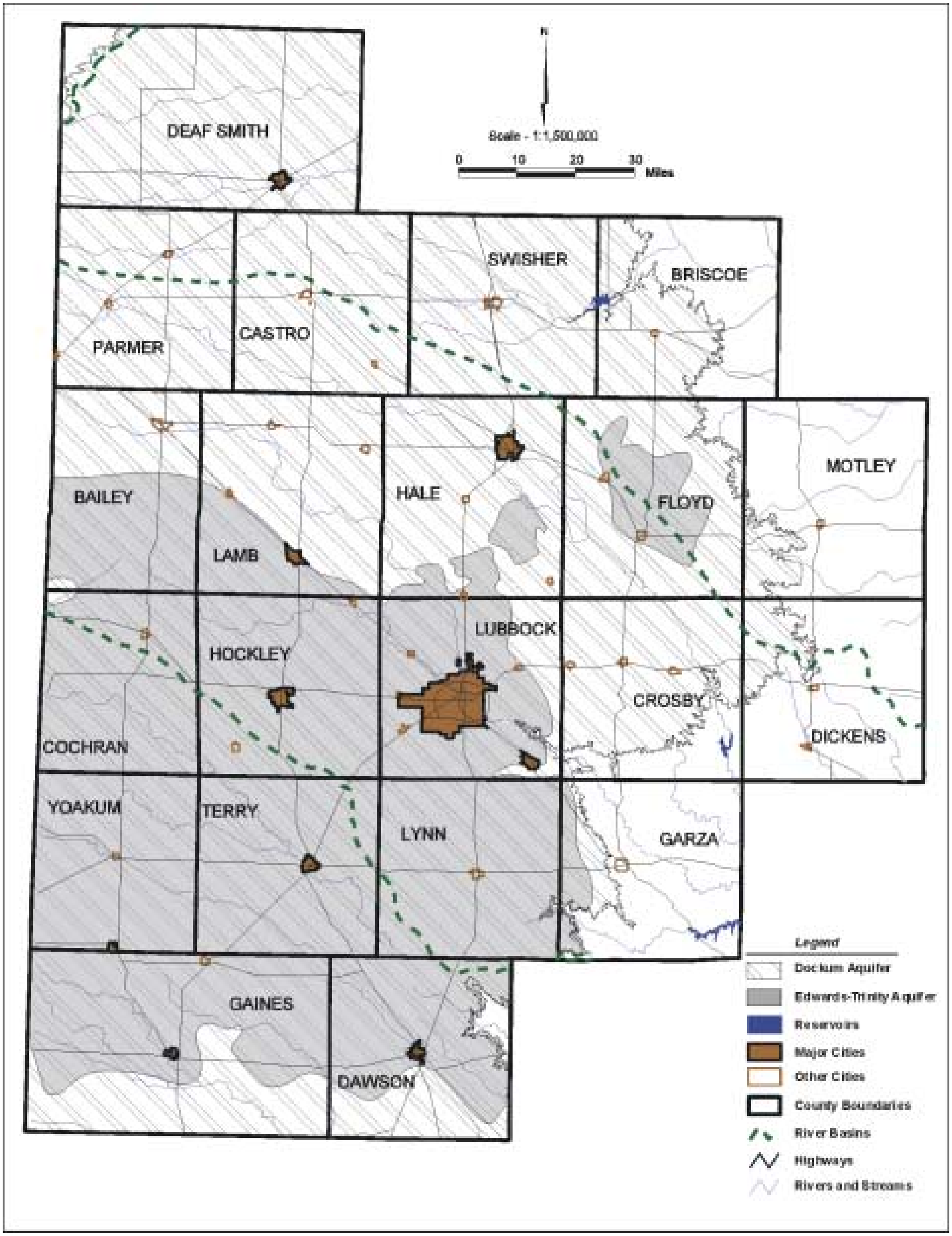

Figure 1-3. Map of Llano Estacado Region — Minor Aquifers and River Basin Boundaries

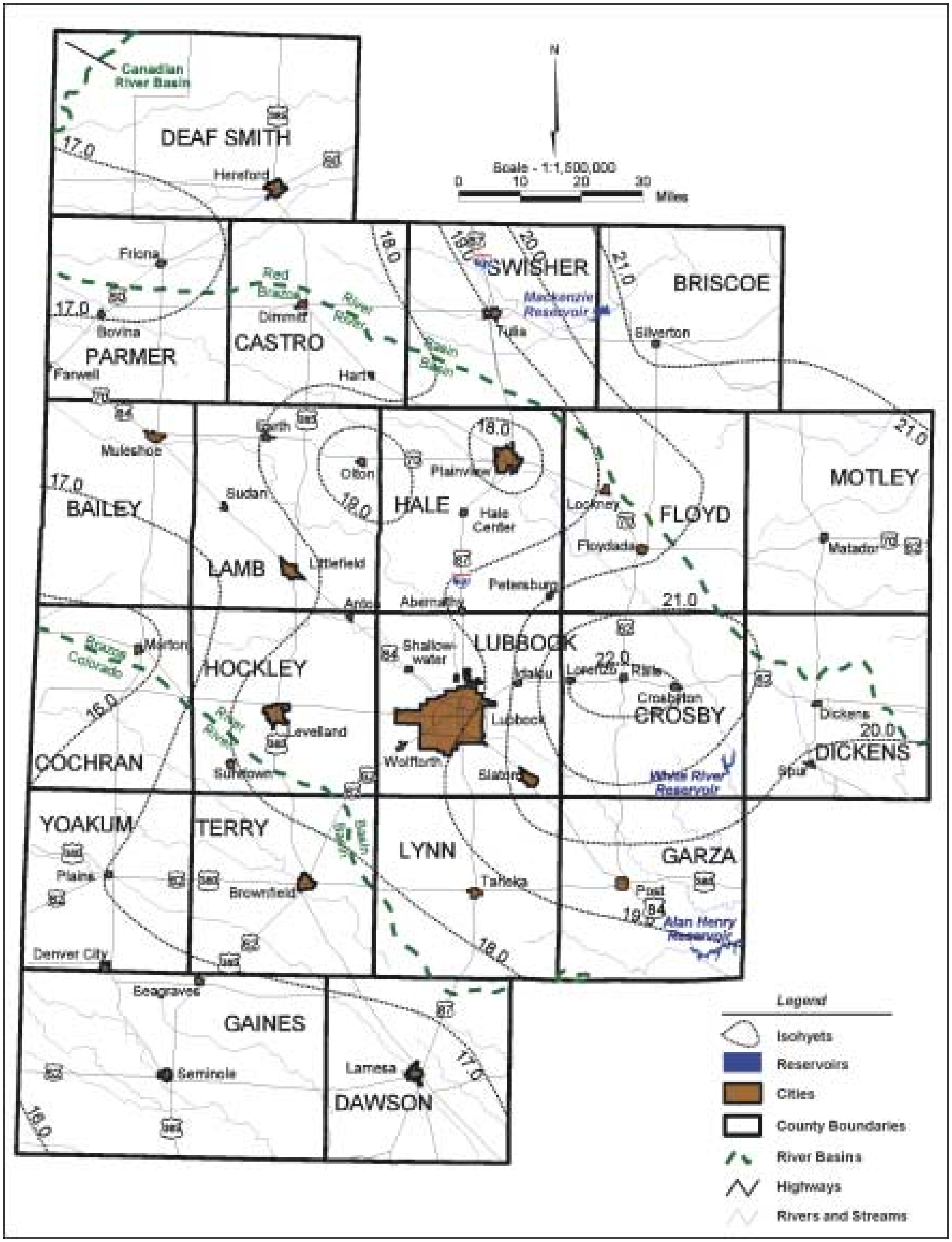

Figure 1-4. Average Annual Precipitation for the Llano Estacado Region (Inches per Year; 1945 to 1997)

holding water only during and for a short period of time after rains, unless augmented by irrigation tail water. Some of the playas are planted to crops, some are left fallow, and some are grazed. Approximately 70 percent of playas are modified with pits to recover rainfall runoff for irrigation or to create a water reserve for grazing livestock or wildlife when the bulk of the water collected in the basin from rainfall runoff has soaked into the soil or evaporated (Section 1.6.4)

1.2.4.2 Land Resources

About 57 percent of the 20,294 square miles of land area in the planning region is in cropland, one-third of which is irrigated. The major irrigated crops are cotton, corn, grain sorghum, wheat, vegetables, peanuts and soybeans. Winter cereals are used for stocker operations in preparation for feedlotting. Rangeland grazing, in the form of cow-calf and stocker operations, are carried out on about 38 percent of the area, with urban and other land uses constituting about 5 percent of the regional land area.

1.2.4.3 Wildlife Resources

Virtually all wildlife habitat in the High Plains is on privately-owned farm and ranchland. Quail and mourning dove are abundant, and whitetail deer, mule deer, turkey, and exotic aoudad sheep provide hunting along the breaks and canyons of the caprock. Antelope were once common, but now only remnant populations are present.[6] Many playa basins provide migratory waterfowl habitat, with as many as 2 million waterfowl and 350,000 to 400,000 sandhill cranes using playa lakes as wintering areas or as rest stops during annual migrations.[7] Pheasants are an economically important gamebird in irrigated areas, but their numbers tend to fluctuate widely with weather and habitat conditions.

In the region, approximately 25 wildlife species are listed by the Texas Parks and Wildlife Department as endangered, threatened, or just rare with no official listing (Appendix A). The list includes the Arkansas River Shiner and the Texas Horned Lizard.

The Arkansas River Shiner is currently listed by the U.S. Fish & Wildlife Service (USFWS) as threatened. Although this species is not found in the Llano Estacado Region, it is found above and below Lake Meredith, in the Canadian River Basin. Lake Meredith supplies municipal water to eight cities (Plainview, Lubbock, Slaton, O'Donnell, Brownfield, Levelland,

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[6] Information from High Plains Ogallala Area Regional Water Management Plan planning effort, 1996.
[7] Ibid.

Lamesa, and Tahoka) located within the region. The Arkansas River Shiner was first proposed for listing as an endangered species in August 1994. At that time, the USFWS contended that it was threatened by habitat destruction and modification from stream dewatering or depletion due to diversion of surface water and historical groundwater pumpage, water quality degradation, and construction of impoundments. However, the USFWS decided to list this species as threatened due to lesser immediacy and magnitude of threats to its existence. It is not anticipated that releases from Lake Meredith will be required as part of the recovery plan being prepared by USFWS biologists.

Texas Horned Lizard (commonly called "horned toads") populations have shown dramatic declines over the eastern portion of its range in the 1950s, '60s and '70s. Declines have been linked to loss of habitat, over-collection by the pet trade, and the accidental introduction of the imported fire ant. Concerns over the depletion of this species led the Texas State Legislature to provide protection as a threatened species in 1967. Despite low numbers in east and central Texas, the Texas Horned Lizard is still locally common in portions of the Rio Grande Plains of south Texas, the Rolling and High Plains of northwest Texas, and the Trans-Pecos of far west Texas.

The American Peregrine Falcon is considered a migrant species in this area. It has recently been delisted.

The Lesser Prairie Chicken has experienced sharp declines within the region. Extensive planning by an interstate working group is being undertaken to slow declines.

The Black-tailed Prairie Dog is currently being considered as a threatened or endangered species due to loss of habitat and evidence of decreasing numbers of species that use prairie dog towns. An interstate working group is currently collecting information and participating in the potential listing process.

1.3 Population and Demography

1.3.1 Historical and Recent Trends in Population

Since 1900, the area's population has grown by approximately 440,000 individuals (from a population of 11,418 in 1900 to a population of approximately 447,781 in 1998), as shown in

Table 1-3 and Figure 1-5.[8] From 1900 to 1920, the region experienced steady population growth as the large ranches that were predominant in the area, such as the XIT Ranch, began to sell land. During this time, railroads were also selling land to potential farmers. This period is characterized by a gradual shift from an economy based upon ranching to a more broad-based economy, which included farming.

Table 1-3.
Population Growth (1900 to 1998)
Llano Estacado Region

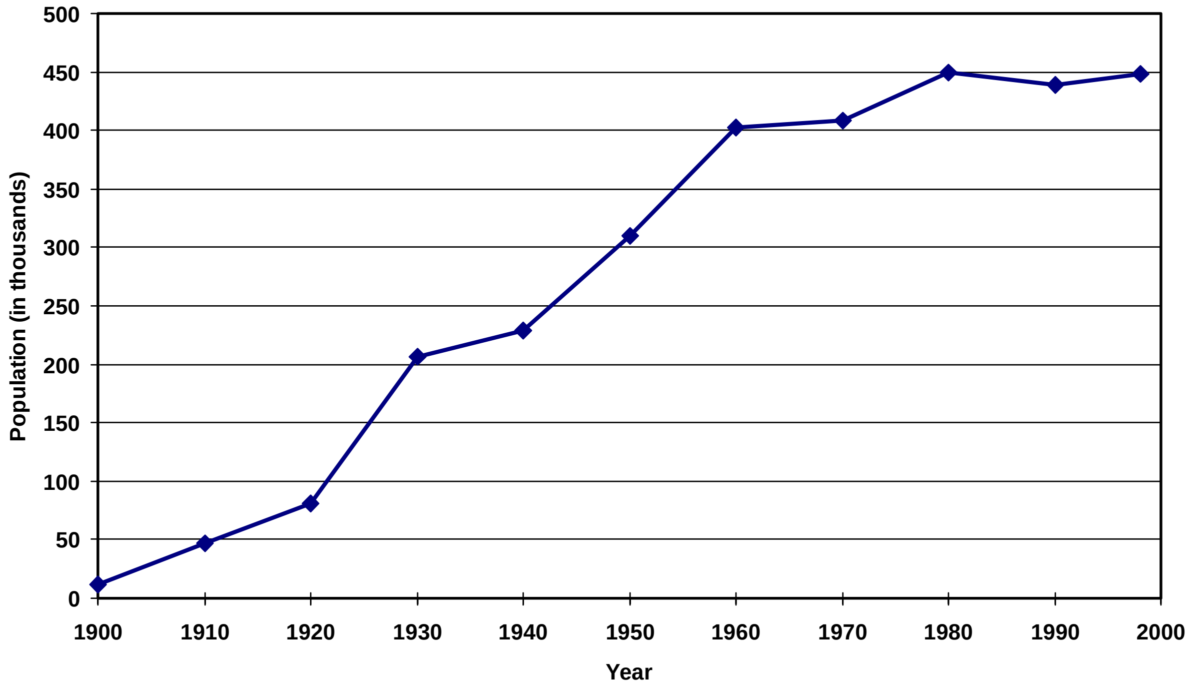
Year	Population
1900	11,420
1910	47,020
1920	80,720
1930	206,020
1940	229,280
1950	309,330
1960	402,530
1970	408,580
1980	449,550
1990	438,490
1998	447,780

Source: U.S. Bureau of the Census and Texas State Data Center.

As settlers moved to the area between 1920 and 1930, the population increased 154 percent. During the late 1920s, the number of farms peaked at 25,595. Due to farm consolidation, the number has declined slightly almost every year since. In 1997, there were 11,027 farms in the region.[9,10]

Irrigation was introduced to the area about 1908. In the late 1940s, following World War II, the irrigated agricultural boom began. During the period from 1940 to 1960, population growth almost rivaled the previous growth rate of the 1920s. It was during this period that oil production also started to increase, particularly in the southern counties of the region. However,

[8] U.S. Bureau of the Census and Texas State Data Center, Texas State Population Estimates and Projections, Texas A&M University, College Station, TX, March 1998.
[9] Inter-University Consortium for Political and Social Research Study 00003: Historical Demographic, Economic, and Social Data: U.S., 1790-1970.
[10] 1997 Census of Agriculture, Volume 1 Geographic Area Series, “Table 1. County Summary Highlights: 1997.”



Source: U.S. Bureau of the Census and Texas State Data Center, Texas State Population Estimates and Projections, Texas A&M University, College Station, TX, March 1998.

Figure 1-5. Population Growth (1900 to 1998) Llano Estacado Region

the region's population growth has leveled out since 1960 (Figure 1-5), with much of this slowdown in growth being attributed to the mechanization of agriculture, other improvements in farm technology, and a reduction in the petroleum and related work force.

Ten cities in the region have a population greater than 5,000 (Table 1-4). These larger urban areas constituted 64 percent of the region's 1998 population of 447,781. The majority of this urban population was in the City of Lubbock, which had a 1998 estimated population of 192,732 persons.[11]

1.3.2 Demographic and Socioeconomic Characteristics

In terms of population density, as shown in Table 1-5, in 1998, Motley County was the least populated, with 1,327 residents (averaging 1.3 persons per square mile). Lubbock County had the highest population in the region, with 231,841 residents (averaging 255.3 persons per square mile).

[11] Ibid.

Table 1-4. Major Cities and Population (1990 and 1998) Llano Estacado Region

City	County	1990 Population	1990 Percent of Region	1998 Population	1998 Percent of Region
Brownfield	Terry	9,560	2.2	9,193	2.1
Denver City	Yoakum	5,145	1.2	5,009	1.1
Hereford	Deaf Smith	14,745	3.4	14,562	3.3
Lamesa	Dawson	10,809	2.5	10,773	2.4
Levelland	Hockley	13,986	3.2	13,938	3.1
Littlefield	Lamb	6,489	1.5	6,381	1.4
Lubbock	Lubbock	186,206	42.5	192,732	43.0
Plainview	Hale	21,700	5.0	22,125	4.9
Seminole	Gaines	6,342	1.4	6,497	1.4
Slaton	Lubbock	6,078	1.4	6,100	1.4
	Total	281,060	64.3	287,310	64.1

Source: U.S. Census and Texas State Data Center.

Table 1-5. County Population and Area Llano Estacado Region

County	Population[1] (1998)	Area[2] (sq. mi.)	County	Population[1] (1998)	Area[2] (sq. mi.)
Bailey	6,769	843	Hale	35,997	1,033
Briscoe	1,919	911	Hockley	24,078	914
Castro	8,678	911	Lamb	15,207	1,013
Cochran	4,050	776	Lubbock	231,841	908
Crosby	7,028	904	Lynn	6,587	893
Dawson	14,911	900	Motley	1,327	994
Deaf Smith	19,193	1,485	Parmer	10,258	854
Dickens	2,314	912	Swisher	8,432	915
Floyd	8,140	1,015	Terry	13,295	904
Gaines	14,251	1,507	Yoakum	8,519	798
Garza	4,987	904	Total	447,781	20,294

[1] Texas State Data Center, March 1998.
[2] General Land Office, State of Texas.

In 1990, the age distribution across the region is fairly uniform from county to county, as shown in Table 1-6.[12] The two age groups that include the highest percentage of the population in 1990 are from 5 to 14 years of age (18.2 percent of the population) and age 60 and above (19.3 percent). The age group with the lowest percentage of the population in 1990 is ages 55 to 59 (4.6 percent).

The regional population can also be characterized by its level of education. Of those residents in the Llano Estacado Region who are 25 years of age or older, 59.2 percent have at least a high school diploma (State of Texas average is 72.1 percent), while only 11 percent have a college degree (State of Texas average is 25.5 percent) (Table 1-7).[13] The region's unemployment rate was 5.7 percent in late 1998. Median income in 1995 was $25,248.[14]

1.4 Economy – Major Sectors and Industries

1.4.1 The Llano Estacado Region's Economy

The region's economic base is agriculture, with significant contributions from manufacturing, oil and gas, and trades and services, such as wholesale and retail trade, and finance, insurance, legal, business, advertising, medical, personal, research, entertainment, repair services, and higher education. Agricultural processing, oilfield equipment and electronics form the core of the region's manufacturing base. Beef cattle and cotton are the dominant agricultural enterprises, although vegetables and oilseed crops are significant contributors to the region's economy. Statistics for the major economic sectors are presented below.

The interests of small business in the region is the same as agricultural interests, since without agriculture, the area would never have been developed and would most likely not be very populated today.

1.4.2 Agricultural Production

According to the most recent Census of Agriculture, all crops grown in the Llano Estacado Region had a combined market value of over $1.2 billion in 1997.[15] Due to the arid climate and limited water, the region can only grow certain crops. The major crops grown are cotton, grain sorghum, wheat, corn, soybeans, and peanuts (Table 1-8).

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[12] 1990 U.S. Census of Population and Housing, U.S. Department of Commerce, Washington, D.C., 1991.
[13] Ibid.
[14] Ibid.
[15] 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997."

Table 1-6.
Age Distribution of the Population in 1990
Llano Estacado Region

County	Total Population (1990)	Age Distribution (values are percent of population)								
		0 - 4	5 - 14	15 - 19	20 - 24	25 - 34	35 - 44	45 - 54	55 - 59	60 +
Bailey	7,064	8.0	18.4	8.0	5.8	14.1	12.7	10.0	4.8	18.2
Briscoe	1,971	6.5	17.0	6.1	3.5	11.1	13.3	11.1	4.9	26.4
Castro	9,070	9.5	20.8	9.3	5.9	13.9	12.5	9.5	4.8	13.8
Cochran	4,377	8.4	19.4	8.6	6.0	15.1	10.7	10.4	4.8	16.6
Crosby	7,304	8.0	18.1	7.9	5.6	13.5	10.6	10.6	5.1	20.6
Dawson	14,349	8.0	18.5	7.9	5.1	13.7	12.4	9.3	4.9	20.1
Deaf Smith	19,153	9.6	20.6	8.2	6.6	15.0	12.6	8.8	4.0	14.7
Dickens	2,571	5.4	13.5	7.6	4.6	10.8	11.6	10.7	4.4	31.5
Floyd	8,497	8.7	18.4	7.2	6.0	13.0	11.3	9.6	4.6	21.1
Gaines	14,123	10.0	21.1	8.1	6.5	16.1	12.2	9.1	4.1	12.9
Garza	5,143	7.9	18.7	7.5	5.1	13.7	12.4	9.9	4.6	20.1
Hale	34,671	9.1	18.2	8.1	7.2	15.5	11.9	9.1	4.3	16.6
Hockley	24,199	8.7	18.9	8.9	6.6	16.7	12.1	9.5	4.3	14.3
Lamb	15,072	7.4	18.0	7.0	5.5	13.4	11.4	9.7	5.0	22.6
Lubbock	222,636	7.7	14.8	8.5	11.8	17.7	13.3	8.7	3.9	13.5
Lynn	6,758	8.2	17.6	7.0	6.2	14.7	10.7	10.3	4.9	20.3
Motley	1,532	5.5	13.3	7.2	3.1	10.8	11.6	10.6	4.7	33.2
Parmer	9,863	9.1	18.7	8.1	6.1	14.9	12.7	10.0	4.2	16.1
Swisher	8,133	8.3	17.5	6.9	5.3	13.1	11.9	9.7	4.9	22.4
Terry	13,218	8.6	19.4	8.3	5.3	13.8	12.0	9.8	4.9	18.0
Yoakum	8,786	8.6	20.9	8.0	5.5	17.3	13.9	9.7	3.8	12.2
Region Totals	438,490	8.2	18.2	7.8	5.9	14.2	12.1	9.8	4.6	19.3
State Totals	16,986,510	8.1	15.9	7.6	7.6	18.4	15.0	9.7	3.9	13.8

Source: 1990 U.S. Census, U.S. Department of Commerce, Washington, D.C., data released in 1991.

Table 1-7.
Summary of Selected Socioeconomic Indicators (1990 and 1998)
Llano Estacado Region

County	High School Graduates (% of Population) (1990)[1]	College Graduates (% of Population) (1990)[1]	Civilian Labor Force (1998)[2]	Unemployment Rate (1998)[2]	Median Household Income (1995)[1]
Bailey	55.4	7.4	3,661	6.1	$25,064
Briscoe	63.0	11.6	971	3.9	$20,421
Castro	58.2	10.5	4,276	4.5	$26,912
Cochran	57.3	10.6	1,501	5.6	$25,567
Crosby	53.1	10.0	3,026	7.7	$21,566
Dawson	54.0	9.0	5,993	6.2	$24,258
Deaf Smith	57.5	11.0	8,097	7.5	$27,320
Dickens	60.3	11.2	1,071	4.7	$18,786
Floyd	60.7	11.2	3,421	8.3	$23,714
Gaines	53.2	9.9	6,996	5.0	$26,815
Garza	57.6	9.8	2,060	7.1	$25,232
Hale	61.1	12.7	17,098	6.1	$26,767
Hockley	64.0	12.4	11,068	6.3	$29,369
Lamb	56.7	11.1	6,535	6.8	$25,187
Lubbock	74.2	23.4	123,409	3.4	$30,202
Lynn	54.2	7.5	3,068	4.8	$23,154
Motley	62.2	10.8	598	4.2	$19,263
Parmer	55.7	8.9	4,364	3.1	$26,035
Swisher	61.8	11.5	3,598	3.9	$25,329
Terry	59.7	9.7	5,527	7.6	$27,488
Yoakum	64.0	10.4	3,531	7.3	$31,756
Region Totals	59.2	11.0	219,869	5.7	$25,248
State Totals	72.1	25.5	10,117,529	4.8	$32,039

1 1990 U.S. Census, U.S. Department of Commerce, Washington, D.C.
2 Texas Workforce Commission.

Table 1-8.
Summary of Farm Production Data (1997)[1]
Llano Estacado Region

County	Selected Crops Harvested						
	Corn (bushels)	Grain Sorghum (bushels)	Wheat (bushels)	Cotton (bales)	Soybeans (bushels)	Peanuts[2] (lbs.)	Hay, alfalfa, other (tons)
Bailey	1,228,974	1,555,680	687,490	72,410	36,032	0	23,716
Briscoe	473,307	467,907	502,108	35,843	11,600	4,593,000	11,803
Castro	14,940,012	1,408,750	3,649,027	84,397	124,037	0	21,480
Cochran	0	1,379,153	179,754	97,689	125,839	5,708,000	1,636
Crosby	148,128	896,966	177,869	217,059	29,494	0	8,053
Dawson	(D)	901,358	103,143	223,069	(D)	67,461,000	4,189
Deaf Smith	5,212,414	4,182,499	5,207,641	14,720	11,465	0	38,439
Dickens	0	131,145	140,560	18,562	(D)	0	7,631
Floyd	2,274,776	2,834,926	1,394,641	152,934	407,801	0	15,098
Gaines	101,932	502,496	801,210	282,317	(D)	231,057,000	7,943
Garza	(D)	95,234	20,566	33,970	0	0	2,696
Hale	9,276,122	3,081,397	1,049,896	245,185	614,295	0	16,056
Hockley	(D)	2,425,632	201,434	195,238	53,903	2,833,000	8,770
Lamb	7,836,953	1,156,798	805,834	209,082	163,996	2,005,000	38,371
Lubbock	143,604	1,299,828	144,456	275,647	135,543	7,631,000	7,853
Lynn	(D)	512,047	97,611	222,794	74,579	5,437,000	897
Motley	0	12,040	67,291	22,186	0	10,336,000	3,887
Parmer	13,611,461	2,256,516	3,749,277	94,240	62,864	0	25,268
Swisher	3,685,815	2,442,895	1,880,954	65,166	294,581	0	19,034
Terry	59,674	997,788	248,061	212,580	24,865	80,726,000	3,059
Yoakum	122,375	775,247	308,690	122,511	19,526	41,120,000	1,309
Region Total[3]	59,115,547	29,316,302	21,417,513	2,897,599	2,190,420	458,907,000	267,188
State Total	219,361,590	175,279,096	108,242,787	4,828,062	10,114,310	611,876,000	9,605,686

1 Source: 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997," except where noted.
2 Source: The Western Peanut Growers Association.
3 Total does not include data that was withheld for individual producers.
(D) – Withheld to avoid disclosing data for individual producers.

Cotton is the leading crop of the region. In 1997, the value of cotton production was $871 million.[16] Cotton is a drought-tolerant crop.

The Llano Estacado Region has seen an increase in acres planted to grain sorghum, grain sorghum yields, and use of grain sorghum during the past 60 years. The region produces 16 percent of the state's grain sorghum, or approximately 29.3 million bushels per year. In 1997, value of grain sorghum production in the area was approximately $73 million.[17]

Approximately 25 percent of the state's corn crop (approximately 60 million bushels) is grown in the Llano Estacado Region.[18] Corn contributes approximately $169 million annually to the region's economy, second only to cotton.

In 1997, 2,190,420 bushels of soybeans with a value of $15.1 million were grown in the Llano Estacado Region. Soybeans are frequently planted in the region as an alternative cash crop if hail destroys cotton; however, soybeans are not a dryland crop.

Peanut production is relatively new to the Llano Estacado Region, with peanut production having become a valuable crop for the region during the past 20 years. The Western Peanut Growers Association reports that the area now produces about 75 percent of the state's peanut crop. According to data provided by the Western Peanut Growers Association, value of production in 1997 was $107.8 million.

1.4.2.1 Irrigated Agriculture

In the semi-arid Llano Estacado Region, irrigation from groundwater is used to supplement precipitation to increase crop yields. During periods of severe drought, such as 1998, only irrigated crops produced an acceptable yield, and more groundwater must be pumped than in a wetter year. The 1997 Census of Agriculture indicates that while irrigated lands comprise about 2.7 million acres (37 percent) of the cropland in the region, irrigation is responsible for $915 million in value of farm sales, or about 75 percent of the value of major crop production.

When irrigation was first begun and for more than two decades, little thought was given to conservation. However, at this time, this region leads the world in adoption of highly efficient water use technology. As new technology becomes available, it is adopted as rapidly as

[16] Ibid.
[17] Ibid.
[18] Ibid.

economics allow. In fact, the region has developed better and better conservation equipment; and is some cases, individual farmers have built prototypes of equipment later picked up and manufactured.

In this region, drought planning is not a contingency plan, but a way of life. The average annual precipitation is about 18 inches. Irrigation from groundwater, which is expensive to pump and apply, is used to supplement precipitation. Farmers are always aware of how precious water is, and they work hard to preserve the groundwater supply and use every drop of precipitation they get.

1.4.2.2 Dryland Agriculture

Dryland farming produces crops without irrigation using only the precipitation provided by nature. The average annual precipitation received in the region (1945 to 1997) was 18.4 inches. Approximately 75 percent of the average annual precipitation, or about 13.8 inches, occurs during the summer crop growing season, which is from May through September. Maximum conservation of this precipitation is the key to producing acceptable crop yields. This is accomplished by holding the rainfall, which often falls in high intensity, short duration precipitation events, in place until it has time to soak into the soil. Methods that are effective at holding rainfall on the soil include bench leveling, parallel terraces, contour farming, furrow dikes, deep chiseling, and crop residue management. Minimum tillage using chemicals to control weeds instead of plowing also conserves moisture. Plowing provides an opportunity for moisture to evaporate when moist soil is turned to the surface.

Crops produced by the dryland farming method include cotton, wheat, rye, and grain sorghum. According to the 1997 Census of Agriculture, approximately 4.7 million acres (63 percent) of the Llano Estacado Region's total cropland was dryland farmed. The value of production from dryland farming in the region was $305 million in 1997, or about 25 percent of the value of farm sales in the region.

1.4.3 Livestock Production

Total livestock water use in 1990 accounted for 0.65 percent of the water used in the Llano Estacado Region in 1990. Major types of livestock produced in the area include fed cattle, range cattle, milk cows, swine, and sheep. The largest classification of livestock in the area is cattle and calves, which includes feedlot livestock, followed by beef cows and swine. Information from the Texas Cattle Feeders Association indicates that the one-time feedlot capacity in 1997 was 1.69 million head (Table 1-9).

1.4.3.1 Beef Cows

Beef cows, which include any cow kept primarily for calf production, make up 3.7 percent of the total livestock in the Llano Estacado Region. In 1997, there were approximately 86,000 beef cows in the region, comprising 1.6 percent of the state's total beef cow population. In 1997, these cows had a market value of $46 million, or 1.8 percent of the total market value for all livestock in the region.[19] The leading counties in beef cow production are Lubbock, Motley, and Castro (Table 1-9).

1.4.3.2 Feedlot Livestock

During the last 25 to 30 years, the South Plains of Texas observed the development of a booming new industry – confined feeding of cattle to finish weights before slaughter. In the early years of development, feedlots were built and operated by individual ranchers to add value to their own cattle. During the 1960s, feedlots began to grow in size and numbers and cattlemen begin feeding cattle for others. This relationship opened up a new market for ranchers across the region – they could now have their own cattle custom-fed in a custom cattle feedlot. Farmers saw immediate grain marketing benefits from the establishment of feedlots in the Llano Estacado Region.

Fed cattle marketings in Texas during the 1960s exploded from 477,000 head in 1960 to 2.7 million in 1969, a 467 percent growth rate as new capital flowed into the industry and many new feedlots were built. During the 1970s, fed cattle marketings grew to 4.9 million head. The more modest 82 percent growth rate reflected the market wreck of 1973 to 1974 that led to fewer new yards and slowed expansion of existing feedlots. During the 1980s, fed cattle marketings peaked at 5.3 million head in 1986, reflecting a 26 percent growth rate for the decade. Industry expansion resulted predominantly from expansion of existing feedlots. The decade of the 90s has seen the industry mature with a 12 percent growth rate and marketings of 6.06 million head in 1998—resulting primarily from expansion of existing yards.

[19] 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997."

Table 1-9.
Summary of Livestock Production Data (1997)[1]
Llano Estacado Region

County	Livestock and Poultry						
	Feedlot Capacity[2] (number)	Cattle & Calves[3] (number)	Beef Cows (number)	Milk Cows (number)	Swine (Hogs & Pigs) (number)	Sheep & Lambs (number)	Layers & Pullets (number)
Bailey	68,000	120,951	(D)	(D)	61	(D)	(D)
Briscoe	0	18,374	(D)	(D)	146	(D)	(D)
Castro	325,000	447,642	12,429	830	(D)	(D)	84
Cochran	36,000	16,555	2,878	0	79	(D)	(D)
Crosby	0	13,480	(D)	(D)	303	110	(D)
Dawson	0	8,452	(D)	(D)	39	277	(D)
Deaf Smith	467,000	521,903	(D)	(D)	313	694	432
Dickens	0	27,444	(D)	(D)	(D)	(D)	76
Floyd	35,000	57,959	(D)	(D)	(D)	(D)	28
Gaines	35,000	47,404	5,763	5	422	695	257
Garza	0	16,771	9,162	44	60	(D)	(D)
Hale	83,000	91,850	(D)	(D)	(D)	1,001	83
Hockley	16,000	21,404	(D)	(D)	434	1,055	203
Lamb	104,000	116,240	(D)	(D)	624	4,722	145
Lubbock	48,000	56,371	18,351	39	10,594	1,438	(D)
Lynn	0	9,474	4,780	65	156	(D)	55
Motley	0	28,832	15,890	0	(D)	(D)	0
Parmer	303,800	360,875	7,883	1,527	264	884	(D)
Swisher	170,000	222,669	8,761	276	1,123	743	144
Terry	0	6,354	(D)	(D)	289	(D)	(D)
Yoakum	0	9,368	(D)	(D)	154	0	(D)
Total [4]	1,691,100	2,220,372	85,897	2,786	15,061	11,619	1,507

[1] Source: 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997" except where noted.
[2] Source: Texas Cattle Feeders Association; 1997 data.
[3] "Cattle and calves" includes feedlot cattle.
[4] Total does not include data that was withheld for individual producers.
(D) – Withheld to avoid disclosing data for individual producers.

Cattle feedlots in the Llano Estacado Region marketed over 3.39 million head of fed cattle in 1998 from 69 feedlots located across the 21 counties in the region. Of the 142 feedlots in the state of Texas, almost 50 percent of them are located in the Llano Estacado Region.

1.4.4 Oil and Gas

In the Llano Estacado Region, most of the oil and gas production activity is concentrated in the southern counties. Gaines County is the leading oil and gas-producing county in the region (Table 1-10).

Oil reservoirs are developed by drilling wells into the production zones of the oil bearing formations; and as primary production approaches its economic limit, perhaps only a few percent and no more than about 25 percent of the crude oil will have been withdrawn from a given reservoir. In response to this, the oil industry has developed methods collectively known as enhanced recovery, which can increase the percentage of recoverable crude oil. In this way, the production of crude oil can be increased to over 50 percent of the original oil in the formation. Two methods of enhanced oil recovery are in use within the region at this time: water injection and carbon dioxide injection. Water injection or water flooding is a process of recycling water through the formation to force the oil out. In the region, some 90 percent of the injected water volumes are recycled water.

Natural gas almost always occurs in connection with oil deposits in the Llano Estacado Region and is brought to the surface with the oil when an oil well is produced. Such gas, called casinghead gas, contains valuable organic elements that are important raw materials of the natural gasoline and chemical industries. Before natural gas is used as fuel, heavy hydrocarbons such as butane, and propane are extracted as liquids. The remaining gas constitutes so-called dry gas, which is piped to domestic and industrial consumers for use as fuels. Composed of the lighter hydrocarbons, methane and ethane, dry gas is also used in the manufacture of plastics, drugs, and dyes.

The first oil discoveries, made in the High Plains Region, occurred during the early 1920s and by 1926, the High Plains was a major oil- and gas-producing region. In the late 1990s, the production of oil and gas in the Llano Estacado Region contributed over $2 billion per year (1999 prices) to the economy.

Table 1-10.
Summary of Oil and Gas Production (1998)
Llano Estacado Region

County	Oil (bbl)	Condensate (bbl)	Casinghead Gas (mcf)	Gas Well Gas (mcf)
Bailey	0	0	0	0
Briscoe	0	0	0	0
Castro	0	0	0	0
Cochran	5,113,652	1,936	4,003,671	486,844
Crosby	838,429	0	85,935	0
Dawson	6,615,440	0	5,961,748	0
Deaf Smith	0	0	0	0
Dickens	871,033	0	14,436	0
Floyd	1,966	0	0	0
Gaines	35,889,515	4,265	50,983,755	2,356,287
Garza	6,014,729	0	1,259,726	0
Hale	1,497,975	0	28,133	0
Hockley	25,820,139	0	42,426,429	0
Lamb	601,350	0	32,469	0
Lubbock	1,804,724	0	52,100	0
Lynn	240,605	0	83,660	0
Motley	89,309	0	3,040	0
Parmer	0	0	0	0
Swisher	0	0	0	0
Terry	5,007,480	0	2,300,065	492,693
Yoakum	29,549,011	0	76,500,527	0
Total	119,955,357	6,201	183,735,694	3,335,824

Source: Railroad Commission of Texas.

1.4.5 Manufacturing

In 1992, the region's 480 manufacturing establishments contributed over $1.3 billion to the region's economy in value of shipments and provided over 8,800 jobs with an annual payroll of over $200 million (Table 1-11).[20] The leading types of manufacturing plants in the region were food and kindred products, agricultural and industrial machinery and equipment, printing and publishing, and fabricated metal products.[21]

1.4.6 Wholesale Trade

The wholesale trade classification includes durable goods such as motor vehicles, furniture and home furnishings, lumber and construction materials, electrical goods and non-durable goods such as farm products, chemicals and allied products, and petroleum and petroleum products. The region's 1,169 wholesale trade establishments contributed over $5 billion to the region's economy in value of shipments and provided over 11,500 jobs with an annual payroll of over $275 million in 1992 (Table 1-12).[22] The leading area of wholesale trade within the Llano Estacado Region is non-durable goods.[23]

1.4.7 Retail Trade

The retail trade classification includes building materials and garden supplies, general merchandise stores, food stores, automotive dealers and service stations, apparel and accessory stores, furniture and home furnishing stores, household appliance stores, restaurants, and retail stores. The region's 2,753 retail trade establishments contributed over $2.8 billion to the region's economy in value of shipments and provided over 29,000 jobs with an annual payroll of over $320 million in 1992 (Table 1-13).[24] The leading areas of retail trade within the Llano Estacado Region are restaurants, food stores, automotive dealers and service stations, and general merchandise stores.[25]

[20] Data for 1992 are the most recent data available.
[21] 1992 County Business Pattern, U.S. Department of Commerce, Washington, D.C., 1993.
[22] Data for 1992 are the most recent data available.
[23] 1992 County Business Patterns, U.S. Department of Commerce, Washington, D.C., 1993.
[24] Data for 1992 are the most recent data available.
[25] 1992 County Business Patterns, U.S. Department of Commerce, Washington, D.C., 1993.

Table 1-11.
Summary of Manufacturing Activity (1992)
Llano Estacado Region

County	***Total Number of Establishments***	***Total Number of Employees***	***Annual Payroll (million dollars)l***	***Value of Shipments (million dollars)***
Bailey	8	(D)	(D)	(D)
Briscoe	5	(D)	0.2	0.9
Castro	7	(D)	(D)	(D)
Cochran	3	(D)	(D)	(D)
Crosby	8	100	1.4	6.7
Dawson	16	200	4.4	31.6
Deaf Smith	38	1,200	24.1	295.8
Dickens	1	(D)	(D)	(D)
Floyd	7	(D)	(D)	(D)
Gaines	10	100	0.8	3.6
Garza	6	100	0.8	3.1
Hale	38	(D)	(D)	(D)
Hockley	17	200	3.4	35.3
Lamb	13	(D)	(D)	(D)
Lubbock	265	6,800	163.9	941.9
Lynn	7	(D)	0.2	0.9
Motley	3	(D)	(D)	(D)
Parmer	7	(D)	(D)	(D)
Swisher	7	100	1.7	4.1
Terry	10	(D)	0.5	1.2
Yoakum	4	(D)	(D)	(D)
Region Total	480	8,800+(D)	201.4+(D)	1,325.1+(D)
State Total	21,662	959,900	29,634.1	83,626.3
(D) – Withheld to avoid disclosing data for individual firms.				

Source: 1992 Census of Manufacturers.

Table 1-12.
Wholesale Trade (1992)
Llano Estacado Region

County	***Total Number of Establishments***	***Total Number of Employees***	***Annual Payroll (million dollars)***	***Value of Shipments (million dollars)***
Bailey	24	296	5.1	104.1
Briscoe	9	54	1.0	15.0
Castro	29	211	4.8	167.4
Cochran	10	61	1.0	12.0
Crosby	17	230	5.3	50.6
Dawson	37	210	3.8	66.4
Deaf Smith	53	426	9.0	140.7
Dickens	2	(D)	(D)	(D)
Floyd	29	173	3.1	79.3
Gaines	31	210	4.5	62.2
Garza	9	31	0.5	4.3
Hale	93	705	13.7	241.0
Hockley	57	281	6.7	79.2
Lamb	38	203	3.6	68.6
Lubbock	588	7,581	195.6	3,513.6
Lynn	7	48	1.1	12.2
Motley	2	(D)	(D)	(D)
Parmer	32	247	5.0	190.4
Swisher	31	211	3.8	78.1
Terry	39	275	5.6	135.1
Yoakum	32	156	3.5	30.6
Region Total	1,169	11,609+(D)	276.7+(D)	5,050.8+(D)
State Total	36,611	408,925	11,799.7	281,273.4

(D) - Withheld to avoid disclosing data for individual firms.

Source: 1992 Economic Census, U.S. Department of Commerce, Washington, D.C., 1995.

Table 1-13.
Retail Trade (1992)
Llano Estacado Region

County	***Total Number of Establishments***	***Total Number of Employees***	***Annual Payroll (million dollars)***	***Value of Shipments (million dollars)***
Bailey	57	370	3.4	29.8
Briscoe	12	49	0.4	3.9
Castro	57	262	2.8	26.3
Cochran	17	87	1.0	8.0
Crosby	35	220	2.0	21.1
Dawson	107	804	8.4	77.6
Deaf Smith	117	870	9.4	89.2
Dickens	19	76	0.6	5.1
Floyd	53	277	2.7	31.4
Gaines	79	528	4.4	42.5
Garza	42	223	2.1	18.1
Hale	217	2,261	22.9	189.9
Hockley	124	1,116	12.0	119.4
Lamb	94	584	6.1	61.7
Lubbock	1,460	19,949	224.2	1,977.9
Lynn	28	147	1.4	13.6
Motley	17	58	0.5	5.0
Parmer	50	276	2.6	28.0
Swisher	46	312	3.2	29.0
Terry	66	522	6.2	56.8
Yoakum	56	423	4.2	36.9
Region Total	2,753	29,414	320.5	2,871.2
State Total	98,404	1,230,404	14,675.7	130,686.4

Source: 1992 Economic Census, U.S. Department of Commerce, Washington, D.C., 1995.

1.4.8 Services

The services group of businesses includes hotels and motels, personal services, photographic studios, beauty shops, barber shops, shoe repair, funeral services, business services, credit reporting, services to buildings, personnel supply services, computer services, auto repair, automobile parking, motion pictures, amusement services, commercial sports, health services, legal services, educational services, social services, membership organizations, engineering services, accounting services, research services, and management services. The region's 2,829 services establishments contributed over $1.1 billion to the region's economy in sales or receipts and provided over 23,000 jobs with an annual payroll of over $405 million in 1992 (Table 1-14).[26] The leading areas of services within the Llano Estacado Region are health services, business services, social services, and membership organizations.[27]

1.4.9 Finance, Insurance, and Real Estate

The finance, insurance and real estate classification includes banks, savings and loans, non-depository institutions, security and commodity brokers, insurance carriers, insurance agents, brokers, and services, real estate, and holding and other investment offices. The region's 997 finance, insurance, and real estate establishments provided over 6,100 jobs with an annual payroll of over $160 million in 1993 (Table 1-15).[28]

1.4.10 Recreation

Most of the area's revenue derived from recreation opportunities comes from spending on hunting and fishing. Based on 1985 data from the USFWS, adjusted for inflation in a 1989 report by Comptroller Bob Bullock, hunters spent $48.2 million in the Llano Estacado Region in 1989 on food, lodging, leases, equipment and other trip-related expenses. This equates to an average of $832 per hunter. Spending on fishing in the High Plains region was reported at $32.3 million in 1989, or an average of $736 per angler. Using a 3 percent rate of inflation, spending on hunting in 1999 is projected to be $64.9 million, while spending on fishing would be $43.4 million, for a total projected recreation spending of $108.3 million.

[26] Data for 1992 are the most recent data available.
[27] 1992 County Business Patterns, U.S. Department of Commerce, Washington, D.C., 1993.
[28] Data for finance, insurance, and real estate were not reported on a county level for the 1992 Economic Census, therefore, the data are from 1993 County Business Patterns conducted by the U.S. Bureau of the Census.

Table 1-14.
Services (1992)
Llano Estacado Region

County	***Total Number of Establishments***	***Total Number of Employees***	***Annual Payroll (million dollars)***	***Value of Receipts (million dollars)***
Bailey	50	159	1.9	7.7
Briscoe	10	19	0.2	0.9
Castro	38	187	3.1	9.7
Cochran	7	40	0.4	1.1
Crosby	27	118	1.4	4.5
Dawson	81	324	3.6	14.2
Deaf Smith	87	434	5.5	19.3
Dickens	7	73	1.0	3.6
Floyd	33	168	2.1	7.0
Gaines	56	297	4.5	14.2
Garza	22	144	2.0	5.6
Hale	199	1,451	20.1	58.5
Hockley	113	775	11.1	32.2
Lamb	59	294	3.4	10.5
Lubbock	1,829	17,715	328.8	920.4
Lynn	17	40	0.6	2.8
Motley	4	15	0.2	0.6
Parmer	37	196	2.3	7.5
Swisher	39	183	2.3	6.3
Terry	70	394	6.9	17.6
Yoakum	44	235	4.5	13.9
Region Total	2,829	23,261	405.9	1,158.1
State Total	123,560	1,430,220	32,401.6	84,763.4

Source: 1992 Economic Census, U.S. Department of Commerce, Washington, D.C., 1995.

Table 1-15.
Finance, Insurance, and Real Estate (1993)
Llano Estacado Region

County	*Total Number of Establishments*	*Total Number of Employees*	*Annual Payroll (million dollars)*
Bailey	12	61	1.5
Briscoe	6	31	0.8
Castro	21	84	1.6
Cochran	5	32	0.6
Crosby	16	70	1.3
Dawson	24	140	3.1
Deaf Smith	35	166	3.9
Dickens	6	28	6.8
Floyd	20	82	1.4
Gaines	23	114	2.1
Garza	7	26	5.2
Hale	68	444	8.8
Hockley	38	203	4.4
Lamb	25	149	2.7
Lubbock	614	4,019	106.1
Lynn	12	71	1.8
Motley	3	12	0.2
Parmer	12	99	2.6
Swisher	16	103	2.2
Terry	21	180	3.0
Yoakum	13	65	1.2
Region Total	997	6,179	161.3

Source: Bureau of the Census, U.S. Department of Commerce, Washington, D.C., 1994.

While hunting and fishing will probably remain a substantial part of the outdoor recreation picture, the area of ecotourism has been growing rapidly in the region since 1980. Ecotourism is defined as discretionary travel to natural areas that conserve the environmental, social and cultural values while generating an economic benefit to the local community. Ecotourists engage in activities including bird watching, wildlife viewing, hiking, rock climbing, backpacking, camping, and outdoor photography. This activity is expected to increase within the Llano Estacado Region in the future, especially where water is available to attract wildlife. Also, landowners can increase opportunities to attract hunters and ecotourists at minimum cost and minimum effort.

1.5 Water Use

There are seven major types of water use in the Llano Estacado Region: (1) municipal; (2) manufacturing; (3) steam-electric power generation; (4) mining; (5) irrigation; (6) livestock (feedlots and range); and (7) environmental and recreation. Each of these types of water use is described below. Projections of demand for each type of use are shown in Section 2, Tables 2-4 through 2-19.

1.5.1 Municipal Water Use

Municipal water use, as defined by the TWDB, includes water used for residential and commercial purposes. Residential water use includes water for drinking, cooking, bathing, flushing toilets, general cleaning and sanitation, swimming pools, car washing, gardening, and lawn watering. A 1984 U.S. Department of Housing and Urban Development study found that toilet flushing (39 percent) and bathing (30 percent) are the largest components of inside household use. Outside household use ranges from near zero in humid areas to 60 percent of total domestic use in arid areas.

The TWDB municipal water use definition also includes water used by commercial facilities such as hotels, restaurants, laundries, car washes, office buildings, educational institutions, prisons, government and military facilities, retail establishments, public swimming pools, fire protection, and irrigation of public parks and open spaces. In the Llano Estacado Region per capita municipal water use in 1990 was about 166 gallons (81,608 acft ÷ 438,490 people x 325,851 ÷ 365) (Tables 2-2 and 2-4).

Effective January 1, 1992, the Water-Efficient Plumbing Standards Act of the 73rd Texas Legislature required that certain plumbing fixtures (toilets, showerheads, and faucet aerators) sold after that date be water-efficient devices. In addition, the Federal Energy Policy Act of 1992 required that all new toilets produced for home use must operate on 1.6 gallons per flush or less. Older toilets used 3.5 to 5 gallons or more of water per flush. Other low-flow plumbing fixtures include low-flow showerheads that use 2.5 gallons per minute (gpm) instead of the standard 4.5 gpm and faucet aerators that can be installed in sinks to reduce water use. Water-conserving dishwashers and washing machines are also available, although they are still much more expensive to buy than other appliances. As these water conserving fixtures and appliances are adopted, it is reasonable to assume a decreased per capita water use within the Llano Estacado Region in future years.

Outside of the home, landscaping which includes directing the water which runs off the roof, sidewalks and driveways onto the lawn, garden, trees and shrubs when it rains can reduce irrigation water demand. Borders can be built around yards, flower beds and gardens to hold their rainfall runoff until it soaks into the soil. Additionally, if humas is used on the soil surfaces in the garden, flower beds, and around shrubs and trees to reduce evaporation from the soil surface, the rainfall harvested plus this conservation effort can reduce outside of the home water use by 50 percent or more.

1.5.2 Manufacturing Water Use

Water is used in a variety of ways for manufacturing purposes, including: process uses (water used in the manufacture of products), cooling of portions of the manufacturing process, wash-down water for cleaning, water for employee drinking purposes, sanitary uses in restrooms, and landscape irrigation. The amount of water used for each purpose is usually particular to the type of industry. In the Llano Estacado Region, the major manufacturing uses of water are for food processing, industrial machinery and equipment, and fabricated metal products.

In response to the high costs to treat and dispose of wastewater, rising energy costs, and environmental considerations, industries use water more efficiently today than they did even a decade ago. Some specific areas where savings are taking place are process modification or substitution, cooling water conservation, and steam and hot water conservation. Methods used in manufacturing to conserve cooling water may include use of saline water or treated wastewater, air cooling, and using recirculating cooling systems. Methods used to conserve water used for steam and hot water manufacturing processes include energy conservation and waste heat recovery.

1.5.3 Steam-Electric Power Water Use

A steam-electric plant basically works by heating water in a boiler until it turns into steam. The steam is used to turn the turbine-generator, which produces electricity, after which the steam is sent to the condenser to be cooled back into water. Most of the water used in steam-electric power generation is to cool the steam back into water. The condensed water is pumped back to the steam generator to become steam again, while the cooling water is discharged as wastewater or is recycled through cooling ponds or towers. Within a steam-electric plant, water is also used for make-up water to replace the water lost as steam, blowdown (purging) of boilers, washing of stacks, and plant and employee sanitation. In the past, in the Llano Estacado Region, steam-electric power generation has occurred only in Lamb and Lubbock Counties. However, a new plant is under construction in Yoakum County and will be in operation in the year 2000.

Steam-electric power generation closely resembles manufacturing uses of water where steam is required; therefore, conservation practices in the two industries closely resemble each other. Since water used for cooling purposes constitutes the majority of water use in a steam-electric plant, this is perhaps where the greatest water saving can be achieved. Methods used to conserve fresh water may include use of saline water or treated wastewater, air cooling, and using recirculating cooling systems.

1.5.4 Mining Water Use

Water is used in differing ways in the various types of mining or extractive industries. The primary water use in the mining industry in the Llano Estacado Region is for enhanced recovery of petroleum, such as with water injection. Water is also used in sand and gravel mining operations for washing mined deposits, although there is very little such activity in the Llano Estacado Region.

Several strategies have been used and continue to be used by the oil and gas industry to conserve water. For example, the use of freshwater has been reduced by the use of poorer quality water for injection. In some oil-producing geologic formations, this is not feasible because of the precipitation of a solid when water that contains a different combination of minerals is introduced into oil and gas formations. This water with a different chemical quality could be treated before use, although in the past, treating this water has proven to be cost-prohibitive. Another optional water supply for the oil and gas industry is treated wastewater. This has been used in the past, but the water must be treated thoroughly to eliminate oxygen and to prevent growth of bacteria, which can clog up the formation in the well. A final option for conserving freshwater in the oil and gas industry would be to develop and use some other method of petroleum recovery.

1.5.5 Irrigation Water Use

In the Llano Estacado Region, water is pumped from aquifers to supplement precipitation for crop production. This means that more water is pumped during periods of drought, and less water is pumped during above average precipitation years. The farm crisis in the mid-1980s brought about by high interest rates, low commodity prices, and high energy prices resulted in a significant reduction in irrigation water use at that time as compared to the quantities of water pumped in the 1960s, 1970s, and during the drought of the 1990s.

The five main methods used in the Llano Estacado Region to irrigate crops are furrow, sprinkler, low-energy precision application, surge valves, and drip (trickle) irrigation. Each method is described below.

Furrow irrigation is used to apply water to row crops, such as cotton, corn, grain sorghum, and vegetables. Water is siphoned or released into furrows and allowed to flow down the furrow until the entire length is wetted.

Sprinkler irrigation uses drop lines that are spaced along a pipe and extend to within 16 inches of the land. A sprinkler head is attached to each drop line to distribute the water evenly across the field. In the Llano Estacado Region, sprinkler systems are usually of the center-pivot type, most of which are sized to irrigate the center 123 acres of a one-quarter section (160 acres) of cropland. The center pad is located in the center of the tract to be irrigated and the system moves in a circular path around the center to irrigate the entire tract. Although more efficient than the furrow method, the center-pivot sprinklers lose a part of the water that is sprayed out to evaporation.

Low-Energy Precision Application (LEPA) is a technological improvement upon the partial drop center-pivot sprinkler irrigation system. LEPA systems use the center-pivot piping and transport systems; but instead of spraying water into the atmosphere, the water is delivered through lines hanging from the overhead transport frame and dragged on or near the land surface between crop rows. The advantages of LEPA systems are low pressure to operate, little evaporation from the application process, and control of rate of delivery of irrigation water. Also, they can be used with furrow dikes to hold moisture in the furrows until it soaks into the ground. More uniform and timely applications of irrigations result in higher yields (uniform production over the entire field). Less water is pumped, which reduces energy cost, and labor cost is lowered.

Surge valves are a variation of furrow irrigation in which gated pipes are used to release irrigation water into the furrows to be irrigated. The gates of the pipes are spaced to deliver a stream of water into a set of furrows. Surge irrigation consists of a time-controlled valve placed between two sets of gated pipe. The system alternately waters two sets of furrows in a series of timed "surges," with each cycle supplying only enough water to flow a part of the length of the field. During the off period of the cycle, the water in the furrow infiltrates into the soil and creates a surface sealing effect that reduces infiltration in that section of furrow when the valve recycles to the set. Through this method of alternating watering of the sets, water flows down the previously wetted section of the furrow more rapidly, reducing deep percolation at the top end of the field. The cycle continues until enough water has been discharged into each set to wet the soil uniformly throughout the field. Surge irrigation improves irrigation efficiency in comparison to the standard furrow method and is low cost in terms of capital investment.

Drip irrigation delivers small but frequent quantities of moisture to plants by means of buried small diameter, plastic tubes with small orifices or holes spaced to allow the release of water near the plant roots. This method ensures a minimum loss of water through evaporation or deep percolation into the ground. Yields have been increased from 500 to 1,500 pounds of lint cotton per acre on some drip irrigation tracts.

Adoption and use of equipment to improve irrigation application efficiencies was begun in the mid-1980s and has continued at a rapid pace to the present. As an example, in 1995, 12,931 center pivot systems were in place. This increased to 16,420 systems by 1998, an increase of about 9 percent per year since 1995. The TWDB inventory of irrigated acres in the

Llano Estacado Region (averaged from 1985 to 1998) is 3,031,293 acres. In 1998, 2,297,406 acres were irrigated with center pivot systems, which is about 75 percent of the total irrigated acres. These systems deliver water at an efficiency of 80 percent or higher (Table 1-16).

Table 1-16.
List of Irrigation Systems and Efficiency
Llano Estacado Region

Irrigation Systems	*Range of Application Efficiency (percent)*
Drip Irrigation	96 to 98%
LEPA Center Pivots	96 to 98%
Center Pivots w/ Low Heads (16")	86 to 90%
Furrow w/ Surge & Tailwater Pit (30 to 40%)	80 to 90%
Furrow w/ Surge (10 to 40%)	80 to 90%
Furrow w/ Tailwater Pit (15 to 20%)	70 to 85%
Over Crop Center Pivots	75 to 80%
Furrow w/ Pipeline (15 to 20%)	50 to 70%
Furrow w/ Ditch	40 to 60%

Source: High Plains Underground Water Conservation District

During the late 1940s and early 1950s, furrow irrigation was the primary method used to provide irrigation water to crops in the region. Water losses of 50 percent or more occurred through deep percolation and irrigation tailwater when open ditches were used to transport the water from the field to the crop. Underground pipelines rapidly replaced open ditches in the late 1950s and 1960s, eliminating a significant portion of previous water loss. Additionally, during the 1960s and 1970s, irrigation tailwater return systems were installed on a high percentage of the farms in the tighter soil (clay) areas to reuse the previously lost water. During this same time period, high pressure and side roll sprinkler systems were used to irrigate the sandy soil areas of the region. Although an improvement over furrow irrigation, these sprinkler systems had water losses in the range of 50 percent due to evaporation from the small drops of water as it was sprayed high above the crops and from the irrigation water that wet the crop canopy.

Beginning in the early 1980s, high pressure center pivot irrigation systems were modified or replaced with center pivot systems equipped with drop lines, which discharge water at lower pressure with a large water drop size at about 4 feet above land surface, reducing losses from 50 percent to about 20 percent.

In 1983, time controlled surge valves were added to the underground pipe systems used to provide water for furrow irrigation. These surge valves provided a method to alternate the flow of water down two sets of furrows on a timed sequence. Their addition greatly reduced deep percolation and irrigation tailwater. Water losses were reduced to about 20 percent.

In the late 1980s and early 1990s, many of these partial drop center pivot systems were further modified to deliver the water into the furrow through socks or drag hoses, further reducing water losses to as little as 2 or 3 percent during irrigation applications.

In 1998, about 75 percent of the total irrigated acreage (2,297,406 acres) in the Llano Estacado Region was irrigated with center pivot irrigation systems. Of the systems, about 25 percent utilized full drops, and about 50 percent had drops 4 feet above the ground. Of the remaining irrigated acreage, about 20 percent was furrow irrigated, utilizing underground pipe and surge valves, with the remaining 5 percent irrigated by some combination of side roll sprinkler systems, hand moved sprinkler line systems, drip irrigation systems, and conventional furrow irrigation systems without surge valves.

At the end of the 1990s tailwater return systems have almost disappeared from use. However, some have been left in place to provide a holding pond for water for wildlife.

1.5.6 Livestock Water Use

Cattle feeding operations constitute approximately 60 to 70 percent of water used for cattle purposes in the Llano Estacado Region. Reducing the amount of water used for dust control is an important component of reducing overall water use at a feedlot. Feedlots continue to experiment and quantify the smallest amount of water for effective dust control. Additionally, feedlot feedmills use a small amount of water to steam-flake grain and for office and sanitary purposes.

1.5.7 Environmental and Recreational Water Use

As previously mentioned, as many as 2 million waterfowl and 350,000 to 400,000 sandhill cranes use playas as wintering areas or as rest stops during annual migrations.[29] In

[29] Information from High Plains Ogallala Area Regional Water Management Plan planning effort, 1996.

addition, small mammals, amphibians, and reptiles depend on playas for water and habitat. Those playas and other areas that have been historically important for waterfowl and sandhill cranes are listed in Table 1-17. In years of good rainfall, habitat is excellent for big game, upland game, and waterfowl; and runoff to the region's few streams, rivers, and area reservoirs benefits fish and water recreational opportunities. Wildlife resources indirectly benefit from the Ogallala and other aquifers, primarily due to irrigation and production of grain crops. In fact, the best pheasant and waterfowl populations are generally found in areas of intensive irrigated grain production.

Since the flows of the rivers or streams (or instream flows) are extremely limited, the productivity and diversity of aquatic species is quite limited. Nevertheless, these intermittent streams are a source of inflow to area lakes, helping to support the aquatic environment and fisheries of those water bodies.

The Llano Estacado Region has several water oriented recreational facilities, which are summarized below. The location of these recreational facilities is shown in Figure 1-6.

White River Lake: White River Lake, located on the Salt Fork tributary of the Brazos River, covers 1,808 acres and supplies water for Crosbyton, Post, Spur, and Ralls. The lake features camping areas, lakeside cabins, boat rentals, picnic areas, and fishing supplies. Principal recreational activities are fishing and water skiing.

Lake Mackenzie: Lake Mackenzie, near Tulia, covers 296 acres and offers facilities for fishing, picnicking, camping, RV hookups, boat ramps, and a swimming area.

Buffalo Springs Lake: Buffalo Springs Lake is a 200-acre lake on the Double Mountain Fork of the Brazos River that serves as a fishing, boating, and picnicking facility.

Lake Meredith National Recreation Center: Lake Meredith, built by the U.S. Bureau of Reclamation and operated by the Canadian River Municipal Water Authority, is located on the Canadian River to the north of the Llano Estacado Region and covers 16,504 acres. Eight public parks are located around the lake with facilities for camping and picnicking.

Lake Alan Henry: Lake Alan Henry, located near Post in Garza County, will cover approximately 3,504 acres when full. The primary recreational activities associated with the lake are fishing, boating, and camping.

Caprock Canyons State Park: Caprock Canyons State Park covers 13,960 acres near Quitaque. The park has facilities for hiking, picnicking, fishing, and swimming in the 100-acre lake.

Table 1-17.
Areas Identified as Historically Important for Waterfowl and Sandhill Cranes Llano Estacado Region

Area Historically Important to Waterfowl	*Location*
Armstrong Playa	Dimmitt
Beefco Cattle Feeders	near Easter
Bud Hill Feedlot	Dimmitt
Buffalo Springs, Ransom Canyon	Lubbock
Bull Lake	Littlefield
Cedar Lake	Seagraves
Dead Horse Lake (at Bartlett Feedyard No. 2)	north of Hereford
Excel Packing, Friona	west of Friona
Excel Packing, Plainview	Plainview
Frost & Gooch Lakes	south of Lubbock
Fry Lake on Frio Draw	near Friona
Great Plains Feedlot	Flagg area in Castro County
GW Sugar Playa	Deaf Smith County
Hale County Feedlot	Hale Center
Happy Feedlot	Happy
Hill Feedlot & Hart Playa	Hart
Holley Sugar Ponds/Sugarland Feed Yard Playa	Hereford
Ivy Lake (east of Easter)	Castro County
Lake Mackenzie	Silverton
Muleshoe NWR	Needmore
Paco-Bovina Feedyards	western Parmer County
Pat Robbins pasture lake	Summerfield
Rafter 3 Feedyard	west of Dimmitt
Rich & Mound Lakes	Brownfield
Simpson Lake (north of Dimmitt Feed Yard)	Dimmitt
Stud Horse Playa	Parmer County
Tahoka-Gordon Lakes	Tahoka
Upper Paul's Lake	Bailey County
Various City Park Lakes	Lubbock
White River Lake	Crosbyton

Source: Playa Lakes Joint Venture Management Board, “Final Implementation Plan,” Albuquerque, NM, November 1994.

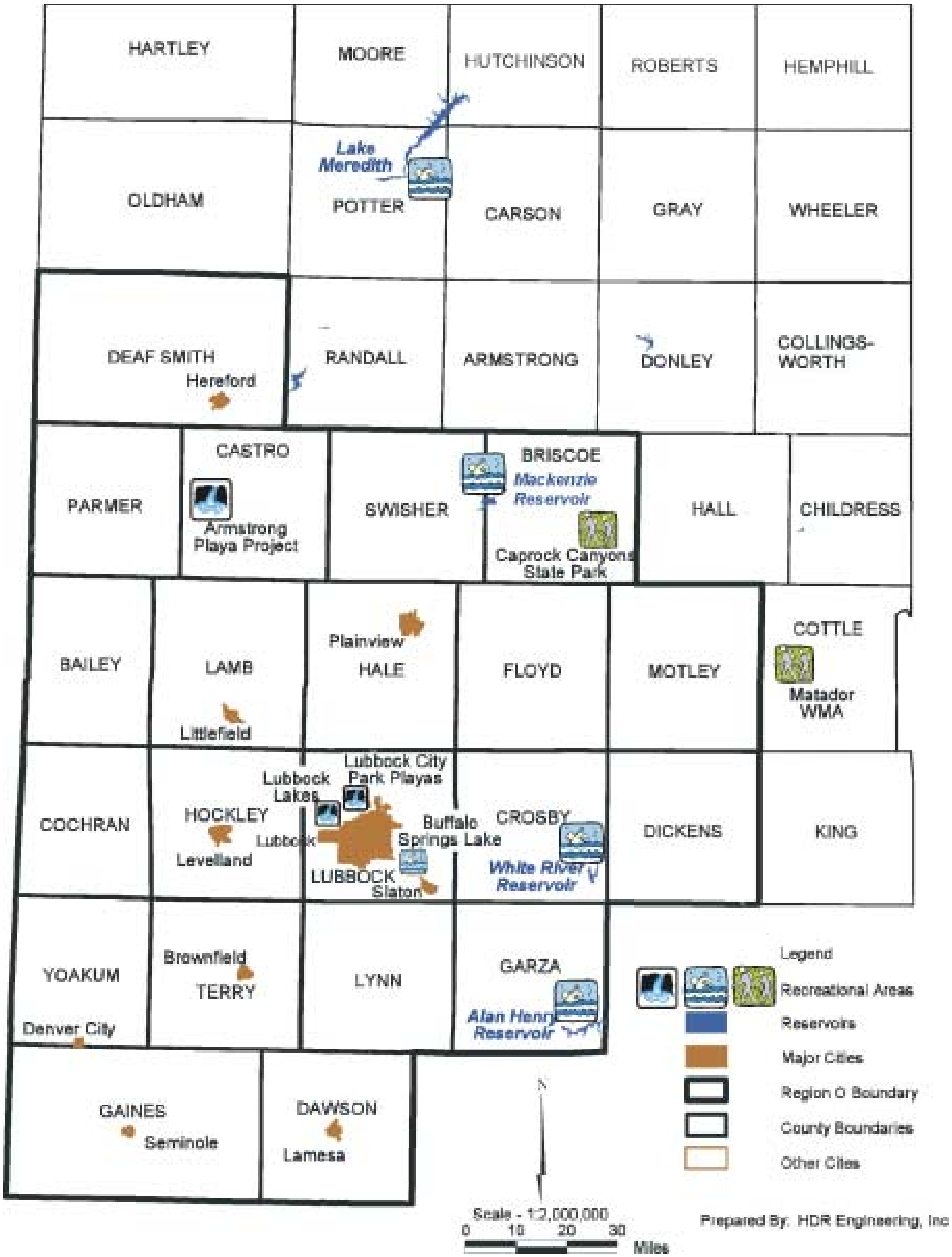

Figure 1-6. Location of Water-Oriented Recreational Facilities Llano Estacado Region

Matador Wildlife Management Area: Matador Wildlife Management Area covers 28,000 acres near Paducah on the Middle Pease and South Pease Rivers. Hunting is allowed by permit only.

Armstrong Playa Project: The Texas Parks and Wildlife Department owns a conservation easement on this property. It is located near Dimmitt in Castro County.

Lubbock City Park Playas: Many of the city parks in Lubbock are located around playa lakes. Many of these lakes are used for recreational purposes such as bird watching, fishing, and picnicking.

Lubbock Lake Landmark State Historical Park: This 336.6-acre, day-use only, historic site, is an archaeological and nature preserve located in Lubbock County. It is jointly operated by Texas Parks and Wildlife Department and Texas Tech University. The park lies along Yellowhouse Draw, a typically dry tributary of the Brazos River.

Hunting and fishing have become important economic enterprises in the Southern High Plains area, with an estimated annual expenditure of sportsmen of over $100 million.

1.5.8 Major Demand Centers

Although most of the Llano Estacado Region has small towns and communities, several major municipal demand centers exist within the region. The City of Lubbock is the largest demand center in the region for municipal and manufacturing water use. The major water demand centers for water used in oil and gas extraction are in counties located in the southern portion of the region, while large cattle feedlots, most of which are located in the north half of the region, are the major demand centers for livestock water. Unlike water demand for municipal, manufacturing, electric power generation, and mining purposes, water demand for irrigation is spread throughout the region.

1.6 Water Supplies

1.6.1 Groundwater[30]

Two major and two minor aquifers supply water to the area. The two major aquifers are the Ogallala and Seymour Aquifers. The two minor aquifers are the Edwards-Trinity (High Plains) and the Dockum Aquifers.

[30] Information from the TWDB.

1.6.1.1 Ogallala Aquifer

The Ogallala Aquifer is the major water-bearing formation of the 21 counties of the Llano Estacado Region. Vertical hydrologic communication occurs between the overlying Quaternary Blackwater Draw Formation where present and the Cretaceous which lies directly below the Ogallala in a portion of the planning region. Although many communities use water from the Ogallala Aquifer as their primary source for drinking water, approximately 95 percent of the water obtained from the Ogallala is used for irrigation.

The Ogallala is composed primarily of sand, gravel, clay, and silt deposited during the Tertiary Period. Groundwater, under water-table conditions, moves slowly through the Ogallala Formation in a southeasterly direction toward the caprock edge or eastern escarpment of the High Plains. Saturated thickness of the aquifer is generally greater in the northern part of the region and thinner in the southern part where the formation overlaps Cretaceous rocks. The saturated thickness, greatest where sediments have filled previously eroded drainage channels, ranges up to approximately 300 feet. Well yields range from as little as 10 gpm to as much as 1,000 gpm. The majority of well yields range from 200 to 600 gpm.

Recharge to the Ogallala occurs primarily by infiltration of precipitation from the surface and, to a lesser extent, by upward leakage from underlying formations. It is estimated that the long term average annual recharge rate is about 3 inches per year. Playa basins appear to be the focal point for the majority of water naturally recharged to the aquifer.

Since the expansion of irrigated agriculture in the mid-1940s, greater amounts of water have been pumped from the aquifer than have been recharged. As a result, some areas have experienced water level declines in excess of 100 feet from predevelopment to 1990. Conservation efforts have resulted in a reduction in the rate of water level declines; and in eleven of the 21 counties of the Llano Estacado Region, water levels were higher in 1995 than they were in 1985.

1.6.1.2 Seymour Aquifer

The Seymour Formation consists of isolated areas of alluvium found in parts of 23 north-central and Panhandle counties, including parts of Briscoe, Motley, Dickens, and Crosby Counties of the Llano Estacado Region. The Seymour Aquifer supplies small quantities of water for municipal uses in these four counties.

1.6.1.3 Edwards-Trinity (High Plains) Aquifer

The Edwards-Trinity (High Plains) Aquifer includes Cretaceous age water-bearing formations of the Fredricksburg and the Trinity Groups. These formations underlie the Ogallala Formation in 11 counties in the southwestern corner of the Llano Estacado Region and extend westward into New Mexico. The majority of the wells completed in the aquifer provide water for irrigation and yield 50 gpm to 200 gpm.

Two distinct groundwater zones occur in the aquifer. One occurs in the basal sand and sandstone deposits of the Antlers Formation (Trinity Group) and is usually under artesian pressure. The other water-bearing zone occurs primarily in the joints, solution cavities, and bedding planes in limestones of the Comanche Peak and Edwards formations. In much of the area, this zone is hydrologically connected to the overlying Ogallala Aquifer. Recharge to the aquifer occurs directly from the bounding Ogallala Formation along northern and western parts of the subcrop and by downward percolation from overlying units at other locations. Upward movement of groundwater from the Triassic Dockum Aquifer into the Edwards-Trinity is also believed to occur in Lynn County.

Groundwater movement is generally to the southeast. In many places, the groundwater potentiometric surface in the Edwards-Trinity Aquifer is higher than in the Ogallala Aquifer, resulting in upward movement of water from the Edwards-Trinity. In these areas, the Edwards-Trinity has a significant impact on the water levels and quality of the overlying Ogallala.

1.6.1.4 Dockum (Santa Rosa) Aquifer

The Dockum Group of Triassic age underlies the Ogallala Formation of the High Plains area of Texas and New Mexico, the northern part of the Edwards Plateau, and the eastern part of the Cenozoic Pecos Alluvium. Where the Dockum Group is exposed east of the High Plains caprock and in the Canadian River Basin, the land surface takes on a reddish color. In the subsurface, the Dockum is commonly referred to as the “red bed.” The primary water-bearing zone in the formation, the Santa Rosa, consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale.

1.6.2 Surface Water

Although the Llano Estacado Region lies within four river basins, the region has very little surface water (Figure 1-2). Dams have been built to take full advantage of what surface water exists. In other segments of rivers, surface water amounts to a trickle and very little water leaves the region.

1.6.2.1 Canadian River Basin

Beginning in northeastern New Mexico, the Canadian River flows eastward across the Texas Panhandle into Oklahoma and merges with the Arkansas River in eastern Oklahoma. Total drainage area of the basin is 12,700 square miles, of which 94 square miles are located in the Llano Estacado Region (Figure 1-2).[31] Most of its course across the Panhandle is in a deep gorge. A tributary dips into Texas' northern Panhandle and then flows to a confluence with the main channel in Oklahoma. Lake Meredith, formed by the Sanford Dam on the Canadian, provides water for 11 Panhandle cities, including Brownfield, Lamesa, Levelland, Lubbock, O'Donnell, Plainview, Slaton, and Tahoka within the Llano Estacado Region.

1.6.2.2 Red River Basin

In the Llano Estacado Region, this basin is bounded on the north by the Canadian River Basin and on the south by the Brazos River Basin (Figure 1-2). The Red River Basin extends from the headwaters in eastern Curry County, New Mexico, across the Texas High Plains to the southwestern corner of Oklahoma, near Childress, Texas, where the river becomes the Texas-Oklahoma border. The Red River Basin encompasses 6,681 square miles in the region.[32] The uppermost tributary of the Red River in Texas is Tierra Blanca Creek, which rises in Curry County, New Mexico, and drains into the Prairie Dog Town Fork a few miles east of Canyon. However, these tributaries do not supply significant quantities of water to water users of the Llano Estacado Region. Major population centers located in the basin include the cities of Hereford (Deaf Smith County) and Tulia (Swisher County).

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[31] Information from the TWDB.
[32] Ibid.

1.6.2.3 Brazos River Basin

In the Llano Estacado Region, the Brazos River Basin is bounded on the north by the Red River Basin and on the south by the Colorado River Basin and includes 8,732 square miles in the Llano Estacado Region (Figure 1-2).[33] In the region, the Brazos River rises in three upper forks, the Double Mountain, Salt, and Clear Forks of the Brazos. However, the Brazos River proper is considered to begin where the Double Mountain and Salt Forks flow together in Stonewall County, east of the Llano Estacado Region. Major population centers located in the basin include the cities of Muleshoe (Bailey County), Littlefield (Lamb County), Plainview (Hale County), Levelland (Hockley County), Lubbock and Slaton (Lubbock County), and Post (Garza County). Alan Henry Reservoir on the Double Mountain Fork in southeastern Garza County was built to supply municipal water and industrial water to Lubbock in future years. At this time, the basin does not supply significant quantities of surface water for use in the Llano Estacado Region.

1.6.2.4 Colorado River Basin

In the Llano Estacado Region this basin is bounded on the north by the Brazos River Basin and on the south by the Rio Grande Basin (Figure 1-2). The Colorado River Basin contains 4,787 square miles in the Llano Estacado Region.[34] The headwaters of the Colorado River occur in eastern New Mexico, and the river course is to the southeast across Texas approximately 600 miles, discharging into Matagorda Bay and the Gulf of Mexico. However, there is very little flow within the Llano Estacado Region. Major population centers of the planning region that are located in the basin include the cities of Brownfield (Terry County), Denver City (Yoakum County), Lamesa (Dawson County), and Seminole (Gaines County). However, neither the Colorado River nor its tributaries supply water to any of these cities.

1.6.3 Developed Surface Water Resources

Development of surface water supply sources has been limited in the Llano Estacado Region simply because the area does not have flowing streams of any significance (Section 1.6.2). However, four reservoirs are located nearby and supply water for municipal and

[33] Ibid.
[34] Ibid.

industrial uses within the region (Figure 1-6). These four reservoirs are identified and described below. Those cities that do not receive water from these reservoirs rely on groundwater to supply their water needs for both municipal and industrial purposes.

1.6.3.1 Lake Meredith

This is the largest lake in the High Plains/South Plains of Texas. Lake Meredith is located in the Canadian River Basin, in Potter, Moore, and Hutchinson Counties. It has a total storage capacity of 920,300 acft and can supply approximately 76,000 acft of water per year when at conservation pool elevation. New projects to use groundwater conjunctively and to reduce source water salt contamination will firm up the reliability and improve the quality of currently contracted supplies. From Lake Meredith a pipeline extends southward and delivers water for municipal and industrial purposes to Brownfield, Lamesa, Levelland, Lubbock, Plainview, O'Donnell, Slaton, and Tahoka within the Llano Estacado Region.

1.6.3.2 Mackenzie Reservoir

This reservoir is located in the Red River Basin in Swisher and Briscoe Counties. Mackenzie Reservoir has a total storage capacity of 45,500 acft and can supply approximately 5,200 acft of water per year when the reservoir is at conservation pool elevation. During recent dry conditions, Lake Makenzie was unable to meet its contracted demands. Mackenzie Reservoir supplies water to Silverton, Tulia, Floydada, and Lockney.

1.6.3.3 White River Reservoir

This reservoir is located in the Brazos River Basin in the southeast corner of Crosby County. It is owned and operated by the White River Municipal Water District, which supplies water to Ralls, Spur, Post, and Crosbyton. It has a surface area of 1,808 acres at conservation pool elevation and a drainage area of 173 square miles. This reservoir has a total storage capacity of 31,846 acft and can supply approximately 4,000 acft/yr when at conservation pool elevation. White River Municipal Water District has purchased groundwater rights and has drilled wells to supply its customers should the water levels in the reservoir drop below the level at which water can be removed. However, rains in 1999 filled the reservoir to within 8 feet of the discharge level of the spillway.

1.6.3.4 Alan Henry Reservoir

This new reservoir is located on the Double Mountain Fork of the Brazos River in Garza and Kent Counties and is owned by the Brazos River Authority (BRA). Alan Henry Reservoir has a total storage capacity of 115,937 acft and can supply approximately 29,900 acft of water per year when at conservation pool elevation. Lake Alan Henry was developed to serve as a future water supply for the City of Lubbock and at present is open for recreational purposes.

1.6.4 Playa Basins

In addition to the rivers and streams in the planning area, there are as many as 20,000 playa basins on the High Plains of Texas, of which about 14,000 are located in the Llano Estacado Region (Table 1-18).[35]

Table 1-18.
Number and Total Area of Playas in Planning Area
Llano Estacado Region

County	*Number*	*Acres Covered*	*County*	*Number*	*Acres Covered*
Bailey	598	4,772	Hale	1,383	23,263
Briscoe	787	12,266	Hockley	1,171	8,388
Castro	621	19,756	Lamb	1,280	13,405
Cochran	395	1,815	Lubbock	934	15,503
Crosby	925	18,278	Lynn	842	9,172
Dawson	702	7,074	Motley	0	0
Deaf Smith	451	14,069	Parmer	455	9,935
Dickens	0	0	Swisher	910	20,117
Floyd	1,783	40,605	Terry	532	3,022
Gaines	65	210	Yoakum	38	187
Garza	283	4,676	**Total**	14,155	226,513

Source: Guthery, F.S., F.C. Bryant, B. Kramer, A. Stoecker, and M. Dvoracek, "Playa Assessment Study," U.S. Water and Power Resources Service, Southwest Region, Amarillo, TX, 1981.

Playas are naturally occurring depressions in the landscape of the Southern High Plains that provide the internal drainage for much of the region. In times of abundant rainfall, they collect water and form lakes. Playa watersheds are closed systems, with playa floors

[35] Playa Lakes Joint Venture Management Board, "Final Implementation Plan," Albuquerque, NM, November 1994.

representing the deepest point of the watershed. Playas have little elevational change as one proceeds across them in a horizontal gradient; playa floors are flat. Some playa floors are defined as wetlands by the presence of hydric, vertisol clay soil, usually Randall Clay.

The majority of playa basins are ephemeral, meaning that they only hold water during and for a period of time after rainfall events. In earlier days, irrigation tailwater kept many playa basins full for part or all of the year. However, as irrigation efficiency has improved, most playas have water in them only after a rainfall event. The amount of rainfall received during the spring months of March, April, and May is the critical factor in the life expectancy of a wet playa. Some playas have been modified by landowners to concentrate the stored water into deeper pools with a smaller surface, which decreases evaporation. Some farmers recirculate this water for irrigation.

Given their sheer number and ability to retain water in arid and semi-arid environs, playas are especially important to numerous wildlife species. The abundance and diversity of wildlife species that use them depend on several factors. There is a general correlation between the size of a basin and its value for wildlife. Since larger basins are less likely to be tilled for crops or weed control, a large basin is more likely than a small basin to have natural vegetation to support wildlife year-round. Agriculture activity around a playa can influence the value of the basin for wildlife purposes. Some studies have found that playas surrounded by grain fields such as grain sorghum, small grains, corn, or some combination of these crops support a wider diversity of species than playas surrounded by cotton, potatoes, or sugar beets.

Despite being surrounded by intensive agricultural activities, playas continue to perform many functions beneficial to humans and biota of the region. Most, if not all species of wildlife in the region use playas, and many species are dependent on playas for their existence. Nearly 200 species of birds have been identified in playas. Nine species of amphibians, which consume a multitude of agricultural pest insects, would not exist in much of the region without playas. A minimum of 37 species of mammals have been associated with playas. Several species of reptiles use playas throughout the year. In fall and spring, migratory birds rest at playas during migration to and from wintering and summering grounds. Playas are of critical importance as habitat for wintering waterfowl. Some birds also use playas as breeding and nesting areas. A total of 346 plants are now reported in playa basins.

About 30 feedyards use playa basins and catchment ponds for feedlot runoff. Testing of pond water and soil below and around the pond shows no leaching of nutrients below 20 feet, and testing around the pond shows no sign of pollution. In fact, research by the A&M Extension Service has shown that a natural Randall Clay bottom on a playa seals the bottom as effectively as any other liner.

Another reason many playas no longer hold water as they did is that in the days of straight row furrow irrigation, soil was washed down into the playas. As they gradually silted in, the water-holding capacity was lessened.

1.6.5 Springs

According to "Major and Historical Springs of Texas," published by the TWDB, four springs are located within the planning area (Hylsey, Roaring, Buffalo, and Couch Springs).[36] Hylsey Springs is located approximately 9 miles north of Vigo Park within Palo Duro Canyon in Briscoe County. Hylsey Springs produces water from the Santa Rosa Sandstone, which is the primary water-bearing unit of the Dockum Aquifer. Roaring Springs is located approximately 4 miles south of the Town of Roaring Springs in Motley County. Roaring Springs produces water from the Santa Rosa Sandstone (Dockum Aquifer) and the Ogallala Aquifer. Buffalo Springs is located approximately 9 miles southeast of the City of Lubbock. Buffalo Springs produces water from the Edwards-Trinity (High Plains) Aquifer. Couch Springs, located approximately 8 miles east of Crosbyton in Crosby County, produces water from the Ogallala Aquifer.

1.7 Water Quality

1.7.1 Groundwater Quality[37]

1.7.1.1 Ogallala Aquifer

The chemical quality of water in the Ogallala Aquifer is generally fresh; however, both dissolved-solids and chloride concentrations increase from north to south. In the Northern portion of the Llano Estacado Region, total dissolved solids are generally less than 400 milligrams per liter (mg/l). Total dissolved-solids concentrations typically exceed 400 mg/l

[36] TWDB, "Major and Historical Springs of Texas (Report #189)," March 1975.
[37] Information from the TWDB.

in the Southern portion of the regional planning area, with some parts of the area having groundwater with concentrations exceeding 1,000 mg/l of total dissolved solids, especially in the vicinity of alkali lakes. Upward leakage and subsequent mixing of water from the underlying Cretaceous aquifers probably influences the chemical quality in the south. Fluoride content is commonly high, and selenium concentrations locally are in excess of drinking water standards.

1.7.1.2 Seymour Aquifer

Water quality in these alluvial remnants generally ranges from fresh to slightly saline. Total dissolved solids range from 500 to 3,000 mg/l in Motley County, while parts of the aquifer underlying Dickens County have a total dissolved solids concentration greater than 3,000 mg/l. High nitrate concentrations in excess of drinking water standards in Seymour groundwater may also occur in these two counties. However, as was noted in Section 1.6.1.2, very little water is used from this aquifer in the Llano Estacado Region.

1.7.1.3 Edwards-Trinity (High Plains) Aquifer

Water quality in the aquifer is typically fresh to slightly saline and is generally poorer in quality than water in the overlying Ogallala Aquifer. Water quality deteriorates in the vicinity of the saline lakes in Lynn, Dawson, Terry, and Grimes Counties.

1.7.1.4 Dockum (Santa Rosa) Aquifer

Concentrations of dissolved solids in the groundwater range from less than 1,000 mg/l near the eastern outcrop to more than 35,000 mg/l in the deeper parts of the aquifer in Hockley, Lubbock, Terry, Lynn, and Garza Counties. Relatively high sodium concentrations make the water undesirable for irrigation use in some areas, although this aquifer is used for irrigation in other areas of the region. Irrigation and public supply use is limited to the areas of the Dockum Aquifer where water quality is acceptable. The Cities of Dickens, Happy, Hereford, and Tulia use or have used water from the aquifer. In addition, some livestock feedlots use water from the aquifer as their primary water supply. In areas where the water quality is not acceptable for irrigation, public supply, or livestock, the water may be suited for use in petroleum related activities.

1.7.2 Surface Water Quality[38]

1.7.2.1 Canadian River Basin

The principal water quality problems in the Canadian River Basin are elevated total dissolved solids and chloride levels. The Canadian River at the New Mexico – Texas state line is moderately saline during low flow due to natural conditions. Additionally, a natural brine artesian aquifer with total dissolved solids greater than 30,000 mg/l seeps into the river near the Texas–New Mexico border. The high chloride levels affect water quality in Lake Meredith. The Canadian River Municipal Water Authority (CRMWA), owner of the lake, is implementing a chloride control project to alleviate this problem. Several towns and cities in the Llano Estacado Water Planning Region are provided water by the CRMWA from Lake Meredith.

1.7.2.2 Red River Basin

Excessive concentrations of total dissolved solids, sulfate, and chloride are a general problem in most streams of the Red River Basin under low flow conditions. The high salt concentrations are caused, in large part, by natural conditions due to the presence of saltwater springs, seeps, and gypsum outcrops. Saltwater springs are located in the western portion of the basin in the upper reaches of the Wichita River, the North and South Forks of the Pease River and the Little Red, which is a tributary to the Prairie Dog Town Fork of the Red River. Gypsum outcrops are found in the area ranging westward from Wichita County to the High Plains Caprock Escarpment. The water in these areas usually contains extremely high levels of dissolved solids. At times, the total dissolved solids are comparable to those found in seawater. However, since streams of the basin supply practically no water to the Llano Estacado Region, the water quality in the basin is of little, if any, importance to this planning effort.

1.7.2.3 Brazos River Basin

Water quality in most reaches of the upper Brazos River Basin is considered to be good, although some parts of the upper basin contain high concentrations of natural salt, which contributes large salt loads to area streams and rivers. Primary sources of salt include the watersheds of the Double Mountain and Salt Forks of the river. The Brazos River segment from the confluence with the Salt Fork Brazos River in Kent County to White River Dam in Crosby

[38] Information obtained from the TNRCC.

County contains above average concentrations of chloride, sulfate, and total dissolved solids. Since this is a source of water for some cities of the region, this quality condition is important to this planning effort.

1.7.2.4 Colorado River Basin

Due to a lack of perennially flowing streams in the upper Colorado River Basin, there are no regularly monitored water quality gauging stations along these streams (i.e., no water, no water quality concerns).

1.7.3 Water Quality Issues

1.7.3.1 Natural Chlorides

Chloride contamination of groundwater in the Ogallala Aquifer in several of the southern counties in the Llano Estacado Region appears to be from wind blowing dry soil material that contains chlorides and other minerals out of some of the older lake basins located in the region. Storm runoff water collects in the lake basins, as does water discharged from springs from the Ogallala. Even though the Ogallala water is considered to be fresh, it does contain minerals. When the water evaporates from the basins, the minerals are left behind. When these minerals dry, they are picked up by the wind and distributed across the countryside. They are then dissolved in rainwater, some of which may find its way into the aquifer (see Sections 1.7.2.1, 1.7.2.2, and 1.7.2.3 for references to natural chlorides in surface water).

1.7.3.2 Saltwater Disposal

Oilfields developed throughout the Llano Estacado Region contribute brine to area aquifers, lakes, streams, and rivers. Collective efforts of several state and local agencies led the oil industry to seek alternative means of brine disposal and eliminate the evaporation pit method. By 1983, most of the produced oilfield brine not utilized in secondary recovery operations was being properly disposed of by injection into deep formations. Both injection and disposal operations are performed under permits issued by the Texas Railroad Commission. However, residual salts contained in and on soils near disposal sites that were in existence prior to 1983 continue to seep into groundwater aquifers in the general proximity of each active or inactive oilfield. Other contributing sources are identified as originating from failures of abandoned wells that were improperly plugged, commingling between saltwater injection zones and freshwater formations, and accidental spills.

1.7.3.3 Pesticides

Several water quality studies that tested for the presence of pesticides in the groundwater have been conducted in the planning region. In 1988, the High Plains Underground Water Conservation District No. 1 sampled approximately 90 wells located within the District's boundaries. The analyzed samples indicated no significant contamination from pesticides. The few wells from which water samples showed trace amounts of pesticides were revisited, and further investigation indicated that the pesticides may have been introduced into the wells through openings in the pumps. Follow-up samples indicated no traces of pesticides.

In addition, in August 1993, the TWDB released a report entitled "Water-Quality Evaluation of the Ogallala Aquifer, Texas," (Report Number 342) which covered all or parts of the 21 counties in the Llano Estacado Region. This study also concluded pesticides were not a significant contaminant in the groundwater underlying the region.

1.7.3.4 Urban Stormwater Runoff [39]

Stormwater runoff from city streets generated during a storm event is perceived as a source of possible contamination of surrounding playa basins. To determine if contamination is occurring, the City of Lubbock initiated the sampling of local playas in 1993 as a part of the application process for the City's National Pollutant Discharge Elimination System Permit. The two playas sampled in this study were located at Buster Long Park and Maxey Park. The results of the sampling showed that lead in both locations exceeded water quality standards on more than one occasion. The level of pesticides was found to be low in both locations, with the exception of chlordane at the Buster Long Park location. Overall, the water quality remained high in both playas. Water in urban playas continues to be monitored to be sure quality remains high.

[39] Information from Stormwater Management Water Quality Report, City of Lubbock, February 1998.

1.7.3.5 Nutrients Associated with Agricultural Production

As provided in much greater detail in Section 1.2, the semi-arid climate, uniform topography, low-permeability soils, large depth to groundwater, and gradually sloping terrain of the Llano Estacado Region restrict the movement of agricultural nutrients. The geographic features of the region, in combination with farm and livestock management practices, minimize the threat to surface water and groundwater quality.

Best Management Practices (BMPs) implemented by farmers include application of fertilizers at rates equivalent to the nutrient requirements for crops, wellhead buffers for land, application of fertilizers, incorporation of fertilizers following application, tillage practices to minimize runoff from fields and other site-specific BMPs.

Just as farmers utilize BMPs, CAFOs are required to use BMPs, pursuant to Texas Natural Resource Conservation Commission (TNRCC) permits. Some of these BMPs include buffer zones around water wells, construction of berms to divert rainwater around the feedlot, protection of retention facilities from 100-year flood events, proper removal of pond sediments to maintain retention capacity, and proper removal of mortalities.

Fertilizers are required for proper plant growth to maximize production of cotton, corn, grain sorghum, peanuts, and wheat throughout the Llano Estacado region. Manure contains many crop nutrients and enhances soil quality by improving the organic matter content in the soil, which increases the water holding capacity of the soil and reduces the demand for irrigation.

1.7.3.6 Confined Animal Feeding Operations

There are approximately 69 cattle feedlots in the planning area, which utilize manmade retention ponds and playa lakes, as allowed by state and federal permits, to contain runoff from the feedlot surface.

Potential point sources of groundwater contamination in livestock feeding operations include open, unpaved feedlots, runoff-holding ponds, manure treatment and storage lagoons, silos and manure stockpiles. Insecticide spray equipment, dipping vats, and disposal sites for waste pesticides, rinsates or containers also may contribute to localized groundwater contamination because of the possibility of direct entry runoff or infiltration around or through well casings or abandoned wells.

The primary constituents of livestock manure that can contaminate groundwater include pathogenic organisms, nitrates, and ammonia. Other constituents such as potassium, sodium, chloride, and sulfate also may leach through the soil and impair the quality of an aquifer. However, studies to evaluate playas as runoff-holding ponds conducted by the USDA Agricultural Research Service in Bushland, Texas, at the time the feedlots were being established indicated this was an environmentally sound practice, because the playa clay bottoms were impermeable and the underlying water-table was generally more than 200 feet below the soil surface.[40]

Results from a recent study conducted by Texas A&M University, Texas Tech University, and the High Plains Underground Water Conservation District involving beef and dairy operations support earlier views that the Randall Clay playas and other properly constructed retention ponds can be used for feedlot waste runoff/storage without posing a significant contamination threat to the underlying groundwater. However, caution needs to be observed around the coarser-textured playa rim, because this area is a more permeable zone, where deeper leaching of soluble nutrients may occur.[41] At the conclusion of the study, it was determined that most accumulations occurred in the top foot of the playa soil surface. Nitrate was the nutrient that leached most. Its maximum concentrations in the top 5 feet of soil were, on average, about 65 parts per million (ppm) reported as N. At no location was there evidence that appreciable nitrate had penetrated the playa bottom proper below 10 feet, indicating no aquifer contamination associated with any feedlot.

Environmental protection has been an integral part of designing, building, operating and maintaining cattle feedlots in the Llano Estacado Region. The dry climate, low average annual rainfall, large depth to groundwater, and farmland application of manure as fertilizer, have provided a means by which feedlots can operate without threatening the natural resources of the region.[42]

For more than 30 years, cattle feedlots have been permitted to operate by the Texas water and air quality agencies, currently the TNRCC. TNRCC permits are among the most stringent in the nation, requiring certification of pond liner permibility and certification of retention pond

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[40] Smith, B.A., et al., "Nitrate and Other Nutrients Associated with Playa Storage of Feedlot Wastes," Texas Agricultural Extension Service, November 1993.
[41] Sweeten, John M., "Groundwater Quality Protection for Livestock Operations," Texas Agricultural Extension Service, October 1993.
[42] Correspondence with Texas Cattle Feeders Association, Amarillo, Texas, July 13, 1999.

capacity by a licensed professional engineer. In addition, feedlots must conduct periodic inspections of the site and document these inspections in a Pollution Prevention Plan maintained at each feedlot.[43]

Feedlot manure has provided an excellent source of crop nutrients for cotton, corn, grain sorghum, peanuts, and wheat throughout much of the region. Manure provides needed nutrients such as nitrogen, phosphorus and potassium, and micronutrients such as iron, magnesium, and sulfur. The addition of natural organic matter from manure also improves the soil structure and water holding capacity of the soil, reducing the demand for irrigation.[44]

TNRCC permits also require implementation of Best Management Practices (BMPs), such as buffer zones around water wells, construction of berms to divert rainwater around feedlots, protection of retention facilities from 100-year flood events, proper removal of pond sediments to maintain retention capacity, and proper removal of mortalities.[45]

1.8 Threats to Agriculture and Natural Resources

Playa basins occupy a large percentage of the farm and ranchland of the Llano Estacado Water Planning Region. As discussed in Section 1.6.4, playa basins serve not only as crop and grazing land, but are the principal habitat for wildlife in this flat, arid region.

1.8.1 Destruction and Reduction of Playas and Corrective Measures

Playa basin habitats may be subject to numerous threats, including:

(a) If the drainage area above a playa basin is improperly managed, soil erosion from washing can occur and the basin can, over time, be filled with silt that robs it of water-holding capacity. This has been a long-term pattern in areas of intensive row-cropping and siltation has resulted in greatly-diminished playa basin capacity over a large portion of the Llano Estacado Region, particularly where irrigation rows have run directly downhill into playa basins.[46] Plowing playa basins that harbor native vegetation can spread noxious weeds onto farmland on surrounding upslopes, denude the basin of emergent vegetation, deprive wildlife species of habitat, and may even diminish the basin's ability to hold water. BMPs, such as farming across the slope of the watershed and leaving buffer strips of native grasses around playa perimeters,

[43] Ibid.
[44] Ibid.
[45] Ibid.
[46] Luo, Hong-Ren, "Effects of Land Use on Sediment Deposition in Playas," submitted to the graduate faculty of Texas Tech University in partial fulfillment of the requirements of the degree of Master of Science, May 1994.

protect playa basins from siltation, ensuring their ability to seasonally pool water and provide wildlife habitat.

(b) Playas produce valuable forages, and grazing is an historic and contemporary use of playa basins, employed in continuous or seasonal patterns. BMPs of prescribed, short duration, or limited grazing that does not remove all vegetation from the basin, can allow utilization of valuable forage, yet ensure protection of naturally-occurring plant and seed production activities of moist soil plants. These plants provide wildlife cover and feed during winter and spring months when they may represent the only pool of available habitat.

(c) Large-scale conversion from furrow irrigation to more efficient sprinkler irrigation has become a practical water-conserving necessity and a BMP to prolong the life of the Ogallala Aquifer in the Llano Estacado Region. Conversion to more efficient irrigation methods has eliminated the tailwater runoff that once supplemented many playa lakes, thus impacting wildlife habitat. With little or no irrigation tailwater flowing into playa basins in years of low rainfall, little open water may be available to ducks, geese, sandhill cranes, and shorebirds in the playas.

1.8.1.2 Playa Enhancements and Protective Measures

Playa habitats may be subject to enhancements. Among them:

(a) Overflow from water troughs in cattle feedlots can collect in and sustain a water level in some playas used as drainage basins. During dry years and in periods of cold weather when shallow playas freeze, overflow from feedpen waterers into drainage playas can be especially important in providing open water areas to migrating and wintering waterfowl. Feedlot drainage playas and municipal and industrial effluent playas provide the only available surface water in dry times and the only open water during freezing weather.

(b) A BMP of maintaining playa basins in condition to catch and hold rainfall runoff by minimizing silt accumulation in them can be important to wildlife in the region and to contributing to recharge of the Ogallala Aquifer. Silted playas will not hold the volume of rainfall runoff that non-silted playas can contain.[47] A BMP of maintaining a native grass cover in areas surrounding playas protects the basins from volume-robbing siltation through natural filtration and can allow playas to more significantly contribute to aquifer recharge.

(c) To a very limited and rapidly diminishing degree due to improving efficiency of irrigation application techniques, irrigation tailwater flowing through drainage ditches can supplement the water in playa lakes and create edge vegetation in playa basins that might otherwise be dry. Moist soil management techniques that

[47] Ibid.

manipulate water in playa basins may also enhance production of moist soil plants that benefit wildlife as food and habitat.

Best Land Management practices and rainfall enhancement can benefit wildlife in the Llano Estacado Region without severely impacting groundwater supplies and can protect and even enhance playa basins.

1.8.2 Drought

1.8.2.1 Drought Impact on Aquatic Ecosystems

Freshwater rivers and streams and reservoirs within the Llano Estacado Region are vulnerable to the effects of drought conditions, manifested as reductions in streamflow and, primarily, in declines in the level of area reservoirs. Immediate drought impacts to freshwater ecosystems in the Llano Estacado Region can be losses in available habitat and a reduction in water available to municipal water supply systems from reservoirs.

Reservoir fisheries can be affected by drought. Reduced reservoir levels can have considerable impacts on reservoir fisheries as the amount of available habitat for spawning, feeding, nursery cover, and resting declines. As water levels decline, brush piles, rocks, and vegetated areas are exposed, affecting habitat complexity. The relative impact will be greatest to those species that utilize habitat close to shore or those fish that prey on such species. Negative impacts to the largemouth bass population in Lake Meredith (Section 1.6.3.1) due to reduced lake levels as a result of drought have been reported. Similar declines in available habitat for fish have also been noted at Lake Mackenzie and White River Lake within the Llano Estacado Region. Impacts include increased mortality of young fish, increased competition for space and food, impaired reproduction and growth rates, and reduced food sources.

Water quality problems may develop with reduced inflows to reservoirs. Lower dissolved oxygen levels, coupled with higher water temperatures, can limit fish distribution or contribute to diminished survival rates. Additional problems could develop or current problems worsen if surrounding land practices or municipal/industrial effluent contributes nutrients, organic matter, and/or toxic material.

1.8.2.2 Drought Impact on Terrestrial Ecosystems

Populations of terrestrial wildlife are put under stress when severe drought conditions develop. Habitat quantity and quality may gradually decline from lack of moisture and increasing competition for limited resources. Animals may eventually suffer from lack of drinking water, forage and cover, and heat stress. This impact may be mitigated slightly in irrigated areas of the Llano Estacado Region. Drought conditions during the crop-growing season dramatically increase pumpage for irrigation water from the Ogallala Aquifer.

Deer on poor range conditions can be severely impacted by drought, as can antelope. Pheasant and wild turkey populations in the Llano Estacado Region are severely reduced in the presence of drought. Quail suffer significant statewide losses due to drought. State data show that no significant or long-term impacts for waterfowl are typically detected for overwintering populations, although lack of playa water in the Llano Estacado Region can leave populations of up to 400,000 sandhill cranes and 2 million waterfowl short of wintering habitat that they must then find elsewhere. Drought has triggered severe outbreaks of botulism in past years that have affected waterfowl and shorebirds. Botulism may occur in the region when playas are drying and anaerobic conditions are created.

In some previous droughts, migratory waterfowl have been crowded on roosting playas. Under these conditions they are more vulnerable to disease transmission outbreaks of avian cholera that have the potential to kill thousands of birds.

Periodic drying of playas can encourage moist-soil plant growth in their basins. If mudflat conditions that give rise to moist-soil plant populations are followed by fall rains, significant quantities of moist-soil plant seeds can be available as food to wintering birds.

Currently, terrestrial wildlife recreation and sportfishing account for a combined estimated $108.3 million impact to the Texas High Plains economy. Significant drought affects aquatic and terrestrial ecosystems in the Llano Estacado Region and participation in terrestrial wildlife recreation and sportfishing activities.

1.8.3 Water Quality

At the present time, the quality of Ogallala Aquifer water, the principle source of water for all water user groups of the region, is well suited for current uses. Obviously, if contamination of existing supplies occurs, the quantities contaminated could become unusable or only usable after treatment, and thereby the quantities of supply would be reduced to the extent that contamination occurs.

1.9 Major Entities with Water Resources Responsibilities

1.9.1 Federal and State

1.9.1.1 U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USCOE) was charged by Congress in 1972 in the Federal Clean Water Act, Section 404, as one of the regulatory agencies to protect our nation's waters (including lakes, rivers, aquifers and coastal areas) from the discharge of dredge and fill material in defined U.S. waters. The Federal Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals:

- Eliminate the discharge of pollutants into the nation's waters; and
- Achieve water quality levels that are fishable and support contact use.

Practically speaking, construction activities occurring in and around defined U.S. waters require the acquisition of a Section 404 permit and associated National Environmental Policy Act (NEPA) review. The USCOE also regulates the construction of dams in navigable waters through its Section 10 permit program.

1.9.1.2 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (USEPA) administers several environmental programs authorized by Congress. The three principal acts and related programs are described below.

The Clean Water Act requires major industries to meet performance standards to ensure pollution control, charges states and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them, provides funding to states and communities to help them meet their clean water infrastructure needs, and requires a permitting process to ensure that development and other activities are conducted in an environmentally sound manner. The Clean Water Act had its beginnings in the Water Pollution Control Act of 1948, which authorized the Surgeon General of the Public Health Service, in cooperation with other Federal, state, and local entities, to prepare comprehensive programs for eliminating or reducing the pollution of interstate water and tributaries and improving the sanitary condition of surface and underground waters. With the Clean Water Act Amendments in 1977, the Federal Water Pollution Control Act became known as the Clean Water Act.

Also included in the Clean Water Act is the National Pollutant Discharge Elimination System (NPDES) Permitting process. Facilities which discharge pollutants from point sources (such as discharge pipes) into waters of the United States are required to obtain a NPDES permit. The NPDES program falls under Section 402 of the Clean Water Act. Wastewater discharges regulated under the NPDES program include industrial wastewater, stormwater, and treated effluent from municipal sewage treatment plants.

The primary objective of the Safe Drinking Water Act of 1974, as amended in 1986 and 1996, is twofold: (1) to protect the Nation's sources of drinking water and (2) to protect public health to the maximum extent possible, using proper water treatment techniques. The Safe Drinking Water Act directs the USEPA and states to establish national primary and secondary drinking water standards and to establish techniques to meet those standards. States are responsible for enforcement and must submit regulatory programs to the USEPA for approval. Underground sources of drinking water are also protected through applying the same drinking water standards, identifying critical aquifer protection areas, and programs to protect wellhead areas from contaminants.

The Resource Conservation and Recovery Act of 1976 governs the disposal of solid waste. Subtitle D of the Act, as amended November 1984, establishes Federal standards and requirements for state and regional solid waste authorities. The objective of this subtitle is to assist in developing and encouraging methods for the disposal of solid waste which are environmentally sound and which maximize the utilization of valuable resources recovered from solid wastes. Subtitle C of this law establishes standards and procedures for the handling, storage, treatment, and disposal of hazardous wastes. Generators, transporters, and owners of treatment, storage, and disposal (TSD) facilities are subject to its regulatory scheme. RCRA also regulates the transportation and tracking of hazardous waste; establishes standards for the storage and treatment of hazardous wastes by generators; provides a procedure for identifying waste as hazardous; provides minimum technology standards for TSDs; provides for corrective actions for historic solid and hazardous waste management units; establishes land disposal prohibitions and restrictions; regulates the installation, testing, and removal and remediation of underground storage tanks; regulates the management of used oil; and provides an enforcement mechanism.

1.9.1.3 Texas Water Development Board

The TWDB was established in 1957 through a state constitutional amendment. The agency's original function was to provide loan assistance to political subdivisions for the development of surface water supply projects that could not be financed through commercial channels. During the 1960s, the Board's responsibilities grew to include the authority to obtain and develop water conservation storage facilities, prepare a state water plan, and assume operations of the Texas Water Commission not related to the question of water rights. The state water planning functions are described in more detail later in Section 1.10.1.

Currently, the TWDB has a number of broad responsibilities. One primary function is still providing loans and grants for local governments for:

- Water supply, water treatment, and distribution;
- Wastewater treatment and other pollution control;
- Municipal and solid waste management;
- Economically distressed areas;
- Flood protection;
- Agricultural water conservation; and
- Regional water, wastewater, and flood protection planning.

The agency is also responsible for collecting data and conducting studies regarding agricultural water conservation, freshwater needs of Texas estuaries and bays, and surface and groundwater resources. As the agency responsible for developing a state water plan, the TWDB uses a number of research programs to assess and project water availability, environmental impact, and water uses for both agricultural and municipal areas. The Board continually collects surface and underground water information through hydrologic monitoring. It provides technical evaluation of water resource problems and promotes programs on conservation education.

1.9.1.4 Texas Natural Resource Conservation Commission

The TNRCC was formed by the Texas Legislature in 1991 by joining the former Texas Water Commission, the Texas Air Control Board, portions of the Texas Department of Health and other smaller agencies into the state's environmental regulatory and enforcement agency.

The TNRCC operates a number of water-related regulatory and pollution prevention programs, including:

- Water rights permitting;
- NPDES wastewater and urban stormwater permitting;
- Clean Rivers (water quality) Program;

- Leaky underground storage tank removal and remediation program;
- Priority Groundwater Management Area program (in conjunction with TWDB);
- Injection and disposal well permitting (in conjunction with the RRC);
- Wellhead protection;
- Solid waste permitting;
- Weather modification permitting; and
- Others.

1.9.1.5 Railroad Commission of Texas

The Railroad Commission of Texas (RRC) is the state agency responsible for regulating the oil and gas industry's safety and compliance. The cornerstone of the Oil and Gas Division's environmental effort are two programs funded by the Oilfield Cleanup (OFC) Fund, which was enacted in SB 1103 in 1991. The OFC Fund provides money to administer the Commission's well plugging and site remediation programs. The Underground Injection Control (UIC) program requires a RRC permit for every injection and disposal well in both productive and non-productive formations. The UIC program coordination has been delegated to the RRC by the USEPA, as mandated by the Safe Drinking Water Act. The RRC rules have been approved by the USEPA and they set very specific standards for well construction and testing to protect fresh water zones.

The RRC also administers several other environmental services. The Rule 8 Permitting Section handles permitting for management of oil and gas wastes at the surface including the use of pits for storage or disposal of waste, disposal methods including discharge to surface water or landspreading and commercial hauling of oil and gas. The Hazardous Waste Program regulates management of hazardous oil and gas wastes under Rule 98. This section coordinates with the TNRCC while actively seeking RCRA authorization from the USEPA for the Commission's hazardous waste program. The Waste Minimization Program works with the oil and gas industry to reduce the volume of waste that must be treated or disposed. The RRC is also responsible for the permitting and monitoring of underground hydrocarbon storage in salt caverns and depleted reservoirs. The Underground Injection Control Program (UIC) administers that portion of the federal UIC program relating to injection/disposal wells for disposal of oil and gas wastes and enhanced recovery of oil and gas under Rules 9 and 46. The RRC rules have been approved by the USEPA and they set very specific standards for well construction and testing to protect fresh water zones.

1.9.2 Regional

1.9.2.1 Underground Water Conservation Districts

The establishment of underground water conservation districts was authorized by the 51st Texas Legislature in 1949 to provide for the conservation, preservation, recharging, and prevention of waste of groundwater, and to control subsidence. Underground water conservation districts are authorized to regulate the use of groundwater and can make and enforce rules providing for the conservation, preservation, protection, and control of those resources. Chapter 36 of the Texas Water Code lays out numerous powers and duties, both required and allowed, of underground water conservation districts.

In addition, these districts may participate in the Agricultural Water Conservation Loan Program. Three of the underground water conservation districts in the region (Sandy Land, South Plains, and High Plains Underground Water Conservation Districts) currently participate in this program. TWDB administers the Agricultural Water Conservation Loan Program, established in 1985 with authority to issue up to $200 million in agricultural water conservation bonds. Districts may use these loans to make improvements to their irrigation facilities, and districts may also serve as lenders, making loans available to individual farmers and ranchers for the purchase and installation of more water-use-efficient irrigation equipment. The funds may also be used to prepare irrigated lands to be converted to dryland conditions and to prepare drylands for more efficient use of natural precipitation.

Six districts are currently in operation in the Llano Estacado Region. Currently active underground water conservation districts are the High Plains, Sandy Land, Mesa, South Plains, Garza County, and Llano Estacado. The Llano Estacado Underground Water Conservation District was confirmed in an election held in November 1998. The Garza County Underground and Freshwater Conservation District was confirmed in 1996. Figure 1-7 shows the area served by each of these districts. All of these older districts have adopted and enforce well spacing rules, have an extensive water-quality and water-level monitoring network, have well spacing regulation rules, and have begun public education programs.

High Plains Underground Water Conservation District No. 1

The Texas State Board of Water Engineers delineated the original boundaries of the High Plains Underground Water Conservation District No. 1 in March 1951. Then, on September 19, 1951, the people in all or parts of 13 Southern High Plains counties voted to create the District in accordance with the Underground Water Conservation Districts Act passed by the Texas Legislature in 1949. Additional territory has been annexed until the District now consists of six full counties (Lubbock, Parmer, Cochran, Lynn, Hale, and Bailey) and parts of nine more counties (Armstrong, Castro, Crosby, Deaf Smith, Floyd, Hockley, Lamb, Potter, and Randall).

The purpose of this District, as stated in the Texas Water Code, Chapter 36, is to provide for the conserving, preserving, protecting, and recharging of the underground water and prevention of waste of the underground water. During its 48-year history, the High Plains Underground Water Conservation District No. 1 has developed a management philosophy, from which management strategies have been developed. The High Plains Underground Water Conservation District No. 1 participates in the Agricultural Water Conservation Equipment Loan Program and has loaned over $15.3 million to area farmers and ranchers who have used these loans to install over 480 new center pivot irrigation systems. The five-member Board has made and enforces rules with advice and consent of 75 County Committee members to best accomplish the purposes of the District. A summary of the District's current activities and programs is shown in Table 1-19.

Mesa Underground Water Conservation District

The citizens of Dawson County, through a local election in January 1990, created the Mesa Underground Water Conservation District. The District boundaries are the same as Dawson County. The District has five board members: one member representing the residents from each of the four county precincts and one at-large member elected by and representing all residents of the county.

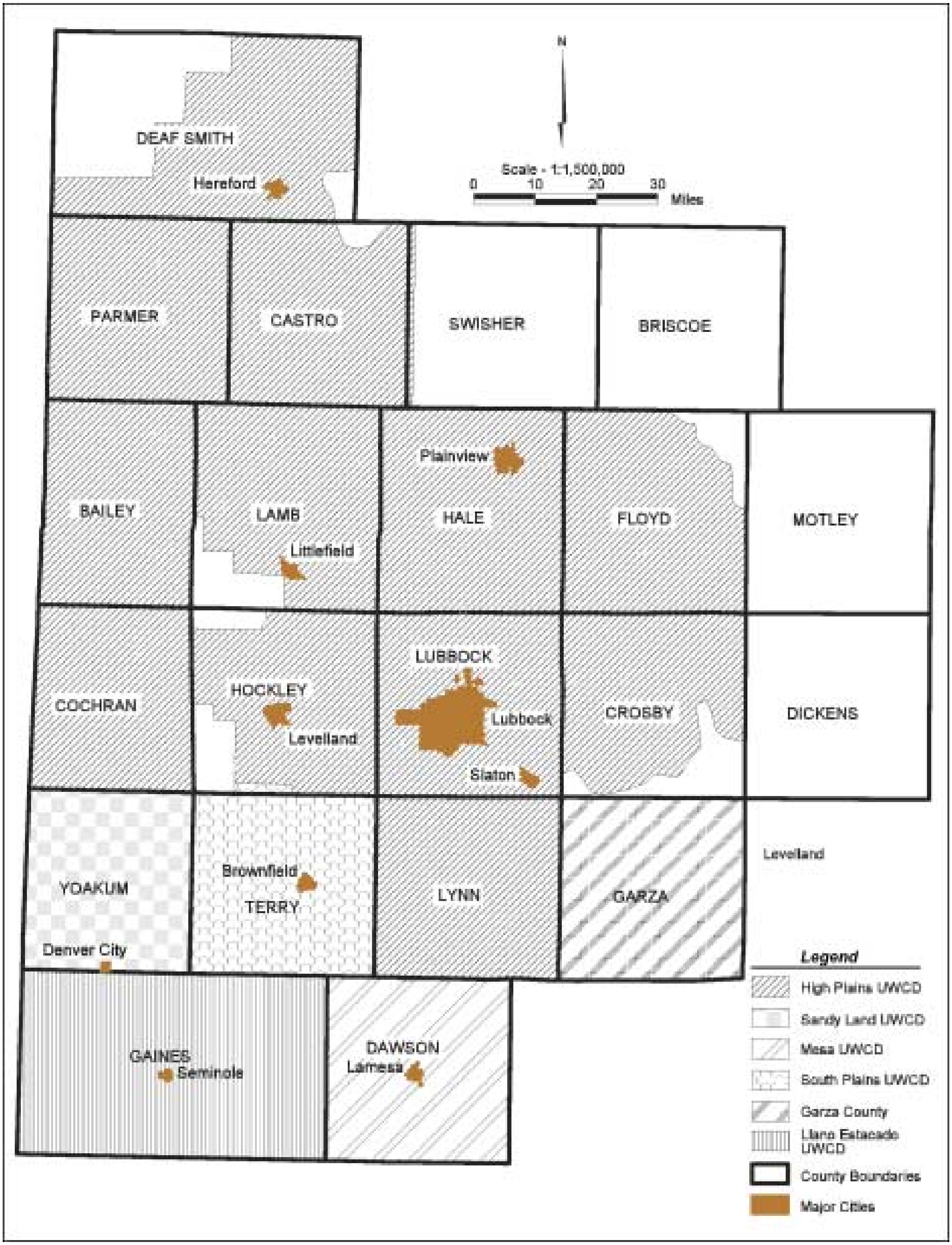

Figure 1-7. Underground Water Conservation District Boundaries (1999) Llano Estacado Region

Table 1-19.
Summary of High Plains UWCD's Activities and Programs

Activities	**Comment**
Well Permitting	The District requires permits for all new wells capable of producing at least 100,000 gpd.
Well Construction Standards	Water Well Drillers and Pump Installers Rules.
Well Spacing	Spacing is based on the size of the new well, with a minimum spacing of 200 yards for a well capable of pumping 265 gpm.
Production Regulations	Production allowable is based on distance from existing wells, starting at 200 yards for a well to produce 70 to 265 gpm.
Water Level Monitoring	Annual measurement is taken in over 1,200 wells over the District.
Water Quality/Quantity Management Programs	Hydrologic atlases showing elevation of land surface, water-table, base of the formation, and saturated thickness are published every 5 years.
Water Quality Testing and Monitoring	A network of approximately 1,000 wells are sampled and analyzed on a 3- to 5-year rotation
Data Collection and Distribution	A database of water quality and approximate quantities of water in storage in the formation is maintained and published in Hydrologic Atlases and in the monthly newsletters.
NPS and Point Source Regulations	Nothing specific, except that contamination of groundwater is considered to be waste, which is a violation of the rules of the District.
Programs	**Comment**
Public Education	Monthly newsletter, frequent Public Service Announcements on radio and TV, distribution of educational materials in public schools, presentations to civic and social groups, TV and radio interviews, and displays in area fairs.
Special Activities	Soil moisture monitoring program, pump plant efficiency testing, tailwater abatement program, open hole closing program, leak detection program for towns and cities, soil chemistry monitoring, low interest agricultural irrigation equipment loan program, cost-in-water income tax depletion allowance program, irrigation scheduling using the potential evapotranspiration network (PET method).

Sandy Land Underground Water Conservation District

The Sandy Land Underground Waster Conservation District (the District) was created in November 1989 by authority of Senate Bill 1777 of the 71st Legislature and has the same areal extent as Yoakum County. The District participates in the Agricultural Water Conservation Loan Program.

The District recognizes that the groundwater resources of the region are of vital importance to the continued vitality of the citizens, economy, and environment within the District. The District's Board feels that the preservation of the groundwater resources can be managed in the most prudent and cost effective manner through the regulation of production as effected by the District's well permitting and well spacing rules. Table 1-20 shows a summary of the District's activities and programs.

Table 1-20.
Summary of Sandy Land UWCD's Activities and Programs

Activities	*Comment*
Well Permitting	The District requires well permits for any wells capable of producing in excess of 25,000 gpd.
Well Construction Standards	The District requires proper completion of wells in accordance with Texas Water Well Driller's Board requirements.
Well Spacing	From property lines: 4-inch or smaller pump - 100 yards from the nearest property line; 5-inch pump - 125 yards from the nearest property line; 6-inch pump - 150 yards from nearest property line; 8-inch pump - 200 yards from nearest property line. Any pump larger than 8-inch - 300 yards from nearest property line.
Production Regulations	5 gpm per acre owned.
Water Level Monitoring	Measures approximately 100 wells within the District annually for water level. Data from measurements sent to the TWDB for their water level database. Data is used by the District to construct annual water level decline maps.
Water Quality/Quantity Management Programs	Water quality program consisting of approximately 100 wells, monitored yearly for various constituents. Coliform bacteria test upon request. Mineral analysis conducted on wells selected by the District upon request.
Water Quality Testing and Monitoring	Maintains an in-house lab where testing can be done at no cost to the well owner as well as no cost through certified labs, if deemed necessary. Works with the Railroad Commission in protecting the groundwater from certain oilfield activities such as saltwater storage and disposal. Conducts pesticide study in the Southern and Northern portions of Yoakum County.
Data Collection and Distribution	Gathers data through the District's annual water level monitoring program. Uses data to construct District's decline maps. Also, supplies data to the TWDB for their water level database. District also collects data from in-house lab.
NPS and Point Source Regulations	Conducts pesticide studies to evaluate point source possibilities.
Programs	***Comment***
Public Education	Educates the public through schools, libraries, speaking engagements and literature distribution.
Special Activities	Pumping efficiency test, flow tests, pumping level and pressure tests for sprinkler systems. Distributes the "Sandy Land News" quarterly. Awards two $1000 scholarships and two $500 scholarships to area high school seniors based on essays relating to conservation and suggestions for future conservation. Free low flow shower heads available to the public. Grants to area farmers, IRS Depletion Program, Ag Water Conservation Equipment Loan Program, managing entity for Yoakum County Landfill. Participates in Precipitation Enhancement Program.

The District believes its most valuable natural resource, water, can be managed at the local level in a prudent and cost effective manner by regulating the spacing of wells and production of water from wells. Table 1-21 shows a summary of these and other activities and programs of the District.

Table 1-21.
Summary of Mesa UWCD's Activities and Programs

Activities	***Comment***
Well Permitting	All new wells are registered prior to drilling.
Well Construction Standards	Consistent with TNRCC Water Well Driller's and Pump Installer's Rules.
Well Spacing	Permitted wells must be drilled no closer than 300 feet from the adjoining landowner's property line. Exceptions may be available with Board approval or with a signed waiver from the adjoining property owner. Exempt wells must meet water well Driller's State Rules.
Production Regulations	5 gpm per acre, not to exceed 4 acft per acre per year.
Water Level Monitoring	The District annually measures 123 wells for baseline comparison. This information is shared with the TWDB.
Water Quality/Quantity Management Programs	The District is involved with the City of Lamesa in a Wellhead Protection Plan. Plans are scheduled for cities of O'Donnell, Ackerly, Welch and Gail.
Water Quality Testing and Monitoring	All wells registered with the District will be tested. The District annually monitors 47 wells for quality comparison.
Data Collection and Distribution	The District collects data and shares data with the TWDB. The District collects data from the used oil collection and used oil filter collection and provides information to the TNRCC.
NPS and Point Source Regulations	The District provides drip oil containers for irrigation wells and is working on an oil drain container for irrigation engines. The District has implemented used oil collection, used oil filter collection and crushing programs.
Programs	***Comment***
Public Education	The District distributes educational materials including conservation book covers to all schools in the District. The District also provides education booths at the County Fair, with presentations of "Willie the Water Dog" to younger students and demonstrations of their water model to older students.
Special Activities	The District provides news articles for the local newspaper and participates in Texas Recycles Day.

South Plains Underground Water Conservation District.

The South Plains Underground Water Conservation District was created on April 23, 1991, when Governor Ann Richards signed HB 281, 72nd Legislature, into law. Originally, the jurisdictional extent of the District was the same as Terry County. However, in 1994, landowners controlling 1,302 acres of land in Hockley County, individually petitioned the District for annexation. Each petition was approved by unanimous vote of the Board.

To accomplish the District's mission of developing, promoting, and implementing management strategies to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater resources, the District has implemented several activities and programs. The District participates in the Agricultural Water Conservation Equipment Loan Program and has loaned approximately $4.7 million to facilitate the installation of 182 water-efficient irrigation systems. Table 1-22 shows a summary of the District's activities and programs.

Garza County Underground and Fresh Water Conservation District

The Garza County Underground and Fresh Water Conservation District was created and organized under the terms and provisions of Section 59, Article XVI, Texas Constitution and House Bill 846, including all amendments and additions, of the 74th Legislature in 1995. The District has all of the rights, powers, privileges, authority, functions, and duties provided by the general laws of this state, including Chapter 36 of the Texas Water Code, Vernon's Texas Codes Annotated, applicable to underground water conservation districts created under Section 59, Article XVI, Texas Constitution.

The District recognizes that the groundwater resources of the region are of vital importance to the residents of the District and that this resource must be managed and protected from contamination and waste. To accomplish these objectives, the District has instituted regulations governing well permitting and well spacing along with other regulations. Table 1-23 shows a summary of the District's activities and programs.

Table 1-22.
Summary of South Plains UWCD's Activities and Programs

Activities	***Comment***
Well Permitting	The District requires drilling permits for wells whose expected production capability will be 25,000 gpd (17.36 gpm) or more.
Well Construction Standards	Same as those set by the state.
Well Spacing	From property lines and between wells. Based on the size of pump installed and corresponding gallon per minute pumping rate.
Production Regulations	5 gpm per acre, not to exceed 4 acft per acre per year.
Water Level Monitoring	Measures approximately 100 wells in the District annually for water level. Data from measurements are sent to the TWDB for their water level database. Data are used by the District to construct annual water decline maps.
Water Quality/Quantity Management Programs	The District works with local and state agencies on water analysis and management programs.
Water Quality Testing and Monitoring	The District annually monitors water quality of approximately 100 domestic and 40 irrigation water wells. Water quality testing services are extended to the general public at no charge and include coliform bacteria testing.
Data Collection and Distribution	The District collects and distributes water level measurement data to state agencies and to local government and individuals upon request.
NPS and Point Source Regulations	The District has well construction standards and addresses pollution of groundwater in its rules.
Programs	***Comment***
Public Education	The District educates the public through schools, speaking engagements, and literature distribution.
Special Activities	The District sponsors free flow testing and efficiency testing for local irrigated agricultural producers. The District participates in the Agricultural Conservation Loan Program administered by the TWDB and since 1994 has loaned over $4.7 million to ag producers and landowners to finance 182 center pivots. The District sponsors Major Rivers educational curriculum for all 4th graders in Terry County. The District sponsors awards for 4-H and assists in Natural Resources projects. The District began participating in a weather modification project May 1, 1998 in conjunction with the High Plains Underground Water Conservation District No. 1, Sandy Land Underground Water Conservation District, and the Llano Estacado Weather Modification Association in New Mexico.

Table 1-23.
Summary of Garza County Underground and Freshwater Conservation District's Activities and Programs

Activities	***Comment***
Well Permitting	The District requires well permits for any well capable of producing in excess of 25,000 gallons of water per day.
Well Construction Standards	The District requires proper completion of wells in accordance with Texas Water Well Driller's Board requirements.
Well Spacing	Based on size of pump installed and corresponding gpm pumping rate.
Production Regulations	Production allowable is based on distance from other wells, starting at 50 yards for a 1.5-inch pump or well producing 40 to 70 gpm.
Water Level Monitoring	Pending.
Water Quality/Quantity Management Programs	The District works with local and state agencies on water analysis and management programs.
Water Quality Testing and Monitoring	Pending.
Data Collection and Distribution	Pending.
NPS and Point Source Regulations	The District rules state that all wells drilled will be at least 150 feet from any contamination (e.g., livestock or poultry yards, septic absorption fields or privies) and not located in an area generally subject to flooding. In case of a flood area, a sanitary water tight seal must be installed at least 24 inches above the known flood level.
Programs	***Comment***
Public Education	Yes.
Special Activities	Yes.

Llano Estacado Underground Water Conservation District

The Llano Estacado Underground Water Conservation District was created in 1991 by the 72nd Texas Legislature and encompasses all of Gaines County. District creation was confirmed by the voters in November 1998. The District is in the process of developing and adopting rules and a management plan.

1.9.2.2 River Authorities

Five river authorities, water authorities, or water districts operate within the Llano Estacado Region: the Canadian River Municipal Water Authority (CRMWA), White River Municipal Water District (WRMWD), Mackenzie Municipal Water Authority (MMWA), Red River Authority (RRA), and the Brazos River Authority (BRA).

Canadian River Municipal Water Authority

The Canadian River project received federal authorization in December 1950, and in November 1953 the legislature authorized the CRMWA to organize as a legal entity and independent political subdivision of Texas. Eleven cities formed the Authority: Amarillo, Borger, Pampa, Plainview, Lubbock, Slaton, Brownfield, Levelland, Lamesa, Tahoka, and O'Donnell. Under a tri-state compact, Texas was entitled to 100,000 acft of water a year for use by the member cities and 51,000 acft for use by industries (See following section). The dam crossing the Canadian River 9 miles west of Borger is 226 feet high and 6,380 feet long. The aqueduct system, with 322 miles of pipeline, ten pumping plants, and three regulating reservoirs, furnishes municipal and industrial water to the cities of the Authority. Table 1-24 shows a summary of CRMWA's programs and activities. CRMWA has acquired extensive groundwater rights from Region A to improve the quality of water delivered to its member cities.

Table 1-24.
Summary of CRMWA's Programs and Activities

Programs & Activities	***Comment***
Chloride Control	The Authority is researching a plan to reduce the natural salt flow into Lake Meredith. According to the plan, saltwater would be pumped from wells drilled into a natural brine artesian aquifer currently discharging into the Canadian River. The saltwater would be disposed of into an injection well.
Water Quality Improvements	The Conjunctive Use Groundwater Supply Project being developed in Roberts and Hutchinson Counties will supply groundwater to be mixed with surface water before being delivered to member cities.
Water Quality Monitoring	The Authority regularly monitors the water quality of Lake Meredith.
Water Supply Programs	The Authority supplies water from Lake Meredith and a well field to its eleven member cities.

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

White River Municipal Water District

The WRMWD owns and operates White River Reservoir, from which the District's water right authorizes the diversion of up to 6,000 acft of water per year for municipal and mining purposes. The District delivers water to Crosbyton, Ralls, Spur, and Post. Table 1-25 shows a summary of WRMWD's activities and programs.

WRMWD has obtained groundwater rights and drilled and equipped several wells so that groundwater will be available to supplement the surface water in times of drought.

Table 1-25.
Summary of White River MWD's Programs and Activities

Programs & Activities	Comment
Water Quality Monitoring	The Authority maintains a water quality monitoring program at its treatment plant.
Water Supply Programs	The Authority supplies water to communities located in five counties.
Public Participation & Education	**Comment**
Educational Programs	The Authority hosts field trips by area schools to view its facilities.

Mackenzie Municipal Water Authority

The MMWA owns and operates Lake Mackenzie located in Swisher and Briscoe Counties. The District delivers water to the Cities of Silverton, Tulia, Floydada, and Lockney. Table 1-26 shows a summary of MMWA's activities and programs.

Table 1-26.
Summary of Mackenzie MWA's Programs and Activities

Programs & Activities	Comment
Water Quality Monitoring	The Authority maintains a water quality monitoring program.
Water Supply Programs	The Authority supplies water to four cities.
Public Participation & Education	**Comment**
Educational Programs	The Authority hosts field trips by area school children to view its facilities.

Brazos River Authority

The BRA was established in 1929 by the Texas Legislature as a public agency of the state of Texas. It has statutory responsibility for developing and conserving the surface water resources of the Brazos River Basin in Texas and for putting these resources to use in the best interest of the people of Texas. The Brazos River Basin covers some 42,000 square miles in Texas, about one-sixth of the area of the state; the boundaries of the river authority include all or part of 65 Texas counties. About 8,732 square miles (43 percent) of the Llano Estacado Region lie in the Brazos Basin or BRA management area. Table 1-27 shows a summary of BRA's programs and activities.

Table 1-27.
Summary of BRA's Programs and Activities

Programs & Activities	***Comment***
Texas Clean Rivers Program	The Authority contracts with the TNRCC to conduct the Clean Rivers Program for the Brazos River Basin.
Watershed Protection	The Authority established the Watershed Protection Program in 1994 to focus attention on watersheds where water quality problems have been identified and to establish instream water quality targets.
Water Quality Monitoring	The Authority evaluates water quality conditions of the reservoirs and stream segments that comprise the Authority's basin-wide water supply system. The Authority also maintains a water quality testing lab.
Water Supply Programs	The Authority supplies water to several entities in the Brazos River Basin.
Public Participation & Education	***Comment***
Newsletter	The Brazos Basin Update is a quarterly newsletter about Authority programs and activities.
Educational Programs	The Authority participates in the Major Rivers Water Education Program which is intended to help fourth-grade children throughout Texas learn about how we get and use water and how important it is for us to conserve water.

Red River Authority

The RRA of Texas, an official agency of the state, was created by an act of the 56th Legislature in 1959. It has jurisdiction over the entire Red River watershed in Texas, including all or part of 43 counties, an area encompassing 40,266 square miles. About 6,681 square miles (32.9 percent) of the Llano Estacado Region in the Red River Basin or RRA management area. The RRA has broad powers over the conservation, storage, control, preservation, quality, and utilization of water along the Red River and its Texas tributaries. Headquarters for the authority is located in Wichita Falls. The Authority assists communities, towns, municipalities, and other entities in an effort to identify and encourage development of potential water-supply sources, to conserve and protect existing water supplies, and to develop and improve water and wastewater facilities. In compliance with the Clean Rivers Act, the RRA has prepared a 5-year work plan for water-quality assessment of the Red River basin. Table 1-28 shows a summary of the RRA's activities and programs.

Table 1-28.
Summary of RRA's Programs and Activities

Programs & Activities	***Comment***
Texas Clean Rivers Program	The RRA contracts to perform Clean River Act duties on behalf of both the Canadian River Basin and the Red River Basin.
Chloride Control	The RRA is playing a role in the Red River Basin Chloride Control Project, a federal endeavor to reduce the naturally occurring levels of chlorides in the Red River and its tributaries.
Water Quality Monitoring	The Authority collects water quality samples to determine quantitative cause and effect relationships of water quality, obtain sufficient data for updating water quality management plans, set effluent limits, identify nonpoint sources of pollution and classify stream segments.
Water Supply Programs	The Authority supplies water to several entities within the Red River Basin.
Public Participation & Education	***Comment***
Texas Rivers Project	The Texas Rivers Project is a grassroots initiative developed as a result of a joint partnership between the RRA and River Bend Nature Works, Inc. of Wichita Falls. The program consists of a multi-disciplinary curriculum with focus on math, science, technology and social studies relating to water ecology and includes volunteer environmental monitoring.
Educational Programs	The Authority participates in the Major Rivers Water Education Program which is intended to help fourth-grade children throughout Texas learn about how we get and use water and how important it is for us to conserve water.

1.9.3 Local

1.9.3.1 City of Lubbock

The City is supplied water by CRMWA and obtains water from its own well fields in Bailey and Lamb Counties. In the foreseeable future, Lubbock will continue to rely on surface water from CRMWA, groundwater from CRMWA's new Roberts County well field and from the City's own well fields to meet its needs. The City also has water rights in Lake Alan Henry. Transportation facilities will have to be constructed before the water can be utilized. No date has been determined that water will be needed from Lake Alan Henry.

1.10 Existing Water-Related Plans

1.10.1 State Water Plan [48]

In Section 16.051 of the Texas Water Code, the Executive Administrator of the TWDB is charged with producing a State Water Plan that addresses the broad public interest of the state. As currently specified in Section 16.055 and 16.056, the Plan is to be periodically reviewed and updated and serves as a flexible guide to state policy for the development of its water resources.

The Plan provides a statewide perspective that places local and regional needs in a broader context. New legislation, passed by the 75th Legislature in 1997, specifies a 5-year update period for the Plan, which is to be based on regional planning studies, and provides that related financial assistance applications must be consistent with the regional and state plans for regulatory approval by state agencies. The ultimate goal of the State Water Plan is to identify those policies and actions that may be needed to meet Texas' near- and long-term water needs, based on a reasonable projected use of water, affordable water supply availability, and a goal of conservation of the state's natural resources.

The following sections provide a summary of recommendations for this region contained in the 1997 Water for Texas Update to the State Water Plan.

1.10.1.1 Canadian River Basin

Due to the scarcity of locally-developable surface water supplies, any additional water needed for the basin will likely come from reuse of present supplies, development of additional well fields in the Ogallala Aquifer, and possible new development of minor aquifers present in the basin. A recent example of additional well field development is the planned CRMWA's well fields in Roberts County, which are expected to supplement and improve the quality of Lake Meredith's surface water. The Authority is permitted to use a maximum of 40,000 acft of groundwater per year from these wells and up to 50,000 acft under unusual or emergency conditions. This approach cannot necessarily be used throughout the area; however, there are certain other areas of the Ogallala that could be developed.

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[48] Texas Water Development Board, "Water for Texas, A Consensus-Based Update to the State Water Plan," August 1997.

1.10.1.2 Red River Basin

Due to the scarcity of locally-developable surface water supplies in the High Plains portion in the upper basin, any additional supplies needed to this area will likely come from reuse of present supplies, development of additional well fields in the Ogallala Aquifer, and possible new development of minor aquifers present in the basin.

1.10.1.3 Brazos River Basin

Due to the scarcity of locally-developable surface water supplies, any additional supplies needed for the Southern High Plains portion of the upper basin will likely come from reuse of present supplies, development of additional well fields in the Ogallala Aquifer, and possible new development of minor aquifers present in the basin. The recently completed Lake Alan Henry will be required to provide additional water supplies to Lubbock. The Post Reservoir project is permitted for development in the Brazos Basin.

The White River Municipal Water District (WRMWD) has a state permit to construct the Post Reservoir project on the North Fork Double Mountain fork of the Brazos River in Garza County, but has yet to apply for the necessary federal permits. The state permit authorizes the owner to impound 57,420 acft of water at elevation 2,430 ft-msl. This project is permitted to supply 10,600 acft of water per year for municipal, industrial and mining use. The estimated cost for the Post project is $35.5 million (1997 prices).

1.10.1.4 Colorado River Basin

Due to scarcity of locally-developable surface water supplies, any additional supplies needed for the Southern High Plains portion of the upper basin will likely come from reuse of present supplies, development of additional well fields in the Ogallala Aquifer, and possible new development of minor aquifers present in the basin.

1.10.2 Regional Drought Contingency and Groundwater Management Plans

1.10.2.1 Brazos River Authority [49]

The Brazos River Authority's drought contingency plan defines triggering conditions, based on reservoir levels, for water shortage conditions and actions designed to lower water use

[49] Brazos River Authority, "Drought Contingency Policy," July 1999, and "Water Conservation Policy," July 1999.

during these conditions. Upon the declaration of drought conditions for a particular reservoir, the Authority will develop a specific drought contingency plan for the system or local use reservoir. In addition to the drought contingency plan, the Authority has also developed a water conservation plan which outlines several goals to encourage water conservation within the Brazos River Basin, including developing and implementing a water conservation education and information program and encouraging and assisting contract users in developing and implementing water conservation programs.

1.10.2.2 Canadian River Municipal Water Authority [50]

The Canadian River Municipal Water Authority (CRMWA) supplies raw water to eleven Member Cities via a 322-mile aqueduct system. The CRMWA's primary source of water is Lake Meredith located in the Canadian River Basin. The CRMWA's water conservation plan provides conservation goals, as well as setting standards for leak control and repair, measurement of diverted water, and records management. The CRMWA has also adopted a drought contingency plan which defines trigger conditions for water shortage conditions and goals of water use reduction while the water shortage condition persists. To achieve the water use reduction goals, during times of water shortages CRMWA's Member Cities will implement their individual drought contingency plans.

1.10.2.3 Garza County Underground and Freshwater Conservation District [51]

This management plan becomes effective upon Certification by the TWDB after adoption by the District Board of Directors and remains in effect until September 1, 2008 or for a period of 10 years, whichever is later. The plan may be revised at any time or after 5 years, when the plan will be reviewed to insure that it is consistent with the applicable Regional Water Plan and the State Water Plan. The overall objective of the District is the conservation, preservation, protection, recharge, and enhancement of the groundwater supplies within the boundaries of the District and to make wise and beneficial use of the resources for the benefit of the citizens and economy of the District. To accomplish these goals, the District plans to implement a program

[50] Canadian River Municipal Water Authority, "Drought Contingency Plan," July 14, 1999, and "Water Conservation Plan," July 14, 1999.
[51] Garza County Underground and Freshwater Conservation District, "Water Management Plan," 1998.

to monitor both the quantity and quality of these water supplies and also to promote a brush control program for the District.

In developing a drought contingency plan, the District will consider the economic effects of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage and weather conditions, and the appropriate conditions under which to implement the contingency plan.

1.10.2.4 High Plains Underground Water Conservation District No. 1[52]

This current management plan is a revision of the management plan adopted by the Board in June 1998. This plan became effective August 11, 1998, upon adoption by the Board of Directors of the District and will remain in effect until a revised plan is approved or until August 31, 2008, whichever is earlier. From the District's inception, the Board of Directors has upheld the philosophy that ownership of the groundwater is a private property right. The Directors continue to support this right for the landowners. The philosophy of groundwater management in the District was established early and formally adopted by the Board; the District is dedicated to the principle that conservation is best accomplished through public education.

The District enforces its rules to conserve, preserve, protect, and prevent the waste of groundwater resources in its jurisdiction. Besides public education, the District management plan outlines its well registration, well spacing, water level monitoring, pre-plant soil moisture, potential evapotranspiration irrigation scheduling, and agricultural water conservation loan equipment programs. The District also publishes an annual report outlining its performance in achieving its goals.

All of the District's programs and activities are directed at promoting maximum conservation of the area's water resources. The adoption and utilization of the best available technology and equipment by area water users, on a continuous basis, is the best drought contingency plan possible. Installing and utilizing equipment that result in minimum loss or waste of water prior to a drought reduces the impact of a drought when one occurs.

[52] High Plains Underground Water Conservation District No. 1, "Management Plan," August 11, 1998.

1.10.2.5 Mackenzie Municipal Water Authority [53]

The Mackenzie Municipal Water Authority owns and operates Lake Mackenzie from which the Authority supplies water to the cities of Floydada, Lockney, Silverton, and Tulia, located within the planning area. The triggering criteria for water allocation in this plan is based entirely on the water level in Lake Mackenzie. This plan also identifies water conservation goals that will be placed into effect during water shortage conditions. Under this plan, during a mild water shortage condition, the Authority will try to achieve a voluntary 10 to 20 percent reduction in total water use, while during a severe water shortage condition, the Authority's goal is to achieve a 50 to 60 percent reduction in total water use.

1.10.2.6 Mesa Underground Water Conservation District [54]

The District management plan became effective August 31, 1998 following adoption by the local Board of Directors and certification by the TWDB. The District management plan will remain in effect for a period of 10 years (minimum planning period), until a revised or amended plan is certified, or September 1, 2008, whichever comes first. The guiding principles in developing the management plan are to better understand groundwater conditions, to encourage the most efficient use of groundwater, to preserve and improve groundwater quality, to increase public awareness and education, and to monitor legislative activities along with rules and orders of state agencies which may affect the private ownership of groundwater including the authority to manage at the local level.

A contingency plan to cope with the effects of water supply shortages due to climatic or other conditions will be developed by the District and will be adopted by the Board after notice and hearing. In developing the contingency plan, the District will consider the economic effect of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydrogeologic conditions of the aquifer, and the appropriate conditions under which to implement the contingency plan.

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[53] Mackenzie Municipal Water Authority, "Drought Contingency Plan for Mackenzie Municipal Water Authority," August 1, 1999.
[54] Mesa Underground Water Conservation District, "Management Plan," August 31, 1998.

1.10.2.7 Sandy Land Underground Water Conservation District [55]

This management plan became effective on September 1, 1998 upon adoption by the Sandy Land Underground Water Conservation District Board of Directors and certification as administratively complete by the TWDB. The plan will remain in effect through September 2008 or until a revised plan is adopted and certified. The Sandy Land Underground Water Conservation District recognizes that the groundwater resources of the region are of vital importance to the continued vitality of the citizens, economy and environment within the District. The District feels that the preservation of the groundwater resources can be managed in the most prudent and cost effective manner through the regulation of production as effected by the District's well permitting and well spacing rules. This management plan is intended as a tool to focus the thoughts and actions of those individuals charged with the responsibility for the execution of District activities.

A contingency plan to cope with the effects of water supply deficits due to climatic or other conditions will be developed by the District and will be adopted by the Board after notice and hearing. In developing the contingency plan, the District will consider the economic effect of conservation measures upon all water resource user groups, the local implications of the degree and effect of changes in water storage conditions, the unique hydrogeologic conditions of the aquifers within the District, and the appropriate conditions under which to implement the contingency plan.

1.10.2.8 South Plains Underground Water Conservation District [56]

This management plan became effective September 1, 1998, upon adoption by the Board of Directors of the District and will remain in effect until a revised plan is approved or until August 31, 2008, whichever is earlier. The District was formed, and has been operated from its inception, with the guiding belief that the ownership and pumpage of groundwater is a private property right. The Board has adopted the principle of "education first" and regulation as a last resort in their effort to encourage conservation of the resource. As a result, the rules of the District were designed to give all landowners a fair and equal opportunity to use the groundwater

[55] Sandy Land Underground Water Conservation District, "Groundwater Management Plan," July 10, 1998.
[56] South Plains Underground Water Conservation District, "Management Plan," September 1, 1998.

resource underlying their property for beneficial purposes. Effective July 1, 1999, the District adopted new rules that regulate the spacing between wells.

In the District, groundwater conservation is stressed at all times. The Board recognizes that irrigated agriculture provides the economic stability to the communities within the District. Therefore, through the notice and hearing provisions required in the development and adoption of this management plan, the Board has adopted the official position that, in times of precipitation shortage, irrigated agricultural producers will not be limited to any less pumpage of groundwater than is provided for by District rules. In order to treat all other groundwater user groups fairly and equally, the District will encourage more stringent measures, where practical, but will not limit groundwater use in any way not already provided for by District rules.

1.10.2.9 White River Municipal Water District [57]

The White River Municipal Water District's primary water supply is obtained from surface water diverted from White River Lake, however the District has purchased groundwater rights and drilled wells to supplement its surface water supply during times of prolonged drought. The District's Water Conservation Plan applies to each of the District's customers which the District bills directly. However, the plan does not apply to the District's member cities (Crosbyton, Post, Ralls, and Spur).

It is the goal of the District to maintain unaccounted-for water at 15 percent or less and to achieve a 1 percent reduction in average day municipal per capita water use by the year 2050. In order to achieve these goals the District will promote water conservation by informing the public of ways to conserve water, adopting a new plumbing code, and instituting a plumbing retrofit program. In addition to these measures, the District will also test or replace meters that appear to have abnormally high or low water usage and will establish a leak detection and repair program.

[57] White River Municipal Water District, "Water Conservation Plan," July 2, 1999.

1.10.3 Local Drought Contingency Plans

1.10.3.1 City of Brownfield [58]

The City of Brownfield's Drought Contingency Plan outlines the city's drought and emergency contingency procedures and identifies the triggering criteria for initiation and termination of drought response stages as well as the water use restrictions in effect during times of water shortages. It is the goal of this plan to reduce total water use by 50 percent during "critical water shortage conditions" and 75 percent during "emergency water shortage conditions." To achieve these goals, the plan contains restrictions on water use to be in effect during water shortages that include irrigation of landscaped areas, use of water to wash any motor vehicle, operation of any ornamental fountain or pond, and other restrictions on outdoor water use. Water uses regulated or prohibited under this plan are considered to be non-essential and continuation of such uses during times of water shortage or other emergency water supply conditions are deemed to constitute a waste of water which subjects the offender to penalties such as fines or citations.

1.10.3.2 City of Denver City [59]

The City of Denver City owns and operates the water system and provides potable water to its residents. The city's current water supply is well water from the Ogallala Aquifer system and the Trinity Group. Six wells are located 1 mile west of the city; and other wells are located 7 miles west of the city. The total pumping capacity of these wells is 6.5 MGD. The city leases the water rights of the wells one-mile west of the city from Exxon, Inc. Additional water rights are owned on two sections 7.5 miles northwest of the city. The city is planning to extend water lines east of the city and expects to provide water to approximately 40 customers who currently have domestic water wells. Some of these privately-owned wells are threatened with contamination.

Denver City's average daily usage was 126 gpcd in 1987 and 149 gpcd in 1988. It is the goal of the water conservation plan to reduce water usage to 140 gpcd.

The city's drought contingency program includes measures to significantly reduce water use on a temporary basis. These measures involve voluntary reductions, restrictions and/or

[58] City of Brownfield, "Drought Contingency Plan for the City of Brownfield," August 19, 1999.
[59] City of Denver City, "Water Conservation and Drought Contingency Plan," December 4, 1989.

elimination of certain types of water use, and water rationing. It is the goal of the drought contingency plan to reduce water use during an emergency or prolonged drought by 35 percent.

1.10.3.3 City of Lamesa[60]

The City of Lamesa's Drought Contingency Plan outlines the city's drought and emergency contingency procedures and identifies the triggering criteria for initiation and termination of drought response stages, as well as the water use restrictions in effect during times of water shortages. It is the goal of this plan to reduce total water use by 50 percent during "critical water shortage conditions" and 75 percent during "emergency water shortage conditions." To achieve these goals, the plan contains restrictions on water use to be in effect during water shortages that include irrigation of landscaped areas, use of water to wash any motor vehicle, operation of any ornamental fountain or pond, and other restrictions on outdoor water use.

1.10.3.4 City of Levelland[61]

The City of Levelland's Drought Contingency Plan outlines the city's drought and emergency contingency procedures and identifies the triggering criteria for initiation and termination of five water shortage conditions, as well as the water use restrictions in effect during these stages. The goals of this plan are to achieve a voluntary 3 percent reduction in daily water demand during mild water shortage conditions and to achieve an 18 percent reduction in daily water demand when under a "critical water shortage condition." To achieve these goals, the plan contains restrictions on water use to be in effect during water shortages that include irrigation of landscaped areas, use of water to wash any motor vehicle, operation of any ornamental fountain or pond, and other restrictions on outdoor water use. Water uses regulated or prohibited under this plan are considered to be non-essential and continuation of such uses during times of water shortage or other emergency water supply conditions are deemed to constitute a waste of water which subjects the offender to penalties such as fines or citations.

[60] City of Lamesa, "Drought Contingency Plan," August 16, 1999.
[61] City of Levelland, "Drought Contingency Plan," July 29, 1999.

1.10.3.5 City of Littlefield [62]

The City of Littlefield owns, operates, and manages the water works system. The city's waterworks system serves approximately 2,921 connections. The majority of these connections are within the city limits of Littlefield. However, a few of the customers live outside the corporate limits of the city. The waterworks system covers approximately 3.5 square miles. Over the past several years the city has experienced moderate growth. The city's water works system has not been exceeded in its available capacity to supply the customers' demand. Littlefield is considering obtaining additional water rights to assure future water for its customers. From the Utility Evaluation, the City of Littlefield has set a goal of per capita water use reduction of 15 percent.

The City of Littlefield's Emergency Water Demand Management Plan contains trigger conditions to stipulate when water use should be curtailed. The plan includes restrictions on lawn watering, car washing, and certain public water uses that are not essential for public health or safety.

1.10.3.6 City of Lubbock [63]

The purpose of the City of Lubbock's Water Conservation Plan is to promote the responsible use of water by (1) supporting public education programs, (2) maintaining policies that support wise use of water, and (3) providing for enforcement of water conservation policies and practices. It is the goal of the Plan to reduce water usage by 20 gpcd by the year 2014. To achieve this goal, the City of Lubbock will continue its programs for universal metering and controlling unaccounted-for uses of water, as well as continue the city's program of continuing education regarding water conservation.

The City of Lubbock's Drought Contingency Plan outlines the city's drought and emergency contingency procedures and identifies the triggering criteria for initiation and termination of the four water shortage conditions, as well as the water use restrictions in effect during times of water shortages. The plan contains restrictions on water use to be in effect

[62] Oller Engineering, Inc. for the City of Littlefield, "Water Conservation Plan and Drought Contingency Plan," March 1997.
[63] City of Lubbock, "Water Conservation Plan," August 26, 1999, and "Drought Contingency Plan," August 26, 1999.

during water shortages that include irrigation of landscaped areas, use of water to wash any motor vehicle, operation of any ornamental fountain or pond, and other restrictions on outdoor water use. Water uses regulated or prohibited under this plan are considered to be non-essential and continuation of such uses during times of water shortage or other emergency water supply conditions are deemed to constitute a waste of water which subjects the offender to penalties such as fines or discontinuance by the city of water services to water utility customers or other users.

1.10.3.7 City of Plainview [64]

The City of Plainview's Conservation and Drought Contingency Plan outlines ordinances the city has put into effect to reduce per capita use and to curtail water use during times of drought. In order to lower the city's per capita water use the city has adopted a plumbing code that limits residential meters to 1-inch or smaller, has initiated a water meter retrofit program, provides educational materials on water conserving landscaping, and maintains a leak detection and repair program.

The city's drought contingency plan outlines the city's drought response procedures. The plan contains restrictions on water use to be in effect during water shortages that include irrigation of landscaped areas, use of water to wash any motor vehicle, and other restrictions on outdoor water use.

1.10.3.8 City of Seminole [65]

The City of Seminole operates a water system for approximately 2,400 utility customers. It has the capability of producing 5.5 mgd of potable water from 18 wells in the Ogallala Aquifer system. Seven of these wells are located inside the city limits with the other eleven scattered over five sections of land. All wells are included in a computerized water automation system in which radio signals sent to a computer control the levels of water in the groundwater storage and elevated storage tanks along with the operation of the wells. This system also allows the city to sequence the wells desired so that different wells turn on at different times and under different conditions.

[64] Freese & Nichols for the City of Plainview, "Drought Contingency Plan," July 26, 1994.
[65] Information transmitted in a letter received from the City of Seminole dated October 26, 1999.

In an additional effort to conserve water, a policy of voluntary conservation is in effect. There are two additional stages of conservation that may be implemented by the Mayor upon the recommendation of the City Administrator and Public Works Director. The first is to move the voluntary conservation policy into a water warning in which outdoor watering is curtailed. The second is to declare a water emergency, prohibit all outdoor watering and limit all other water use to essential domestic purposes.

1.10.3.9 City of Tulia [66]

The City of Tulia waterworks system serves approximately 2,033 connections. The majority of these connections are within the city limits of Tulia, although a few customers live outside the corporate limits of the city. The waterworks system covers approximately 3.72 square miles. Over the past several years the city has experienced moderate growth. The city's waterworks system has not been exceeded in its available capacity to supply the customers' demand. Tulia is a member of the Mackenzie Municipal Water Authority, but since drought conditions in the area have reduced the reservoir's available supply to all member cities Tulia has obtained its own groundwater supplies to assure future water supplies for its customers.

The City of Tulia's Emergency Water Demand Management plan contains trigger conditions to stipulate when water use should be curtailed. The plan includes restrictions on lawn watering, car washing, and certain public water uses that are not essential for public health or safety.

1.10.4 Water Availability Requirements Promulgated by County Commissioners Courts

In Region O, there are no known actions by county commissioners courts to establish water availability requirements.

1.10.5 Summary of Current Preparations for Drought

During periods of drought, water usage quite often exceeds the capacity of the distribution systems of many of the small towns in the region. Citizens are notified by the local news media that they need to curtail usage to prevent emptying the water tower storage. The reason given is that water may be needed to fight a fire. Most citizens readily comply without

[66] Oller Engineering, Inc. for the City of Tulia, "Water Conservation Plan and Drought Contingency Plan," March 1997.

ordinances. Most water supply entities have indicated they will adopt mandatory water conservation during times of prolonged drought, which may include limitations on outdoor and recreational water use. Because of recent droughts in the region, many local planning authorities are now looking more towards future drought planning.

1.10.6 Other Relevant Natural Resource Plans

1.10.6.1 Playa Lakes Joint Venture [67]

The Playa Lakes Joint Venture (PLJV) was organized to implement the North American Waterfowl Management Plan in the Playa Lakes Region (PLR). The PLR includes portions of southeastern Colorado, southwestern Kansas, eastern New Mexico, western Oklahoma, and northwestern Texas. The goal of the PLJV is successful accommodation of objective numbers of waterfowl, migratory birds, and other wildlife, wintering in, migrating through, and breeding in the PLR. The five general objectives of the PLJV are:

- No loss or further degradation of playa wetlands, saline lakes, reservoirs, tanks, riparian areas, or other wetlands in the PLR;
- To have sufficient high-quality wetland habitat to permit wide-spread dispersion of waterfowl within the PLR;
- To have sufficient seasonal food resources for waterfowl and other wetland-dependent wildlife populations in the PLR;
- To have healthy and secure wetland and upland habitats to ensure optimum survival and diversity of waterfowl and other wildlife in the PLR; and
- To maintain successful reproduction of waterfowl and other wildlife breeding in the PLR.

There are six specific habitat objectives:

- Protection of valuable historical migratory bird use areas;
- Protection and enhancement of wetland areas that are adequately distributed throughout the PLR;
- Direct conservation of 10 percent of playas and associated uplands;
- Indirect conservation of 10 percent of playas and associated uplands;
- Protection and enhancement of important riparian areas; and
- Conservation of at least 10,000 acres of other wetlands (e.g., seepage areas, saline lakes) and their associated habitats.

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[67] Playa Lakes Joint Venture Management Board, “Final Implementation Plan,” Albuquerque, NM, November 1994.

1.10.6.2 Major Water Providers

The TWDB's definition of a Major Water Provider (MWP) is as follows:

"A MWP 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."

At its meeting on April 22, 1999 the LERWPG identified the MWPs for the Llano Estacado Region. The list of MWPs for the Llano Estacado Region and the cities within the region to which they provide water is as follows:

Canadian River Municipal Water Authority (CRMWA) (see page 1-76)

1) City of Brownfield
2) City of Lamesa
3) City of Levelland
4) City of Lubbock
5) City of O'Donnell
6) City of Plainview
7) City of Slaton
8) City of Tahoka

White River Municipal Water District (WRMWD) (see page 1-77)

1) City of Crosbyton
2) City of Post
3) City of Ralls
4) City of Spur

Mackenzie Municipal Water Authority (MMWA) (see page 1-77)

1) City of Floydada
2) City of Lockney
3) City of Silverton
4) City of Tulia

1.11 Laws of Physics Which Affect Water Well Yields--Described and Illustrated for the Ogallala, Dockum, and Cretaceous Formation in The Llano Estacado Regional Water Planning Area

1.11.1 The Ogallala Aquifer

The laws of physics, as they relate to estimating changes in well yields following prolonged periods of pumpage from the Ogallala Aquifer, are complicated by the fact that the Ogallala Formation within the Llano Estacado Regional Water Planning Area is not homogeneous. It is made up of multiple layers of sand, silt, clays, and gravel, with varying particle sizes and assortments of these materials within short distances.

If the formation were homogeneous, changes in well yields would be easier to predict. For example, if a well completely penetrated a section of 100-foot thick saturated material and if the pump were set at the bottom of the well with a maximum yield of 800 gallons per minute, then future changes in well yields in relationship to changes in saturated thickness would be as follows: 50 feet of saturated material would support well yields of about 200 gallons per minute; 25 feet of saturated material would support well yields of 50 gallons per minute; and 12.5 feet of saturated material would support well yields of 12.5 gallons per minute.

The decreased weight of the water column or head pressure plus the decrease in the gradient in the cone of depression are factors affecting the rate of well yield decline in relationship to the decrease in saturated thickness.

These same factors affect well yields or changes in the well yield as the saturated thickness changes in geologic sections that are not homogeneous. In geologic sections that are not homogeneous, the permeability of each layer of formation material at the well site is a major factor in how much the well will yield and future changes in well yields should the water table decline.

Permeability relates to how readily water will move through the formation material (i.e., a layer of small gravel has a higher permeability than a layer of clay). Thus water will move more rapidly through small gravel than through clay.

The water moving in the formation must move through the open spaces between the sand, gravel, clay, silt, or other grains of material which make up the formation. These open spaces quite often are not connected. Therefore, the water must move over and/or around the grains of formation materials.

The larger and more uniform in size formation materials usually have large openings between the formation particles, allowing the water to flow more freely than through smaller-sized formation materials, even though more water is present in the formation with smaller-sized materials. You can observe this by filling a glass container with ping-pong or golf balls or something of a similar size and another container of the same size with small marbles or BB's. If you then fill the two containers with water, you will find the container with the smaller particles of material will hold more water than the container with the larger particles, even though the opening between the larger particles is greater.

When a well drilled into the Ogallala Formation is pumped, water flows into the well by the force of gravity, and a cone of depression develops around the well. The longer the well is pumped, the deeper and wider the cone of depression becomes. As it extends out from the well after a sustained period of pumpage, the slope of the cone to the well becomes flatter, causing the water to move into the well at a slower rate. Therefore, the well yield declines.

The outer edge of a cone of depression of a 4-inch well pumping 200 gallons per minute from the Ogallala for an extended period of time will be approximately 100 yards in all directions from the well. The cone of depression extends out about 150 yards from a 6-inch well pumping 560 gallons per minute and 200 yards from an 8-inch well pumping 800 gallons per minute. The low point of the cone of depression will obviously be at the well in all instances.

The rate of flow of water through the formation is about 2,400 feet per year at a gradient of 40 feet per mile. When the cone flattens to a gradient of about 20 feet per mile, the rate of water flow through the formation decreases to about 600 feet per year. When the gradient flattens to 10 feet per mile, the rate of flow through the formation decreases to about 150 feet per year.

After several months of continuous pumping, the cones of depressions around most wells are deep and wide. When the pump is stopped, water continues to flow toward the well through the formation. In essence, water seeks its own level. The cone will fill rapidly for the first few days and then more slowly as the slope of the water table on top of the cone becomes flatter. The cone will likely fill to within a few feet of where the static water level was in the formation before a season of pumpage began. After a season of pumpage, a small depression will likely remain around most wells, and the well yields will be a little less than they were at the beginning of the prior pumping season.

Many other factors, such as the condition of the pump, can affect well yields. If the pump bowls are worn, then they may not produce all the water that the well will yield. Also, encrustation in the perforations of the casing may retard the movement of water from the formation to the well. Drilling mud caked on the walls of wells can also reduce the rate of flow of the water from the formation into the well.

A step draw-down test can be used to obtain estimates of what a well will yield in the future with changes in water levels. This involves measuring the well yield and pumping water levels at various rates of production to determine the yield from each layer of geologic material at the well site.

Utilizing the water well driller's log as a guide, first measure and record the static water level in the well. Next, screw down the valve on the discharge line so that only a small flow of water is produced when the pump is started. After the pump is started, measure the pumping water level and adjust the discharge valve until you stabilize the pumping water level at the base or bottom of the first layer of formation for which you wish to obtain an estimated yield of the well.

Record the pumping level and well yield, then divide the number of feet of change from the static water level to pumping level into the rate of flow (gallons per minute of the well). For example, if the drawdown in the water level was 10 feet and the flow was 50 gallons per minute, the yield from the formation would be 5 gallons per minute per foot.

Continue the same procedure for each layer of formation as indicated by the driller's log until you reach the maximum the pump will produce or the pumping water level reaches the bottom of the well.

One may find that the majority of the high-yielding formation material is located in the upper portion of the formation at the well site. If this is the case, then the yield of the well may decrease significantly with only a few feet of decline in the water level. At this same well site, the lower portion of the formation may consist of fine-grained material which could yield relatively small quantities of water to the well for a long period of time.

In contrast, if the coarse-grained material is located in the lower section of the formation at the well site, the yield of the well may remain fairly high, even with significant decline in the water table. The loss of head pressure and the flattening of the cone of depression as the water table declines will affect future well yields. However, it will not have the same impact as they do on homogeneous formations. Two illustrations are provided to help explain the effects of multi-layered formation materials on well yields. In the first illustration, the more permeable material (gravel) is located at the base of the section. In the second illustration, less permeable material (silt and fine sand) is located at the base of the section. The following describes how the calculations were made for the two different examples.

Example one: In a homogeneous formation, the yield would be divided by four to obtain an estimate of what the yield of the well would be when the aquifer thins by 50 percent (i.e., $850 \div 4 = 212.5$). The specific yield test for this example indicates that the upper half of the formation yielded 400 gallons per minute and the lower half yielded 450 gallons per minute. The yield from the lower portion of the formation will be 450 gallons per minute less the effects of the head pressure gradient from the 50 feet of dewatered section which yielded 400 gallons per minute, which can be estimated by dividing 400 gallons per minute by four which yields 100 gallons per minute of yield loss effect. Therefore, reducing the 450 gallons per minute by 100 gallons per minute would indicate a yield potential of 350 gallons per minute (Figure 1-8).

Example two: In a homogeneous formation, the yield would be divided by four to obtain an estimate of what the yield of the well would be when the aquifer thins by 50 percent (i.e., $590 \div 4 = 147.5$). The specific yield test for this example indicates that the upper half of the formation yielded 400 gallons per minute and the lower half yielded 190 gallons per minute. The yield from the lower portion of the formation will be 190 gallons per minute less the effects of the head pressure gradient from the 50 feet of dewatered section which yielded 400 gallons per minute, which can be estimated by dividing 400 gallons per minute by four which yields 100 gallons per minute of yield loss effect. Therefore, reducing the 190 gallons per minute by 100 gallons per minute would indicate a yield potential of 90 gallons per minute (Figure 1-9).

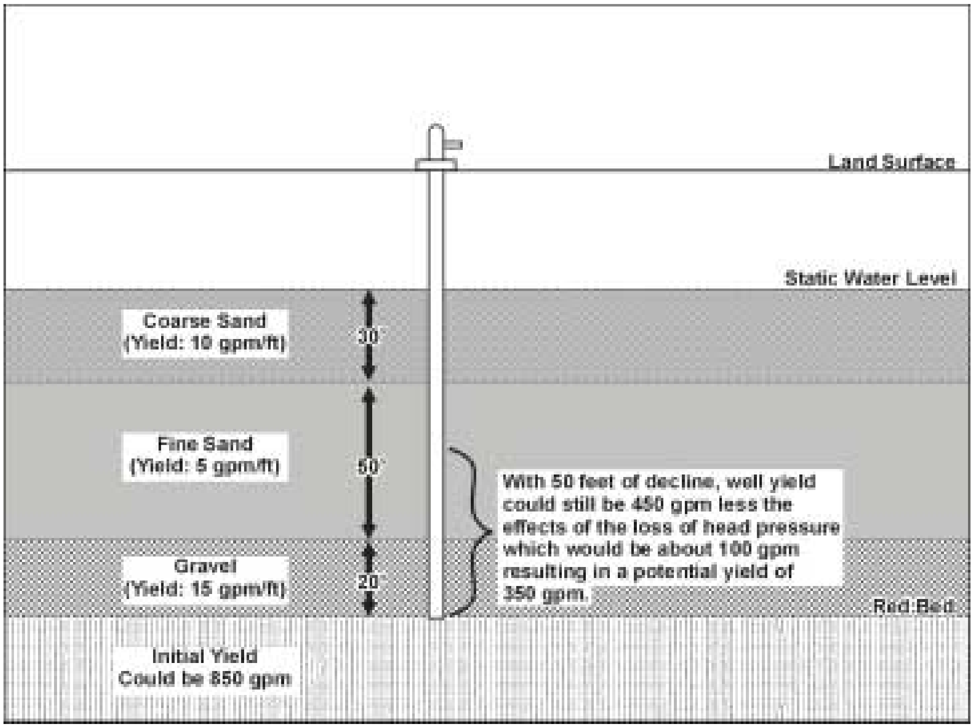

Figure 1-8. Illustration of Well Yield as Head Pressure Changes — Gravel at Bottom of Formation

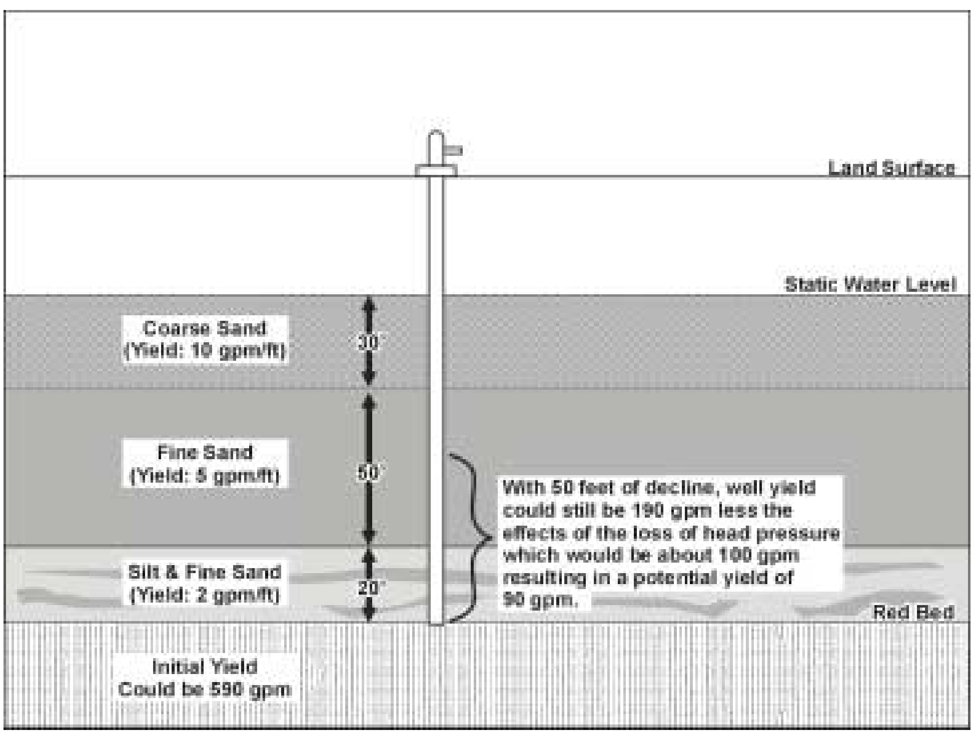

Figure 1-9. Illustration of Well Yield as Head Pressure Changes — Silt and Fine Sand at Bottom of Formation

1.11.2 The Dockum Aquifer

The Dockum Aquifer underlies the entire area of the Llano Estacado Regional Water Planning area and contains a primary water-bearing zone commonly known as the "Santa Rosa." The Santa Rosa section consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Ground water stored in the Santa Rosa is under artesian conditions. Recharge to the Santa Rosa is from rainfall occurring on the outcrop. The long-term annual average recharge to the Santa Rosa has been estimated to be less than 50,000 acre-feet.

The best way to evaluate the Santa Rosa is by comparison with the Ogallala Aquifer. The first consideration is the physical locations of the two respective aquifers. The Ogallala Aquifer lies near the land surface, while the Santa Rosa lies below the Ogallala and can be found several hundred feet below land surface in most of the area.

The co-efficient of storage in the Ogallala is about 0.15, or about 15 percent, while the co-efficient of storage in the Santa Rosa is about 0.0001. This indicates that at least 100 times more water can be recovered from 100 feet of saturated Ogallala material than could be recovered from 100 feet of decline in the artesian head (water level) of the Santa Rosa. The permeability of the Ogallala is about 400 gallons per day per square foot, as compared to the 250 gallons per day per square foot for the Santa Rosa.

The decline in feet from the static water level when a well is pumped at the center of a grid of nine wells evenly spaced 440 yards apart at 600 gallons of water per minute from the Ogallala Aquifer, with a permeability of 400 gallons of water per day per square foot, a storage co-efficient of 0.15 percent, and a saturated thickness of 100 feet would be about 31 feet after 15 days of continuous pumping, 41 feet after 30 days of continuous pumping, 58 feet after 60 days of continuous pumping, and 73 feet after 90 days of continuous pumping. This assumes that all nine wells are being pumped for the time periods illustrated.

The decline in feet from the static water levels when a well is pumped at the center of a grid of nine wells evenly spaced 440 yards apart, pumping 600 gallons of water per minute from the Santa Rosa Aquifer, with a transmissibility of 22,000 gallons of water per day per foot and a storage co-efficient of 0.0001 would be about 215 feet after 15 days of continuous pumping, 234 feet after 30 days of continuous pumping, 254 feet after 60 days of continuous pumping, and 265 feet after 90 days of continuous pumping. This assumes that all nine wells are being pumped for the time periods illustrated. The recommended spacing between Santa Rosa wells is 1 mile.

A well completed in the Santa Rosa should completely penetrate the sand section through the entire thickness of the aquifer. As the artesian head (water level in the well) declines, the well yield should remain fairly constant as long as the drawdown in the well does not lower the hydrostatic head below the bottom of the upper confining bed. This is because the artesian pressure will remain until the hydrostatic head drops below the upper confining bed. At that time, the artesian pressure is lost, and the well yield will decline significantly.

The yield of the well should be approximately proportioned to the drawdown in the well; i.e., should the static water level be 500 feet and the well yield 750 gallons with 200 feet of drawdown, the total pumping lift would be 700 feet. The yield should remain the same when the static water level drops 50 feet, although the pumping level would drop to approximately 750 feet. This again assumes that the hydrostatic head does not drop below the bottom of the first confining layer.

It is very important that the design capacity of the pump match the quantities of water desired to be pumped with the maximum pumping depth that could occur in the well, such as the depth to the bottom of the first confining level.

1.11.3 The Cretaceous Formation

Cretaceous age material lies directly below the Ogallala. It generally is present only in the southern portion of the Llano Estacado Regional Water Planning area. There are three sections of the cretaceous age material that contains formation material that will yield ground water to wells that are utilized in the area. The upper most section is the Edwards, which is a limestone rock formation. The limestone rock sometimes contains cavities and solution channels. When solution channels are encountered when drilling a well, they sometimes are described as honey comb rock on water well drillers' logs. The Edwards is hydrologically connected to the Ogallala; that is, water from the Ogallala drains into the cavities and solution channels in the Edwards. Wells drilled into the rock which penetrate cavities and/or solution channels are yield dependent on the size of the cavity and/or solution channel. Large cavities will sometime yield large yields of water until the water in the cavity is pumped out. Then, the yield will normally decline to a volume equal to the volume of water which flows through the cracks in the rock or solution channels that feed the cavity. Wells completed in solution channels or honey comb rock are also yield dependent upon the quantity of water that can flow through the solution channels to the well from the point of contact with the Ogallala.

Should the water level in the Ogallala drop below the feeder point, the cavity(s) or solution channels have limited water holding capacities and the wells producing water from the cavities and/or solution channels will run dry. Actual declines in the water levels in the Ogallala or declines in the water level resulting from the cones of depression created from nearby pumping wells can cut off the flow of water into the Edwards.

The next layer of the cretaceous is the Duck Creek section, which is generally identified by a marker bed of yellow clay. Generally, below the yellow clay, a thin layer or a few feet of sand occurs. This sand section generally will yield small quantities of water and is also thought to be hydrologically connected to the Ogallala.

Below the Duck Creek, and in instances where the Duck Creek is not present, the next layer of cretaceous material that has a section which will yield water to wells is the Kimichi. The marker bed of the Kimichi is generally brown or green clay. Below the clay a thin bed of sand contains some small gravel. This layer generally contains a high concentration of calcareous material, a cement like material which fills the voids between the sand and gravel. A drop of acid on formation obtained from the section will produce bubbles, indicating the presence of the calcareous material. Blue clay or shale is generally located at the base of this section and extends down to the red bed of Triassic material.

Even though important for livestock and domestic well use, neither of these sections will yield enough water for irrigation, municipal or industrial use. Both sections are thought to be interconnected with the Ogallala. However, changes in water levels in the Ogallala will not likely affect well yields from either of the sections unless the Ogallala is totally depleted, which is unlikely to happen.

1.12 Major Municipal and Manufacturing Water Providers[68]

The TWDB has defined a major water provider as follows: “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 LERWPG has identified three major municipal and manufacturing water providers in the Llano Estacado Region, as follows: the Canadian River Municipal Water Authority, the White River Municipal Water District, and the

[68] This section contains information provided by the major municipal and manufacturing water providers.

Mackenzie Municipal Water Authority. Each major water provider is briefly described below. Detail water demand projections for each major water provider are presented in Section 2.10.

1.12.1 Canadian River Municipal Water Authority (CRMWA)

The Canadian River Project received federal authorization in December 1950, and in 1953 the legislature authorized the CRMWA to organize as a legal entity and independent policital subdivision of Texas. Eleven cities formed the Authority: Amarillo, Borger, Pampa, Plainview, Lubbock, Slaton, Brownfield, Levelland, Lamesa, Tahoka, and O'Donnell. Under a tri-state compact, Texas was entitled to 100,000 acft of water a year for use by the member cities and 51,000 acft for use by industries. The dam crossing the Canadian River 9 miles west of Borger is 226 feet high and 6,380 feet long. The aqueduct system, with 322 miles of pipeline, ten pumping plants, and three regulating reservoirs, furnishes raw water to its members for municipal and industrial purposes. CRMWA has acquired extensive groundwater rights in Roberts County to increase the quantity and improve the quality of water delivered to its member cities.

1.12.2 White River Municipal Water District (WRMWD)

The WRMWD owns and operates White River Reservoir, from which the District's water right authorized the diversion of up to 6,000 acft of water per year for municipal and mining purposes. The District delivers water to Crosbyton, Ralls, Spur, and Post. The WRMWD has obtained groundwater rights and drilled and equipped several wells so the groundwater will be available to supplement the surface water in times of drought.

1.12.3 Mackenzie Municipal Water Authority (MMWA)

The MMWA owns and operates Lake Mackenzie located in Swisher and Briscoe Counties and delivers water to the Cities of Silverton, Tulia, Floydada, and Lockney. The Authority's water right authorizes the diversion of up to 5,200 acft of water per year. However, the MMWA has indicated from recent experiences that it can supply only about 40 percent of this, or 2,080 acft/yr. The individual city water supply analysis performed by staff of the HPUWCD No. 1 indicated that the historical quantity of water obtained by the City of Silverton from Lake Mackenzie was approximately 85 acft/yr, the City of Tulia has historically obtained approximately 420 acft/yr (417 acft/yr for municipal and 3 acft/yr for industry), the City of

Floydada has historically obtained approximately 212 acft/yr, and the City of Lockney has historically obtained approximately 152 acft/yr (150 acft/yr for municipal and 2 acft/yr for industry), for a total of 869 acft/yr. These have been the quantities of water available to each city respectively during recent years, and are the quantities used in the Regional Plan.

Section 2
Population and Water Demand Projections

In order to develop water plans to meet future water needs, it is necessary to make projections of future population and water demands for the region. The Texas Water Development Board (TWDB) has made both population and water demand projections for cities, rural areas, and water use purposes for each of the 21 counties in the region. These counties are located in four major river basins (Canadian, Red, Brazos, and Colorado) (Table 2-1). In accordance with TWDB Rules, Section 357.5(d), these projections are presented below.

2.1 Population Projections

The 1996 estimates published by the U.S. Bureau of the Census indicate that Texas currently ranks as the second most populated state in the nation, with a population of more than 18.3 million. The population of the Llano Estacado Region was estimated at 452,827 in 1996 and is projected to be 586,156 in 2050 (Table 2-2 and Figure 2-1). Nearly 80 percent of the population of the region is projected to reside in the Brazos River Basin. The population projections for 53 individual cities and 35 rural areas of each county and part of county of each river basin area of the region are shown in Table 2-3.

Table 2-1.
Llano Estacado Region--List of Counties
Location by River Basin

County Number	County	River Basin[1] Canadian Basin	Red Basin	Brazos Basin	Colorado Basin
1	Bailey			X	
2	Briscoe		X		
3	Castro		X	X	
4	Cochran			X	X
5	Crosby		X	X	
6	Dawson			X	X
7	Deaf Smith	X	X		
8	Dickens		X	X	
9	Floyd		X	X	
10	Gaines				X
11	Garza			X	X
12	Hale		X	X	
13	Hockley			X	X
14	Lamb			X	
15	Lubbock			X	
16	Lynn			X	X
17	Motley		X		
18	Parmer		X	X	
19	Swisher		X	X	
20	Terry			X	X
21	Yoakum				X

[1] An X in the column indicates that all or part of the county is located in the River Basin named in the column heading

Table 2-2.
Population Projections*
Llano Estacado Region
Individual Counties with River Basin Summaries

County Number	County	Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	7,064	6,841	7,315	7,463	7,416	6,358	4,821	3,555
2	Briscoe	1,971	2,038	1,977	2,043	2,051	2,009	1,964	1,915
3	Castro	9,070	8,395	10,000	11,076	11,830	12,126	12,334	12,372
4	Cochran	4,377	4,250	4,763	5,158	5,408	5,475	5,499	5,453
5	Crosby	7,304	7,187	7,448	7,486	7,348	6,951	6,899	6,850
6	Dawson	14,349	15,011	15,009	15,952	16,572	16,710	16,885	16,953
7	Deaf Smith	19,153	19,403	21,405	23,924	26,098	27,471	28,706	29,769
8	Dickens	2,571	2,372	2,555	2,580	2,565	2,562	2,547	2,514
9	Floyd	8,497	8,398	8,789	9,321	9,625	9,622	9,369	9,101
10	Gaines	14,123	14,742	15,380	16,603	17,262	17,300	17,369	17,438
11	Garza	5,143	4,954	5,302	5,573	5,676	5,545	5,377	5,167
12	Hale	34,671	36,336	37,246	39,602	41,946	43,598	44,194	44,798
13	Hockley	24,199	24,209	26,567	27,983	29,082	28,939	28,402	27,467
14	Lamb	15,072	15,162	15,701	16,812	17,666	18,150	18,613	18,934
15	Lubbock	222,636	233,496	242,837	261,695	279,223	294,044	306,038	315,784
16	Lynn	6,758	6,769	7,057	7,401	7,612	7,529	7,375	7,145
17	Motley	1,532	1,436	1,474	1,416	1,322	1,229	1,106	967
18	Parmer	9,863	10,401	10,686	11,643	12,438	12,770	13,066	13,276
19	Swisher	8,133	9,420	8,794	9,385	9,964	10,462	10,986	11,431
20	Terry	13,218	13,361	14,616	16,072	17,271	18,309	19,172	19,914
21	Yoakum	8,786	8,646	9,976	11,417	12,567	13,600	14,466	15,353
	Total	438,490	452,827	474,897	510,605	540,942	560,759	575,188	586,156
River Basin Summary**									
	Canadian	27	28	31	35	38	40	42	42
	Red	37,848	39,343	41,112	44,880	48,002	49,924	51,682	53,069
	Brazos	346,335	357,895	374,593	401,096	424,377	439,926	450,599	458,420
	Colorado	54,280	55,561	59,161	64,594	68,525	70,869	72,865	74,625
	Total	438,490	452,827	474,897	510,605	540,942	560,759	575,188	586,156

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basins tabulations of counties, cities, and rural areas.

Note: Texas population in 1990 was 16,986,510. TWDB projections of Texas population in year 2000 are 20,220,182, and in 2050 are 36,587,631 (1.287% compound annual growth rate).

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case.

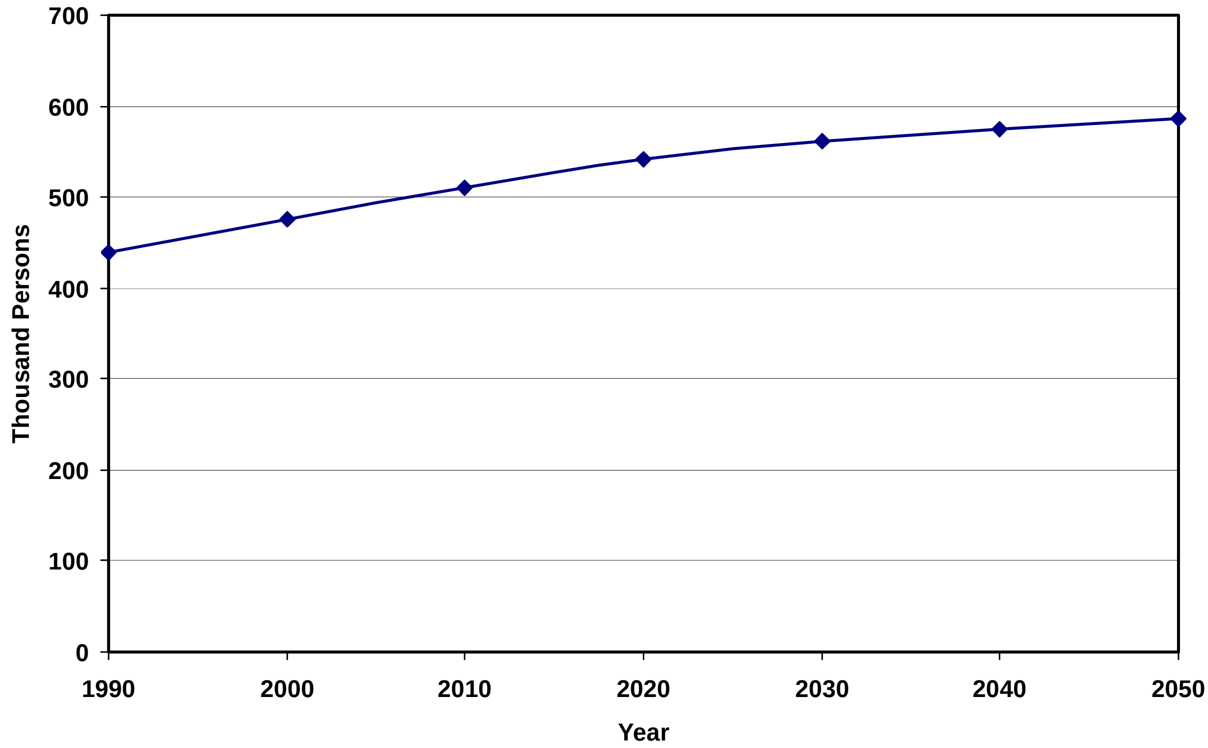

Figure 2-1. Summary of Llano Estacado Region's Projected Population

Table 2-3.
Population Projections
Llano Estacado Region
River Basins, Counties, and Cities*

Basin/County/City/Rural		Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Canadian Basin (part)									
Deaf Smith (part)									
Rural		27	28	31	35	38	40	42	42
	Total	27	28	31	35	38	40	42	42
Canadian Basin Total		**27**	**28**	**31**	**35**	**38**	**40**	**42**	**42**
Red Basin (part)									
Briscoe (all)									
Quitaque		513	504	415	412	379	376	386	371
Silverton		779	810	787	813	816	799	781	762
Rural		679	724	775	818	856	834	797	782
	Total	1,971	2,038	1,977	2,043	2,051	2,009	1,964	1,915
Castro (part)									
Rural		1,509	1,335	1,577	1,699	1,743	1,734	1,744	1,679
	Total	1,509	1,335	1,577	1,699	1,743	1,734	1,744	1,679
Crosby (part)									
Rural		44	42	47	50	50	50	52	52
	Total	44	42	47	50	50	50	52	52
Deaf Smith (part)									
Hereford		14,745	14,817	16,327	18,148	19,824	20,895	21,864	22,878
Rural		4,381	4,558	5,047	5,741	6,236	6,536	6,800	6,849
	Total	19,126	19,375	21,374	23,889	26,060	27,431	28,664	29,727
Dickens (part)									
Rural		295	283	278	283	280	279	276	268
	Total	295	283	278	283	280	279	276	268
Floyd (part)									
Rural		898	897	920	978	1,014	1,042	1,046	1,043
	Total	898	897	920	978	1,014	1,042	1,046	1,043
Hale (part)									
Rural		46	54	54	62	68	75	81	87
	Total	46	54	54	62	68	75	81	87
Motley (all)									
Matador		790	731	757	727	679	631	568	497
Rural		742	705	717	689	643	598	538	470
	Total	1,532	1,436	1,474	1,416	1,322	1,229	1,106	967

Continued on next page

Table 2-3 (continued)

Basin/County/City/Rural	Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Parmer (part)								
Friona	3,688	3,869	3,975	4,437	4,836	5,069	5,316	5,575
Rural	1,012	1,018	1,093	1,117	1,126	1,086	1,021	921
Total	4,700	4,887	5,068	5,554	5,962	6,155	6,337	6,496
Swisher (part)								
Kress	739	749	693	650	597	557	542	530
Tulia	4,699	5,237	4,981	5,332	5,629	5,873	6,127	6,392
Rural	2,289	3,010	2,669	2,924	3,226	3,490	3,743	3,913
Total	7,727	8,996	8,343	8,906	9,452	9,920	10,412	10,835
Red Basin Total	**37,848**	**39,343**	**41,112**	**44,880**	**48,002**	**49,924**	**51,682**	**53,069**
Brazos Basin (part)								
Bailey (all)								
Muleshoe	4,571	4,416	4,814	4,999	5,013	4,337	3,318	2,538
Rural	2,493	2,425	2,501	2,464	2,403	2,021	1,503	1,017
Total	7,064	6,841	7,315	7,463	7,416	6,358	4,821	3,555
Castro (part)								
Dimmitt	4,408	4,184	4,958	5,523	5,947	6,130	6,248	6,368
Hart	1,221	1,166	1,446	1,679	1,909	2,042	2,108	2,176
Rural	1,932	1,710	2,019	2,175	2,231	2,220	2,234	2,149
Total	7,561	7,060	8,423	9,377	10,087	10,392	10,590	10,693
Cochran (part)								
Morton	2,597	2,536	2,830	3,065	3,213	3,253	3,268	3,240
Whiteface	512	491	488	456	418	383	366	361
Rural	489	472	599	721	816	867	889	884
Total	3,598	3,499	3,917	4,242	4,447	4,503	4,523	4,485
Crosby (part)								
Crosbyton	2,026	2,047	2,008	1,990	1,942	1,812	1,781	1,776
Lorenzo	1,208	1,268	1,208	1,190	1,159	1,076	1,054	1,047
Ralls	2,172	2,039	2,216	2,145	2,077	1,894	1,829	1,793
Rural	1,854	1,791	1,969	2,111	2,120	2,119	2,183	2,182
Total	7,260	7,145	7,401	7,436	7,298	6,901	6,847	6,798
Dawson (part)								
Rural	116	136	121	129	133	133	134	133
Total	116	136	121	129	133	133	134	133
Dickens (part)								
Dickens	322	304	328	323	321	321	319	315
Spur	1,300	1,158	1,332	1,346	1,344	1,342	1,340	1,338
Rural	654	627	617	628	620	620	612	593
Total	2,276	2,089	2,277	2,297	2,285	2,283	2,271	2,246

Continued on next page

Table 2-3 (continued)

Basin/County/City/Rural	Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Floyd (part)								
Floydada	3,896	3,875	4,051	4,297	4,437	4,435	4,319	4,195
Lockney	2,207	2,131	2,286	2,418	2,485	2,408	2,262	2,125
Rural	1,496	1,495	1,532	1,628	1,689	1,737	1,742	1,738
Total	7,599	7,501	7,869	8,343	8,611	8,580	8,323	8,058
Garza (part)								
Post	3,768	3,611	3,924	4,126	4,204	4,108	3,986	3,868
Rural	1,370	1,338	1,373	1,442	1,467	1,432	1,386	1,294
Total	5,138	4,949	5,297	5,568	5,671	5,540	5,372	5,162
Hale (part)								
Abernathy (part)	2,132	2,082	2,279	2,424	2,567	2,668	2,705	2,742
Hale Center	2,067	2,088	2,157	2,292	2,426	2,521	2,457	2,395
Petersburg	1,292	1,287	1,514	1,743	1,944	2,145	2,306	2,479
Plainview	21,700	22,063	22,469	23,055	23,805	23,959	23,465	22,981
Rural	7,434	8,762	8,773	10,026	11,136	12,230	13,180	14,114
Total	34,625	36,282	37,192	39,540	41,878	43,523	44,113	44,711
Hockley (part)								
Anton	1,212	1,253	1,350	1,397	1,474	1,478	1,455	1,432
Levelland	13,986	13,998	15,609	16,271	16,744	16,505	16,056	15,619
Rural	6,806	6,770	7,136	7,579	7,894	7,881	7,764	7,260
Total	22,004	22,021	24,095	25,247	26,112	25,864	25,275	24,311
Lamb (all)								
Amherst	742	748	722	684	634	587	568	554
Earth	1,228	1,352	1,282	1,373	1,446	1,492	1,539	1,587
Littlefield	6,489	6,395	6,751	7,232	7,584	7,772	7,940	8,112
Olton	2,116	2,107	2,177	2,331	2,449	2,516	2,580	2,625
Sudan	983	971	1,020	1,090	1,141	1,163	1,169	1,175
Rural	3,514	3,589	3,749	4,102	4,412	4,620	4,817	4,881
Total	15,072	15,162	15,701	16,812	17,666	18,150	18,613	18,934
Lubbock (all)								
Abernathy (part)	588	649	852	966	1,069	1,159	1,238	1,322
Idalou	2,074	2,116	2,286	2,507	2,789	3,166	3,310	3,461
Lubbock	186,206	194,188	204,026	220,707	236,144	249,249	259,970	271,152
New Deal	521	609	586	605	611	640	678	715
Ransom Canyon	763	888	942	1,008	1,060	1,138	1,238	1,338
Reese AFB	1,263	1,319	1,263	1,263	1,263	1,263	1,263	1,263
Shallowater	1,708	2,001	2,018	2,213	2,462	2,792	2,918	3,050
Slaton	6,078	6,199	6,481	6,683	6,884	7,816	8,316	8,848
Wolfforth	1,941	2,372	2,390	2,621	2,916	3,309	3,458	3,614
Rural	21,494	23,155	21,993	23,122	24,025	23,512	23,649	21,021
Total	222,636	233,496	242,837	261,695	279,223	294,044	306,038	315,784

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Table 2-3 (continued)

Basin/County/City/Rural		Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Lynn (part)									
Tahoka		2,868	2,786	3,076	3,315	3,509	3,536	3,477	3,419
Wilson		568	571	517	493	447	440	431	428
Rural		2,213	2,231	2,300	2,369	2,392	2,298	2,237	2,096
Total		5,649	5,588	5,893	6,177	6,348	6,274	6,145	5,943
Parmer (part)									
Bovina		1,549	1,772	1,690	1,908	2,097	2,216	2,350	2,492
Farwell		1,373	1,488	1,507	1,708	1,885	1,994	2,118	2,250
Rural		2,241	2,254	2,421	2,473	2,494	2,405	2,261	2,038
	Total	5,163	5,514	5,618	6,089	6,476	6,615	6,729	6,780
Swisher (part)									
Rural		406	424	451	479	512	542	574	596
	Total	406	424	451	479	512	542	574	596
Terry (part)									
Rural		168	188	186	202	214	224	231	231
	Total	168	188	186	202	214	224	231	231
Brazos Basin Total		**346,335**	**357,895**	**374,593**	**401,096**	**424,377**	**439,926**	**450,599**	**458,420**
Colorado Basin (part)									
Cochran (part)									
Rural		779	751	846	916	961	972	976	968
	Total	779	751	846	916	961	972	976	968
Dawson (part)									
Lamesa		10,809	10,880	11,308	12,018	12,485	12,589	12,721	12,772
O'Donnell (part)		134	128	143	158	187	224	247	272
Rural		3,290	3,867	3,437	3,647	3,767	3,764	3,783	3,776
	Total	14,233	14,875	14,888	15,823	16,439	16,577	16,751	16,820
Gaines (all)									
Seagraves		2,398	2,392	2,493	2,729	2,736	2,742	2,747	2,752
Seminole		6,342	6,698	7,144	7,861	8,308	8,460	8,677	8,900
Rural		5,383	5,652	5,743	6,013	6,218	6,098	5,945	5,786
	Total	14,123	14,742	15,380	16,603	17,262	17,300	17,369	17,438
Garza (part)									
Rural		5	5	5	5	5	5	5	5

Continued on next page

Table 2-3 (continued)

Basin/County/City/Rural	Total in 1990	Total in 1996	Projections 2000	2010	2020	2030	2040	2050
Total	5	5	5	5	5	5	5	5
Hockley (part)								
Sundown	1,759	1,754	2,015	2,250	2,464	2,570	2,630	2,691
Rural	436	434	457	486	506	505	497	465
Total	2,195	2,188	2,472	2,736	2,970	3,075	3,127	3,156
Lynn (part)								
O'Donnell (part)	968	1,039	1,021	1,079	1,120	1,116	1,095	1,074
Rural	141	142	143	145	144	139	135	128
Total	1,109	1,181	1,164	1,224	1,264	1,255	1,230	1,202
Terry (part)								
Brownfield	9,560	9,271	10,555	11,665	12,602	13,431	14,141	14,889
Meadow	547	601	620	632	631	619	594	558
Rural	2,943	3,301	3,255	3,573	3,824	4,035	4,206	4,236
Total	13,050	13,173	14,430	15,870	17,057	18,085	18,941	19,683
Yoakum (all)								
Denver City	5,145	5,076	6,044	6,978	7,714	8,451	9,129	9,861
Plains	1,422	1,405	1,530	1,724	1,889	2,000	2,068	2,138
Rural	2,219	2,165	2,402	2,715	2,964	3,149	3,269	3,354
Total	8,786	8,646	9,976	11,417	12,567	13,600	14,466	15,353
Colorado Basin Total	**54,280**	**55,561**	**59,161**	**64,594**	**68,525**	**70,869**	**72,865**	**74,625**
Llano Estacado Region Total	**438,490**	**452,827**	**474,897**	**510,605**	**540,942**	**560,759**	**575,188**	**586,156**
River Basin Summary								
Canadian	27	28	31	35	38	40	42	42
Red	37,848	39,343	41,112	44,880	48,002	49,924	51,682	53,069
Brazos	346,335	357,895	374,593	401,096	424,377	439,926	450,599	458,420
Colorado	54,280	55,561	59,161	64,594	68,525	70,869	72,865	74,625
Llano Estacado Region Total	**438,490**	**452,827**	**474,897**	**510,605**	**540,942**	**560,759**	**575,188**	**586,156**

* Parts of Canadian, Red, Brazos, and Colorado River Basins.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case.

2.2 Municipal Water Demand Projections

The projected quantity of water needed for municipal purposes depends upon population growth, climatic conditions, and water conservation measures. For planning purposes, municipal water demand includes residential and commercial water uses. Commercial water use includes business establishments and public offices and institutions. Residential and commercial uses are categorized together because they are similar types of uses (i.e., they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering).

Although per capita water use, in gallons per person per day, is projected to decline over the planning period, this will be more than offset by the projected increase in population, which is expected to cause municipal water demand to increase by 13.4 percent over the planning period (Table 2-4 and Figure 2-2). For example, total municipal water use in the Llano Estacado Region in 1990 was 81,608 acft/yr. Projected municipal water demand for the region in 2050 is 92,529 acft/yr (Table 2-4). The projected municipal water demands for individual counties of the region are shown in Table 2-4. Since Lubbock County has the largest population, it also has the largest projected water demand, with slightly over 50 percent of the total (Table 2-4).

2.3 Industrial Water Demand Projections

The use of water for the production of goods for domestic and foreign markets varies widely among manufacturing industries in Texas. Manufactured products in Texas range from food and clothing to refined chemical and petroleum products to computers and automobiles. Some processes require direct consumption of water as part of the products being manufactured; others require very little water consumption, but large volumes of water for cooling or cleaning purposes.

Five manufacturing industries account for approximately 90 percent of water used by all manufacturing industries in Texas. These five water-intensive industries are chemical products, petroleum refining, pulp and paper, food and kindred products, and primary metals. The chemical and petroleum refining industries account for nearly 60 percent of the state's annual manufacturing water use.

Table 2-4.
Municipal Water Demand Projections
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	1,425	1,236	1,411	1,370	1,296	1,070	806	598
2	Briscoe	323	274	345	336	320	303	288	280
3	Castro	1,567	1,775	1,940	2,027	2,062	2,066	2,061	2,059
4	Cochran	931	845	965	989	981	974	960	946
5	Crosby	1,195	1,211	1,219	1,151	1,063	965	938	919
6	Dawson	2,285	2,572	2,826	2,838	2,790	2,745	2,712	2,705
7	Deaf Smith	4,409	3,749	5,024	5,304	5,503	5,673	5,836	6,081
8	Dickens	508	670	494	472	444	433	419	411
9	Floyd	1,185	1,296	1,287	1,284	1,241	1,203	1,125	1,083
10	Gaines	2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
11	Garza	959	560	1,158	1,160	1,123	1,072	1,016	981
12	Hale	6,375	7,142	6,621	6,617	6,590	6,627	6,491	6,444
13	Hockley	3,755	3,400	4,146	4,121	4,035	3,910	3,726	3,588
14	Lamb	2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
15	Lubbock	42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
16	Lynn	942	1,001	1,085	1,074	1,045	1,005	950	917
17	Motley	302	326	326	297	261	235	211	183
18	Parmer	2,248	1,921	2,340	2,430	2,481	2,514	2,544	2,617
19	Swisher	1,523	1,528	1,618	1,637	1,644	1,677	1,720	1,778
20	Terry	1,947	2,321	2,164	2,226	2,257	2,319	2,366	2,441
21	Yoakum	1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
	Total	81,608	87,071	87,357	89,101	89,534	90,752	91,089	92,529
River Basin Summary									
	Canadian	3	4	4	4	4	4	4	4
	Red	7,927	7,212	8,736	9,044	9,210	9,378	9,554	9,843
	Brazos	64,091	70,105	67,743	68,849	69,074	70,014	70,105	71,034
	Colorado	9,587	9,750	10,874	11,204	11,246	11,356	11,426	11,648
	Total	81,608	87,071	87,357	89,101	89,534	90,752	91,089	92,529

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case, below normal rainfall and average water conservation.

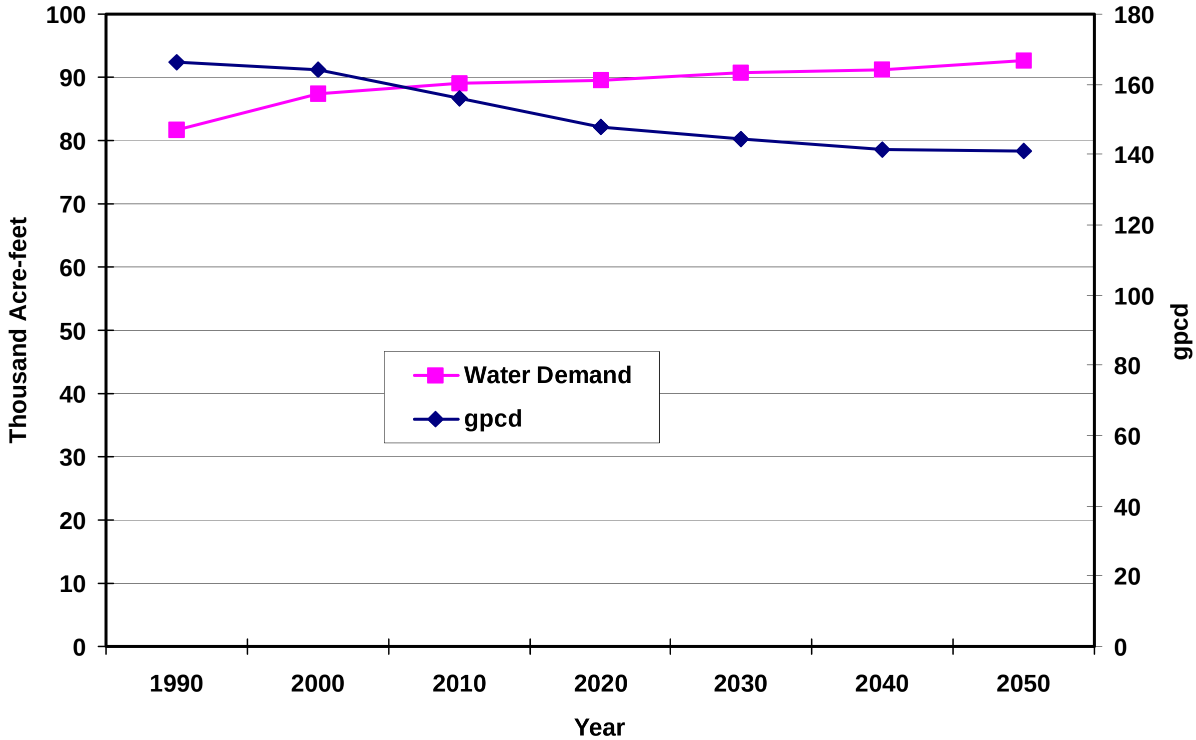

Figure 2-2. Projected Per Capita Water Use and Municipal Water Demand; Llano Estacado Region – 1990 to 2050

The Llano Estacado Region's major water using manufacturing sectors are food processing, industrial machinery and equipment, and fabricated metals. These industries used 8,494 acft of water in 1990 and are projected to have a demand of 15,697 acft/yr in 2050 (Table 2-5 and Figure 2-3). As can be seen in Figure 2-3, industrial water demand is projected to rise at an increasing rate throughout the planning period.

2.4 Steam-Electric Power Water Demand Projections

Although Texas is the second most-populated state in the United States, it is the largest generator and consumer of electricity. It is also the largest user of coal-generated power. Power production in Texas is concentrated primarily in ten privately owned utilities, which account for 85 percent of production. Nine percent is both publicly and privately held, while only 6 percent are publicly owned. The industry has faced and will continue to face significant changes in the structure of power generation. These changes range from new generation technology to government regulations on the marketing of electricity. These changes will not only have an impact on how and where power will be generated, but also on how water will be used in the process.

Only three counties (Lamb, Lubbock, and Yoakum) of the Llano Estacado Region currently use water in steam-electric power production or are projected to use water in steam-electric power production. In 1990, 14,302 acft of water was used for steam-electric power generation; and by the year 2050, it is estimated that 37,200 acft of water will be needed for the production of steam-electric power (Table 2-6 and Figure 2-3).

2.5 Mining Water Demand Projections

Although the Texas mineral industry is foremost in the production of crude petroleum and natural gas in the United States, it also produces a wide variety of important non-fuel minerals. Texas is the only state to produce native asphalt and is the leading producer nationally of Frasch-mined sulfur. It is also one of the leading states in the production of clay, gypsum, lime, salt, stone, and aggregate. In the Llano Estacado Region, the principal uses of water for mining are for recovery of crude petroleum and for sand and gravel washing.

In the region, mining water demand is projected to reach a peak of 30,384 acft in 2000, followed by a decline to 11,824 acft in 2050 (Table 2-7 and Figure 2-3). Overall, water use in this sector is expected to decline by 61 percent by 2050, due to the fact that the presently used "water flood" technology will no longer be used, as many of the oil fields of the region will have reached their economic limit, suspended operations, and plugged wells. The continuation of the industry in the region will hinge on yet to be developed technologies to recover the oil remaining in the reservoirs.

Table 2-5.
Industrial Water Demand Projections
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	147	163	172	199	224	247	281	315
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	2,177	1,699	2,559	2,978	3,333	3,653	4,152	4,650
4	Cochran	0	0	0	0	0	0	0	0
5	Crosby	7	3	7	6	6	6	6	6
6	Dawson	44	70	46	47	47	47	49	51
7	Deaf Smith	498	1,394	537	575	603	626	679	730
8	Dickens	0	0	0	0	0	0	0	0
9	Floyd	1	53	1	1	2	2	2	2
10	Gaines	303	412	331	358	205	381	412	442
11	Garza	2	2	2	3	3	4	5	5
12	Hale	1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
13	Hockley	67	55	82	98	117	138	161	188
14	Lamb	753	448	711	655	593	593	593	593
15	Lubbock	1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
16	Lynn	0	0	0	0	0	0	0	0
17	Motley	0	2	4	4	5	6	7	8
18	Parmer	1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
19	Swisher	3	3	3	3	3	3	3	3
20	Terry	0	4	0	0	0	0	0	0
21	Yoakum	0	0	0	0	0	0	0	0
	Total	8,494	10,210	9,401	10,466	10,909	11,764	13,085	15,697
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	2,395	3,410	2,615	2,833	2,979	3,094	3,355	3,609
	Brazos	5,752	6,314	6,409	7,228	7,678	8,242	9,269	11,595
	Colorado	347	486	377	405	252	428	461	493
	Total	8,494	10,210	9,401	10,466	10,909	11,764	13,085	15,697

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case, below normal rainfall and average water conservation.

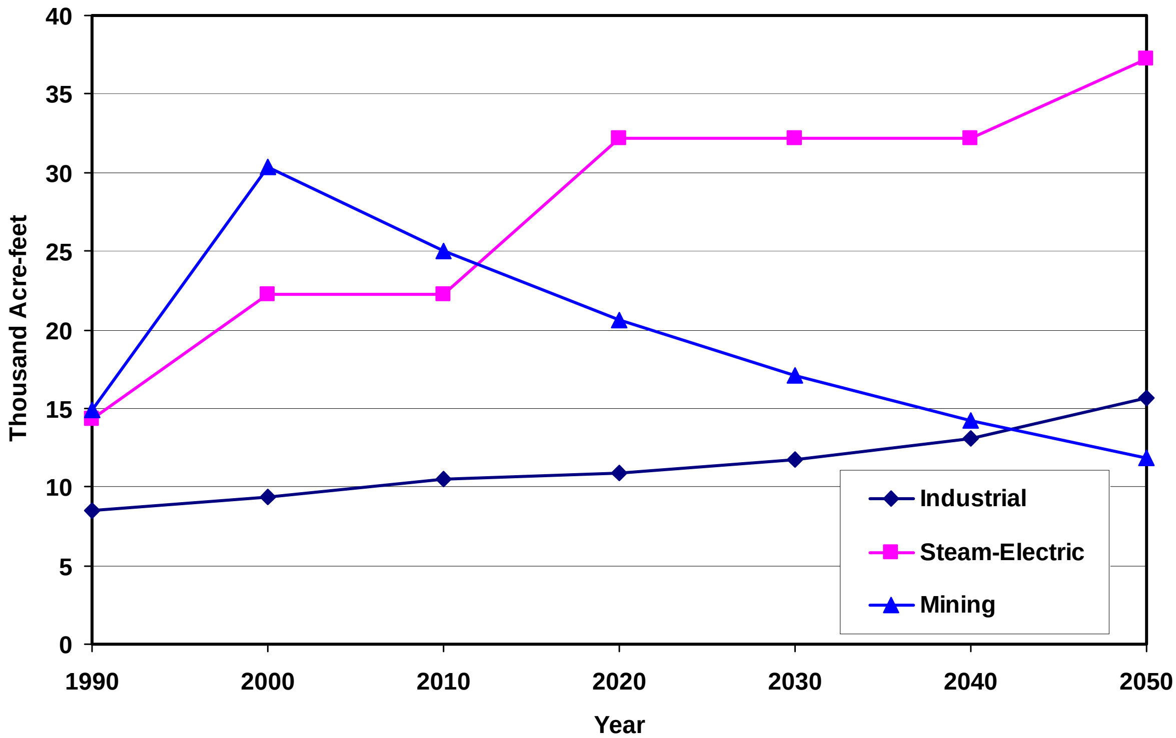

Figure 2-3. Projections of Industrial, Steam-Electric, and Mining Water Demands; Llano Estacado Region – 1990 to 2050

The mining data in Table 2-7 and plotted in Figure 2-3 depict a significant increase from 1990 to 2000. This is due not to a major change in water use, but may be due to insufficient data for 1990.

Table 2-6.
Steam-Electric Water Demand Projections
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	0	0	0	0	0	0	0	0
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	0	0	0	0	0	0	0	0
4	Cochran	0	0	0	0	0	0	0	0
5	Crosby	0	0	0	0	0	0	0	0
6	Dawson	0	0	0	0	0	0	0	0
7	Deaf Smith	0	0	0	0	0	0	0	0
8	Dickens	0	0	0	0	0	0	0	0
9	Floyd	0	0	0	0	0	0	0	0
10	Gaines	0	0	0	0	0	0	0	0
11	Garza	0	0	0	0	0	0	0	0
12	Hale	0	0	0	0	0	0	0	0
13	Hockley	0	0	0	0	0	0	0	0
14	Lamb	12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
15	Lubbock	1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
16	Lynn	0	0	0	0	0	0	0	0
17	Motley	0	0	0	0	0	0	0	0
18	Parmer	0	0	0	0	0	0	0	0
19	Swisher	0	0	0	0	0	0	0	0
20	Terry	0	0	0	0	0	0	0	0
21	Yoakum	0	0	2,200	2,200	2,200	2,200	2,200	2,200
	Total	14,302	14,857	22,200	22,200	32,200	32,200	32,200	37,200
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	0	0	0	0	0	0	0	0
	Brazos	14,302	14,857	20,000	20,000	30,000	30,000	30,000	35,000
	Colorado	0	0	2,200	2,200	2,200	2,200	2,200	2,200
	Total	14,302	14,857	22,200	22,200	32,200	32,200	32,200	37,200

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case, below normal rainfall and average water conservation.

Table 2-7.
Mining Water Demand Projections
*Llano Estacado Region**
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	20	23	25	25	25	27	27	27
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	0	0	0	0	0	0	0	0
4	Cochran	924	1,142	1,264	1,033	844	689	563	460
5	Crosby	843	883	855	863	889	916	943	970
6	Dawson	654	781	1,635	1,336	1,092	892	729	595
7	Deaf Smith	0	0	0	0	0	0	0	0
8	Dickens	13	32	215	176	144	117	96	78
9	Floyd	63	64	66	50	47	46	45	45
10	Gaines	3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
11	Garza	575	1,138	1,487	1,215	993	811	663	542
12	Hale	166	312	370	302	247	202	165	135
13	Hockley	3,552	6,704	6,379	5,212	4,259	3,480	2,843	2,323
14	Lamb	76	125	138	107	97	94	92	95
15	Lubbock	191	1,255	446	364	298	243	199	162
16	Lynn	116	227	60	49	40	33	27	22
17	Motley	23	24	26	26	27	28	28	28
18	Parmer	0	0	0	0	0	0	0	0
19	Swisher	0	6	4	2	1	1	0	0
20	Terry	822	276	1,237	1,011	826	675	551	451
21	Yoakum	3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
	Total	14,851	27,556	30,384	24,989	20,629	17,078	14,181	11,824
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	344	350	372	353	357	366	373	382
	Brazos	4,207	7,684	8,091	6,919	5,895	5,051	4,368	3,764
	Colorado	10,300	19,522	21,921	17,717	14,377	11,661	9,440	7,678
	Total	14,851	27,556	30,384	24,989	20,629	17,078	14,181	11,824

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case, below normal rainfall and average water conservation.

2.6 Irrigation Water Demand Projections

Irrigated agriculture accounts for almost 65 percent of the total water used in the state. Currently, approximately 10 million acre-feet (acft) of water is used to grow a variety of crops ranging from food and feed grains to fruits, vegetables, and cotton. Of this 10 million acft, groundwater resources provide approximately 70 percent of the water used for irrigation purposes, with surface water supplies accounting for the remaining 30 percent. The TWDB irrigation water use data show annual use for irrigation in the Llano Estacado Region in 1990 of 3,657,740 acft/yr, or 37 percent of the total irrigation water use in Texas in 1990 (Table 2-8 and Figure 2-4). For average precipitation conditions, the TWDB's projected irrigation water demands for the region in 2050 are 2,562,079 acft/yr, or 30 percent less than in 1990 (Table 2-8 and Figure 2-4). The projected declining trend in irrigation water demand in future years is based upon increased irrigation efficiency, economic factors, and reduced government programs affecting the profitability of irrigated agriculture.

Irrigation water demands for average precipitation, instead of for the "below average" precipitation conditions, were selected for use in calculating projected irrigation water needs in the Llano Estacado Water Planning Region. The reason for this was that use of projected irrigation water demands for "below average" precipitation conditions would have, in effect, placed a drought condition irrigation water demand upon the source of supply (Ogallala Aquifer) every year, or 100 percent of the time. If this level of irrigation water demand had been used, then the quantity of water to be withdrawn from the aquifer would have been significantly overstated, resulting in highly erroneous projections of aquifer drawdown; e.g., if irrigation water demand is projected to be at below normal precipitation levels (drought condition levels every year), then these overstated annual demands would exhaust the supplies available from the Ogallala Aquifer much earlier than will or can really happen. The result would have been the calculation of erroneous irrigation needs in the planning region.

Table 2-8.
Irrigation Water Demand Projections
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
2	Briscoe	39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
3	Castro	351,189	519,038	306,596	294,840	283,537	272,666	262,212	252,159
4	Cochran	32,679	165,163	50,969	49,001	47,111	45,293	43,544	41,863
5	Crosby	105,634	138,358	88,164	84,612	81,203	77,931	74,791	71,779
6	Dawson	39,097	143,326	36,475	34,418	32,478	30,647	28,919	27,289
7	Deaf Smith	285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
8	Dickens	4,779	8,551	3,792	3,679	3,569	3,463	3,360	3,259
9	Floyd	131,706	224,791	148,304	142,397	136,726	131,280	126,050	121,030
10	Gaines	392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
11	Garza	4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
12	Hale	461,931	433,633	365,594	353,481	341,769	330,445	319,497	308,911
13	Hockley	92,968	168,853	97,282	93,478	89,822	86,311	82,934	79,692
14	Lamb	351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
15	Lubbock	230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
16	Lynn	39,988	56,334	38,454	36,384	34,427	32,575	30,822	29,164
17	Motley	3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
18	Parmer	475,000	448,516	324,951	321,500	318,087	314,710	311,369	308,063
19	Swisher	139,650	168,688	148,055	147,209	141,036	145,532	144,701	143,874
20	Terry	131,901	148,061	106,860	101,381	96,183	91,252	86,574	82,135
21	Yoakum	122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
	Total	3,657,740	4,377,327	3,065,373	2,956,053	2,845,961	2,750,835	2,654,487	2,562,079
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	730,231	808,302	640,957	623,447	603,478	590,136	574,291	558,963
	Brazos	2,226,798	2,673,812	1,818,113	1,757,222	1,696,434	1,642,484	1,588,389	1,536,367
	Colorado	700,711	895,213	606,303	575,384	546,049	518,215	491,807	466,749
	Total	3,657,740	4,377,327	3,065,373	2,956,053	2,845,961	2,750,835	2,654,487	2,562,079

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case, average rainfall and average water conservation.

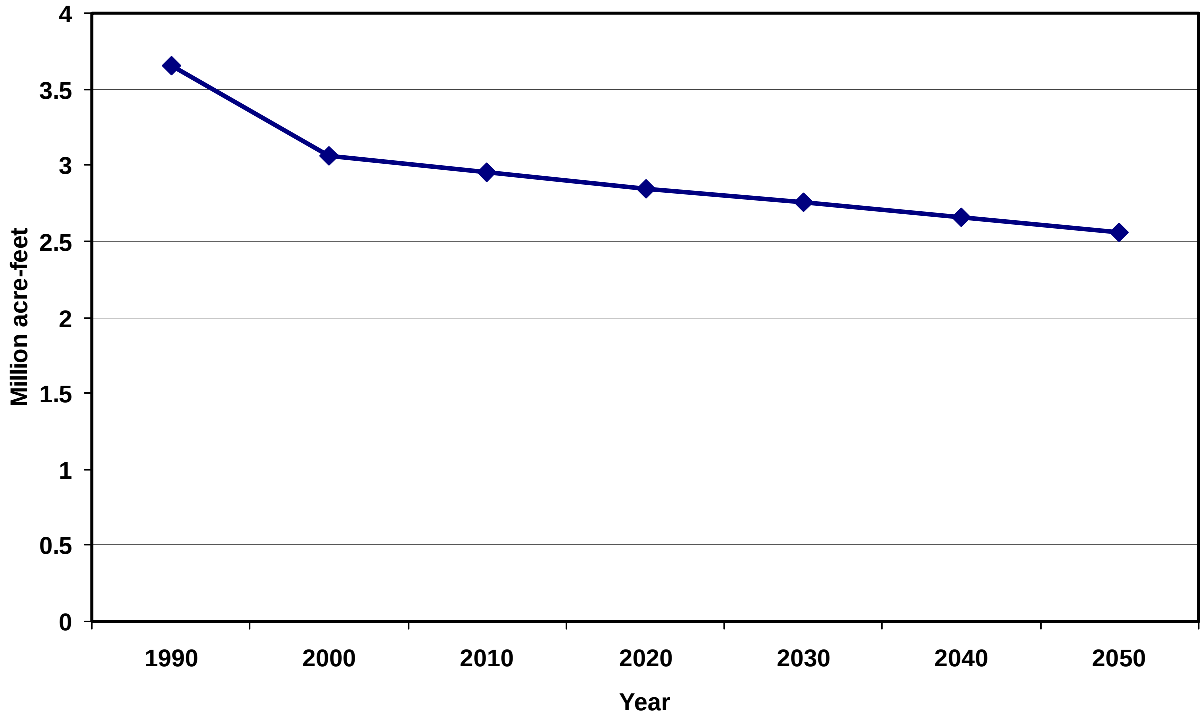

Figure 2-4. Projections of Irrigation Water Demands; Llano Estacado Region – 1990 to 2050

2.7 Livestock Water Demand Projections

For the Llano Estacado Region, livestock water demand projections are presented separately for beef cattle feedlots, swine feedlots, dairies, horses, range beef cows/bulls, range beef stocker cattle, sheep, and poultry.[1] The projections for all types of livestock were based upon data obtained from the Texas Cattle Feeders Association and the Texas A&M University and Research Center. In 1990, water use in the Llano Estacado Region for beef cattle feedlot purposes was estimated at 24,696 acft/yr, with projections of beef cattle feedlot water demands in 2050 of 53,933 acft/yr (Table 2-9 and Figure 2-5).

Swine feedlot water use in the region in 1990 was estimated at 129 acft/yr with projected demands of 1,766 acft/yr in 2050, an increase of over 12.5 times the estimated 1990 use (Table 2-10).

[1] The TWDB presented livestock water demand for all types of livestock grouped together. For purposes of this report, beef cattle feedlot, swine feedlot, dairy, horse, range beef cows/bulls, range beef stocker cattle, sheep, and poultry livestock water demands are shown separately (Tables 2-9 through 2-16).

In 1990, water use in the Llano Estacado Region for dairies was estimated at 741 acft/yr, with projections of dairy water demands in 2050 of 1,141 acft/yr (Table 2-11). Only six counties (Bailey, Castro, Deaf Smith, Lamb, Parmer, and Yoakum) in the Llano Estacado Region have one or more dairies located within them (Table 2-11).

Horse water use in the region in 1990 was estimated at 92 acft/yr with projected demands of 214 acft/yr in 2050, an increase of 1.3 times the estimated 1990 use (Table 2-12).

In 1990, water use in the Llano Estacado Region for range beef cows and bulls was estimated at 3,764 acft/yr (Table 2-13). The water use for this type of livestock is projected to remain constant at 3,764 acft/yr throughout the planning period (Table 2-13).

Range beef stocker cattle water use in the region in 1990 was estimated at 6,944 acft/yr with projected demands of 12,697 acft/yr in 2050, or an 83 percent increase over the estimated 1990 use (Table 2-14).

In 1990, sheep water use in the Llano Estacado Region was estimated at 75 acft/yr (Table 2-15). Water use for this type of livestock is projected to increase to 105 acft/yr by 2050 (Table 2-15).

Poultry water use in the region in 1990 was estimated at 51 acft/yr and is projected to remain constant throughout the planning period (Table 2-16). All commercial poultry water demand occurs in Lubbock County.

Total livestock water demand projections for the Llano Estacado Region are the sum of water demand projections for beef cattle feedlots, swine feedlots, dairies, horses, range beef cows/bulls, range beef stocker cattle, sheep, and poultry (Tables 2-9 through 2-16) and are shown in Table 2-17. Total livestock water use in 1990 was estimated to be 36,492 acft/yr (Table 2-17). Projected total livestock water demand for the region is 73,671 acft/yr in 2050 (Table 2-17).

Projections of total livestock water demand for all livestock other than beef feedlot livestock is the difference between the projections for total livestock water demand and beef feedlot water demand (Tables 2-17 and 2-9) and is shown in Table 2-18 and Figure 2-5. Livestock water demand for all livestock other than beef feedlot livestock was estimated to be 11,796 acft/yr in 1990 (Table 2-18 and Figure 2-5). Projected water demand for all types of livestock other than beef cattle feedlot for the region is 19,738 acft/yr in 2050 (Table 2-18 and Figure 2-5).

Table 2-9.
Beef Cattle Feedlots Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997[1] (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	4,591	5,461	5,711	6,626	7,690	8,494	9,384	10,365
4	Cochran	496	605	633	734	852	941	1,039	1,148
5	Crosby	0	0	0	0	0	0	0	0
6	Dawson	0	0	0	0	0	0	0	0
7	Deaf Smith	6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
8	Dickens	0	0	0	0	0	0	0	0
9	Floyd	854	588	615	714	828	915	1,011	1,116
10	Gaines	482	588	615	714	828	915	1,011	1,116
11	Garza	0	0	0	0	0	0	0	0
12	Hale	1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
13	Hockley	331	269	281	326	379	418	462	510
14	Lamb	1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
15	Lubbock	689	807	843	979	1,136	1,255	1,386	1,531
16	Lynn	0	0	0	0	0	0	0	0
17	Motley	0	0	0	0	0	0	0	0
18	Parmer	4,694	5,105	5,338	6,195	7,188	7,941	8,771	9,689
19	Swisher	2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
20	Terry	0	0	0	0	0	0	0	0
21	Yoakum	0	0	0	0	0	0	0	0
	Total	24,696	28,414	29,713	34,482	40,016	44,202	48,826	53,933
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	13,610	16,054	16,788	19,482	22,609	24,976	27,587	30,473
	Brazos	10,604	11,772	12,310	14,286	16,579	18,311	20,228	22,344
	Colorado	482	588	615	714	828	915	1,011	1,116
	Total	24,696	28,414	29,713	34,482	40,016	44,202	48,826	53,933

[1] Although this column represents water use in 1997, it is included in the 1996 water use column in Tables 2-19 and 2-21.

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Beef Cattle (No. Head)	Water Demand[1] (acft)
1990	1,470,000	24,696
1997	1,691,100	28,414
2000	1,768,383	29,713
2010	2,052,209	34,482
2020	2,381,588	40,016
2030	2,630,702	44,202
2040	2,905,874	48,825
2050	3,209,828	53,933

[1] Calculated at 15 gallons per head per day.

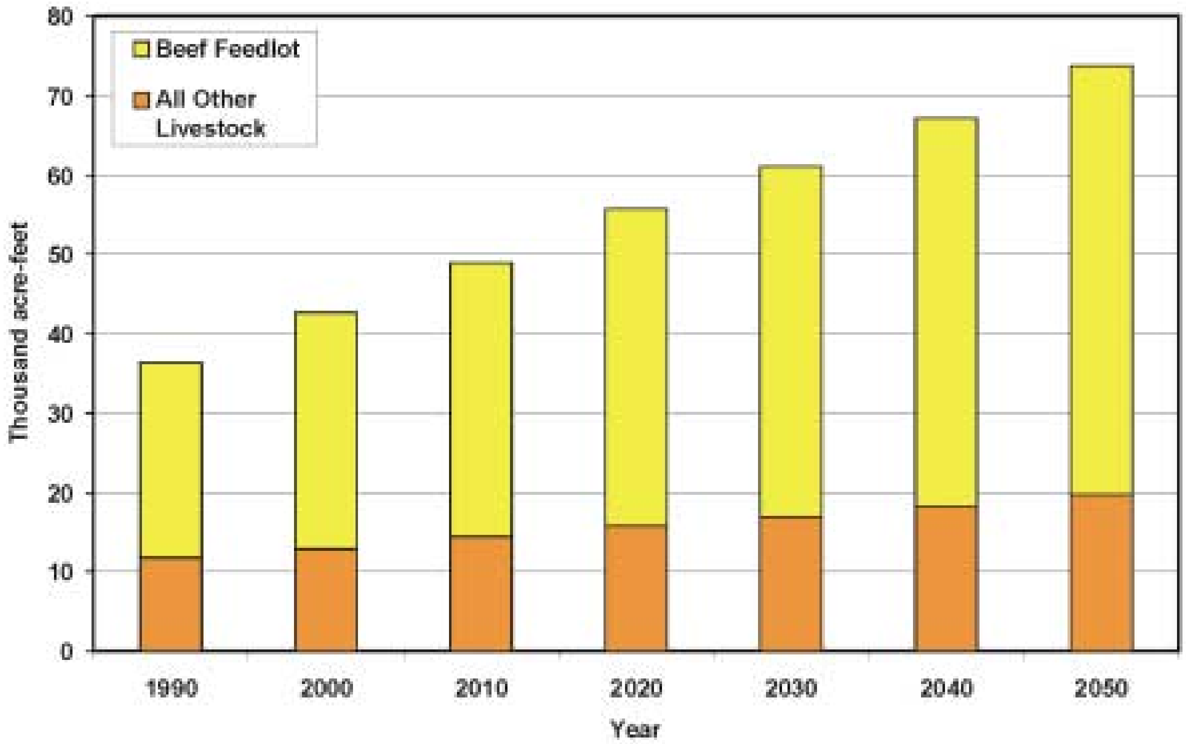

Figure 2-5. Projections of Beef Feedlot and All Other Livestock Water Demands; Llano Estacado Region – 1990 to 2050

Table 2-10.
Swine Feedlots Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	0	1	2	12	14	16	19	22
2	Briscoe	1	2	3	12	14	17	19	22
3	Castro	2	3	4	12	14	17	19	22
4	Cochran	1	1	2	12	14	16	19	22
5	Crosby	3	4	5	13	15	17	19	23
6	Dawson	0	0	2	12	14	16	19	22
7	Deaf Smith	3	4	5	12	14	17	19	23
8	Dickens	2	3	4	12	14	17	19	22
9	Floyd	2	3	4	12	14	17	19	22
10	Gaines	4	5	6	13	15	17	20	23
11	Garza	0	1	2	12	14	16	19	22
12	Hale	2	3	4	12	14	17	19	22
13	Hockley	4	5	6	12	15	17	20	23
14	Lamb	6	8	8	13	15	17	19	23
15	Lubbock	80	130	151	371	430	497	579	671
16	Lynn	1	2	3	12	14	16	19	22
17	Motley	2	3	4	12	14	17	19	22
18	Parmer	2	3	4	12	14	17	19	22
19	Swisher	11	14	45	371	430	497	579	671
20	Terry	2	4	4	12	14	17	19	23
21	Yoakum	1	2	3	12	14	16	19	22
	Total	129	201	271	973	1,130	1,311	1,521	1,766
River Basin Summary**									
	Canadian	0	0	0	1	1	1	1	1
	Red	20	26	59	384	445	516	600	695
	Brazos	100	162	195	528	615	715	827	961
	Colorado	9	13	17	60	69	79	93	109
	Total	129	201	271	973	1,130	1,311	1,521	1,766

*As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Swine (No. Head)	Water Demand[1] (acft)
1990	12,900	129
1997	16,311	201
2000	22,010	271
2010	79,000	973
2020	91,680	1,130
2030	106,394	1,311
2040	123,470	1,521
2050	143,287	1,766

[1] Calculated at 11 gallons per head per day.

Table 2-11.
Dairy Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	252	260	268	296	327	344	362	380
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	104	109	113	124	137	144	152	159
4	Cochran	0	0	0	0	0	0	0	0
5	Crosby	0	0	0	0	0	0	0	0
6	Dawson	0	0	0	0	0	0	0	0
7	Deaf Smith	157	168	173	192	212	222	233	245
8	Dickens	0	0	0	0	0	0	0	0
9	Floyd	0	0	0	0	0	0	0	0
10	Gaines	0	0	0	0	0	0	0	0
11	Garza	0	0	0	0	0	0	0	0
12	Hale	0	0	0	0	0	0	0	0
13	Hockley	0	0	0	0	0	0	0	0
14	Lamb	102	109	113	124	137	144	152	159
15	Lubbock	0	0	0	0	0	0	0	0
16	Lynn	0	0	0	0	0	0	0	0
17	Motley	0	0	0	0	0	0	0	0
18	Parmer	88	93	95	105	116	122	128	136
19	Swisher	0	0	0	0	0	0	0	0
20	Terry	0	0	0	0	0	0	0	0
21	Yoakum	38	42	43	48	53	56	58	62
	Total	741	781	805	889	982	1,032	1,085	1,141
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	157	168	173	192	212	222	233	245
	Brazos	546	571	589	649	717	754	794	834
	Colorado	38	42	43	48	53	56	58	62
	Total	741	781	805	889	982	1,032	1,085	1,141

*As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Dairy Cattle (No. Head)	Water Demand[1] (acft)
1990	8,820	741
1997	9,300	781
2000	9,582	805
2010	10,584	889
2020	11,691	982
2030	12,289	1,032
2040	12,916	1,085
2050	13,577	1,141

[1] Calculated at 75 gallons per head per day.

Table 2-12.
Horse Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	3	3	3	3	4	4	5	5
2	Briscoe	5	5	5	5	6	7	8	9
3	Castro	3	3	3	3	4	4	4	5
4	Cochran	1	1	2	2	2	2	2	3
5	Crosby	2	2	2	2	2	3	3	4
6	Dawson	2	2	2	2	3	3	3	3
7	Deaf Smith	8	8	8	8	10	11	12	14
8	Dickens	8	8	9	9	11	12	14	14
9	Floyd	2	2	2	2	2	2	3	3
10	Gaines	3	3	4	4	4	5	5	6
11	Garza	6	6	6	6	8	9	9	10
12	Hale	5	5	5	5	6	7	7	8
13	Hockley	4	4	4	4	5	6	6	7
14	Lamb	3	3	3	3	4	4	4	5
15	Lubbock	14	14	14	14	17	19	22	23
16	Lynn	3	3	3	3	3	3	4	4
17	Motley	3	3	3	3	4	4	5	5
18	Parmer	8	8	8	8	10	11	12	13
19	Swisher	5	5	6	6	7	8	8	9
20	Terry	1	1	1	1	2	2	2	3
21	Yoakum	3	3	43	48	52	55	59	61
	Total	92	92	136	141	166	181	197	214
River Basin Summary**									
	Canadian	1	1	1	1	1	1	1	1
	Red	27	27	28	28	36	39	45	49
	Brazos	53	53	54	54	66	74	80	88
	Colorado	11	11	53	58	63	67	71	76
	Total	92	92	136	141	166	181	197	214

*As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Horses (No. Head)	Water Demand[1] (acft)
1990	6,836	92
1997	6,836	92
2000	7,043	136
2010	7,780	141
2020	8,594	166
2030	9,493	181
2040	10,485	197
2050	11,582	214

[1] Calculated at 12 gallons per head per day.

Table 2-13.
Range Beef Cows/Bulls Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft) 2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	157	157	157	157	157	157	157	157
2	Briscoe	134	134	134	134	134	134	134	134
3	Castro	269	269	269	269	269	269	269	269
4	Cochran	46	46	46	46	46	46	46	46
5	Crosby	179	179	179	179	179	179	179	179
6	Dawson	90	90	90	90	90	90	90	90
7	Deaf Smith	493	493	493	493	493	493	493	493
8	Dickens	224	224	224	224	224	224	224	224
9	Floyd	179	179	179	179	179	179	179	179
10	Gaines	157	157	157	157	157	157	157	157
11	Garza	314	314	314	314	314	314	314	314
12	Hale	90	90	90	90	90	90	90	90
13	Hockley	157	157	157	157	157	157	157	157
14	Lamb	112	112	112	112	112	112	112	112
15	Lubbock	246	246	246	246	246	246	246	246
16	Lynn	134	134	134	134	134	134	134	134
17	Motley	246	246	246	246	246	246	246	246
18	Parmer	134	134	134	134	134	134	134	134
19	Swisher	179	179	179	179	179	179	179	179
20	Terry	90	90	90	90	90	90	90	90
21	Yoakum	134	134	134	134	134	134	134	134
	Total	3,764	3,764	3,764	3,764	3,764	3,764	3,764	3,764
River Basin Summary**									
	Canadian	32	32	32	32	32	32	32	32
	Red	1,210	1,210	1,210	1,210	1,210	1,210	1,210	1,210
	Brazos	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988
	Colorado	534	534	534	534	534	534	534	534
	Total	3,764	3,764	3,764	3,764	3,764	3,764	3,764	3,764

*As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Range Beef Cows/Bulls (No. Head)	Water Demand[1] (acft)
1990	168,000	3,764
1997	168,000	3,764
2000	168,000	3,764
2010	168,000	3,764
2020	168,000	3,764
2030	168,000	3,764
2040	168,000	3,764
2050	168,000	3,764

[1] Calculated at 20 gallons per head per day.

Table 2-14.
Range Beef Stocker Cattle Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1999[1] (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	656	711	734	811	895	989	1,092	1,206
2	Briscoe	227	247	255	282	311	343	379	419
3	Castro	1,520	1,648	1,698	1,878	2,074	2,291	2,529	2,793
4	Cochran	143	155	158	176	194	215	238	262
5	Crosby	168	181	186	206	228	251	278	306
6	Dawson	105	114	116	129	142	158	174	193
7	Deaf Smith	674	731	754	833	918	1,014	1,123	1,238
8	Dickens	340	369	380	419	465	511	565	626
9	Floyd	285	308	318	352	390	428	473	524
10	Gaines	154	167	171	188	210	231	255	282
11	Garza	207	225	233	256	283	313	346	382
12	Hale	111	119	122	136	150	165	183	202
13	Hockley	68	73	75	84	91	100	111	122
14	Lamb	153	164	168	187	207	230	253	279
15	Lubbock	104	112	117	126	140	157	170	190
16	Lynn	117	127	132	145	161	178	196	217
17	Motley	357	387	400	443	488	538	595	658
18	Parmer	707	767	790	873	965	1,065	1,178	1,300
19	Swisher	652	708	731	805	890	983	1,086	1,200
20	Terry	79	85	89	98	108	121	131	143
21	Yoakum	117	126	89	97	109	123	138	155
	Total	6,944	7,524	7,716	8,524	9,419	10,404	11,493	12,697
River Basin Summary**									
	Canadian	43	47	49	53	59	65	72	79
	Red	3,064	3,328	3,427	3,793	4,183	4,622	5,109	5,642
	Brazos	3,272	3,539	3,654	4,032	4,459	4,923	5,433	6,002
	Colorado	565	610	586	646	718	794	879	974
	Total	6,944	7,524	7,716	8,524	9,419	10,404	11,493	12,697

[1] Although this column represents water use in 1999, it is included in the 1997 water use column in the total livestock water demand table (Table 2-17).
* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.
** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Range Beef Stocker Cattle (No. Head)	Water Demand[1] (acft)
1990	309,960	6,944
1997	560,072	7,524
2000	577,042	7,716
2010	637,401	8,524
2020	704,073	8,419
2030	777,719	10,404
2040	859,068	11,493
2050	948,927	12,697

[1] Calculated at 20 gallons per head per day.

Table 2-15.
Sheep Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	1	1	1	1	2	2	2	2
2	Briscoe	1	1	1	2	2	2	2	2
3	Castro	1	1	1	1	1	1	1	2
4	Cochran	1	1	1	1	2	2	2	2
5	Crosby	1	1	1	1	1	1	1	1
6	Dawson	2	2	2	2	2	2	2	2
7	Deaf Smith	4	4	4	4	4	4	4	5
8	Dickens	1	1	1	2	2	2	2	2
9	Floyd	1	1	1	1	1	2	2	2
10	Gaines	4	4	4	4	4	4	5	5
11	Garza	1	1	1	2	2	2	2	2
12	Hale	6	6	6	6	6	6	7	7
13	Hockley	6	6	6	6	6	7	7	8
14	Lamb	24	27	28	28	29	30	32	34
15	Lubbock	8	9	9	9	9	9	10	10
16	Lynn	1	1	1	2	2	2	2	2
17	Motley	1	1	1	1	2	2	2	2
18	Parmer	5	6	6	6	6	6	6	6
19	Swisher	4	4	4	4	4	5	5	5
20	Terry	1	1	1	1	1	2	2	2
21	Yoakum	1	1	2	2	2	2	2	2
	Total	75	80	82	86	90	95	100	105
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	13	14	14	16	16	17	17	18
	Brazos	52	55	56	58	62	66	70	74
	Colorado	10	11	12	12	12	12	13	13
	Total	75	80	82	86	90	95	100	105

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.
**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Sheep (No. Head)	Water Demand[1] (acft)
1990	13,370	75
1997	14,369	80
2000	14,586	82
2010	15,331	86
2020	16,115	90
2030	16,938	95
2040	17,804	100
2050	18,714	105

[1] Calculated at 12 gallons per head per day.

Table 2-16.
Poultry Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	0	0	0	0	0	0	0	0
2	Briscoe	0	0	0	0	0	0	0	0
3	Castro	0	0	0	0	0	0	0	0
4	Cochran	0	0	0	0	0	0	0	0
5	Crosby	0	0	0	0	0	0	0	0
6	Dawson	0	0	0	0	0	0	0	0
7	Deaf Smith	0	0	0	0	0	0	0	0
8	Dickens	0	0	0	0	0	0	0	0
9	Floyd	0	0	0	0	0	0	0	0
10	Gaines	0	0	0	0	0	0	0	0
11	Garza	0	0	0	0	0	0	0	0
12	Hale	0	0	0	0	0	0	0	0
13	Hockley	0	0	0	0	0	0	0	0
14	Lamb	0	0	0	0	0	0	0	0
15	Lubbock	51	51	51	51	51	51	51	51
16	Lynn	0	0	0	0	0	0	0	0
17	Motley	0	0	0	0	0	0	0	0
18	Parmer	0	0	0	0	0	0	0	0
19	Swisher	0	0	0	0	0	0	0	0
20	Terry	0	0	0	0	0	0	0	0
21	Yoakum	0	0	0	0	0	0	0	0
	Total	51	51	51	51	51	51	51	51
River Basin Summary**									
	Canadian	0	0	0	0	0	0	0	0
	Red	0	0	0	0	0	0	0	0
	Brazos	51	51	51	51	51	51	51	51
	Colorado	0	0	0	0	0	0	0	0
	Total	51	51	51	51	51	51	51	51

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.
**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Poultry (No. Head)	Water Demand[1] (acft)
1990	504,433	51
1997	504,433	51
2000	504,433	51
2010	504,433	51
2020	504,433	51
2030	504,433	51
2040	504,433	51
2050	504,433	51

[1] Calculated at 0.09 gallons per head per day.

Table 2-17.
Total Livestock Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	2,007	2,275	2,360	2,667	3,008	3,289	3,600	3,941
2	Briscoe	368	389	398	435	467	503	542	586
3	Castro	6,490	7,494	7,799	8,913	10,189	11,220	12,358	13,615
4	Cochran	688	809	842	971	1,110	1,222	1,346	1,483
5	Crosby	353	367	373	401	425	451	480	513
6	Dawson	199	208	212	235	251	269	288	310
7	Deaf Smith	7,873	9,260	9,647	11,070	12,710	13,977	15,376	16,921
8	Dickens	575	605	618	666	716	766	824	888
9	Floyd	1,323	1,081	1,119	1,260	1,414	1,543	1,687	1,846
10	Gaines	804	924	957	1,080	1,218	1,329	1,453	1,589
11	Garza	528	547	556	590	621	654	690	730
12	Hale	1,387	1,617	1,685	1,941	2,230	2,454	2,702	2,976
13	Hockley	570	514	529	589	653	705	763	827
14	Lamb	1,902	2,170	2,259	2,588	2,965	3,255	3,575	3,929
15	Lubbock	1,192	1,369	1,431	1,796	2,029	2,234	2,464	2,722
16	Lynn	256	267	273	296	314	333	355	379
17	Motley	609	640	654	705	754	807	867	933
18	Parmer	5,638	6,116	6,375	7,333	8,433	9,296	10,248	11,300
19	Swisher	3,263	3,766	3,952	4,831	5,532	6,115	6,765	7,486
20	Terry	173	181	185	202	215	232	244	261
21	Yoakum	294	308	314	341	364	386	410	436
	Total	36,492	40,907	42,538	48,910	55,618	61,040	67,037	73,671
River Basin Summary**									
	Canadian	76	80	82	87	93	99	106	113
	Red	18,101	20,827	21,699	25,105	28,711	31,602	34,801	38,332
	Brazos	16,666	18,191	18,897	21,646	24,537	26,882	29,471	32,342
	Colorado	1,649	1,809	1,860	2,072	2,277	2,457	2,659	2,884
	Total	36,492	40,907	42,538	48,910	55,618	61,040	67,037	73,671

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.
**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Livestock (No. Head)	Water Demand[1] (acft)
1990	See Table 2-8 through Table 2-15 for numbers of each type of Livestock	36,492
1997		40,907
2000		42,538
2010		48,910
2020		55,618
2030		61,040
2040		67,037
2050		73,671

[1] Sum of Tables 2-8 through 2-15.

Table 2-18.
All Livestock Other than Beef Feedlot Livestock Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1997 (acft)	Projections (acft)					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	1,069	1,133	1,165	1,280	1,399	1,512	1,637	1,772
2	Briscoe	368	389	398	435	467	503	542	586
3	Castro	1,899	2,033	2,088	2,287	2,499	2,726	2,974	3,250
4	Cochran	192	204	209	237	258	281	307	335
5	Crosby	353	367	373	401	425	451	480	513
6	Dawson	199	208	212	235	251	269	288	310
7	Deaf Smith	1,339	1,408	1,437	1,542	1,651	1,761	1,884	2,018
8	Dickens	575	605	618	666	716	766	824	888
9	Floyd	469	493	504	546	586	628	676	730
10	Gaines	322	336	342	366	390	414	442	473
11	Garza	528	547	556	590	621	654	690	730
12	Hale	214	223	227	249	266	285	306	329
13	Hockley	239	245	248	263	274	287	301	317
14	Lamb	400	423	432	467	504	537	572	612
15	Lubbock	503	562	588	817	893	979	1,078	1,191
16	Lynn	256	267	273	296	314	333	355	379
17	Motley	609	640	654	705	754	807	867	933
18	Parmer	944	1,011	1,037	1,138	1,245	1,355	1,477	1,611
19	Swisher	851	910	965	1,365	1,510	1,672	1,857	2,064
20	Terry	173	181	185	202	215	232	244	261
21	Yoakum	294	308	314	341	364	386	410	436
	Total	11,796	12,493	12,825	14,428	15,602	16,838	18,211	19,738
River Basin Summary**									
	Canadian	76	80	82	87	93	99	106	113
	Red	4,491	4,773	4,911	5,623	6,102	6,626	7,214	7,859
	Brazos	6,062	6,419	6,587	7,360	7,956	8,573	9,243	9,998
	Colorado	1,167	1,221	1,245	1,358	1,449	1,542	1,048	1,768
	Total	11,796	12,493	12,825	14,428	15,600	16,840	18,211	19,738

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

**See Table 2-21 for River Basin tabulations of counties, cities, and rural areas

Source: Weinheimer, Ben, and Sweeten, John M.; Texas Cattle Feeders Assn., and Texas A&M University research and Extension Center, Amarillo, Texas, July 1999.

Year	Livestock (No. Head)	Water Demand[1] (acft)
1990	See Table 2-9 through Table 2-15 for numbers of each type of Livestock	11,796
1997		12,493
2000		12,825
2010		14,428
2020		15,600
2030		16,840
2040		18,211
2050		19,738

[1] Sum of Tables 2-9 through 2-15.

2.8 Total Water Demand Projections

Total water demand projections for the Llano Estacado Region are the sum of water demand projections for municipal, industrial, steam-electric power generation, mining, irrigation, and total livestock water demand projections (Tables 2-4, 2-5, 2-6, 2-7, 2-8, and 2-17), and are shown in Table 2-19 and Figure 2-6. Total water use in 1990 was estimated to be 3,813,487 acft/yr (Table 2-19). Projected total water demand for the region is 2,963,671 acft/yr in 2030 and 2,793,000 acft/yr in 2050 (Table 2-19 and Figure 2-6). Projections of future water demands for municipal, industrial, steam-electric power, and livestock increase, while projections for irrigation and mining purposes decrease. The reasons for the decline in the projections of demand in future years for irrigation are predictions of increased efficiency in irrigation, economic factors adversely affecting the profitability of irrigation in future years, and expectation of decreased government programs supporting agricultural incomes. Projections for mining water demand decrease due to the expectation that secondary recovery of crude petroleum using water flooding will decrease in future years as this method is phased out or is no longer a viable technology for the industry in the Llano Estacado Region.

Projections of future water demands for the Llano Estacado Region show irrigation demand at 93 percent of total demand in 2030 and 91.7 percent in 2050 (Table 2-20). Municipal demand, as a percent of total demand, increases from 2.14 percent in 1990 to 3.3 percent in 2050 (Table 2-20), with beef cattle feedlot livestock demand as a percent of total demand increasing from 0.65 percent in 1990 to 1.93 percent in 2050 (Table 2-20).

Table 2-19.
Total Water Demand Projections (SB1)
Llano Estacado Region*
Individual Counties with River Basin Summaries

County Number	County	Use in 1990 (acft)	Use in 1996 (acft)	Projections					
				2000	2010	2020	2030	2040	2050
Counties									
1	Bailey	224,374	253,872	176,237	172,397	168,656	164,799	161,038	157,454
2	Briscoe	40,283	21,597	33,327	32,172	31,049	29,970	28,935	27,951
3	Castro	361,423	530,006	318,894	308,758	299,121	289,605	280,783	272,483
4	Cochran	35,222	167,959	54,040	51,994	50,046	48,178	46,413	44,752
5	Crosby	108,032	140,822	90,618	87,033	83,586	80,269	77,158	74,187
6	Dawson	42,279	146,957	41,194	38,874	36,658	34,600	32,697	30,950
7	Deaf Smith	298,239	296,429	266,320	260,105	254,270	248,270	242,662	237,509
8	Dickens	5,875	9,858	5,119	4,993	4,871	4,779	4,699	4,636
9	Floyd	134,278	227,285	150,777	144,992	139,430	134,076	128,909	124,006
10	Gaines	400,317	427,239	368,695	348,805	329,883	312,425	295,901	280,420
11	Garza	6,447	12,772	6,732	6,290	5,868	5,485	5,146	4,868
12	Hale	471,380	444,936	375,913	364,115	352,740	341,756	331,093	322,205
13	Hockley	100,912	179,526	108,418	103,498	98,886	94,544	90,427	86,618
14	Lamb	369,020	400,885	312,503	301,656	298,247	288,255	278,689	274,573
15	Lubbock	277,626	296,010	207,897	200,736	196,164	189,995	183,952	178,873
16	Lynn	41,302	57,829	39,872	37,804	35,826	33,944	32,154	30,483
17	Motley	4,817	5,126	4,697	4,609	4,517	4,443	4,379	4,320
18	Parmer	484,388	458,426	335,265	332,957	330,759	328,320	326,086	324,022
19	Swisher	144,439	173,991	153,632	153,682	148,216	153,328	153,189	153,141
20	Terry	134,843	150,843	110,446	104,820	99,481	94,478	89,735	85,288
21	Yoakum	127,991	155,560	96,657	91,429	86,575	82,149	78,034	74,261
	Total	3,813,487	4,557,928	3,257,253	3,151,719	3,054,849	2,963,671	2,872,079	2,793,000
River Basin Summary**									
	Canadian	79	84	86	91	97	103	110	117
	Red	758,998	840,101	674,379	660,782	644,735	634,576	622,374	611,129
	Brazos	2,331,816	2,790,963	1,939,253	1,881,864	1,833,616	1,782,675	1,731,602	1,690,102
	Colorado	722,594	926,780	643,535	608,982	576,401	546,317	517,993	491,652
	Total	3,813,487	4,557,928	3,257,253	3,151,719	3,054,849	2,963,671	2,872,079	2,793,000

* As specified in Texas Water Development Board Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998.

** See Table 2-21 for River Basin tabulations of counties, cities, and rural areas.

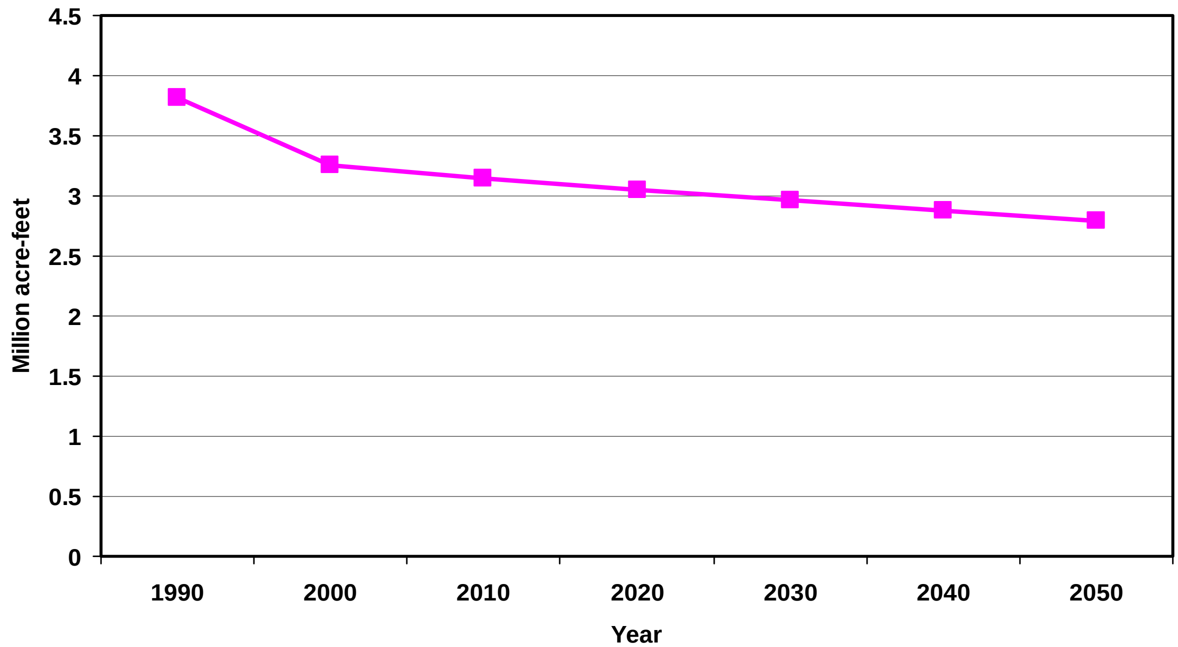

Figure 2-6. Total Water Demand Projections; Llano Estacado Region – 1990 to 2050

Table 2-20.
Composition of Total Water Use
Llano Estacado Region
1990, 2030, and 2050

	1990		*2030*		*2050*	
Purpose of Use	***acft***	***% of total***	***(acft)***	***% of total***	***(acft)***	***% of total***
Municipal	81,608	2.14%	90,752	3.06%	92,529	3.31%
Industrial	8,494	0.22%	11,764	0.40%	15,697	0.56%
Steam-Electric Power	14,302	0.38%	32,200	1.09%	37,200	1.33%
Mining	14,851	0.39%	17,078	0.58%	11,824	0.42%
Irrigation	3,657,740	95.92%	2,750,835	92.82%	2,562,079	91.74%
Beef Feedlot Livestock	24,696	0.65%	44,202	1.49%	53,933	1.93%
Range & All Other Livestock	11,796	0.31%	16,840	0.57%	19,738	0.71%
Total	3,813,487	100.00%	2,963,671	100.00%	2,793,000	100.00%

2.9 Water Demand Projections for Counties and Parts of Counties of River Basins of the Llano Estacado Region

For purposes of this regional planning project, and in accordance with TWDB Rules, Section 357.7(a)(2), water demand projections are tabulated by river basin, county or part of county located within a river basin, as well as city and rural areas of each county or part of county for the Llano Estacado Water Planning Region (Table 2-21).[2] For example, a part of the rural area of Deaf Smith County is located in the Canadian River Basin. The projected 4 acft/yr of water demand for the people who live in this rural area is shown as municipal water demand (Table 2-21). There is no industry, steam-electric power, irrigation, mining, or beef livestock demand projected for the part of Deaf Smith County located in the Canadian River Basin. However, there is a range and all other livestock demand of 76 acft/yr in 1990 with a projection of 113 acft/yr in 2050 (Table 2-21).

All of Briscoe County is located in the Red River Basin. Most of the county is rural, but it contains the cities of Quitaque and Silverton. The municipal water use by Quitaque in 1990 was 129 acft/yr, and projected municipal water demand in 2050 is 91 acft/yr (Table 2-21). Water use in 1990 by Silverton was 135 acft/yr, with projected 2050 demands of 110 acft/yr (Table 2-21). Rural areas of Briscoe County located in the Red River Basin used 59 acft/yr for household purposes (municipal type of water use), with projections for 2050 of 79 acft/yr (Table 2-21).

There are no industrial, steam-electric power, mining, nor feedlot livestock demand in Briscoe County in the Red River Basin. However, an estimated 39,592 acft/yr of water was used for irrigation in 1990, with projected irrigation water demand in 2050 of 27,085 acft/yr (Table 2-21). Range and all other livestock water demand in Briscoe County was estimated at 368 acft/yr in 1990 and is projected to increase to 586 acft/yr in 2050 (Table 2-21).

Total water use in Briscoe County in 1990 was 40,283 acft/yr, with projected total water demand of 27,951 acft/yr in 2050 (Table 2-21).

[2] 31 Texas administrative code, Chapter 357, Regional Water Planning Guidelines Rules, Texas Water Development Board, Austin, Texas, March 11, 1998.

Projections for each county or part of county of each respective river basin of the region are shown in Table 2-21. Total projections for counties and parts of counties of each river basin area located in the Llano Estacado Planning Region are shown at the end of the listing of individual counties and parts of counties of each river basin. In addition, the basin totals are listed at the end of Table 2-21. For example, total water use in 1990 in the Red River Basin part of the Llano Estacado Planning Region was 758,998 acft/yr, of which 7,927 acft/yr was for municipal purposes, 2,395 acft/yr was for industrial purposes, 730,231 acft/yr was for irrigation, 344 acft/yr was for mining, 13,610 acft/yr was for beef feedlot livestock, and 4,491 acft/yr was for range and all other livestock (Page 2-47). Projected water demand for the Red River Basin part of the planning region in 2050 is 611,129 acft/yr, with 9,843 acft/yr being municipal demand, 3,609 acft/yr being for industry, 558,963 acft/yr being for irrigation, 382 acft/yr being for mining, 30,473 acft/yr being for beef feedlot livestock, and 7,859 acft/yr being for range and all other livestock (Page 2-47). The reader can readily see the projections, by type of demand, for the Canadian, Red, Brazos, and Colorado River Basin areas of the Llano Estacado Planning Region in Table 2-21, Page 2-47.

Total water use in the Llano Estacado Region was 3,813,487 acft/yr in 1990, with projected 2050 water demands of 2,793,000 (Page 2-50). The quantity of projected water demands in 2050 are 117 acft/yr for the Canadian River Basin, 611,129 acft/yr for the Red River Basin, 1,690,102 acft/yr for the Brazos River Basin, and 491,652 acft/yr for the Colorado River Basin (Page 2-48).

Table 2-21.
Water Demand Projections
Llano Estacado Region
River Basins, Counties, and Cities*

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Canadian Basin (part)								
Deaf Smith (part)								
Rural (Municipal)	3	4	4	4	4	4	4	4
Total Municipal Demand	3	4	4	4	4	4	4	4
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	0	0	0	0	0	0	0	0
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	76	80	82	87	93	99	106	113
Total Demand	79	84	86	91	97	103	110	117
Canadian Basin Total	**79**	**84**	**86**	**91**	**97**	**103**	**110**	**117**
Red Basin (part)								
Briscoe County (all)								
Quitaque (Municipal)	129	120	115	109	96	94	95	91
Silverton (Municipal)	135	111	136	132	126	119	113	110
Rural (Municipal)	59	43	94	95	98	90	80	79
Total Municipal Demand	323	274	345	336	320	303	288	280
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	368	389	398	435	467	503	542	586
Total Demand	40,283	21,597	33,327	32,172	31,049	29,970	28,935	27,951
Castro County (part)								
Rural (Municipal)	221	209	238	240	232	223	219	207
Total Municipal Demand	221	209	238	240	232	223	219	207
Industrial Demand	392	138	472	557	610	659	741	826
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	115,892	176,473	101,176	97,297	93,567	89,979	86,529	83,212
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	2,689	3,198	3,345	3,881	4,504	4,975	5,496	6,071
Range & All Other Livestock Demand	855	917	940	1,031	1,126	1,231	1,346	1,473
Total Demand	120,049	180,935	106,171	103,006	100,039	97,067	94,331	91,789
Crosby County (part)								
Rural (Municipal)	5	6	6	5	5	5	5	5
Total Municipal Demand	5	6	6	5	5	5	5	5
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	2,113	4,151	1,763	1,692	1,624	1,559	1,496	1,436
Mining Demand	291	291	315	315	324	334	344	354
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	4	4	4	5	5	5	6	6
Total Demand	2,413	4,452	2,088	2,017	1,958	1,903	1,851	1,801

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Deaf Smith (part)								
Hereford (Municipal)	3,869	3,167	4,426	4,676	4,863	5,032	5,192	5,433
Rural (Municipal)	537	578	594	624	636	637	640	644
Total Municipal Demand	4,406	3,745	5,020	5,300	5,499	5,669	5,832	6,077
Industrial Demand	498	1,394	537	575	603	626	679	730
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
Range & All Other Livestock Demand	1,263	1,328	1,355	1,455	1,558	1,662	1,778	1,905
Total Demand	298,160	296,345	266,234	260,014	254,173	248,167	242,552	237,392
Dickens County (part)								
Rural (Municipal)	34	81	49	47	44	43	41	40
Total Municipal Demand	34	81	49	47	44	43	41	40
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	2,055	2,907	1,630	1,581	1,534	1,488	1,444	1,401
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	213	224	227	246	265	284	306	329
Total Demand	2,302	3,212	1,906	1,874	1,843	1,815	1,791	1,770
Floyd County (part)								
Rural (Municipal)	107	111	109	108	104	104	100	98
Total Municipal Demand	107	111	109	108	104	104	100	98
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	59,268	65,189	66,737	64,079	61,527	59,076	56,723	54,463
Mining Demand	30	29	27	10	5	3	1	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	259	276	281	305	325	350	377	406
Total Demand	59,664	65,605	67,154	64,502	61,961	59,533	57,201	54,967
Hale County (part)								
Rural (Municipal)	6	10	7	7	7	8	8	8
Total Municipal Demand	6	10	7	7	7	8	8	8
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	4,619	4,336	3,656	3,535	3,418	3,304	3,195	3,089
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	0	1	1	1	1	1	1	1
Total Demand	4,625	4,347	3,664	3,543	3,426	3,313	3,204	3,098
Motley County (all)								
Matador (Municipal)	221	209	227	208	185	168	151	131
Rural (Municipal)	81	117	99	89	76	67	60	52
Total Municipal Demand	302	326	326	297	261	235	211	183
Industrial Demand	0	2	4	4	5	6	7	8
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
Mining Demand	23	24	26	26	27	28	28	28
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	609	640	654	705	754	807	867	933
Total Demand	4,817	5,126	4,697	4,609	4,517	4,443	4,379	4,320

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft) 2000	2010	2020	2030	2040	2050
Parmer County (part)								
Friona (Municipal)	912	816	939	994	1,029	1,056	1,090	1,137
Rural (Municipal)	138	156	136	130	122	113	99	91
Total Municipal Demand	1,050	972	1,075	1,124	1,151	1,169	1,189	1,228
Industrial Demand	1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	137,750	130,070	94,236	93,235	92,245	91,266	90,297	89,338
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	1,975	2,148	2,246	2,607	3,024	3,342	3,691	4,077
Range & All Other Livestock Demand	322	344	354	388	423	462	507	554
Total Demand	142,599	135,407	99,510	99,048	98,601	98,039	97,609	97,239
Swisher County (part)								
Kress (Municipal)	101	87	95	84	72	65	61	59
Tulia (Municipal)	1,062	1,110	1,135	1,156	1,163	1,188	1,219	1,264
Rural (Municipal)	310	281	331	340	352	366	381	394
Total Municipal Demand	1,473	1,478	1,561	1,580	1,587	1,619	1,661	1,717
Industrial Demand	3	3	3	3	3	3	3	3
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	79,600	118,082	84,376	83,894	80,377	82,939	82,465	81,994
Mining Demand	0	6	4	2	1	1	0	0
Beef Feedlot Livestock Demand	2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
Range & All Other Livestock Demand	598	650	697	1,052	1,178	1,321	1,484	1,666
Total Demand	84,086	123,075	89,628	89,997	87,168	90,326	90,521	90,802
Red Basin Total								
Total Municipal Demand	7,927	7,212	8,736	9,044	9,210	9,378	9,554	9,843
Industrial Demand	2,395	3,410	2,615	2,833	2,979	3,094	3,355	3,609
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	730,231	808,302	640,957	623,447	603,478	590,136	574,291	558,963
Mining Demand	344	350	372	353	357	366	373	382
Beef Feedlot Livestock Demand	13,610	16,054	16,788	19,482	22,609	24,976	27,587	30,473
Range & All Other Livestock Demand	4,491	4,773	4,911	5,623	6,102	6,626	7,214	7,859
Total Demand	758,998	840,101	674,379	660,782	644,735	634,576	622,374	611,129
Brazos Basin (part)								
Bailey County (all)								
Muleshoe (Municipal)	1,073	910	1,078	1,064	1,016	850	643	489
Rural (Municipal)	352	326	333	306	280	220	163	109
Total Municipal Demand	1,425	1,236	1,411	1,370	1,296	1,070	806	598
Industrial Demand	147	163	172	199	224	247	281	315
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
Mining Demand	20	23	25	25	25	27	27	27
Beef Feedlot Livestock Demand	938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
Range & All Other Livestock Demand	1,069	1,133	1,165	1,280	1,399	1,512	1,637	1,772
Total Demand	224,374	253,872	176,237	172,397	168,656	164,799	161,038	157,454

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Castro County (part)								
Dimmitt (Municipal)	894	1,050	1,144	1,206	1,239	1,250	1,253	1,270
Hart (Municipal)	187	248	246	267	287	300	302	310
Rural (Municipal)	265	268	312	314	304	293	287	272
Total Municipal Demand	1,346	1,566	1,702	1,787	1,830	1,843	1,842	1,852
Industrial Demand	1,785	1,561	2,087	2,421	2,723	2,994	3,411	3,824
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	235,297	342,565	205,420	197,543	189,970	182,687	175,683	168,947
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	1,902	2,263	2,366	2,745	3,186	3,519	3,888	4,294
Range & All Other Livestock Demand	1,044	1,116	1,148	1,256	1,373	1,495	1,628	1,777
Total Demand	241,374	349,071	212,723	205,752	199,082	192,538	186,452	180,694
Cochran County (part)								
Morton (Municipal)	631	546	656	676	673	670	663	653
Whiteface (Municipal)	117	127	115	102	89	80	75	74
Rural (Municipal)	59	66	45	60	70	77	78	77
Total Municipal Demand	807	739	816	838	832	827	816	804
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	20,915	128,827	32,615	31,356	30,146	28,983	27,864	26,788
Mining Demand	0	0	12	12	12	11	11	10
Beef Feedlot Livestock Demand	496	605	633	734	852	941	1,039	1,148
Range & All Other Livestock Demand	67	70	72	81	91	100	110	119
Total Demand	22,285	130,241	34,148	33,021	31,933	30,862	29,840	28,869
Crosby County (part)								
Crosbyton (Municipal)	409	438	389	368	339	306	297	294
Lorenzo (Municipal)	227	221	265	249	231	209	202	199
Ralls (Municipal)	313	302	318	288	261	227	217	209
Rural (Municipal)	241	244	241	241	227	218	217	212
Total Municipal Demand	1,190	1,205	1,213	1,146	1,058	960	933	914
Industrial Demand	7	3	7	6	6	6	6	6
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	103,521	134,207	86,401	82,920	79,579	76,372	73,295	70,343
Mining Demand	552	592	540	548	565	582	599	616
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	349	363	369	396	420	446	474	507
Total Demand	105,619	136,370	88,530	85,016	81,628	78,366	75,307	72,386
Dawson (part)								
Rural (Municipal)	14	18	15	15	14	14	13	13
Total Municipal Demand	14	18	15	15	14	14	13	13
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	391	513	365	344	325	307	289	273
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	2	2	1	3	2	3	3	4
Total Demand	407	533	381	362	341	324	305	290

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft) 2000	2010	2020	2030	2040	2050
Dickens County (part)								
Dickens (Municipal)	99	105	91	86	81	80	78	76
Spur (Municipal)	251	306	245	234	221	215	210	207
Rural (Municipal)	124	178	109	105	98	95	90	88
Total Municipal Demand	474	589	445	425	400	390	378	371
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	2,724	5,644	2,162	2,098	2,035	1,975	1,916	1,858
Mining Demand	13	32	215	176	144	117	96	78
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	362	381	391	420	449	482	518	559
Total Demand	3,573	6,646	3,213	3,119	3,028	2,964	2,908	2,866
Floyd County (part)								
Floydada (Municipal)	570	620	622	621	601	586	552	531
Lockney (Municipal)	321	381	374	374	362	340	307	290
Rural (Municipal)	187	184	182	181	174	173	166	164
Total Municipal Demand	1,078	1,185	1,178	1,176	1,137	1,099	1,025	985
Industrial Demand	1	53	1	1	2	2	2	2
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	72,438	159,602	81,567	78,318	75,199	72,204	69,327	66,567
Mining Demand	33	35	39	40	42	43	44	45
Beef Feedlot Livestock Demand	854	588	615	714	828	915	1,011	1,116
Range & All Other Livestock Demand	210	217	223	241	261	280	299	324
Total Demand	74,614	161,680	83,623	80,490	77,469	74,543	71,708	69,039
Garza County (part)								
Post (Municipal)	770	386	967	971	942	902	857	832
Rural (Municipal)	188	173	190	188	180	169	158	148
Total Municipal Demand	958	559	1,157	1,159	1,122	1,071	1,015	980
Industrial Demand	2	2	2	3	3	4	5	5
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
Mining Demand	575	1,138	1,487	1,215	993	811	663	542
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	528	547	556	590	621	654	690	730
Total Demand	6,446	12,771	6,731	6,289	5,867	5,484	5,145	4,867
Hale County (part)								
Abernathy (part) (Municipal)	395	427	398	399	403	406	403	405
Hale Center (Municipal)	410	472	406	408	410	415	394	384
Petersburg (Municipal)	222	219	244	264	277	298	313	333
Plainview (Municipal)	4,421	4,431	4,505	4,416	4,320	4,267	4,074	3,939
Rural (Municipal)	921	1,583	1,061	1,123	1,173	1,233	1,299	1,375
Total Municipal Demand	6,369	7,132	6,614	6,610	6,583	6,619	6,483	6,436
Industrial Demand	1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	457,312	429,297	361,938	349,946	338,351	327,141	316,302	305,822
Mining Demand	166	312	370	302	247	202	165	135
Beef Feedlot Livestock Demand	1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
Range & All Other Livestock Demand	214	222	226	248	265	284	305	328
Total Demand	466,755	440,589	372,249	360,572	349,314	338,443	327,889	319,107

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Hockley County (part)								
Anton (Municipal)	200	201	263	258	258	253	243	237
Levelland (Municipal)	2,377	1,954	2,518	2,479	2,401	2,311	2,176	2,099
Rural (Municipal)	771	896	895	891	867	830	791	732
Total Municipal Demand	3,348	3,051	3,676	3,628	3,526	3,394	3,210	3,068
Industrial Demand	67	55	82	98	117	138	161	188
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	83,764	155,345	87,554	84,130	80,840	77,680	74,641	71,723
Mining Demand	2,465	3,953	4,770	4,088	3,435	2,890	2,446	2,032
Beef Feedlot Livestock Demand	331	269	281	326	379	418	462	510
Range & All Other Livestock Demand	199	204	207	219	229	240	252	265
Total Demand	90,174	162,877	96,570	92,489	88,526	84,760	81,172	77,786
Lamb County (all)								
Amherst (Municipal)	147	152	155	140	124	112	106	102
Earth (Municipal)	312	277	320	325	326	331	334	343
Littlefield (Municipal)	1,010	1,430	1,165	1,175	1,164	1,158	1,156	1,172
Olton (Municipal)	457	513	585	598	598	606	610	617
Sudan (Municipal)	283	207	313	320	320	322	318	319
Rural (Municipal)	443	498	487	504	514	523	532	536
Total Municipal Demand	2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
Industrial Demand	753	448	711	655	593	593	593	593
Steam-Electric Power Demand	12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
Irrigation Demand	351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
Mining Demand	76	125	138	107	97	94	92	95
Beef Feedlot Livestock Demand	1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
Range & All Other Livestock Demand	400	423	432	467	504	537	572	612
Total Demand	369,020	400,885	312,503	301,656	298,247	288,255	278,689	274,573
Lubbock County (all)								
Abernathy (part) (Municipal)	109	133	149	159	168	177	184	195
Idalou (Municipal)	356	380	423	438	459	507	523	543
Lubbock (Municipal)	36,656	40,225	38,394	39,556	40,206	41,600	42,516	44,041
New Deal (Municipal)	96	105	106	104	100	102	105	110
Ransom Canyon (Municipal)	162	222	215	220	221	232	247	265
Reese AFB (Municipal)	657	750	662	638	615	610	606	603
Shallowater (Municipal)	325	352	364	377	397	438	448	468
Slaton (Municipal)	865	756	915	891	864	946	969	1,021
Wolfforth (Municipal)	337	375	391	402	421	467	476	494
Rural (Municipal)	2,779	4,587	2,619	2,562	2,495	2,328	2,222	1,945
Total Municipal Demand	42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
Industrial Demand	1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
Steam-Electric Power Demand	1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
Irrigation Demand	230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
Mining Demand	191	1,255	446	364	298	243	199	162
Beef Feedlot Livestock Demand	689	807	843	979	1,136	1,255	1,386	1,531
Range & All Other Livestock Demand	503	562	588	817	893	979	1,078	1,191
Total Demand	277,626	296,010	207,897	200,736	196,164	189,995	183,952	178,873

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Lynn County (part)								
Tahoka (Municipal)	488	483	517	527	527	519	495	483
Wilson (Municipal)	53	67	64	57	49	46	43	42
Rural (Municipal)	278	291	327	315	298	276	256	241
Total Municipal Demand	819	841	908	899	874	841	794	766
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	39,616	55,264	38,108	36,058	34,117	32,283	30,545	28,903
Mining Demand	116	219	49	42	37	31	26	22
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	235	246	252	272	289	307	326	349
Total Demand	40,786	56,570	39,317	37,271	35,317	33,462	31,691	30,040
Parmer County (part)								
Bovina (Municipal)	316	331	350	372	388	402	419	441
Farwell (Municipal)	410	273	429	461	486	507	531	562
Rural (Municipal)	472	345	486	473	456	436	405	386
Total Municipal Demand	1,198	949	1,265	1,306	1,330	1,345	1,355	1,389
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	337,250	318,446	230,715	228,265	225,842	223,444	221,072	218,725
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	2,719	2,957	3,092	3,588	4,164	4,599	5,080	5,612
Range & All Other Livestock Demand	622	667	683	750	822	893	970	1,057
Total Demand	341,789	323,019	235,755	233,909	232,158	230,281	228,477	226,783
Swisher County (part)								
Rural (Municipal)	50	50	57	57	57	58	59	61
Total Municipal Demand	50	50	57	57	57	58	59	61
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	60,050	50,606	63,679	63,315	60,659	62,593	62,236	61,880
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	253	260	268	313	332	351	373	398
Total Demand	60,353	50,916	64,004	63,685	61,048	63,002	62,668	62,339
Terry County (part)								
Rural (Municipal)	21	23	23	24	23	24	24	23
Total Municipal Demand	21	23	23	24	23	24	24	23
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	6,595	8,884	5,343	5,069	4,809	4,563	4,329	4,107
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	5	6	6	7	6	10	8	6
Total Demand	6,621	8,913	5,372	5,100	4,838	4,597	4,361	4,136

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Brazos Basin Total								
Total Municipal Demand	64,091	70,105	67,743	68,849	69,074	70,014	70,105	71,034
Industrial Demand	5,752	6,314	6,409	7,228	7,678	8,242	9,269	11,595
Steam-Electric Power Demand	14,302	14,857	20,000	20,000	30,000	30,000	30,000	35,000
Irrigation Demand	2,226,798	2,673,812	1,818,113	1,757,222	1,696,434	1,642,484	1,588,389	1,536,367
Mining Demand	4,207	7,684	8,091	6,919	5,895	5,051	4,368	3,764
Beef Feedlot Livestock Demand	10,604	11,772	12,310	14,286	16,579	18,311	20,228	22,344
Range & All Other Livestock Demand	6,062	6,419	6,587	7,360	7,956	8,573	9,243	9,998
Total Demand	2,331,816	2,790,963	1,939,253	1,881,864	1,833,616	1,782,675	1,731,602	1,690,102
Colorado Basin (part)								
Cochran County (part)								
Rural (Municipal)	124	106	149	151	149	147	144	142
Total Municipal Demand	124	106	149	151	149	147	144	142
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	11,764	36,336	18,354	17,645	16,965	16,310	15,680	15,075
Mining Demand	924	1,142	1,252	1,021	832	678	552	450
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	125	134	137	156	167	181	197	216
Total Demand	12,937	37,718	19,892	18,973	18,113	17,316	16,573	15,883
Dawson County (part)								
Lamesa (Municipal)	1,827	2,023	2,369	2,383	2,349	2,313	2,294	2,289
O'Donnell (Municipal)	15	17	22	23	26	30	32	35
Rural (Municipal)	429	514	420	417	401	388	373	368
Total Municipal Demand	2,271	2,554	2,811	2,823	2,776	2,731	2,699	2,692
Industrial Demand	44	70	46	47	47	47	49	51
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	38,706	142,813	36,110	34,074	32,153	30,340	28,630	27,016
Mining Demand	654	781	1,635	1,336	1,092	892	729	595
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	197	206	211	232	249	266	285	306
Total Demand	41,872	146,424	40,813	38,512	36,317	34,276	32,392	30,660
Gaines County (all)								
Seagraves (Municipal)	555	495	559	581	555	547	535	533
Seminole (Municipal)	1,676	1,688	1,945	2,034	2,047	2,056	2,080	2,123
Rural (Municipal)	689	745	701	680	655	622	579	557
Total Municipal Demand	2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
Industrial Demand	303	412	331	358	205	381	412	442
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
Mining Demand	3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
Beef Feedlot Livestock Demand	482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock Demand	322	336	342	366	390	414	442	473
Total Demand	400,317	427,239	368,695	348,805	329,883	312,425	295,901	280,420

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Garza County (part)								
Rural (Municipal)	1	1	1	1	1	1	1	1
Total Municipal Demand	1	1	1	1	1	1	1	1
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	0	0	0	0	0	0	0	0
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	0	0	0	0	0	0	0	0
Total Demand	1	1	1	1	1	1	1	1
Hockley (part)								
Sundown (Municipal)	353	292	413	436	453	463	465	473
Rural (Municipal)	54	57	57	57	56	53	51	47
Total Municipal Demand	407	349	470	493	509	516	516	520
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	9,204	13,508	9,728	9,348	8,982	8,631	8,293	7,969
Mining Demand	1,087	2,751	1,609	1,124	824	590	397	291
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	40	41	41	44	45	47	49	52
Total Demand	10,738	16,649	11,848	11,009	10,360	9,784	9,255	8,832
Lynn County (part)								
O'Donnell (Municipal)	106	141	157	156	153	148	141	137
Rural (Municipal)	17	19	20	19	18	16	15	14
Total Municipal Demand	123	160	177	175	171	164	156	151
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	372	1,070	346	327	310	293	277	262
Mining Demand	0	8	11	7	3	2	1	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	21	21	21	24	25	26	29	30
Total Demand	516	1,259	555	533	509	485	463	443
Terry County (part)								
Brownfield (Municipal)	1,481	1,738	1,655	1,712	1,750	1,805	1,853	1,935
Meadow (Municipal)	87	152	64	60	56	52	47	44
Rural (Municipal)	358	408	422	430	428	438	442	439
Total Municipal Demand	1,926	2,298	2,141	2,202	2,234	2,295	2,342	2,418
Industrial Demand	0	4	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	125,306	139,177	101,517	96,312	91,374	86,689	82,245	78,028
Mining Demand	822	276	1,237	1,011	826	675	551	451
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	168	175	179	195	209	222	236	255
Total Demand	128,222	141,930	105,074	99,720	94,643	89,881	85,374	81,152

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Yoakum County (all)								
Denver City (Municipal)	1,079	764	1,198	1,298	1,357	1,458	1,544	1,657
Plains (Municipal)	438	309	410	438	457	477	486	501
Rural (Municipal)	298	281	312	328	335	342	344	353
Total Municipal Demand	1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation Demand	122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
Mining Demand	3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	294	308	314	341	364	386	410	436
Total Demand	127,991	155,560	96,657	91,429	86,575	82,149	78,034	74,261
Colorado Basin Total								
Total Municipal Demand	9,587	9,750	10,874	11,204	11,246	11,356	11,426	11,648
Industrial Demand	347	486	377	405	252	428	461	493
Steam-Electric Power Demand	0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation Demand	700,711	895,213	606,303	575,384	546,049	518,215	491,807	466,749
Mining Demand	10,300	19,522	21,921	17,717	14,377	11,661	9,440	7,678
Beef Feedlot Livestock Demand	482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock Demand	1,167	1,221	1,245	1,358	1,449	1,542	1,648	1,768
Total Demand	722,594	926,780	643,535	608,982	576,401	546,317	517,993	491,652
Llano Estacado Region River Basin Totals								
Canadian River Basin (part)								
Total Municipal Demand	3	4	4	4	4	4	4	4
Industrial Demand	0	0	0	0	0	0	0	0
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	0	0	0	0	0	0	0	0
Mining Demand	0	0	0	0	0	0	0	0
Beef Feedlot Livestock Demand	0	0	0	0	0	0	0	0
Range & All Other Livestock Demand	76	80	82	87	93	99	106	113
Total Demand	79	84	86	91	97	103	110	117
Red River Basin (part)								
Total Municipal Demand	7,927	7,212	8,736	9,044	9,210	9,378	9,554	9,843
Industrial Demand	2,395	3,410	2,615	2,833	2,979	3,094	3,355	3,609
Steam-Electric Power Demand	0	0	0	0	0	0	0	0
Irrigation Demand	730,231	808,302	640,957	623,447	603,478	590,136	574,291	558,963
Mining Demand	344	350	372	353	357	366	373	382
Beef Feedlot Livestock Demand	13,610	16,054	16,788	19,482	22,609	24,976	27,587	30,473
Range & All Other Livestock Demand	4,491	4,773	4,911	5,623	6,102	6,626	7,214	7,859
Total Demand	758,998	840,101	674,379	660,782	644,735	634,576	622,374	611,129
Brazos River Basin (part)								
Total Municipal Demand	64,091	70,105	67,743	68,849	69,074	70,014	70,105	71,034
Industrial Demand	5,752	6,314	6,409	7,228	7,678	8,242	9,269	11,595
Steam-Electric Power Demand	14,302	14,857	20,000	20,000	30,000	30,000	30,000	35,000
Irrigation Demand	2,226,798	2,673,812	1,818,113	1,757,222	1,696,434	1,642,484	1,588,389	1,536,367
Mining Demand	4,207	7,684	8,091	6,919	5,895	5,051	4,368	3,764
Beef Feedlot Livestock Demand	10,604	11,772	12,310	14,286	16,579	18,311	20,228	22,344
Range & All Other Livestock Demand	6,062	6,419	6,587	7,360	7,956	8,573	9,243	9,998
Total Demand	2,331,816	2,790,963	1,939,253	1,881,864	1,833,616	1,782,675	1,731,602	1,690,102

Table 2-21 (continued)

Basin/County/City/Rural	Total in 1990 (acft)	Total in 1996 (acft)	Projections (acft)					
			2000	2010	2020	2030	2040	2050
Colorado River Basin (part)								
Total Municipal Demand	9,587	9,750	10,874	11,204	11,246	11,356	11,426	11,648
Industrial Demand	347	486	377	405	252	428	461	493
Steam-Electric Power Demand	0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation Demand	700,711	895,213	606,303	575,384	546,049	518,215	491,807	466,749
Mining Demand	10,300	19,522	21,921	17,717	14,377	11,661	9,440	7,678
Beef Feedlot Livestock Demand	482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock Demand	1,167	1,221	1,245	1,358	1,449	1,542	1,648	1,768
Total Demand	722,594	926,780	643,535	608,982	576,401	546,317	517,993	491,652
Llano Estacado Region Total								
Total Municipal Demand	81,608	87,071	87,357	89,101	89,534	90,752	91,089	92,529
Industrial Demand	8,494	10,210	9,401	10,466	10,909	11,764	13,085	15,697
Steam-Electric Power Demand	14,302	14,857	22,200	22,200	32,200	32,200	32,200	37,200
Irrigation Demand	3,657,740	4,377,327	3,065,373	2,956,053	2,845,961	2,750,835	2,654,487	2,562,079
Mining Demand	14,851	27,556	30,384	24,989	20,629	17,078	14,181	11,824
Beef Feedlot Livestock Demand	24,696	28,414	29,713	34,482	40,016	44,202	48,826	53,933
Range & All Other Livestock Demand	11,796	12,493	12,825	14,428	15,600	16,840	18,211	19,738
Total Demand	3,813,487	4,557,928	3,257,253	3,151,719	3,054,849	2,963,671	2,872,079	2,793,000
River Basin Summary								
Canadian	79	84	86	91	97	103	110	117
Red	758,998	840,101	674,379	660,782	644,735	634,576	622,374	611,129
Brazos	2,331,816	2,790,963	1,939,253	1,881,864	1,833,616	1,782,675	1,731,602	1,690,102
Colorado	722,594	926,780	643,535	608,982	576,401	546,317	517,993	491,652
Llano Estacado Region Total	3,813,487	4,557,928	3,257,253	3,151,719	3,054,849	2,963,671	2,872,079	2,793,000

* Parts of the Canadian, Red, Brazos, and Colorado River Basins.

Source: Texas Water Development Board; 1997 Consensus Water Plan, Most Likely Case.

2.10 Water Demand Projections for Major Water Providers in the Llano Estacado Region

The Texas Water Development Board's (TWDB) definition of a Major Water Provider (MWP) is as follows:

> "A MWP 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."

It is the intent that the RWPG plan: "1) for each water user that contracts with a wholesale water supplier, and 2) for the wholesale supplier that is defined as a MWP. 31 TAC Chapter 357.7(a) requires that : 1) the presentation of current and projected population and water demands, 2) evaluation of current water supplies available, and 3) water supply and demand analysis be reported for the MWPs. 31 TAC Chapter 357.7(a)(1) requires that the regional water plans describe the MWPs and Appendix B to the contract between the TWDB and the High Plains Underground Water Conservation District No. 1 (political subdivision acting as principal contractor for the Llano Estacado Region) states that the definition of a MWP will be determined by the RWPG based on the characteristics and needs of the region."

At its meeting on April 22, 1999 the LERWPG identified the MWPs for the Llano Estacado Region. The list of MWPs for the Llano Estacado Region and the cities to which they provide water is as follows:

Canadian River Municipal Water Authority (CRMWA)

1) City of Brownfield
2) City of Lamesa
3) City of Levelland
4) City of Lubbock
5) City of O'Donnell
6) City of Plainview
7) City of Slaton
8) City of Tahoka

White River Municipal Water District (WRMWD)

1) City of Crosbyton
2) City of Post
3) City of Ralls
4) City of Spur

Mackenzie Municipal Water Authority (MMWA)

1) City of Floydada
2) City of Lockney
3) City of Silverton
4) City of Tulia

2.10.1 Canadian River Municipal Water Authority (CRMWA) [3]

The Canadian River Municipal Water Authority (CRMWA) supplies water to eight cities (Brownfield, Lamesa, Levelland, Lubbock, O'Donnell, Plainview, Slaton, and Tahoka) located within the Llano Estacado Planning Area as well as several entities located outside of the planning region.[4] Additionally, the City of Lubbock, a customer of CRMWA, supplies water to the Cities of Ransom Canyon and Shallowater. Historically, CRMWA has been the sole provider of water to the City of O'Donnell; however, the remaining seven cities have historically obtained a portion of their water supply from self-supplied groundwater. The total amount of water supplied by CRWA in 1990 to meet these customers' demands was 40,837 acft (Table 2-22). The total amount of water needed by CRMWA to meet these customers' projected demands in 2030 is 102,277 acft/yr, and 101,614 acft/yr in 2050 (Table 2-22).

CRMWA is not projected to supply water to any industrial customers located within the region, however some cities to which CRMWA supplies water may utilize water obtained from CRMWA for industrial purposes over the planning period. However, in Table 2-22, these amounts are included in the municipal total for CRMWA's customers.

2.10.2 White River Municipal Water District (WRMWD)

The White River Municipal Water District supplies water to four cities (Crosbyton, Post, Ralls, and Spur). Historically, the District has been the sole water provider for these cities. The total amount of water supplied by the District in 1990 was 1,751 acft, of which 1,743 acft was for municipal purposes, and 8 acft was for industrial purposes (Table 2-22). The total amount of water needed by the District to meet its customers' projected demands in 2030 is 1,659 acft/yr,

[3] The values in Table 2-22 for CRMWA during planning years 2000 through 2050 reflect the lesser of the Cities' combined entire municipal demand and the maximum delivery rate from CRMWA.
[4] The Cities of Ransom Canyon and Shallowater obtain water from the City of Lubbock, which obtains part of its water supply from CRMWA.

Table 2-22.
Water Demand Projections for Major Water Providers
Llano Estacado Region

Major Water Providers	Total in 1990 (acft)	Total in 1996 (acft)	Projected Water Demand (acft) 2000	2010	2020	2030	2040	2050	Notes
Canadian River Municipal Water Authority (CRMWA)									
Municipal	40,837	72,958	91,893	101,239	101,846	102,277	101,887	101,614	
Industrial	0	0	0	0	0	0	0	0	
Demand from Panhandle Region (Region A)	—	35,351	49,163	49,629	49,606	49,068	48,979	48,891	
City of Brownfield									
Municipal	1,366	1,173	1,311	1,712	1,719	1,719	1,719	1,719	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the City's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
City of Lamesa									
Municipal	1,357	1,591	1,677	2,194	2,194	2,194	2,194	2,194	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the City's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
City of Levelland									
Municipal	2,067	1,578	1,867	2,302	2,302	2,302	2,176	2,099	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the City's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
Lubbock									
City of Lubbock Municipal	31,855	29,250	33,424	39,199	39,841	40,732	40,713	40,688	City of Lubbock's demand adjusted for maximum delivery rate from CRMWA.
City of Lubbock Industrial	0	0	0	0	0	0	0	0	
City of Ransom Canyon Municipal[1]	162	222	215	220	221	232	247	265	City of Ransom Canyons' total municipal water demand.
City of Shallowater Municipal[1]	0	128	132	137	144	159	163	170	Year 1990 & 1996 from TWDB; projected using growth rate of municipal water demand for the City.
Lubbock Total	32,977	29,600	33,771	39,556	40,206	41,123	41,123	41,123	Total of preceding lines
City of O'Donnell									
Municipal	121	166	168	179	179	178	173	172	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the City's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
City of Plainview									
Municipal	1,764	2,657	2,735	4,296	4,296	4,267	4,074	3,939	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the City's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	

Table 2-22 (continued)

Major Water Providers	Total in 1990 (acft)	Total in 1996 (acft)	Projected Water Demand (acft) 2000	2010	2020	2030	2040	2050	Notes
City of Slaton									
Municipal	862	683	827	891	864	946	969	997	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the city's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
City of Tahoka									
Municipal	323	325	374	480	480	480	480	480	Year 1990 & 1996 values from CRMWA; year 2000 through 2050 values are the lesser of the city's entire municipal demand and the maximum delivery rate from CRMWA.
Industrial	0	0	0	0	0	0	0	0	
White River Municipal Water District (WRMWD)									
Municipal	1,743	1,432	1,919	1,861	1,763	1,650	1,581	1,542	
Industrial	8	5	8	8	8	9	10	10	
City of Crosbyton									
Municipal	409	438	389	368	339	306	297	294	City of Crosbyton's total municipal water demand.
Industrial	0	0	0	0	0	0	0	0	
City of Post									
Municipal	770	386	967	971	942	902	857	832	City of Post's total municipal water demand
Industrial	2	2	2	3	3	4	5	5	
City of Ralls									
Municipal	313	302	318	288	261	227	217	209	City of Ralls' total municipal water demand.
Industrial	6	3	6	5	5	5	5	5	
City of Spur									
Municipal	251	306	245	234	221	215	210	207	City of Spur's total municipal water demand.
Industrial	0	0	0	0	0	0	0	0	
Mackenzie Municipal Water Authority (MMWA)									
Municipal	2,088	2,222	864	864	864	864	864	864	
Industrial	4	4	4	4	5	5	5	5	
City of Floydada									
Municipal	570	620	212	212	212	212	212	212	That portion of the City of Floydada's municipal water demand to be met by MMWA. The remainder is to be met from groundwater sources.
Industrial	0	0	0	0	0	0	0	0	
City of Lockney									
Municipal	321	381	150	150	150	150	150	150	That portion of the City of Lockney's municipal water demand to be met by MMWA. The remainder is to be met from groundwater sources.
Industrial	1	1	1	1	2	2	2	2	
City of Silverton									
Municipal	135	111	85	85	85	85	85	85	That portion of the City of Silverton's municipal water demand to be met by MMWA. The remainder is to be met from groundwater sources.
Industrial	0	0	0	0	0	0	0	0	
City of Tulia									
Municipal	1,062	1,110	417	417	417	417	417	417	That portion of the City of Tulia's municipal water demand to be met by MMWA. The remainder is to be met from groundwater sources.
Industrial	3	3	3	3	3	3	3	3	

[1] The Cities of Ransom Canyon and Shallowater obtain water from the City of Lubbock, which obtains part of its water supply from CRMWA.

with 1,650 acft/yr being for municipal purposes and 9 acft/yr being for industrial purposes, and 1,552 acft/yr in 2050, with 1,542 acft/yr being for municipal purposes, and 10 acft/yr being for industrial purposes (Table 2-22). White River Municipal Water District purchased groundwater rights in Crosby County in 1998. They drilled several wells in 1999. The groundwater will be used only during periods of drought when the water level in the reservoir is low.

Two of the District's customers (the Cities of Post and Ralls) are projected to utilize water obtained from the District for industrial purposes over the planning period (Table 2-22).

2.10.3 Mackenzie Municipal Water Authority (MMWA)

The Mackenzie Municipal Water Authority supplies water to four cities (Floydada, Lockney, Silverton, and Tulia). Floydada, Lockney, and Tulia also obtain a portion of their water supply from self-supplied groundwater. The total amount of water supplied by the Authority in 1990 was 2,092 acft, of which 2,088 acft was for municipal purposes, and 4 acft was for industrial purposes (Table 2-22). The total amount of water needed by the Authority to meet its customers' projected demands in 2030 and 2050 is 869 acft/yr, with 864 acft/yr being for municipal purposes and 5 acft/yr being for industrial purposes (Table 2-22).

Two of the Authority's customers (the Cities of Lockney and Tulia) are projected to utilize water obtained from the Authority for industrial purposes over the planning period (Table 2-22).

Section 3
Water Supplies Identified by Water User Group

3.1 Groundwater

Two major and two minor aquifers supply water to the area. The two major aquifers are the Ogallala and Seymour Aquifers. The two minor aquifers are the Edwards-Trinity (High Plains) and the Dockum Aquifers.

3.1.1 Ogallala Aquifer

The Ogallala Aquifer is the major water-bearing formation in most of the 21 counties of the Llano Estacado Region. Most of the communities above the escarpment within the region obtain water from the Ogallala Aquifer as their primary source of drinking water. Approximately 95 percent of the water obtained from the Ogallala is used by farmers and ranchers of the rural areas for irrigation.

3.1.2 Seymour Aquifer

The Seymour Formation consists of isolated areas of alluvium found in parts of 23 north-central and High Plains counties, including parts of Briscoe, Motley, Dickens, and Crosby Counties of the Llano Estacado Region. The Seymour Aquifer is projected to supply small quantities of water for municipal and irrigation use in these four counties.

3.1.3 Edwards-Trinity (High Plains) Aquifer

The Edwards-Trinity (High Plains) Aquifer includes Cretaceous age water-bearing formations of the Fredricksburg and the Trinity Groups. These formations underlie the Ogallala Formation in 11 counties in the southwestern corner of the Llano Estacado Region and extend westward into New Mexico. The Edwards-Trinity (High Plains) Aquifer is projected to supply water for municipal and irrigation use in Lynn County.

3.1.4 Dockum (Santa Rosa) Aquifer

The Dockum Group of Triassic age underlies the Ogallala Formation of the High Plains area of Texas and New Mexico, the northern part of the Edwards Plateau, and the eastern part of the Cenozoic Pecos Alluvium. The Dockum Aquifer is projected to supply small quantities of water for municipal and irrigation use in Briscoe, Deaf Smith, Garza, and Swisher Counties.

3.2 Surface Water

Although the Llano Estacado Region lies within the headwaters areas of four river basins (Canadian, Red, Brazos, and Colorado), the region has very little surface water, with dams having been built to take full advantage of existing surface water. In this regard, four reservoirs are located within or near the region and supply water for municipal and industrial uses within the region. These four reservoirs are identified and described below. Those cities that do not obtain water from these reservoirs rely upon groundwater to supply their water needs for both municipal and industrial purposes. In other segments of rivers, surface water amounts to a trickle and very little water leaves the region.

3.2.1 Lake Meredith

Lake Meredith is located in the Canadian River Basin to the north of the Llano Estacado Region, in Potter, Moore, and Hutchinson Counties. It has a total storage capacity of 920,300 acft and has a firm yield of approximately 74,350 acft of water per year. New projects to add groundwater from the Ogallala Aquifer in Roberts County will increase the supply to present entities obtaining water from Lake Meredith. In addition, the water from the Ogallala Aquifer in Roberts County will firm up the reliability and improve the quality of currently contracted supplies. From Lake Meredith a pipeline extends southward and delivers water for municipal and industrial purposes to Brownfield, Lamesa, Levelland, Lubbock, Plainview, O'Donnell, Slaton, and Tahoka within the Llano Estacado Region.

3.2.2 Mackenzie Reservoir

Mackenzie Reservoir is located in the Red River Basin in Swisher and Briscoe Counties in the Llano Estacado Region. Mackenzie Reservoir has a total storage capacity of 45,500 acft and can supply approximately 5,200 acft of water per year when the reservoir is at conservation pool elevation. Mackenzie Reservoir supplies water to Silverton, Tulia, Floydada, and Lockney. During recent dry conditions, Mackenzie Reservoir was unable to meet its contracted demands.

3.2.3 White River Reservoir

White River Reservoir is located in the Brazos River Basin in the southeast corner of Crosby County. It is owned and operated by the White River Municipal Water District, which supplies water to Ralls, Spur, Post, and Crosbyton. It has a surface area of 1,808 acres at conservation pool elevation and a drainage area of 173 square miles. This reservoir has a total storage capacity of 31,846 acft and can supply approximately 4,000 acft/yr when at conservation pool elevation. White River Municipal Water District has purchased groundwater rights and has drilled wells to supply its customers should the water levels in the reservoir drop below the level at which water can be removed. However, rains in 1999 filled the reservoir to within 8 feet of the discharge level of the spillway.

3.2.4 Alan Henry Reservoir

Alan Henry Reservoir is located on the Double Mountain Fork of the Brazos River in Garza and Kent Counties and is owned the City of Lubbock. Alan Henry Reservoir has a total storage capacity of 115,937 acft and can supply approximately 29,900 acft of water per year when at conservation pool elevation. Alan Henry Reservoir was developed to serve as a future water supply for the City of Lubbock and at present is open for recreational purposes.

3.3 Methodology to Calculate the Water Supplies Available to the Llano Estacado Region and Methodology for Calculating Water Supplies Available for Water User Groups

The water supplies available to the Llano Estacado Region during the **"drought of record"** were calculated from the following data sources:

A. Groundwater availability from the Ogallala Aquifer was determined by calculating estimates of the volume of groundwater in storage in 1995 from saturated thickness maps of the Ogallala Aquifer constructed by the High Plains Underground Water Conservation District (HPUWCD) for those counties served by the Water District.

   HDR Engineering, Inc., the subcontractor for the Llano Estacado Regional Water Plan, was commissioned to make a set of saturated thickness maps for the remaining counties in the Llano Estacado Regional Water Planning Area, using data from the Texas Water Development Board electronic files. A detailed description of how these maps were made by the HPUWCD and by HDR Engineering is available in the planning group files at the HPUWCD office. A summary of the methodology is presented below.

   The HPUWCD maps were planimetered by HPUWCD staff to determine the volume of the saturated portion of the formation in each county. The volume of saturated material in each county was then multiplied by 15 percent, which is the coefficient of gravity storage of the Ogallala Aquifer, to determine the volume of groundwater in storage. HDR Engineering performed similar calculations for the remaining 9 counties.

The estimated volume of groundwater which will remain in storage on a county-by-county basis by decade from 2000 to 2050 was estimated using existing 1985 saturated thickness maps for the HPUWCD, and a similar data set for 1985 was prepared by HDR Engineering for the other 9 counties in the planning region. Utilizing the average annual change in the volume of water in storage (net depletion) that occurred between 1985 and 1995, projections were made of the volume of groundwater likely to be in storage at future dates. County-by-county values are listed in Table 3-1 for the calculated volumes of water in storage for 1985 and 1995, the 10-year change, and the average annual net change (net depletion or net gain).[1]

Utilizing net depletion eliminated the need to make estimates of individual withdrawals, natural recharge, and irrigation recirculation. A straight-line projection was made from 1995 to the year 2000. Thereafter, the net depletion rate was reduced by 10 percent by decade (1 percent per year) to reflect increased conservation and declining well yields due to thinning of the aquifer.

The calculated volumes of water in storage for several counties was greater in 1995 than it was in 1985, indicating that natural recharge exceeded withdrawals for this period. Upon completion of this task, four underground water conservation districts (Mesa serving Dawson County; South Plains serving Terry County; Sandy Land serving Yoakum County; and Llano Estacado serving Gaines County) requested that their individual calculations of the volume of water in storage and projections of future availability be substituted for the Planning Group values. The Planning Group approved their request and their values have been used in the calculations in Task 3 (Table 3-1).

B. Groundwater availability by aquifer for the Dockum, Edwards-Trinity (High Plains), and Seymour Aquifers was obtained from the Texas Water Development Board. The groundwater availability by county was further subdivided into river basin parts of each county according to the TWDB estimates.

C. Surface water availability for cities obtaining all or part of their water supply from surface water sources was estimated from water use data supplied by surface water suppliers and cities within the planning region that use surface water.

[1] In the case of Dawson, Gaines, Terry and Yoakum Counties, the rates of decline were calculated by the respective underground water conservation districts (UWCDs). The UWCD's estimates were used for these four counties.

Table 3-1.
Water Supply Projections
Llano Estacado Region
Individual Counties with River Basin Summaries

	Counties	Estimated Volume of Water in Storage in 1995 (acft)	Estimated Annual Net Change1 1985 to 1995 (acft)	Estimated Volume of Water in Storage[2] – Revised[3] Year 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
1	Bailey[3]	6,058,316	-29,074	5,912,946	5,651,280	5,415,781	5,203,831	5,013,077	4,841,398
2	Briscoe	1,695,000	23,700	1,695,000	1,695,000	1,695,000	1,695,000	1,695,000	1,695,000
3	Castro	9,023,308	-133,104	8,357,788	7,159,852	6,081,710	5,111,381	4,238,086	3,452,120
4	Cochran	3,076,092	18,632	3,076,092	3,076,092	3,076,092	3,076,092	3,076,092	3,076,092
5	Crosby	5,893,647	82,672	5,893,647	5,893,647	5,893,647	5,893,647	5,893,647	5,893,647
6	Dawson[4]	6,962,000	121,500	6,436,000	5,069,000	4,178,000	3,710,000	4,240,000	4,770,000
7	Deaf Smith	6,397,823	-97,998	5,907,833	5,025,851	4,232,067	3,517,662	2,874,697	2,296,029
8	Dickens	1,168,000	16,800	1,168,000	1,168,000	1,168,000	1,168,000	1,168,000	1,168,000
9	Floyd	7,615,602	-94,617	7,142,517	6,290,964	5,524,566	4,834,808	4,214,026	3,655,322
10	Gaines[4, 5]	13,583,711	136,771	12,439,509	10,241,536	8,237,611	6,417,178	4,770,089	3,287,325
11	Garza	678,000	5,300	678,000	678,000	678,000	678,000	678,000	678,000
12	Hale	8,988,379	-183,140	8,072,679	6,424,419	4,940,985	3,605,894	2,404,313	1,322,889
13	Hockley	3,539,374	44,829	3,539,374	3,539,374	3,539,374	3,539,374	3,539,374	3,539,374
14	Lamb[3]	7,211,222	-96,139	6,730,527	5,865,276	5,086,550	4,385,697	3,754,929	3,187,238
15	Lubbock	5,120,761	-46,536	4,888,081	4,469,257	4,092,315	3,753,068	3,447,744	3,172,953
16	Lynn	3,909,248	55,732	3,909,248	3,909,248	3,909,248	3,909,248	3,909,248	3,909,248
17	Motley[3]	366,000	-2,291	354,545	333,926	315,369	298,668	283,636	270,108
18	Parmer[3]	7,843,473	-159,944	7,043,753	5,604,257	4,308,711	3,142,719	2,093,326	1,148,873
19	Swisher	4,481,000	-6,300	4,449,500	4,392,800	4,341,770	4,295,843	4,254,509	4,217,309
20	Terry[4]	4,339,000	-28,000	4,216,000	3,996,938	3,835,695	3,729,167	3,674,419	3,668,673
21	Yoakum[4]	4,758,000	-202	4,756,990	4,231,345	3,749,359	3,307,180	2,902,009	2,530,768
	Total	112,707,956	-371,409	106,668,029	94,716,062	84,299,849	75,272,456	68,124,221	61,780,366
River Basin Summary									
Canadian		70,377	-1,078	64,986	55,285	46,553	38,694	31,622	25,256
Red		24,991,374	-256,292	23,549,133	20,953,098	18,616,667	16,513,879	14,621,370	12,918,113
Brazos		55,350,792	-367,358	52,541,935	47,480,603	42,930,964	38,841,865	35,175,357	31,877,582
Colorado		32,295,413	253,319	30,511,975	26,227,076	22,705,665	19,878,018	18,295,872	16,959,415
Total		112,707,956	-371,409	106,668,029	94,716,062	84,299,849	75,272,456	68,124,221	61,780,366

1 Negative values are estimates of net depletion of storage, while positive values are net increases in storage.

2 Calculated based upon estimates that net depletion rate will decline by 10% per decade after year 2000 due to decreases in well yields as a result of thinning of saturated thickness of the aquifer, and as water conservation increases. Counties indicating an increase in storage between 1985 and 1995, except Dawson and Gaines, are projected to remain constant, although local areas within these counties are anticipated to experience some depletion during the projection period.

3 Rate of depletion in Bailey, Lamb, Motley, and Parmer Counties was adjusted upward to meet future water demand estimates in an amount that the estimates exceed the average annual water use between 1985 and 1995.

4 Values for these four counties were estimated by the underground water conservation districts serving the counties, respectively; Mesa for Dawson, Llano Estacado for Gaines, South Plains for Terry, and Sandy Land for Yoakum.

5 It is important to note that estimates for Gaines County are based upon only a few years of data, e.g.; the Llano Estacado Underground Water Conservation District has been in operation for only one year.

D. Water availability from reclaimed water was obtained from discharge permits provided by the TNRCC.

E. Range and all other livestock water supply was allocated to local sources and set at projected range and all other livestock water demands.

The methods used to distribute each respective water supply to its appropriate use category are presented below.

1) Municipal Use from the Ogallala Aquifer:

   a. For cities using water from the Ogallala Aquifer, their supply was based upon an analysis by the HPUWCD which summarized the amount of theoretically recoverable groundwater in storage beneath each city's well fields or other areas of city control having groundwater deposits as of 1995. For each city relying only on groundwater sources for supply, that city's municipal supply was set equal to the projected demand for each year within the planning horizon (i.e., a city, industry, or other water user would withdraw only what it needed for each year of the projections period). For those cities obtaining water from both groundwater and surface water sources, the projected surface water supplies were estimated from water use data supplied by the respective surface water suppliers.

   b. For rural areas, it was assumed that the rural household (municipal type) demand would be met locally from aquifers underlying that river basin portion of the county. The rural supply was set equal to the projected demand for each year within the planning horizon.

2) Industrial Use from the Ogallala Aquifer:

   The industrial supply was set equal to the projected industrial demand for each year within the planning horizon and is assumed to be obtained from the aquifer at the nearest available location of supply.

3) Steam-Electric Use from Ogallala Aquifer:

   The steam-electric supply was set equal to the projected steam-electric demand for each year within the planning horizon and is assumed to be obtained from the aquifer at the nearest available location of supply.

4) Irrigation Use from the Ogallala Aquifer:

   It was estimated that irrigation demand would be met from the aquifer underlying the respective irrigation tracts of the river basin portion of the county. The irrigation supply was set equal to the projected demand for each year within the planning horizon. However, when projected total demand for all uses was greater than the estimated total groundwater supply from the Ogallala Aquifer for river basin portions of individual counties, the quantity available for irrigation was the total supply of the river basin portion of the county remaining after municipal, industrial, steam-electric power, mining, and beef feedlot livestock uses had been met.

5) Mining Use from the Ogallala Aquifer:

   The mining supply was set equal to the projected mining demand for each year within the planning horizon, and is assumed to be obtained from the aquifer at the nearest available location of supply.

6) Surface Water Availability within the Planning Region:

   Surface water availability for cities obtaining all or part of their water supply from surface water sources was estimated from water use data supplied by the surface water suppliers and cities within the planning region that use surface water.

7) Beef Feedlot Livestock Use from the Ogallala Aquifer:

   The beef feedlot livestock supply was set equal to the projected demand for each year within the planning horizon and is assumed to be obtained from the aquifer at the nearest available location of supply.

8) Range and All Other Livestock Water Supply:

   For all areas within the planning region, range and all other livestock water demand was assumed to be met from local sources such as stock tanks, windmills, and in the case of dairy and poultry, from wells located as near as possible to the points of use. Range and all other livestock water supply was set equal to projected range and all other livestock water demand.

9) Irrigation Use of Reclaimed Water

   The quantity of reclaimed water available for irrigation use from municipal sources, such as cities, was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value was held constant throughout the projection period. In the case of reclaimed water from industry, the quantity was calculated as 75 percent of the maximum waste discharge permit. The estimated total quantity of reclaimed water was added to the available supply of irrigation water in the county where the reclaimed water is located. If the county had a surplus of irrigation supply, the reclaimed water offset an equal quantity of water pumped from the aquifer.

3.4 Groundwater Modeling for the Southern High Plains — Summary Report; Texas Tech University Water Resource Center

A MODFLOW computer model was developed by the Texas Tech University Water Resources Center for the Llano Estacado Water Planning Region, referred to in the following discussion as Region O.[2] The model has a grid of one cell per square mile, and is calibrated to water level contour maps constructed by the High Plains Underground Water Conservation District Number 1 for the District Counties for 1985 and 1995, and information obtained from the Texas Groundwater Database maintained by TWDB. The purpose of the modeling study was to develop a tool that can be used to project changes in aquifer storage caused by withdrawal and recharge to the aquifer, compute volume of water in storage for each county, and construct detailed maps of saturated thickness of the Ogallala formation.

A summary of the results of the groundwater availability modeling study performed by the Water Resources Center of Texas Tech University, as a part of the regional water plan developed by the Llano Estacado Regional Water Planning Group, is presented below. A more detailed summary is presented in Appendix E. Complete documentation and results of the modeling study can be found in the report entitled "Groundwater Modeling for the Southern High Plains."[3] The following cases were simulated: (1) Baseline; (2) Future occurrences of the drought of record; (3) Precipitation enhancement; (4) Reduction in irrigation demand; and (5) Uniform decline of 1 percent per year in saturated thickness. The underlying assumptions of each simulation are presented in the discussion of the simulations, respectively.

3.4.1 Baseline Simulation

<u>Storage Predictions</u>: The baseline simulation predicts the effects of groundwater pumpage using TWDB water demand projections for Region O. Historical water table measurements published by TWDB and High Plains Underground Water conservation District No. 1 (HPUWCD#1) show that the Ogallala aquifer underlying Region O held approximately 132,360,000 acre-feet of water, calculated using a range of values for the specific yield, or coefficient of gravity storage, in the aquifer as determined by aquifer tests and numerical model calibrations. Using these projections, the model indicates that approximately 104,000,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050. This number represents 79 percent of the volume of water in storage measured in 1995. Of the 21 counties in the region, 12 counties have at least 80 percent of the 1995 volume in storage

[2] This work was performed under separate contract for the Llano Estacado Regional Water Planning Group (LERWPG), and is included here at the direction of the LERWPG, as of August 17, 2000, and December 15, 2000. HDR Engineering, Inc. does not accept responsibility for the technical accuracy of the model nor the information produced by the model.

remaining in 2050. The remaining nine counties have from 21 to 78 percent of the 1995 volume in storage remaining. Castro, Garza, Lamb, and Parmer counties have less than 50 percent of the 1995 volume in storage remaining.

It should be noted that the computer model had difficulty representing the behavior of the aquifer in Garza, Dickens, Motley, and Briscoe counties because of the lack of adequate hydrologic and geologic information from local or state agencies and their positions along the boundary of the aquifer. Each of these counties has only a small area underlain by the Ogallala aquifer as limited by the Caprock escarpment, and production levels are very small compared to the central and western counties in Region O. Earlier modeling efforts by the TWDB and others used larger cell sizes, 2.9 miles by 2.9 miles as opposed to the 1 mile by 1 mile cells in the current model, and assigned most of the Ogallala area in these counties as constant head boundary cells, thus no previous effort was spent on gathering more detailed information in these counties. It is anticipated that the Groundwater Availability Modeling study planned in the near future by the TWDB will provide the time and effort to deal with these counties more precisely.

Calibrated Recharge Plus Irrigation Return Flow Estimates: Recharge plus irrigation return flow estimates for each county were developed by a detailed calibration of the model for the period 1985 to 1995 in the area served by the HPUWCD#1 and additional calibration with limited data elsewhere in Texas. In the HPUWCD#1 calibration area, the water table elevation simulated by the calibrated model was within 10 feet of the measured water table elevation at 90 percent of the observed locations. The absolute mean error of the calibrated model was 4.7 feet. For the entire extent of the Ogallala aquifer in the Southern High Plains, the simulated water table elevation was within 10 feet of the measured water table elevation at 69 percent of observed locations, and the absolute mean error was 8.6 feet. These calibration results were the best attainable in light of the accepted uncertainties in the reported estimates of irrigation pumping by county, distribution of irrigation pumpage within the counties, and historical maps of saturated thickness and water table elevation as provided by the TWDB, HPUWCD#1, and others. Further refinement of the calibration would require assignment of recharge plus irrigation return flow values that are unreasonably large at many locations, so the calibration effort was closed. It should be noted that the achieved agreement between the observed and

[3] "Groundwater Modeling for the Southern High Plains," Stovall, Jeff, Ken Rainwater, and Scott Frailey, Texas Tech University Water Resources Center, Texas Tech University, Lubbock, Texas, 2000.

simulated values was much better than that reported in previous calibrations of regional groundwater models for the Southern High Plains.

Satisfied Demand for Groundwater: The output of the computer model was also used to calculate the satisfied demand percentage for areas in the planning region. The satisfied demand percentage is the ratio of groundwater demand occurring in the model to total groundwater demand as provided by TWDB and accepted by LERWPG. This number represents the ratio of supply to demand. The irrigation water demand accounted for over 96 percent of groundwater use in Region O in 1996 and is projected to account for a similar percentage throughout the planning period. Under the baseline simulation, the model indicates that approximately 65 percent of the total groundwater demand for Region O can be met in 2050. Seven counties in Region O are capable of supplying at least 80 percent of the projected demand, while 4 counties supply less than 50 percent of the demand. Due to boundary effects of the groundwater model and the limited data available for these counties, demand percentages were not calculated for Briscoe, Dickens, Garza, and Motley counties.

County Groundwater Distribution: The output of the computer model was also used to construct saturated thickness maps of each county for the years 2000, 2030, and 2050. The 1995 initial saturated thickness condition used for simulation is shown in Figure 3-1. The simulation results at 2000, 2030, and 2050 are shown in Figures 3-2, 3-3, and 3-4. Maps for each county are available as part of the full report of the modeling study.

3.4.2 Simulation of Future Occurrences of Drought of Record

A simulation was made for drought of record precipitation and water demand conditions to examine the effects of increased water demand on the aquifer. The drought was simulated as a four-year drought cycle occurring in 2015 and again in 2035 based on the observed historical droughts that have occurred in the 1930s, 1950s, 1970s, and 1990s. From historical precipitation data, the drought of record was determined to be a period in the 1950s during which the average annual precipitation was 6.5 inches below normal. In the model, the drought was represented as 6.5 inches of additional water demand for each irrigated acre in the region. The model indicates that approximately 96,600,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050 under the assumed drought conditions. This number represents 73 percent of the volume of water in storage measured in 1995. Under the drought

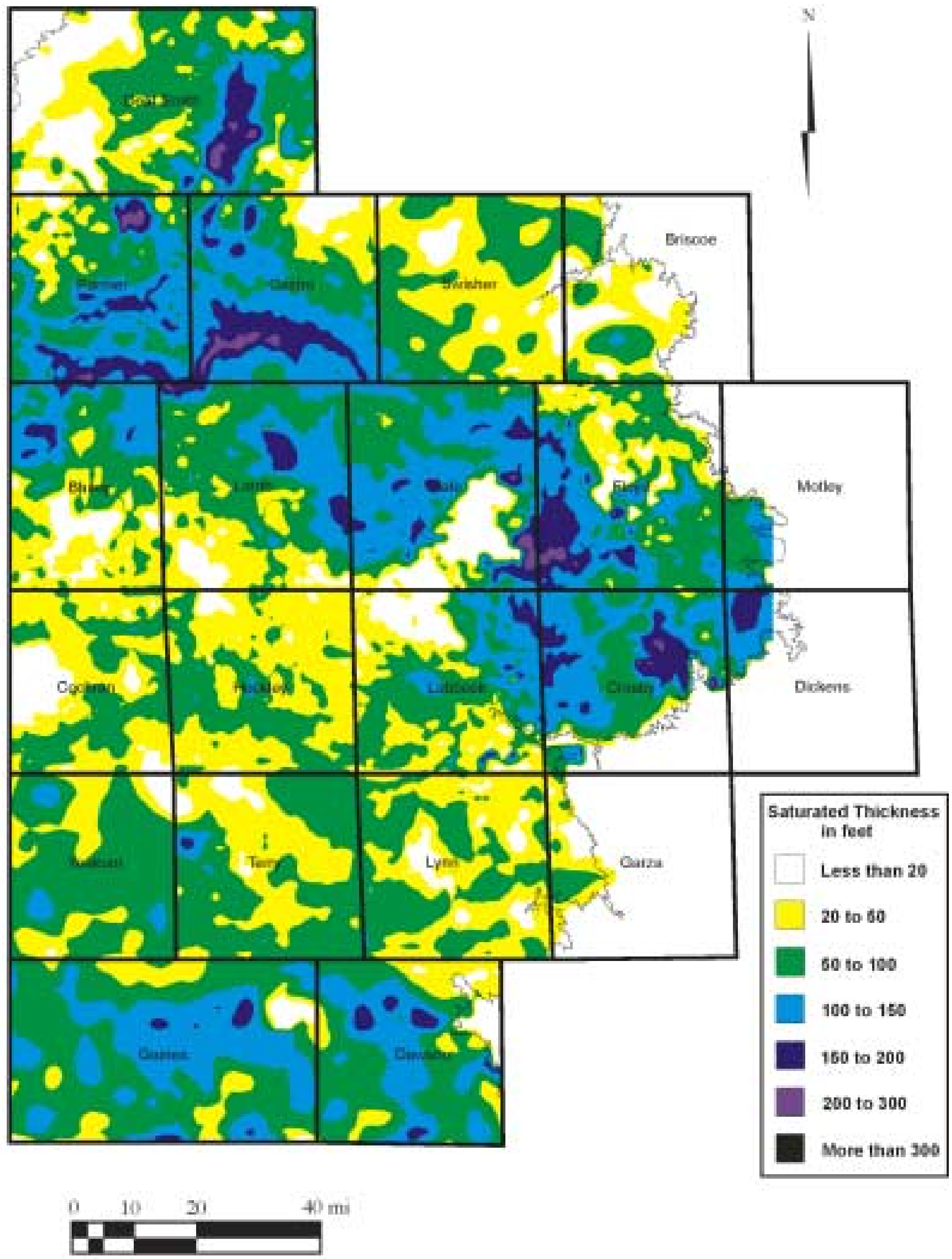

Figure 3-1. 1995 Region O Saturated Thickness

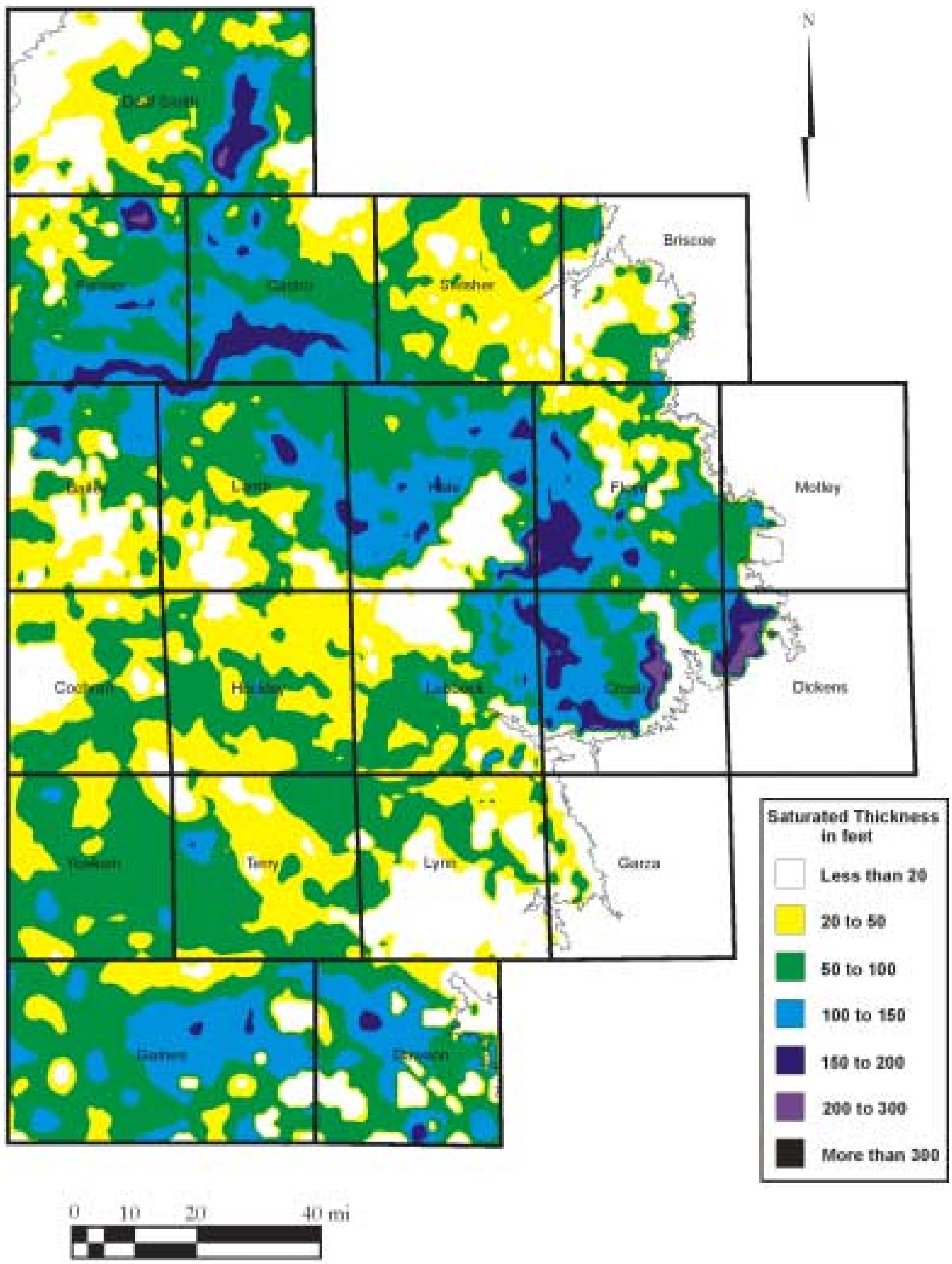

Figure 3-2. 2000 Region O Simulated Saturated Thickness, Baseline Simulation

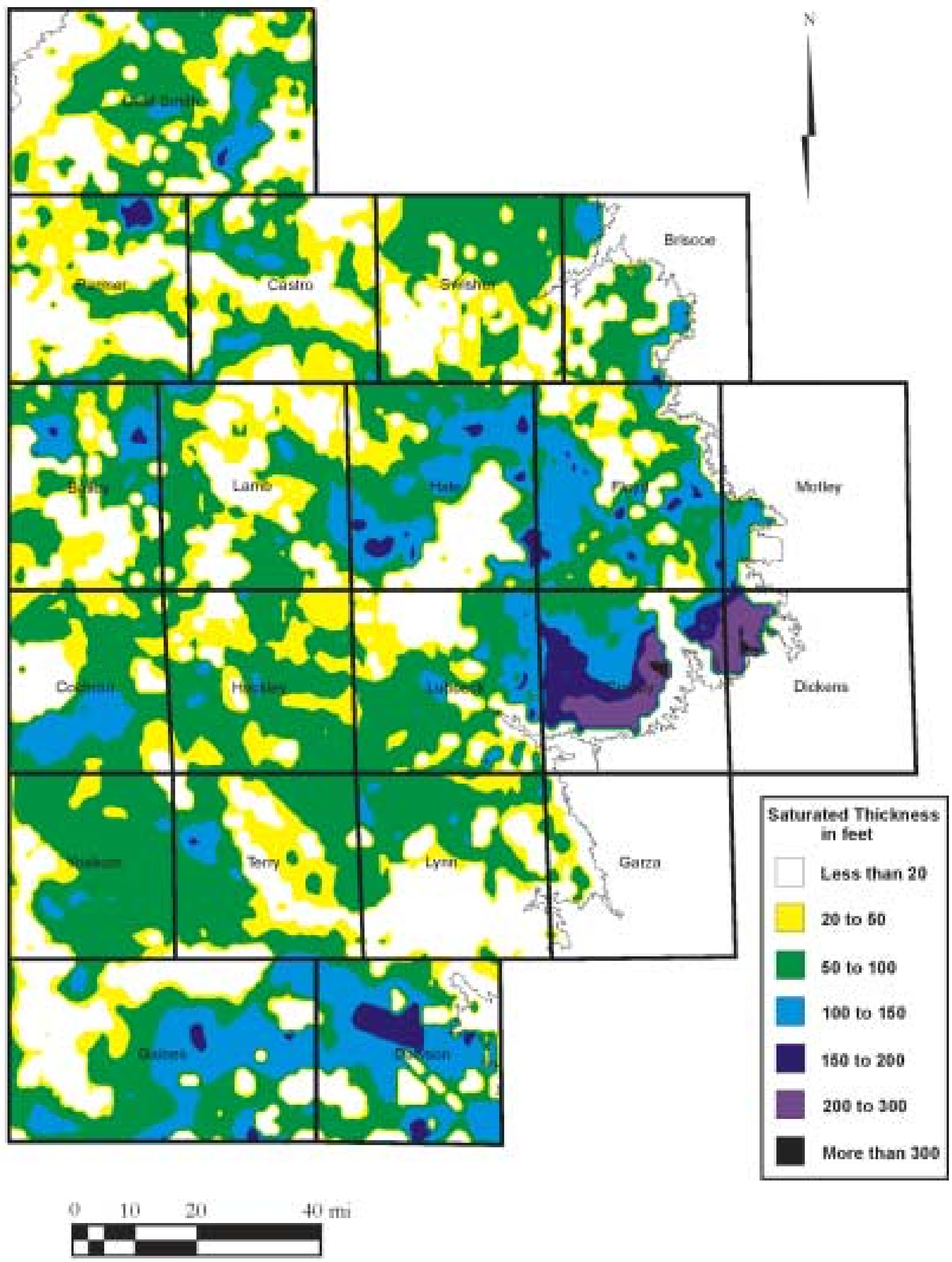

Figure 3-3. 2030 Region O Simulated Saturated Thickness, Baseline Simulation

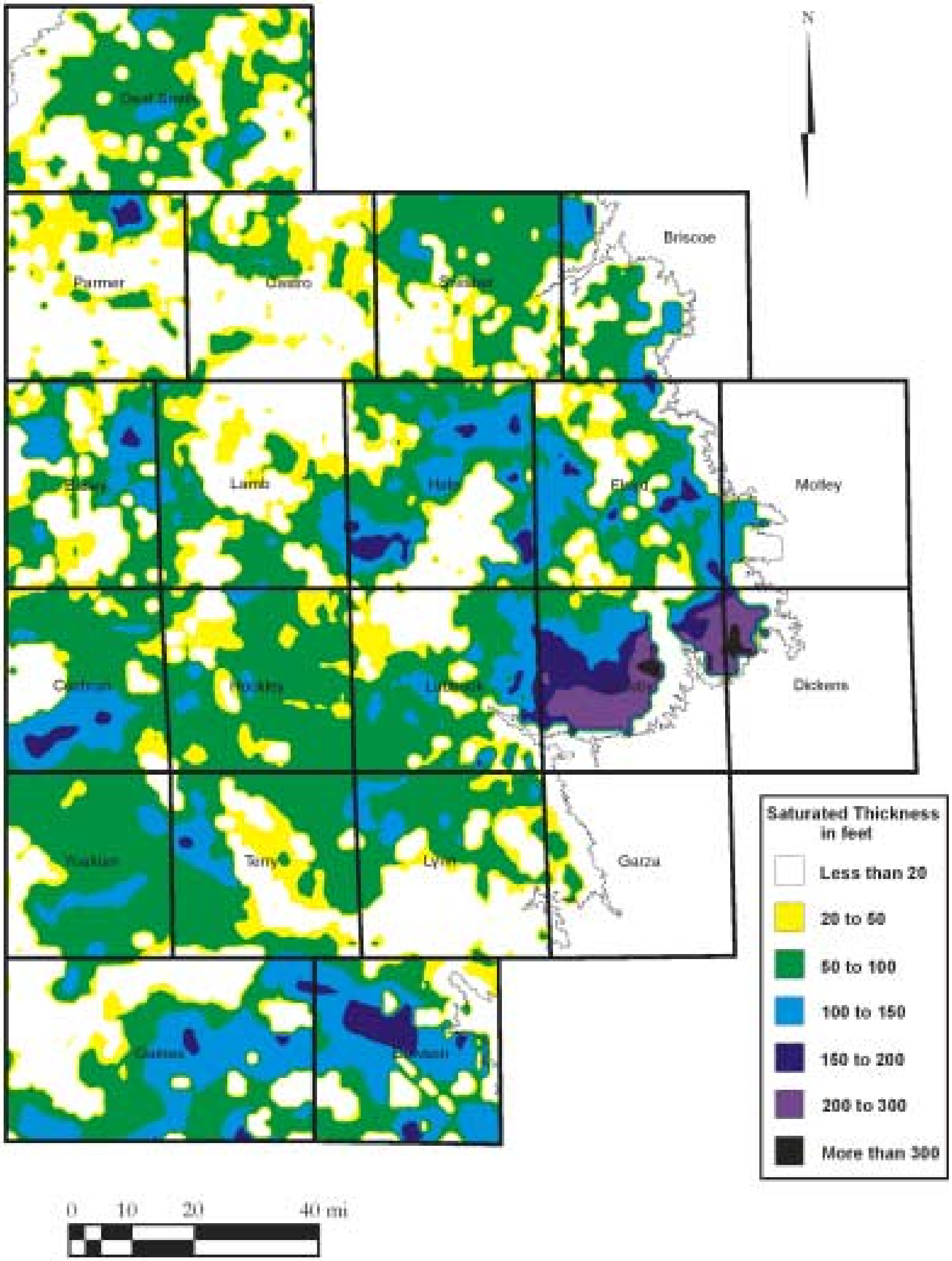

Figure 3-4. 2050 Region O Simulated Saturated Thickness, Baseline Simulation

simulation, the model indicates that approximately 59 percent of the total groundwater demand for Region O could be met in 2050.

3.4.3 Simulation of the Precipitation Enhancement Program

A simulation of the precipitation enhancement program was made to examine the effects of increased precipitation on the aquifer. The effects of 2 inches of additional precipitation were simulated as a reduction in pumpage of 1 inch across the region and an increase in annual recharge of 0.25 inch across the region. The model indicates that approximately 119,000,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050 under the assumed conditions. This represents 90 percent of the volume of water in storage measured in 1995. Under the precipitation enhancement simulation, the model indicates that approximately 72 percent of the total groundwater demand for Region O could be met in 2050.

3.4.4 Simulation of a Reduction in Irrigation Demand

A pumpage reduction simulation was performed to examine the effects of reduced pumpage due to a combination of improvements in irrigation efficiency, application efficiency, plant genetics, crop use, land management, and other agricultural advancements on the aquifer. The effects of these improvements were simulated as a reduction in the predicted irrigation demands of 5 percent every 5 years to a maximum of 25 percent in the year 2020. The model indicates that approximately 109,000,000 acre-feet of water would remain in the Ogallala formation underlying Region O in the year 2050 under the assumed conditions. This represents 82 percent of the volume of water in storage measured in 1995. Under the pumpage reduction simulation, the model indicates that approximately 76 percent of the total groundwater demand for Region O could be met in 2050.

The following figure shows the total volume of water in storage in Region O as observed in 1995 and as predicted for the year 2050 according to the four simulations described above.

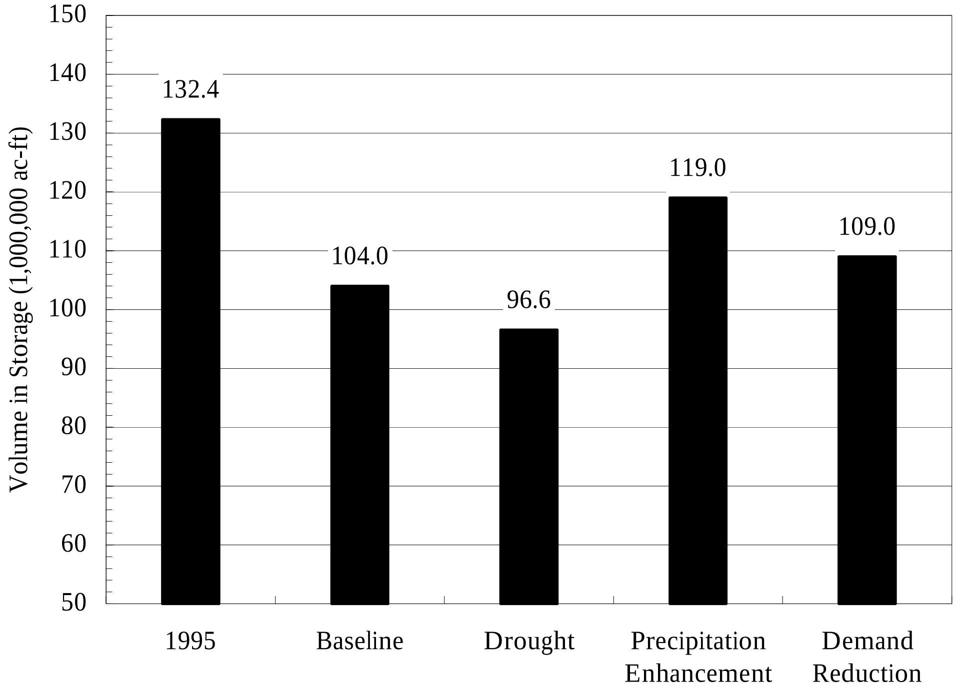

Figure 3-5. Comparison of Volume in Storage in the Ogallala Aquifer, 2050.

3.4.5 Simulation of Uniform Decline in Saturated Thickness

The final simulation completed for this study assumes a uniform decline in saturated thickness of the formation of 1 percent per year. The model was used to compute the withdrawal required to result in this assumed decline. This simulation required the model to be used in an inverse fashion where future water levels are assumed and the pumping rate is adjusted so that water levels calculated by the model match the assumed water levels. Comparison of the total for Region O reveals that the simulated volume in storage matches the volume in storage calculated for an assumed uniform decline to within 1.5 percent for all decades. Pumping rates were divided into zones for calibration according to the 1995 saturated thickness of each cell. For example, cells having an initial saturated thickness ranging from 0 to 5 feet were assigned to zone 1, cells having an initial saturated thickness ranging from 5 to 10 feet were assigned to zone 2, and so on. An initial withdrawal rate was then assigned by assuming a total withdrawal for the model and distributing that total among the cells according to the initial saturated thickness. Cells with greater initial saturated thickness were initially assigned a higher pumping rate.

Section 4
Projected Water Supplies, Water Needs, and Social and Economic Impacts of Failure to Meet Projected Water Needs for Counties and Parts of Counties of River Basins of the Llano Estacado Region

4.1 Water Needs Projections by Water User Group

For purposes of this regional planning project, and in accordance with TWDB Rules, water supply projections and needs projections are tabulated by river basin, county or part of county located within the river basin, and city and rural areas of each county or part of county for the Llano Estacado Region (Tables 4-1 through 4-22).[1] For each county the water demands by river basin and water user group were brought forward from "Llano Estacado Region, Water Plan; Introduction, Description of the Planning Region (Task 1) and Population and Water Demand Projections (Task 2), Tables 2-4 through 2-19; Llano Estacado Regional Planning Group, HDR Engineering, Inc., Lubbock, TX, January 2000."

An illustration of how to read Tables 4-1 through 4-22 is given below. However, each table will not be verbalized here. For example, as shown in Table 4-3, a portion of Castro County is located in the Red River Basin, and a portion is located in the Brazos River Basin. The total projected water supplies available to Castro County in 2000 are 328,587 acft, of which 155,126 acft is located in the Red Basin and 173,461 acft is located in the Brazos Basin. The county's projected water supplies are shown by river basin for each decade of the planning period (Table 4-3). Of the total projected water supply of 328,587 acft in 2000 for Castro County, 323,229 acft is projected to be available from the Ogallala Aquifer, of which 190,125 acft comes from aquifer natural recharge/irrigation recirculation and 133,104 acft comes from aquifer storage (Table 4-3). Castro County is not projected to obtain water from any other aquifers during the planning period. However, in addition to the projected groundwater supplies, Castro County is projected to obtain 3,270 acft of reclaimed water and 2,088 acft of water from local supplies for range and all other livestock use in 2000 (Table 4-3). Castro County is not projected to obtain water supplies from any other surface source other than reclaimed water and local livestock supplies throughout the planning period (Table 4-3).

That part of Castro County located in the Brazos River Basin contains the cities of Dimmitt and Hart. In addition, rural areas of Castro County are located in the Brazos River

[1] 31 Texas Administrative Code, Chapter 357, Regional Water Planning Guideline Rules, Texas Water Development Board, Austin, Texas, March 11, 1998.

Basin. The projected municipal water demand for Dimmitt is 1,144 acft in 2000 and 1,270 acft in 2050, while the projected municipal water supply for Dimmitt is 1,144 acft in 2000 and 0 acft in 2050 (Table 4-3) (See Section 3.3 for methodology of computing water supplies for water user groups). Comparing the projected demands with the projected supplies for Dimmitt in Castro County results in a surplus/shortage of 0 acft in 2000 and a shortage of 1,270 acft in 2050 (Table 4-3). This type of analysis is shown for each water user group for each county located within the Llano Estacado Region.

Total projections for counties and parts of counties of each river basin area located in the Llano Estacado Region are shown at the end of each county's supplies and needs analysis table. In addition, the basin totals are listed in Table 4-22. For example, total water supply in the Red River Basin is projected to be 671,966 acft in 2000, of which 8,736 acft is for municipal purposes, 2,615 acft is for industrial purposes, 638,544 acft is for irrigation purposes, 372 acft is for mining purposes, 16,788 is for beef feedlot livestock purposes, and 4,911 is for range and all other livestock purposes (Table 4-22). In 2000 the Red River Basin part of the Llano Estacado Region is projected to have an irrigation water shortage of 2,413 acft and in 2050 is projected to have a municipal water shortage of 3,913 acft and an irrigation shortage of 1,953 acft (Table 4-22). The reader can readily see the projections for water demand, water supply, and projected surplus/shortage, by type of demand, for the Canadian, Red, Brazos, and Colorado River Basin areas of the Llano Estacado Region (Table 4-22).

Total projected water supply in the Llano Estacado Region in 2000 is 3,102,356 acft and in 2050 is 2,631,795 acft (Table 4-22). The projected water supply in 2050 is 118,424 acft for municipal use, 15,697 acft for industrial use, 37,705 acft for steam-electric use, 2,374,474 acft for irrigation use, 11,824 acft for mining use, 53,933 acft for beef feedlot livestock use, and 19,738 acft for range and other livestock use. In 2000 the Llano Estacado Region is projected to have a municipal water surplus of 14,229 acft and an irrigation water shortage of 171,925 acft; in 2050 the region is projected to have a municipal water shortage of 14,599 acft and an irrigation water shortage of 187,605 acft (Table 4-22). Of the 164 water user groups of the region (74 municipalities and rural domestic users, 15 industry groups, 3 steam-electric users, 21 counties with irrigation use, 17 counties with mining water use, 13 counties with beef feed-lot uses, and 21 counties with range and other livestock uses), it has been calculated that 37 user groups will have a shortage sometime during the 50 year projection period. Of the estimated 37 user groups showing shortages, 26 are municipalities and 11 are counties in which projected irrigation water demands exceed projected irrigation water supplies.

Table 4-1
Projected Water Demands, Supplies, and Needs
Bailey County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				145,608	145,608	145,608	145,608	145,608	145,608
	Aquifer Storage[2]	Net Depletion			29,074	26,167	23,550	21,195	19,075	17,167
	Subtotal GW (Ogallala)[3]				174,682	171,775	169,158	166,803	164,683	162,775
	Local Surface	Stock Tanks and Windmills			1,164	1,279	1,399	1,511	1,637	1,772
	Reclaimed Water[4]				790	790	790	790	790	790
	Total Supply				176,636	173,844	171,347	169,104	167,110	165,337
	Demand from Ogallala (Bailey County)				167,004	163,864	161,117	158,483	156,180	153,967
	Demand from Ogallala (Lubbock County)[5]				7,678	7,911	8,041	8,320	8,503	8,808
	Total Demand from Ogallala				174,682	171,775	169,158	166,803	164,683	162,775
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Muleshoe			1,073	910	1,078	1,064	1,016	850	643	489
Rural			352	326	333	306	280	220	163	109
	Subtotal		1,425	1,236	1,411	1,370	1,296	1,070	806	598
Total Municipal Demand			1,425	1,236	1,411	1,370	1,296	1,070	806	598
Municipal Existing Supply										
Brazos Basin										
Muleshoe		Ogallala			1,078	1,064	1,016	850	643	489
Rural		Ogallala			333	306	280	220	163	109
	Subtotal				1,411	1,370	1,296	1,070	806	598
Total Municipal Existing Supply					1,411	1,370	1,296	1,070	806	598
Municipal Surplus/Shortage										
Brazos Basin										
Muleshoe					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					0	0	0	0	0	0
Municipal New Supply Need										
Brazos Basin										
Muleshoe					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Brazos Basin			147	163	172	199	224	247	281	315
Total Industrial Demand			147	163	172	199	224	247	281	315
Industrial Existing Supply										
Brazos Basin		Ogallala			172	199	224	247	281	315
Total Industrial Existing Supply					172	199	224	247	281	315
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0

Table 4-1
Projected Water Demands, Supplies, and Needs
Bailey County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Steam-Electric New Supply Need									
Brazos Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Brazos Basin		220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
Total Irrigation Demand		220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
Irrigation Supply									
Brazos Basin	Ogallala			164,201	160,883	157,963	155,362	153,103	150,858
	Reclaimed Water			790	790	790	790	790	790
Total Irrigation Supply				164,991	161,673	158,753	156,152	153,893	151,648
Irrigation Surplus/Shortage									
Brazos Basin				-7,278	-6,463	-5,350	-4,014	-2,431	-925
Total Irrigation Surplus/Shortage				-7,278	-6,463	-5,350	-4,014	-2,431	-925
Mining Demand									
Brazos Basin		20	23	25	25	25	27	27	27
Total Mining Demand		20	23	25	25	25	27	27	27
Mining Supply									
Brazos Basin	Ogallala			25	25	25	27	27	27
Total Mining Supply				25	25	25	27	27	27
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
Total Beef Feedlot Livestock Demand		938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
Beef Feedlot Livestock Supply									
Brazos Basin	Ogallala			1,195	1,387	1,609	1,777	1,963	2,169
Total Beef Feedlot Livestock Supply				1,195	1,387	1,609	1,777	1,963	2,169
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		1,069	1,133	1,164	1,279	1,399	1,511	1,637	1,772
Total Range & All Other Livestock Demand		1,069	1,133	1,164	1,279	1,399	1,511	1,637	1,772
Range & All Other Livestock Supply									
Brazos Basin	Local			1,164	1,279	1,399	1,511	1,637	1,772
Total Range & All Other Livestock Supply				1,164	1,279	1,399	1,511	1,637	1,772
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,425	1,236	1,411	1,370	1,296	1,070	806	598
Industrial		147	163	172	199	224	247	281	315
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
Mining		20	23	25	25	25	27	27	27
Beef Feedlot Livestock		938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
Range & All Other Livestock		1,069	1,133	1,164	1,279	1,399	1,511	1,637	1,772
Total County Demand		224,374	253,872	176,236	172,396	168,656	164,798	161,038	157,454
Total Supply									
Municipal				1,411	1,370	1,296	1,070	806	598
Industrial				172	199	224	247	281	315
Steam-Electric				0	0	0	0	0	0
Irrigation				164,991	161,673	158,753	156,152	153,893	151,648
Mining				25	25	25	27	27	27
Beef Feedlot Livestock				1,195	1,387	1,609	1,777	1,963	2,169
Range & All Other Livestock				1,164	1,279	1,399	1,511	1,637	1,772
Total County Supply				168,958	165,933	163,306	160,784	158,607	156,529
Total Surplus/Shortage									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-7,278	-6,463	-5,350	-4,014	-2,431	-925
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0

Table 4-1
Projected Water Demands, Supplies, and Needs
Bailey County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-7,278	-6,463	-5,350	-4,014	-2,431	-925

Table 4-1
Projected Water Demands, Supplies, and Needs
Bailey County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Demand									
Brazos									
Municipal		1,425	1,236	1,411	1,370	1,296	1,070	806	598
Industrial		147	163	172	199	224	247	281	315
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		220,775	250,175	172,269	168,136	164,103	160,166	156,324	152,573
Mining		20	23	25	25	25	27	27	27
Beef Feedlot Livestock		938	1,142	1,195	1,387	1,609	1,777	1,963	2,169
Range & All Other Livestock		1,069	1,133	1,164	1,279	1,399	1,511	1,637	1,772
Total Brazos Basin Demand		224,374	253,872	176,236	172,396	168,656	164,798	161,038	157,454
Total Basin Supply									
Brazos									
Municipal				1,411	1,370	1,296	1,070	806	598
Industrial				172	199	224	247	281	315
Steam-Electric				0	0	0	0	0	0
Irrigation				164,991	161,673	158,753	156,152	153,893	151,648
Mining				25	25	25	27	27	27
Beef Feedlot Livestock				1,195	1,387	1,609	1,777	1,963	2,169
Range & All Other Livestock				1,164	1,279	1,399	1,511	1,637	1,772
Total Brazos Basin Supply				168,958	165,933	163,306	160,784	158,607	156,529
Total Basin Surplus/Shortage									
Brazos									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-7,278	-6,463	-5,350	-4,014	-2,431	-925
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-7,278	-6,463	-5,350	-4,014	-2,431	-925

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from the City of Muleshoe and Minsa Southwest. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entites, the quantity was calculated as 75 percent of the maximum waste discharge permit.

[5] Twenty percent of the City of Lubbock's projected municipal demand.

Table 4-2
Projected Water Demands, Supplies, and Needs
Briscoe County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				33,560	33,560	33,560	33,560	33,560	33,560
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				33,560	33,560	33,560	33,560	33,560	33,560
	Dockum Aquifer				100	100	100	100	100	100
	Seymour Aquifer				4,063	4,063	4,063	1,821	1,821	1,821
	Other Aquifer				115	109	96	94	95	91
	Local Surface	Stock Tanks and Windmills			393	434	466	503	542	585
	Other Surface	Lake Mackenzie			85	85	85	85	85	85
	Total Supply				38,316	38,351	38,370	36,163	36,203	36,242
	Total Demand from Ogallala				28,566	27,380	26,238	27,367	26,292	25,268
WATER DEMANDS										
Municipal Demand										
Red Basin										
Quitaque			129	120	115	109	96	94	95	91
Silverton			135	111	136	132	126	119	113	110
Rural			59	43	94	95	98	90	80	79
	Subtotal		323	274	345	336	320	303	288	280
Total Municipal Demand			323	274	345	336	320	303	288	280
Municipal Existing Supply										
Red Basin										
Quitaque		Other Aquifer			115	109	96	94	95	91
Silverton		Ogallala			51	47	41	34	28	25
		Lake Mackenzie			85	85	85	85	85	85
Silverton Subtotal					136	132	126	119	113	110
Rural		Ogallala			94	95	98	90	80	79
	Subtotal				345	336	320	303	288	280
Total Municipal Existing Supply					345	336	320	303	288	280
Municipal Surplus/Shortage										
Red Basin										
Quitaque					0	0	0	0	0	0
Silverton					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					0	0	0	0	0	0
Municipal New Supply Need										
Red Basin										
Quitaque					0	0	0	0	0	0
Silverton					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Red Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			0	0	0	0	0	0	0	0
Industrial Existing Supply										
Red Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0

Table 4-2
Projected Water Demands, Supplies, and Needs
Briscoe County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Steam-Electric Demand									
Red Basin		0	0	0	0	0	0	0	0
Total Steam-Electric Demand		0	0	0	0	0	0	0	0
Steam-Electric Existing Supply									
Red Basin				0	0	0	0	0	0
Total Steam-Electric Existing Supply				0	0	0	0	0	0
Steam-Electric Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage				0	0	0	0	0	0
Steam-Electric New Supply Need									
Red Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Red Basin		39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
Total Irrigation Demand		39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
Irrigation Supply									
Red Basin	Ogallala			28,421	27,238	26,099	27,243	26,184	25,164
	Dockum			100	100	100	100	100	100
	Seymour			4,063	4,063	4,063	1,821	1,821	1,821
Total Irrigation Supply				32,584	31,401	30,262	29,164	28,105	27,085
Irrigation Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Red Basin		0	0	0	0	0	0	0	0
Total Mining Demand		0	0	0	0	0	0	0	0
Mining Supply									
Red Basin				0	0	0	0	0	0
Total Mining Supply				0	0	0	0	0	0
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		368	389	393	434	466	503	542	585
Total Range & All Other Livestock Demand		368	389	393	434	466	503	542	585
Range & All Other Livestock Supply									
Red Basin	Local			393	434	466	503	542	585
Total Range & All Other Livestock Supply				393	434	466	503	542	585
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		323	274	345	336	320	303	288	280
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		368	389	393	434	466	503	542	585
Total County Demand		40,283	21,597	33,322	32,171	31,048	29,970	28,935	27,950

Table 4-2
Projected Water Demands, Supplies, and Needs
Briscoe County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Supply									
Municipal				345	336	320	303	288	280
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				32,584	31,401	30,262	29,164	28,105	27,085
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				393	434	466	503	542	585
Total County Supply				33,322	32,171	31,048	29,970	28,935	27,950
Total Surplus/Shortage									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	0	0	0	0	0
Total Basin Demand									
Red									
Municipal		323	274	345	336	320	303	288	280
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		368	389	393	434	466	503	542	585
Total Red Basin Demand		40,283	21,597	33,322	32,171	31,048	29,970	28,935	27,950
Total Basin Supply									
Red									
Municipal				345	336	320	303	288	280
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				32,584	31,401	30,262	29,164	28,105	27,085
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				393	434	466	503	542	585
Total Red Basin Supply				33,322	32,171	31,048	29,970	28,935	27,950
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	0	0	0

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-3										
Projected Water Demands, Supplies, and Needs										
Castro County										
Llano Estacado Region										
			Total in	**Total in**	**Projections**					
Basin		**Source**	**1990**	**1996**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
			(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				90,689	90,689	90,689	90,689	90,689	90,689
	Aquifer Storage[2]	Net Depletion			63,497	57,147	51,432	46,289	41,660	37,494
	Subtotal GW (Ogallala)[3]				154,186	147,836	142,121	136,978	132,349	128,183
	Local Surface	Stock Tanks and Windmills			940	1,031	1,126	1,231	1,346	1,473
	Other Surface				0	0	0	0	0	0
	Total Supply				155,126	148,867	143,247	138,209	133,695	129,656
	Total Demand from Ogallala				105,231	101,975	98,913	95,836	92,985	90,316
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				99,436	99,436	99,436	99,436	99,436	99,436
	Aquifer Storage[2]	Net Depletion			69,607	62,647	56,382	50,744	45,669	41,103
	Subtotal GW (Ogallala)[3]				169,043	162,083	155,818	150,180	145,105	140,539
	Local Surface	Stock Tanks and Windmills			1,148	1,254	1,371	1,493	1,628	1,776
	Reclaimed Water[4]				3,270	3,270	3,270	3,270	3,270	3,270
	Total Supply				173,461	166,607	160,459	154,943	150,003	145,585
	Total Demand from Ogallala				169,043	162,083	155,818	150,180	145,105	140,539
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				190,125	190,125	190,125	190,125	190,125	190,125
	Aquifer Storage[2]	Net Depletion			133,104	119,794	107,814	97,033	87,330	78,597
	Subtotal GW (Ogallala)[3]				323,229	309,919	297,939	287,158	277,455	268,722
	Local Surface	Stock Tanks and Windmills			2,088	2,285	2,497	2,724	2,974	3,249
	Reclaimed Water[4]				3,270	3,270	3,270	3,270	3,270	3,270
	Total Supply				328,587	315,474	303,706	293,152	283,699	275,241
	Total Demand from Ogallala				274,274	264,058	254,731	246,016	238,090	230,855
WATER DEMANDS										
Municipal Demand										
Red Basin										
Rural			221	209	238	240	232	223	219	207
	Subtotal		221	209	238	240	232	223	219	207
Brazos Basin										
Dimmitt			894	1,050	1,144	1,206	1,239	1,250	1,253	1,270
Hart			187	248	246	267	287	300	302	310
Rural			265	268	312	314	304	293	287	272
	Subtotal		1,346	1,566	1,702	1,787	1,830	1,843	1,842	1,852
Total Municipal Demand			1,567	1,775	1,940	2,027	2,062	2,066	2,061	2,059
Municipal Existing Supply										
Red Basin										
Rural		Ogallala			238	240	232	223	219	207
	Subtotal				238	240	232	223	219	207
Brazos Basin										
Dimmitt		Ogallala			1,144	1,206	1,239	0	0	0
Hart		Ogallala			246	267	287	300	0	0
Rural		Ogallala			312	314	304	293	287	272
	Subtotal				1,702	1,787	1,830	593	287	272
Total Municipal Existing Supply					1,940	2,027	2,062	816	506	479
Municipal Surplus/Shortage										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Dimmitt					0	0	0	-1,250	-1,253	-1,270
Hart					0	0	0	0	-302	-310
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	-1,250	-1,555	-1,580
Total Municipal Surplus/Shortage					0	0	0	-1,250	-1,555	-1,580
Municipal New Supply Need										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0

Table 4-3
Projected Water Demands, Supplies, and Needs
Castro County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos Basin										
Dimmitt					0	0	0	1,250	1,253	1,270
Hart					0	0	0	0	302	310
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	1,250	1,555	1,580
Total Municipal New Supply Need					0	0	0	1,250	1,555	1,580
Industrial Demand										
Red Basin			392	138	472	557	610	659	741	826
Brazos Basin			1,785	1,561	2,087	2,421	2,723	2,994	3,411	3,824
Total Industrial Demand			2,177	1,699	2,559	2,978	3,333	3,653	4,152	4,650
Industrial Existing Supply										
Red Basin		Ogallala			472	557	610	659	741	826
Brazos Basin		Ogallala			2,087	2,421	2,723	2,994	3,411	3,824
Total Industrial Existing Supply					2,559	2,978	3,333	3,653	4,152	4,650
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			115,892	176,473	101,176	97,297	93,567	89,979	86,529	83,212
Brazos Basin			235,297	342,565	205,419	197,543	189,970	182,686	175,683	168,946
Total Irrigation Demand			351,189	519,038	306,595	294,840	283,537	272,665	262,212	252,158
Irrigation Supply										
Red Basin		Ogallala			101,176	97,297	93,567	89,979	86,529	83,212
Brazos Basin		Ogallala			162,888	155,130	148,079	143,074	137,519	132,149
		Reclaimed Water			3,270	3,270	3,270	3,270	3,270	3,270
Brazos Basin Subtotal					166,158	158,400	151,349	146,344	140,789	135,419
Total Irrigation Supply					267,334	255,697	244,916	236,323	227,318	218,631
Irrigation Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					-39,261	-39,143	-38,621	-36,342	-34,894	-33,527
Total Irrigation Surplus/Shortage					-39,261	-39,143	-38,621	-36,342	-34,894	-33,527
Mining Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Mining Demand			0	0	0	0	0	0	0	0
Mining Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Mining Supply					0	0	0	0	0	0

Table 4-3
Projected Water Demands, Supplies, and Needs
Castro County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		2,689	3,198	3,345	3,881	4,504	4,975	5,496	6,071
Brazos Basin		1,902	2,263	2,366	2,745	3,186	3,519	3,888	4,294
Total Beef Feedlot Livestock Demand		4,591	5,461	5,711	6,626	7,690	8,494	9,384	10,365
Beef Feedlot Livestock Supply									
Red Basin	Ogallala			3,345	3,881	4,504	4,975	5,496	6,071
Brazos Basin	Ogallala			2,366	2,745	3,186	3,519	3,888	4,294
Total Beef Feedlot Livestock Supply				5,711	6,626	7,690	8,494	9,384	10,365
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		855	917	940	1,031	1,126	1,231	1,346	1,473
Brazos Basin		1,044	1,116	1,148	1,254	1,371	1,493	1,628	1,776
Total Range & All Other Livestock Demand		1,899	2,033	2,088	2,285	2,497	2,724	2,974	3,249
Range & All Other Livestock Supply									
Red Basin	Local			940	1,031	1,126	1,231	1,346	1,473
Brazos Basin	Local			1,148	1,254	1,371	1,493	1,628	1,776
Total Range & All Other Livestock Supply				2,088	2,285	2,497	2,724	2,974	3,249
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,567	1,775	1,940	2,027	2,062	2,066	2,061	2,059
Industrial		2,177	1,699	2,559	2,978	3,333	3,653	4,152	4,650
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		351,189	519,038	306,595	294,840	283,537	272,665	262,212	252,158
Mining		0	0	0	0	0	0	0	
Beef Feedlot Livestock		4,591	5,461	5,711	6,626	7,690	8,494	9,384	10,365
Range & All Other Livestock		1,899	2,033	2,088	2,285	2,497	2,724	2,974	3,249
Total County Demand		361,423	530,006	318,893	308,756	299,119	289,602	280,783	272,481
Total Supply									
Municipal				1,940	2,027	2,062	816	506	479
Industrial				2,559	2,978	3,333	3,653	4,152	4,650
Steam-Electric				0	0	0	0	0	0
Irrigation				267,334	255,697	244,916	236,323	227,318	218,631
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				5,711	6,626	7,690	8,494	9,384	10,365
Range & All Other Livestock				2,088	2,285	2,497	2,724	2,974	3,249
Total County Supply				279,632	269,613	260,498	252,010	244,334	237,374
Total Surplus/Shortage									
Municipal				0	0	0	-1,250	-1,555	-1,580
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-39,261	-39,143	-38,621	-36,342	-34,894	-33,527
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-39,261	-39,143	-38,621	-37,592	-36,449	-35,107
Total Basin Demand									
Red									
Municipal		221	209	238	240	232	223	219	207
Industrial		392	138	472	557	610	659	741	826
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		115,892	176,473	101,176	97,297	93,567	89,979	86,529	83,212
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		2,689	3,198	3,345	3,881	4,504	4,975	5,496	6,071
Range & All Other Livestock		855	917	940	1,031	1,126	1,231	1,346	1,473
Total Red Basin Demand		120,049	180,935	106,171	103,006	100,039	97,067	94,331	91,789

Table 4-3
Projected Water Demands, Supplies, and Needs
Castro County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos									
Municipal		1,346	1,566	1,702	1,787	1,830	1,843	1,842	1,852
Industrial		1,785	1,561	2,087	2,421	2,723	2,994	3,411	3,824
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		235,297	342,565	205,419	197,543	189,970	182,686	175,683	168,946
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		1,902	2,263	2,366	2,745	3,186	3,519	3,888	4,294
Range & All Other Livestock		0	0	1,148	1,254	1,371	1,493	1,628	1,776
Total Brazos Basin Demand		240,330	347,955	212,722	205,750	199,080	192,535	186,452	180,692
Total Basin Supply									
Red									
Municipal				238	240	232	223	219	207
Industrial				472	557	610	659	741	826
Steam-Electric				0	0	0	0	0	0
Irrigation				101,176	97,297	93,567	89,979	86,529	83,212
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				3,345	3,881	4,504	4,975	5,496	6,071
Range & All Other Livestock				940	1,031	1,126	1,231	1,346	1,473
Total Red Basin Supply				106,171	103,006	100,039	97,067	94,331	91,789
Brazos									
Municipal				1,702	1,787	1,830	593	287	272
Industrial				2,087	2,421	2,723	2,994	3,411	3,824
Steam-Electric				0	0	0	0	0	0
Irrigation				166,158	158,400	151,349	146,344	140,789	135,419
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				2,366	2,745	3,186	3,519	3,888	4,294
Range & All Other Livestock				1,148	1,254	1,371	1,493	1,628	1,776
Total Brazos Basin Supply				173,461	166,607	160,459	154,943	150,003	145,585
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	0	0	0
Brazos									
Municipal				0	0	0	-1,250	-1,555	-1,580
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-39,261	-39,143	-38,621	-36,342	-34,894	-33,527
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-39,261	-39,143	-38,621	-37,592	-36,449	-35,107

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from the City of Dimmitt, Nazareth Water & Sewer Supply, City of Hart, and Cerestar USA Dimmitt Inc. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projeciton period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-4
Projected Water Demands, Supplies, and Needs
Cochran County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				20,661	20,661	20,661	20,661	20,661	20,661
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				20,661	20,661	20,661	20,661	20,661	20,661
	Local Surface	Stock Tanks and Windmills			74	82	92	101	110	120
	Reclaimed Water[4]				233	233	233	233	233	233
	Total Supply				20,968	20,976	20,986	20,995	21,004	21,014
	Total Demand from Ogallala				20,661	20,661	20,661	20,661	20,661	20,661
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				37,011	37,011	37,011	37,011	37,011	37,011
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				37,011	37,011	37,011	37,011	37,011	37,011
	Local Surface	Stock Tanks and Windmills			137	156	167	181	197	216
	Reclaimed Water[4]				27	27	27	27	27	27
	Total Supply				37,175	37,194	37,205	37,219	37,235	37,254
	Total Demand from Ogallala				19,728	18,790	17,919	17,108	16,349	15,640
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				57,672	57,672	57,672	57,672	57,672	57,672
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				57,672	57,672	57,672	57,672	57,672	57,672
	Local Surface	Stock Tanks and Windmills			211	238	259	282	307	336
	Reclaimed Water[4]				260	260	260	260	260	260
	Total Supply				58,143	58,170	58,191	58,214	58,239	58,268
	Total Demand from Ogallala				40,389	39,451	38,580	37,769	37,010	36,301
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Morton			631	546	656	676	673	670	663	653
Whiteface			117	127	115	102	89	80	75	74
Rural			59	66	45	60	70	77	78	77
	Subtotal		807	739	816	838	832	827	816	804
Colorado Basin										
Rural			124	106	149	151	149	147	144	142
	Subtotal		124	106	149	151	149	147	144	142
Total Municipal Demand			931	845	965	989	981	974	960	946
Municipal Existing Supply										
Brazos Basin										
Morton		Ogallala			656	676	0	0	0	0
Whiteface		Ogallala			115	102	89	0	0	0
Rural		Ogallala			45	60	70	77	78	77
	Subtotal				816	838	159	77	78	77
Colorado Basin										
Rural		Ogallala			149	151	149	147	144	142
	Subtotal				149	151	149	147	144	142
Total Municipal Existing Supply					965	989	308	224	222	219
Municipal Surplus/Shortage										
Brazos Basin										
Morton					0	0	-673	-670	-663	-653
Whiteface					0	0	0	-80	-75	-74
Rural					0	0	0	0	0	0
	Subtotal				0	0	-673	-750	-738	-727
Colorado Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					0	0	-673	-750	-738	-727
Municipal New Supply Need										
Brazos Basin										
Morton					0	0	673	670	663	653
Whiteface					0	0	0	80	75	74
Rural					0	0	0	0	0	0
	Subtotal				0	0	673	750	738	727

Table 4-4
Projected Water Demands, Supplies, and Needs
Cochran County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	673	750	738	727
Industrial Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			0	0	0	0	0	0	0	0
Industrial Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			20,915	128,827	32,615	31,356	30,146	28,983	27,864	26,788
Colorado Basin			11,764	36,336	18,354	17,645	16,965	16,310	15,680	15,075
Total Irrigation Demand			32,679	165,163	50,969	49,001	47,111	45,293	43,544	41,863
Irrigation Supply										
Brazos Basin		Ogallala			19,201	19,077	19,638	19,632	19,533	19,426
		Reclaimed Water			233	233	233	233	233	233
Brazos Basin Subtotal					19,434	19,310	19,871	19,865	19,766	19,659
Colorado Basin		Ogallala			18,327	17,618	16,938	16,283	15,653	15,048
		Reclaimed Water			27	27	27	27	27	27
Colorado Basin Subtotal					18,354	17,645	16,965	16,310	15,680	15,075
Total Irrigation Supply					37,788	36,955	36,836	36,175	35,446	34,734
Irrigation Surplus/Shortage										
Brazos Basin					-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Mining Demand										
Brazos Basin			0	0	11	12	12	11	11	10
Colorado Basin			924	1,142	1,252	1,021	832	678	552	450
Total Mining Demand			924	1,142	1,263	1,033	844	689	563	460
Mining Supply										
Brazos Basin		Ogallala			11	12	12	11	11	10
Colorado Basin		Ogallala			1,252	1,021	832	678	552	450
Total Mining Supply					1,263	1,033	844	689	563	460
Mining Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Mining Surplus/Shortage					0	0	0	0	0	0

Table 4-4
Projected Water Demands, Supplies, and Needs
Cochran County
Llano Estacado Region

			Total in	Total in	Projections						
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050	
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	

Table 4-4
Projected Water Demands, Supplies, and Needs
Cochran County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Beef Feedlot Livestock Demand									
Brazos Basin		496	605	633	734	852	941	1,039	1,148
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		496	605	633	734	852	941	1,039	1,148
Beef Feedlot Livestock Supply									
Brazos Basin	Ogallala			633	734	852	941	1,039	1,148
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				633	734	852	941	1,039	1,148
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		67	70	74	82	92	101	110	120
Colorado Basin		125	134	137	156	167	181	197	216
Total Range & All Other Livestock Demand		192	204	211	238	259	282	307	336
Range & All Other Livestock Supply									
Brazos Basin	Local			74	82	92	101	110	120
Colorado Basin	Local			137	156	167	181	197	216
Total Range & All Other Livestock Supply				211	238	259	282	307	336
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		931	845	965	989	981	974	960	946
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		32,679	165,163	50,969	49,001	47,111	45,293	43,544	41,863
Mining		924	1,142	1,263	1,033	844	689	563	460
Beef Feedlot Livestock		496	605	633	734	852	941	1,039	1,148
Range & All Other Livestock		192	204	211	238	259	282	307	336
Total County Demand		35,222	167,959	54,041	51,995	50,047	48,179	46,413	44,753
Total Supply									
Municipal				965	989	308	224	222	219
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				37,788	36,955	36,836	36,175	35,446	34,734
Mining				1,263	1,033	844	689	563	460
Beef Feedlot Livestock				633	734	852	941	1,039	1,148
Range & All Other Livestock				211	238	259	282	307	336
Total County Supply				40,860	39,949	39,099	38,311	37,577	36,897
Total Surplus/Shortage									
Municipal				0	0	-673	-750	-738	-727
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-13,181	-12,046	-10,948	-9,868	-8,836	-7,856
Total Basin Demand									
Brazos									
Municipal		807	739	816	838	832	827	816	804
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		20,915	128,827	32,615	31,356	30,146	28,983	27,864	26,788
Mining		0	0	11	12	12	11	11	10
Beef Feedlot Livestock		496	605	633	734	852	941	1,039	1,148
Range & All Other Livestock		0	0	74	82	92	101	110	120
Total Brazos Basin Demand		22,218	130,171	34,149	33,022	31,934	30,863	29,840	28,870

Table 4-4
Projected Water Demands, Supplies, and Needs
Cochran County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado									
Municipal		124	106	149	151	149	147	144	142
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		11,764	36,336	18,354	17,645	16,965	16,310	15,680	15,075
Mining		924	1,142	1,252	1,021	832	678	552	450
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		0	0	137	156	167	181	197	216
Total Colorado Basin Demand		12,812	37,584	19,892	18,973	18,113	17,316	16,573	15,883
Total Basin Supply									
Brazos									
Municipal				816	838	159	77	78	77
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				19,434	19,310	19,871	19,865	19,766	19,659
Mining				11	12	12	11	11	10
Beef Feedlot Livestock				633	734	852	941	1,039	1,148
Range & All Other Livestock				74	82	92	101	110	120
Total Brazos Basin Supply				20,968	20,976	20,986	20,995	21,004	21,014
Colorado									
Municipal				149	151	149	147	144	142
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				18,354	17,645	16,965	16,310	15,680	15,075
Mining				1,252	1,021	832	678	552	450
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				137	156	167	181	197	216
Total Colorado Basin Supply				19,892	18,973	18,113	17,316	16,573	15,883
Total Basin Surplus/Shortage									
Brazos									
Municipal				0	0	-673	-750	-738	-727
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-13,181	-12,046	-10,948	-9,868	-8,836	-7,856
Colorado									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				0	0	0	0	0	0

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from the City of Morton, Girls Town USA, and City of Whiteface. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waster discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-5
Projected Water Demands, Supplies, and Needs
Crosby County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
					Projections					
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				1,905	1,905	1,905	1,905	1,905	1,905
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				1,905	1,905	1,905	1,905	1,905	1,905
	Local Surface	Stock Tanks and Windmills			4	5	5	5	6	6
	Other Surface				0	0	0	0	0	0
	Total Supply				1,909	1,910	1,910	1,910	1,911	1,911
	Total Demand from Ogallala				1,905	1,905	1,905	1,898	1,845	1,795
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				89,508	89,508	89,508	89,508	89,508	89,508
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				89,508	89,508	89,508	89,508	89,508	89,508
	Seymour Aquifer				483	483	483	474	474	474
	Local Surface	Stock Tanks and Windmills			370	396	420	447	474	508
	Other Surface	White River Reservoir			707	707	707	707	707	707
	Reclaimed Water[4]				562	562	562	562	562	562
	Total Supply				91,630	91,656	91,680	91,698	91,725	91,759
	Total Demand from Ogallala				86,408	82,918	79,563	76,351	73,283	70,340
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				91,413	91,413	91,413	91,413	91,413	91,413
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				91,413	91,413	91,413	91,413	91,413	91,413
	Seymour Aquifer				483	483	483	474	474	474
	Local Surface	Stock Tanks and Windmills			374	401	425	452	480	514
	Other Surface	White River Reservoir			707	707	707	707	707	707
	Reclaimed Water[4]				562	562	562	562	562	562
	Total Supply				93,539	93,566	93,590	93,608	93,636	93,670
	Total Demand from Ogallala				88,313	84,823	81,468	78,249	75,128	72,135
WATER DEMANDS										
Municipal Demand										
Red Basin										
Rural			5	6	6	5	5	5	5	5
	Subtotal		5	6	6	5	5	5	5	5
Brazos Basin										
Crosbyton			409	438	389	368	339	306	297	294
Lorenzo			227	221	265	249	231	209	202	199
Ralls			313	302	318	288	261	227	217	209
Rural			241	244	241	241	227	218	217	212
	Subtotal		1,190	1,205	1,213	1,146	1,058	960	933	914
Total Municipal Demand			1,195	1,211	1,219	1,151	1,063	965	938	919
Municipal Existing Supply										
Red Basin										
Rural		Ogallala			6	5	5	5	5	5
	Subtotal				6	5	5	5	5	5
Brazos Basin										
Crosbyton		White River Reservoir			389	389	389	389	389	389
Lorenzo		Ogallala			265	249	231	209	202	199
Ralls		White River Reservoir			318	318	318	318	318	318
Rural		Ogallala			141	141	127	118	117	112
		Seymour			100	100	100	100	100	100
Rural Subtotal					241	241	227	218	217	212
	Subtotal				1,213	1,197	1,165	1,134	1,126	1,118
Total Municipal Existing Supply					1,219	1,202	1,170	1,139	1,131	1,123
Municipal Surplus/Shortage										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Crosbyton					0	21	50	83	92	95
Lorenzo					0	0	0	0	0	0
Ralls					0	30	57	91	101	109
Rural					0	0	0	0	0	0
	Subtotal				0	51	107	174	193	204
Total Municipal Surplus/Shortage					0	51	107	174	193	204

Table 4-5
Projected Water Demands, Supplies, and Needs
Crosby County
Llano Estacado Region

			Total in	Total in	Projections					
Basin		**Source**	**1990**	**1996**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
			(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**
Municipal New Supply Need										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Crosbyton					0	0	0	0	0	0
Lorenzo					0	0	0	0	0	0
Ralls					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			7	3	7	6	6	6	6	6
Total Industrial Demand			7	3	7	6	6	6	6	6
Industrial Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin		Ogallala			7	6	6	6	6	6
Total Industrial Existing Supply					7	6	6	6	6	6
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Shortage/Surplus					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			2,113	4,151	1,763	1,692	1,624	1,559	1,496	1,436
Brazos Basin			103,521	134,207	86,400	82,919	79,579	76,372	73,295	70,343
Total Irrigation Demand			105,634	138,358	88,163	84,611	81,203	77,931	74,791	71,779
Irrigation Supply										
Red Basin		Ogallala			1,584	1,585	1,576	1,559	1,496	1,436
Brazos Basin		Ogallala			85,455	81,974	78,634	75,436	72,359	69,407
		Seymour			383	383	383	374	374	374
		Reclaimed Water			562	562	562	562	562	562
Brazos Basin Subtotal					86,400	82,919	79,579	76,372	73,295	70,343
Total Irrigation Supply					87,984	84,504	81,155	77,931	74,791	71,779
Irrigation Surplus/Shortage										
Red Basin					-179	-107	-48	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					-179	-107	-48	0	0	0
Mining Demand										
Red Basin			291	291	315	315	324	334	344	354
Brazos Basin			552	592	540	548	565	582	599	616
Total Mining Demand			843	883	855	863	889	916	943	970

Table 4-5
Projected Water Demands, Supplies, and Needs
Crosby County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Supply									
Red Basin	Ogallala			315	315	324	334	344	354
Brazos Basin	Ogallala			540	548	565	582	599	616
Total Mining Supply				855	863	889	916	943	970
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Brazos Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		4	4	4	5	5	5	6	6
Brazos Basin		349	363	370	396	420	447	474	508
Total Range & All Other Livestock Demand		353	367	374	401	425	452	480	514
Range & All Other Livestock Supply									
Red Basin	Local			4	5	5	5	6	6
Brazos Basin	Local			370	396	420	447	474	508
Total Range & All Other Livestock Supply				374	401	425	452	480	514
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,195	1,211	1,219	1,151	1,063	965	938	919
Industrial		7	3	7	6	6	6	6	6
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		105,634	138,358	88,163	84,611	81,203	77,931	74,791	71,779
Mining		843	883	855	863	889	916	943	970
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		353	367	374	401	425	452	480	514
Total County Demand		108,032	140,822	90,618	87,032	83,586	80,270	77,158	74,188
Total Supply									
Municipal				1,219	1,202	1,170	1,139	1,131	1,123
Industrial				7	6	6	6	6	6
Steam-Electric				0	0	0	0	0	0
Irrigation				87,984	84,504	81,155	77,931	74,791	71,779
Mining				855	863	889	916	943	970
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				374	401	425	452	480	514
Total County Supply				90,439	86,976	83,645	80,444	77,351	74,392
Total Surplus/Shortage									
Municipal				0	51	107	174	193	204
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-179	-107	-48	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-179	-56	59	174	193	204
Total Basin Demand									
Red									
Municipal		5	6	6	5	5	5	5	5
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		2,113	4,151	1,763	1,692	1,624	1,559	1,496	1,436
Mining		291	291	315	315	324	334	344	354
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		4	4	4	5	5	5	6	6
Total Red Basin Demand		2,413	4,452	2,088	2,017	1,958	1,903	1,851	1,801

Table 4-5 Projected Water Demands, Supplies, and Needs Crosby County Llano Estacado Region											
			Total in	Total in	Projections						
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)

Table 4-5
Projected Water Demands, Supplies, and Needs
Crosby County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos									
Municipal		1,190	1,205	1,213	1,146	1,058	960	933	914
Industrial		7	3	7	6	6	6	6	6
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		103,521	134,207	86,400	82,919	79,579	76,372	73,295	70,343
Mining		552	592	540	548	565	582	599	616
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		349	363	370	396	420	447	474	508
Total Brazos Basin Demand		105,619	136,370	88,530	85,015	81,628	78,367	75,307	72,387
Total Basin Supply									
Red									
Municipal				6	5	5	5	5	5
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				1,584	1,585	1,576	1,559	1,496	1,436
Mining				315	315	324	334	344	354
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				4	5	5	5	6	6
Total Red Basin Supply				1,909	1,910	1,910	1,903	1,851	1,801
Brazos									
Municipal				1,213	1,197	1,165	1,134	1,126	1,118
Industrial				7	6	6	6	6	6
Steam-Electric				0	0	0	0	0	0
Irrigation				86,400	82,919	79,579	76,372	73,295	70,343
Mining				540	548	565	582	599	616
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				370	396	420	447	474	508
Total Brazos Basin Supply				88,530	85,066	81,735	78,541	75,500	72,591
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-179	-107	-48	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				-179	-107	-48	0	0	0
Brazos									
Municipal				0	51	107	174	193	204
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				0	51	107	174	193	204

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from City of Lorenzo, City of Ralls, City of Crosbyton, and the White River MWD. The quantity of reclaimed water availabe from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-6
Projected Water Demands, Supplies, and Needs
Dawson County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				673	673	673	673	673	673
	Aquifer Storage[2]	Net Depletion			2,652	2,236	1,378	0	0	0
	Subtotal GW (Ogallala)[3]				3,325	2,909	2,051	673	673	673
	Local Surface	Stock Tanks and Windmills			2	3	3	3	3	3
	Other Surface				0	0	0	0	0	0
	Total Supply				3,327	2,912	2,054	676	676	676
	Total Demand from Ogallala				380	359	339	320	302	286
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				52,327	52,327	52,327	52,327	52,327	52,327
	Aquifer Storage[2]	Net Depletion			201,348	169,764	104,622	0	0	0
	Subtotal GW (Ogallala)[3]				253,675	222,091	156,949	52,327	52,327	52,327
	Other Ground	Ogallala (CRMWA - Roberts Co.)			892	892	892	892	892	892
	Local Surface	Stock Tanks and Windmills			211	232	249	266	285	306
	Other Surface	Lake Meredith (CRMWA)			1,694	1,694	1,694	1,694	1,694	1,694
	Total Supply				256,472	224,909	159,784	55,179	55,198	55,219
	Total Demand from Ogallala				38,211	35,874	33,693	31,667	29,781	28,030
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				53,000	53,000	53,000	53,000	53,000	53,000
	Aquifer Storage[2]	Net Depletion			204,000	172,000	106,000	0	0	0
	Subtotal GW (Ogallala)[3]				257,000	225,000	159,000	53,000	53,000	53,000
	Other Ground	Ogallala (CRMWA - Roberts Co.)			892	892	892	892	892	892
	Local Surface	Stock Tanks and Windmills			213	235	252	269	288	309
	Other Surface	Lake Meredith (CRMWA)			1,694	1,694	1,694	1,694	1,694	1,694
	Total Supply				259,799	227,821	161,838	55,855	55,874	55,895
	Total Demand from Ogallala				38,591	36,233	34,032	31,987	30,083	28,316
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Rural			14	18	15	15	14	14	13	13
	Subtotal		14	18	15	15	14	14	13	13
Colorado Basin										
Lamesa			1,827	2,023	2,369	2,383	2,349	2,313	2,294	2,289
O'Donnell (part)			15	17	22	23	26	30	32	35
Rural			429	514	420	417	401	388	373	368
	Subtotal		2,271	2,554	2,811	2,823	2,776	2,731	2,699	2,692
Total Municipal Demand			2,285	2,572	2,826	2,838	2,790	2,745	2,712	2,705
Municipal Existing Supply										
Brazos Basin										
Rural		Ogallala			15	15	14	14	13	13
	Subtotal				15	15	14	14	13	13
Colorado Basin										
Lamesa		Ogallala			0	0	0	0	0	0
		Lake Meredith (CRMWA)[4]			1,656	1,656	1,656	1,656	1,656	1,656
		Ogallala (CRMWA - Roberts Co.)[4]			872	872	872	872	872	872
Lamesa Subtotal					2,528	2,528	2,528	2,528	2,528	2,528
O'Donnell (part)		Lake Meredith (CRMWA)			38	38	38	38	38	38
		Ogallala (CRMWA - Roberts Co.)			20	20	20	20	20	20
O'Donnell (part) Subtotal					58	58	58	58	58	58
Rural		Ogallala			420	417	401	388	373	368
	Subtotal				3,006	3,003	2,987	2,974	2,959	2,954
Total Municipal Existing Supply					3,021	3,018	3,001	2,988	2,972	2,967
Municipal Surplus/Shortage										
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Colorado Basin										
Lamesa					159	145	179	215	234	239
O'Donnell (part)					36	35	32	28	26	23
Rural					0	0	0	0	0	0
	Subtotal				195	180	211	243	260	262
Total Municipal Surplus/Shortage										
Municipal New Supply Need										
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0

Table 4-6
Projected Water Demands, Supplies, and Needs
Dawson County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado Basin										
Lamesa					0	0	0	0	0	0
O'Donnell (part)					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			44	70	46	47	47	47	49	51
Total Industrial Demand			44	70	46	47	47	47	49	51
Industrial Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin		Ogallala			46	47	47	47	49	51
Total Industrial Existing Supply					46	47	47	47	49	51
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			391	513	365	344	325	306	289	273
Colorado Basin			38,706	142,813	36,110	34,074	32,153	30,340	28,630	27,016
Total Irrigation Demand			39,097	143,326	36,475	34,418	32,478	30,646	28,919	27,289
Irrigation Supply										
Brazos Basin		Ogallala			365	344	325	306	289	273
Colorado Basin		Ogallala			36,110	34,074	32,153	30,340	28,630	27,016
Total Irrigation Supply					36,475	34,418	32,478	30,646	28,919	27,289
Irrigation Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					0	0	0	0	0	0
Mining Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			654	781	1,635	1,336	1,092	892	729	595
Total Mining Demand			654	781	1,635	1,336	1,092	892	729	595
Mining Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin		Ogallala			1,635	1,336	1,092	892	729	595
Total Mining Supply					1,635	1,336	1,092	892	729	595
Mining Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Mining Surplus/Shortage					0	0	0	0	0	0

Table 4-6
Projected Water Demands, Supplies, and Needs
Dawson County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Beef Feedlot Livestock Demand									
Brazos Basin		0	0	0	0	0	0	0	0
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		2	2	2	3	3	3	3	3
Colorado Basin		197	206	211	232	249	266	285	306
Total Range & All Other Livestock Demand		199	208	213	235	252	269	288	309
Range & All Other Livestock Supply									
Brazos Basin	Local			2	3	3	3	3	3
Colorado Basin	Local			211	232	249	266	285	306
Total Range & All Other Livestock Supply				213	235	252	269	288	309
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		2,285	2,572	2,826	2,838	2,790	2,745	2,712	2,705
Industrial		44	70	46	47	47	47	49	51
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		39,097	143,326	36,475	34,418	32,478	30,646	28,919	27,289
Mining		654	781	1,635	1,336	1,092	892	729	595
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		199	208	213	235	252	269	288	309
Total County Demand		42,279	146,957	41,195	38,874	36,659	34,599	32,697	30,949
Total Supply									
Municipal				3,021	3,018	3,001	2,988	2,972	2,967
Industrial				46	47	47	47	49	51
Steam-Electric				0	0	0	0	0	0
Irrigation				36,475	34,418	32,478	30,646	28,919	27,289
Mining				1,635	1,336	1,092	892	729	595
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				213	235	252	269	288	309
Total County Supply				41,390	39,054	36,870	34,842	32,957	31,211
Total Surplus/Shortage									
Municipal				195	180	211	243	260	262
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				195	180	211	243	260	262
Total Basin Demand									
Brazos									
Municipal		14	18	15	15	14	14	13	13
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		391	513	365	344	325	306	289	273
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		0	0	2	3	3	3	3	3
Total Brazos Basin Demand		405	531	382	362	342	323	305	289
Colorado									
Municipal		2,271	2,554	2,811	2,823	2,776	2,731	2,699	2,692
Industrial		44	70	46	47	47	47	49	51
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		38,706	142,813	36,110	34,074	32,153	30,340	28,630	27,016
Mining		654	781	1,635	1,336	1,092	892	729	595
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		197	206	211	232	249	266	285	306
Total Colorado Basin Demand		41,872	146,424	40,813	38,512	36,317	34,276	32,392	30,660

Table 4-6
Projected Water Demands, Supplies, and Needs
Dawson County
Llano Estacado Region

			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)

Table 4-6
Projected Water Demands, Supplies, and Needs
Dawson County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Supply									
Brazos									
Municipal				15	15	14	14	13	13
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				365	344	325	306	289	273
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				2	3	3	3	3	3
Total Brazos Basin Supply				382	362	342	323	305	289
Colorado									
Municipal				3,006	3,003	2,987	2,974	2,959	2,954
Industrial				46	47	47	47	49	51
Steam-Electric				0	0	0	0	0	0
Irrigation				36,110	34,074	32,153	30,340	28,630	27,016
Mining				1,635	1,336	1,092	892	729	595
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				211	232	249	266	285	306
Total Colorado Basin Supply				41,008	38,692	36,528	34,519	32,652	30,922
Total Basin Surplus/Shortage									
Brazos									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				0	0	0	0	0	0
Colorado									
Municipal				195	180	211	243	260	262
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				195	180	211	243	260	262

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] The city's supply from CRMWA. Since the city's supply from CRMWA exceeds CRMWA's delivery capacity, the city must have terminal storage in order to use its full supply from CRMWA.

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Table 4-7										
Projected Water Demands, Supplies, and Needs										
Deaf Smith County										
Llano Estacado Region										
			Total in	**Total in**	**Projections**					
Basin		**Source**	**1990**	**1996**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
			(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**
WATER SUPPLIES										
	Canadian Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				1,854	1,854	1,854	1,854	1,854	1,854
	Aquifer Storage[2]	Net Depletion			1,044	940	846	761	685	617
	Subtotal GW (Ogallala)[3]				2,898	2,794	2,700	2,615	2,539	2,471
	Local Surface	Stock Tanks and Windmills			82	87	93	99	106	113
	Other Surface				0	0	0	0	0	0
	Total Supply				2,980	2,881	2,793	2,714	2,645	2,584
	Total Demand from Ogallala				4	4	4	4	4	4
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				172,120	172,120	172,120	172,120	172,120	172,120
	Aquifer Storage[2]	Net Depletion			96,954	87,258	78,532	70,679	63,611	57,250
	Subtotal GW (Ogallala)[3]				269,074	259,378	250,652	242,799	235,731	229,370
	Dockum Aquifer				2,654	2,804	2,916	5,032	5,192	5,432
	Local Surface	Stock Tanks and Windmills			1,354	1,454	1,559	1,663	1,777	1,906
	Reclaimed Water[4]				2,985	2,985	2,985	2,985	2,985	2,985
	Total Supply				276,067	266,621	258,112	252,479	245,685	239,693
	Total Demand from Ogallala				260,567	254,172	248,172	238,488	232,597	227,069
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				173,974	173,974	173,974	173,974	173,974	173,974
	Aquifer Storage[2]	Net Depletion			97,998	88,198	79,378	71,441	64,296	57,867
	Subtotal GW (Ogallala)[3]				271,972	262,172	253,352	245,415	238,270	231,841
	Dockum Aquifer				2,654	2,804	2,916	5,032	5,192	5,432
	Local Surface	Stock Tanks and Windmills			1,436	1,541	1,652	1,762	1,883	2,019
	Reclaimed Water[4]				2,985	2,985	2,985	2,985	2,985	2,985
	Total Supply				279,047	269,502	260,905	255,194	248,330	242,277
	Total Demand from Ogallala				260,571	254,176	248,176	238,492	232,601	227,073
WATER DEMANDS										
Municipal Demand										
Canadian Basin										
Rural			3	4	4	4	4	4	4	4
	Subtotal		3	4	4	4	4	4	4	4
Red Basin										
Hereford			3,869	3,167	4,426	4,676	4,863	5,032	5,192	5,433
Rural			537	578	594	624	636	637	640	644
	Subtotal		4,406	3,745	5,020	5,300	5,499	5,669	5,832	6,077
Total Municipal Demand			4,409	3,749	5,024	5,304	5,503	5,673	5,836	6,081
Municipal Existing Supply										
Canadian Basin										
Rural		Ogallala			4	4	4	4	4	4
	Subtotal				4	4	4	4	4	4
Red Basin										
Hereford[5]		Ogallala			3,099	3,274	3,405	0	0	0
		Dockum (Santa Rosa)			1,327	1,402	1,458	2,516	2,596	2,716
Hereford Subtotal					4,426	4,676	4,863	2,516	2,596	2,716
Rural		Ogallala			594	624	636	637	640	644
	Subtotal				5,020	5,300	5,499	3,153	3,236	3,360
Total Municipal Existing Supply					5,024	5,304	5,503	3,157	3,240	3,364
Municipal Surplus/Shortage										
Canadian Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Red Basin										
Hereford					0	0	0	-2,516	-2,596	-2,717
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	-2,516	-2,596	-2,717
Total Municipal Surplus/Shortage					0	0	0	-2,516	-2,596	-2,717
Municipal New Supply Need										
Canadian Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Red Basin										
Hereford					0	0	0	2,516	2,596	2,717
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	2,516	2,596	2,717

Table 4-7 Projected Water Demands, Supplies, and Needs Deaf Smith County Llano Estacado Region										
			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Total Municipal New Supply Need					0	0	0	2,516	2,596	2,717

Table 4-7
Projected Water Demands, Supplies, and Needs
Deaf Smith County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Industrial Demand									
Canadian Basin		0	0	0	0	0	0	0	0
Red Basin		498	1,394	537	575	603	626	679	730
Total Industrial Demand		498	1,394	537	575	603	626	679	730
Industrial Existing Supply									
Canadian Basin				0	0	0	0	0	0
Red Basin	Ogallala			537	575	603	626	679	730
Total Industrial Existing Supply				537	575	603	626	679	730
Industrial Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Industrial Surplus/Shortage				0	0	0	0	0	0
Industrial New Supply Need									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Industrial New Supply Need				0	0	0	0	0	0
Steam-Electric Demand									
Canadian Basin		0	0	0	0	0	0	0	0
Red Basin		0	0	0	0	0	0	0	0
Total Steam-Electric Demand		0	0	0	0	0	0	0	0
Steam-Electric Existing Supply									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Steam-Electric Existing Supply				0	0	0	0	0	0
Steam-Electric Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage				0	0	0	0	0	0
Steam-Electric New Supply Need									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Canadian Basin		0	0	0	0	0	0	0	0
Red Basin		285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
Total Irrigation Demand		285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
Irrigation Supply									
Canadian Basin				0	0	0	0	0	0
Red Basin	Ogallala			248,127	240,171	232,469	225,009	217,786	210,792
	Reclaimed Water			2,985	2,985	2,985	2,985	2,985	2,985
Red Basin Subtotal				251,112	243,156	235,454	227,994	220,771	213,777
Total Irrigation Supply				251,112	243,156	235,454	227,994	220,771	213,777
Irrigation Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Canadian Basin		0	0	0	0	0	0	0	0
Red Basin		0	0	0	0	0	0	0	0
Total Mining Demand		0	0	0	0	0	0	0	0
Mining Supply									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Mining Supply				0	0	0	0	0	0
Mining Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Canadian Basin		0	0	0	0	0	0	0	0
Red Basin		6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
Total Beef Feedlot Livestock Demand		6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
Beef Feedlot Livestock Supply									
Canadian Basin				0	0	0	0	0	0
Red Basin	Ogallala			8,210	9,528	11,059	12,216	13,492	14,903

Table 4-7 Projected Water Demands, Supplies, and Needs Deaf Smith County Llano Estacado Region										
		Total in	Total in	Projections						
Basin	Source	1990	1996	2000	2010	2020	2030	2040	2050
		(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Total Beef Feedlot Livestock Supply				8,210	9,528	11,059	12,216	13,492	14,903

Table 4-7
Projected Water Demands, Supplies, and Needs
Deaf Smith County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Beef Feedlot Livestock Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Canadian Basin		76	80	82	87	93	99	106	113
Red Basin		1,263	1,328	1,354	1,454	1,559	1,663	1,777	1,906
Total Range & All Other Livestock Demand		1,339	1,408	1,436	1,541	1,652	1,762	1,883	2,019
Range & All Other Livestock Supply									
Canadian Basin	Local			82	87	93	99	106	113
Red Basin	Local			1,354	1,454	1,559	1,663	1,777	1,906
Total Range & All Other Livestock Supply				1,436	1,541	1,652	1,762	1,883	2,019
Range & All Other Livestock Surplus/Shortage									
Canadian Basin				0	0	0	0	0	0
Red Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		4,409	3,749	5,024	5,304	5,503	5,673	5,836	6,081
Industrial		498	1,394	537	575	603	626	679	730
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
Range & All Other Livestock		1,339	1,408	1,436	1,541	1,652	1,762	1,883	2,019
Total County Demand		298,239	296,429	266,319	260,104	254,271	248,271	242,661	237,510
Total Supply									
Municipal				5,024	5,304	5,503	3,157	3,240	3,364
Industrial				537	575	603	626	679	730
Steam-Electric				0	0	0	0	0	0
Irrigation				251,112	243,156	235,454	227,994	220,771	213,777
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				8,210	9,528	11,059	12,216	13,492	14,903
Range & All Other Livestock				1,436	1,541	1,652	1,762	1,883	2,019
Total County Supply				266,319	260,104	254,271	245,755	240,065	234,793
Total Surplus/Shortage									
Municipal				0	0	0	-2,516	-2,596	-2,717
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	0	0	-2,516	-2,596	-2,717
Total Basin Demand									
Canadian									
Municipal		3	4	4	4	4	4	4	4
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		0	0	0	0	0	0	0	0
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		0	0	82	87	93	99	106	113
Total Canadian Basin Demand		3	4	86	91	97	103	110	117
Red									
Municipal		4,406	3,745	5,020	5,300	5,499	5,669	5,832	6,077
Industrial		498	1,394	537	575	603	626	679	730
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		285,459	282,026	251,112	243,156	235,454	227,994	220,771	213,777
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		6,534	7,852	8,210	9,528	11,059	12,216	13,492	14,903
Range & All Other Livestock		1,263	1,328	1,354	1,454	1,559	1,663	1,777	1,906
Total Red Basin Demand		298,160	296,345	266,233	260,013	254,174	248,168	242,551	237,393
Total Basin Supply									
Canadian									
Municipal				4	4	4	4	4	4
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				82	87	93	99	106	113

Table 4-7											
Projected Water Demands, Supplies, and Needs											
Deaf Smith County											
Llano Estacado Region											
			Total in	**Total in**	**Projections**						
Basin		**Source**	**1990**	**1996**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
			(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**
Total Canadian Basin Supply					86	91	97	103	110	117

Table 4-7
Projected Water Demands, Supplies, and Needs
Deaf Smith County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Red									
Municipal				5,020	5,300	5,499	3,153	3,236	3,360
Industrial				537	575	603	626	679	730
Steam-Electric				0	0	0	0	0	0
Irrigation				251,112	243,156	235,454	227,994	220,771	213,777
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				8,210	9,528	11,059	12,216	13,492	14,903
Range & All Other Livestock				1,354	1,454	1,559	1,663	1,777	1,906
Total Red Basin Supply				266,233	260,013	254,174	245,652	239,955	234,676
Total Basin Surplus/Shortage									
Canadian									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Canadian Basin Surplus/Shortage				0	0	0	0	0	0
Red									
Municipal				0	0	0	-2,516	-2,596	-2,717
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	-2,516	-2,596	-2,717

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from T.J. Powers & Co., Nutra-Feeds, Caviness Meat Packing Co., Hereford Grain Corp., Dick Barrett Produce, City of Hereford, M.W. Carrot Inc., M. Bradford Cattle Truck Washing, and Hereford Bi-Products. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held constant throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

[5] Hereford is obtaining a part of its municipal water from the Santa Rosa Formation. Although studies in which the quantity of water available from the Santa Rosa have not been completed, the information available indicates that the aquifer can supply the quantities shown here from the projection period.

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Table 4-8 Projected Water Demands, Supplies, and Needs Dickens County Llano Estacado Region										
			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				1,682	1,682	1,682	1,682	1,682	1,682
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				1,682	1,682	1,682	1,682	1,682	1,682
	Seymour Aquifer				7,937	7,937	7,937	5,217	5,217	5,217
	Local Surface	Stock Tanks and Windmills			227	246	265	284	306	329
	Other Surface				0	0	0	0	0	0
	Total Supply				9,846	9,865	9,884	7,183	7,205	7,228
	Total Demand from Ogallala				1,679	1,628	1,578	1,531	1,485	1,441
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				2,524	2,524	2,524	2,524	2,524	2,524
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				2,524	2,524	2,524	2,524	2,524	2,524
	Seymour Aquifer				4,348	4,348	4,348	2,858	2,858	2,858
	Local Surface	Stock Tanks and Windmills			391	421	450	483	519	558
	Other Surface	White River Reservoir			369	369	369	369	369	369
	Total Supply				7,632	7,662	7,691	6,234	6,270	6,309
	Total Demand from Ogallala				2,486	2,379	2,277	2,187	2,102	2,024
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				4,206	4,206	4,206	4,206	4,206	4,206
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				4,206	4,206	4,206	4,206	4,206	4,206
	Seymour Aquifer				12,285	12,285	12,285	8,075	8,075	8,075
	Local Surface	Stock Tanks and Windmills			618	667	715	767	825	887
	Other Surface	White River Reservoir			369	369	369	369	369	369
	Total Supply				17,478	17,527	17,575	13,417	13,475	13,537
	Total Demand from Ogallala				4,165	4,007	3,855	3,718	3,587	3,465
WATER DEMANDS										
Municipal Demand										
Red Basin										
Rural			34	81	49	47	44	43	41	40
	Subtotal		34	81	49	47	44	43	41	40
Brazos Basin										
Dickens			99	105	91	86	81	80	78	76
Spur			251	306	245	234	221	215	210	207
Rural			124	178	109	105	98	95	90	88
	Subtotal		474	589	445	425	400	390	378	371
Total Municipal Demand			508	670	494	472	444	433	419	411
Municipal Existing Supply										
Red Basin										
Rural		Ogallala			49	47	44	43	41	40
	Subtotal				49	47	44	43	41	40
Brazos Basin										
Dickens		Seymour			91	86	81	80	78	76
Spur		White River Reservoir			369	369	369	369	369	369
Rural		Ogallala			109	105	98	95	90	88
	Subtotal				569	560	548	544	537	533
Total Municipal Existing Supply					618	607	592	587	578	573
Municipal Surplus/Shortage										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Dickens					0	0	0	0	0	0
Spur					124	135	148	154	159	162
Rural					0	0	0	0	0	0
	Subtotal				124	135	148	154	159	162
Total Municipal Surplus/Shortage					124	135	148	154	159	162

Table 4-8
Projected Water Demands, Supplies, and Needs
Dickens County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Municipal New Supply Need										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Dickens					0	0	0	0	0	0
Spur					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			0	0	0	0	0	0	0	0
Industrial Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			2,055	2,907	1,630	1,581	1,534	1,488	1,444	1,401
Brazos Basin			2,724	5,644	2,162	2,098	2,035	1,975	1,916	1,858
Total Irrigation Demand			4,779	8,551	3,792	3,679	3,569	3,463	3,360	3,259
Irrigation Supply										
Red Basin		Ogallala			1,630	1,581	1,534	1,488	1,444	1,401
Brazos Basin		Ogallala			2,162	2,098	2,035	1,975	1,916	1,858
Total Irrigation Supply					3,792	3,679	3,569	3,463	3,360	3,259
Irrigation Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					0	0	0	0	0	0
Mining Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			13	32	215	176	144	117	96	78
Total Mining Demand			13	32	215	176	144	117	96	78

Table 4-8
Projected Water Demands, Supplies, and Needs
Dickens County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin	Ogallala			215	176	144	117	96	78
Total Mining Supply				215	176	144	117	96	78
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Brazos Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		213	224	227	246	265	284	306	329
Brazos Basin		362	381	391	421	450	483	519	558
Total Range & All Other Livestock Demand		575	605	618	667	715	767	825	887
Range & All Other Livestock Supply									
Red Basin	Local			227	246	265	284	306	329
Brazos Basin	Local			391	421	450	483	519	558
Total Range & All Other Livestock Supply				618	667	715	767	825	887
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		508	670	494	472	444	433	419	411
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		4,779	8,551	3,792	3,679	3,569	3,463	3,360	3,259
Mining		13	32	215	176	144	117	96	78
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		575	605	618	667	715	767	825	887
Total County Demand		5,875	9,858	5,119	4,994	4,872	4,780	4,700	4,635
Total Supply									
Municipal				618	607	592	587	578	573
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				3,792	3,679	3,569	3,463	3,360	3,259
Mining				215	176	144	117	96	78
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				618	667	715	767	825	887
Total County Supply				5,243	5,129	5,020	4,934	4,859	4,797
Total Surplus/Shortage									
Municipal				124	135	148	154	159	162
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				124	135	148	154	159	162
Total Basin Demand									
Red									
Municipal		34	81	49	47	44	43	41	40
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		2,055	2,907	1,630	1,581	1,534	1,488	1,444	1,401
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		213	224	227	246	265	284	306	329
Total Red Basin Demand		2,302	3,212	1,906	1,874	1,843	1,815	1,791	1,770

Table 4-8											
Projected Water Demands, Supplies, and Needs											
Dickens County											
Llano Estacado Region											
			Total in	Total in	Projections						
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050	
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	

Table 4-8
Projected Water Demands, Supplies, and Needs
Dickens County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos									
Municipal		474	589	445	425	400	390	378	371
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		2,724	5,644	2,162	2,098	2,035	1,975	1,916	1,858
Mining		13	32	215	176	144	117	96	78
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		362	381	391	421	450	483	519	558
Total Brazos Basin Demand		3,573	6,646	3,213	3,120	3,029	2,965	2,909	2,865
Total Basin Supply									
Red									
Municipal				49	47	44	43	41	40
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				1,630	1,581	1,534	1,488	1,444	1,401
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				227	246	265	284	306	329
Total Red Basin Supply				1,906	1,874	1,843	1,815	1,791	1,770
Brazos									
Municipal				569	560	548	544	537	533
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				2,162	2,098	2,035	1,975	1,916	1,858
Mining				215	176	144	117	96	78
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				391	421	450	483	519	558
Total Brazos Basin Supply				3,337	3,255	3,177	3,119	3,068	3,027
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	0	0	0
Brazos									
Municipal				124	135	148	154	159	162
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				124	135	148	154	159	162

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-9
Projected Water Demands, Supplies, and Needs
Floyd County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				39,928	39,928	39,928	39,928	39,928	39,928
	Aquifer Storage[2]	Net Depletion			59,287	53,359	48,023	43,220	38,898	35,009
	Subtotal GW (Ogallala)[3]				99,215	93,287	87,951	83,148	78,826	74,937
	Local Surface	Stock Tanks and Windmills			281	305	325	350	377	406
	Other Surface				0	0	0	0	0	0
	Total Supply				99,496	93,592	88,276	83,498	79,203	75,343
	Total Demand from Ogallala				66,873	64,197	61,636	59,183	56,824	54,561
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				23,793	23,793	23,793	23,793	23,793	23,793
	Aquifer Storage[2]	Net Depletion			35,330	31,797	28,617	25,755	23,180	20,862
	Subtotal GW (Ogallala)[3]				59,123	55,590	52,410	49,548	46,973	44,655
	Local Surface	Stock Tanks and Windmills			223	240	259	279	299	323
	Other Surface	Lake Mackenzie			362	362	362	362	362	362
	Reclaimed Water[4]				498	498	498	498	498	498
	Total Supply				60,206	56,690	53,529	50,687	48,132	45,838
	Total Demand from Ogallala				58,973	55,440	52,260	49,548	46,973	44,655
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				63,721	63,721	63,721	63,721	63,721	63,721
	Aquifer Storage[2]	Net Depletion			94,617	85,155	76,640	68,976	62,078	55,870
	Subtotal GW (Ogallala)[3]				158,338	148,876	140,361	132,697	125,799	119,591
	Local Surface	Stock Tanks and Windmills			504	545	584	629	676	729
	Other Surface	Lake Mackenzie			362	362	362	362	362	362
	Reclaimed Water[4]				498	498	498	498	498	498
	Total Supply				159,702	150,281	141,805	134,186	127,335	121,180
	Total Demand from Ogallala				125,846	119,637	113,896	108,731	103,797	99,216
WATER DEMANDS										
Municipal Demand										
Red Basin										
Rural			107	111	109	108	104	104	100	98
	Subtotal		107	111	109	108	104	104	100	98
Brazos Basin										
Floydada			570	620	622	621	601	586	552	531
Lockney			321	381	374	374	362	340	307	290
Rural			187	184	182	181	174	173	166	164
	Subtotal		1,078	1,185	1,178	1,176	1,137	1,099	1,025	985
Total Municipal Demand			1,185	1,296	1,287	1,284	1,241	1,203	1,125	1,083
Municipal Existing Supply										
Red Basin										
Rural		Ogallala			109	108	104	104	100	98
	Subtotal				109	108	104	104	100	98
Brazos Basin										
Floydada		Ogallala			410	409	389	374	340	319
		Lake Mackenzie			212	212	212	212	212	212
Floydada Subtotal					622	621	601	586	552	531
Lockney		Ogallala			224	224	212	0	0	0
		Lake Mackenzie			150	150	150	150	150	150
Lockney Subtotal					374	374	362	150	150	150
Rural		Ogallala			182	181	174	173	166	164
	Subtotal				1,178	1,176	1,137	909	868	845
Total Municipal Existing Supply					1,287	1,284	1,241	1,013	968	943
Municipal Surplus/Shortage										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Floydada					0	0	0	0	0	0
Lockney					0	0	0	-190	-157	-140
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	-190	-157	-140
Total Municipal Surplus/Shortage					0	0	0	-190	-157	-140
Municipal New Supply Need										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0

Table 4-9
Projected Water Demands, Supplies, and Needs
Floyd County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos Basin										
Floydada					0	0	0	0	0	0
Lockney					0	0	0	190	157	140
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	190	157	140
Total Municipal New Supply Need					0	0	0	190	157	140
Industrial Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			1	53	1	1	2	2	2	2
Total Industrial Demand			1	53	1	1	2	2	2	2
Industrial Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin		Ogallala			1	1	2	2	2	2
Total Industrial Existing Supply					1	1	2	2	2	2
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			59,268	65,189	66,737	64,079	61,527	59,076	56,723	54,463
Brazos Basin			72,438	159,602	81,567	78,318	75,199	72,204	69,328	66,566
Total Irrigation Demand			131,706	224,791	148,304	142,397	136,726	131,280	126,051	121,029
Irrigation Supply										
Red Basin		Ogallala			66,737	64,079	61,527	59,076	56,723	54,463
Brazos Basin		Ogallala			57,502	53,871	50,613	48,041	45,410	43,009
		Reclaimed Water			498	498	498	498	498	498
Brazos Basin Subtotal					58,000	54,369	51,111	48,539	45,908	43,507
Total Irrigation Supply					124,737	118,448	112,638	107,615	102,631	97,970
Irrigation Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					-23,567	-23,949	-24,088	-23,665	-23,420	-23,059
Total Irrigation Surplus/Shortage					-23,567	-23,949	-24,088	-23,665	-23,420	-23,059
Mining Demand										
Red Basin			30	29	27	10	5	3	1	0
Brazos Basin			33	35	39	40	42	43	44	45
Total Mining Demand			63	64	66	50	47	46	45	45
Mining Supply										
Red Basin		Ogallala			27	10	5	3	1	0
Brazos Basin		Ogallala			39	40	42	43	44	45
Total Mining Supply					66	50	47	46	45	45
Mining Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Mining Surplus/Shortage					0	0	0	0	0	0

Table 4-9
Projected Water Demands, Supplies, and Needs
Floyd County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Brazos Basin		854	588	615	714	828	915	1,011	1,116
Total Beef Feedlot Livestock Demand		854	588	615	714	828	915	1,011	1,116
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin	Ogallala			615	714	828	915	1,011	1,116
Total Beef Feedlot Livestock Supply				615	714	828	915	1,011	1,116
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		259	276	281	305	325	350	377	406
Brazos Basin		210	217	223	240	259	279	299	323
Total Range & All Other Livestock Demand		469	493	504	545	584	629	676	729
Range & All Other Livestock Supply									
Red Basin	Local			281	305	325	350	377	406
Brazos Basin	Local			223	240	259	279	299	323
Total Range & All Other Livestock Supply				504	545	584	629	676	729
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,185	1,296	1,287	1,284	1,241	1,203	1,125	1,083
Industrial		1	53	1	1	2	2	2	2
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		131,706	224,791	148,304	142,397	136,726	131,280	126,051	121,029
Mining		63	64	66	50	47	46	45	45
Beef Feedlot Livestock		854	588	615	714	828	915	1,011	1,116
Range & All Other Livestock		469	493	504	545	584	629	676	729
Total County Demand		134,278	227,285	150,777	144,991	139,428	134,075	128,910	124,004
Total Supply									
Municipal				1,287	1,284	1,241	1,013	968	943
Industrial				1	1	2	2	2	2
Steam-Electric				0	0	0	0	0	0
Irrigation				124,737	118,448	112,638	107,615	102,631	97,970
Mining				66	50	47	46	45	45
Beef Feedlot Livestock				615	714	828	915	1,011	1,116
Range & All Other Livestock				504	545	584	629	676	729
Total County Supply				127,210	121,042	115,340	110,220	105,333	100,805
Total Surplus/Shortage									
Municipal				0	0	0	-190	-157	-140
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-23,567	-23,949	-24,088	-23,665	-23,420	-23,059
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-23,567	-23,949	-24,088	-23,855	-23,577	-23,199
Total Basin Demand									
Red									
Municipal		107	111	109	108	104	104	100	98
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		59,268	65,189	66,737	64,079	61,527	59,076	56,723	54,463
Mining		30	29	27	10	5	3	1	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		259	276	281	305	325	350	377	406
Total Red Basin Demand		59,664	65,605	67,154	64,502	61,961	59,533	57,201	54,967
Brazos									
Municipal		1,078	1,185	1,178	1,176	1,137	1,099	1,025	985
Industrial		1	53	1	1	2	2	2	2
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		72,438	159,602	81,567	78,318	75,199	72,204	69,328	66,566
Mining		33	35	39	40	42	43	44	45
Beef Feedlot Livestock		854	588	615	714	828	915	1,011	1,116
Range & All Other Livestock		210	217	223	240	259	279	299	323
Total Brazos Basin Demand		74,614	161,680	83,623	80,489	77,467	74,542	71,709	69,037

Table 4-9 Projected Water Demands, Supplies, and Needs Floyd County Llano Estacado Region											
			Total in	Total in	Projections						
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050	
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	

Table 4-9
Projected Water Demands, Supplies, and Needs
Floyd County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Supply									
Red									
Municipal				109	108	104	104	100	98
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				66,737	64,079	61,527	59,076	56,723	54,463
Mining				27	10	5	3	1	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				281	305	325	350	377	406
Total Red Basin Supply				67,154	64,502	61,961	59,533	57,201	54,967
Brazos									
Municipal				1,178	1,176	1,137	909	868	845
Industrial				1	1	2	2	2	2
Steam-Electric				0	0	0	0	0	0
Irrigation				58,000	54,369	51,111	48,539	45,908	43,507
Mining				39	40	42	43	44	45
Beef Feedlot Livestock				615	714	828	915	1,011	1,116
Range & All Other Livestock				223	240	259	279	299	323
Total Brazos Basin Supply				60,056	56,540	53,379	50,687	48,132	45,838
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	0	0	0
Brazos									
Municipal				0	0	0	-190	-157	-140
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-23,567	-23,949	-24,088	-23,665	-23,420	-23,059
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-23,567	-23,949	-24,088	-23,855	-23,577	-23,199

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from the City of Lockney and the City of Floydada. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste dicharge permit.

Table 4-10
Projected Water Demands, Supplies, and Needs
Gaines County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				139,860	139,860	139,860	139,860	139,860	139,860
	Aquifer Storage[2]	Net Depletion			228,840	208,947	190,128	172,367	155,521	139,584
	Subtotal GW (Ogallala)[3]				368,700	348,807	329,988	312,227	295,381	279,444
	Local Surface	Stock Tanks and Windmills			347	368	390	415	443	473
	Other Surface				0	0	0	0	0	0
	Total Supply				369,047	349,175	330,378	312,642	295,824	279,917
	Total Demand from Ogallala				368,353	347,858	328,938	311,464	294,924	279,414
WATER DEMANDS										
Municipal Demand										
Colorado Basin										
Seagraves			555	495	559	581	555	547	535	533
Seminole			1,676	1,688	1,945	2,034	2,047	2,056	2,080	2,123
Rural			689	745	701	680	655	622	579	557
	Subtotal		2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
Total Municipal Demand			2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
Municipal Existing Supply										
Colorado Basin										
Seagraves		Ogallala			559	0	0	0	0	0
Seminole		Ogallala			1,945	2,034	2,047	2,056	2,080	2,123
Rural		Ogallala			701	680	655	622	579	557
	Subtotal				3,205	2,714	2,702	2,678	2,659	2,680
Total Municipal Existing Supply					3,205	2,714	2,702	2,678	2,659	2,680
Municipal Surplus/Shortage										
Colorado Basin										
Seagraves					0	-581	-555	-547	-535	-533
Seminole					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	-581	-555	-547	-535	-533
Total Municipal Surplus/Shortage					0	-581	-555	-547	-535	-533
Municipal New Supply Need										
Colorado Basin										
Seagraves					0	581	555	547	535	533
Seminole					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	581	555	547	535	533
Total Municipal New Supply Need					0	581	555	547	535	533
Industrial Demand										
Colorado Basin			303	412	331	358	205	381	412	442
Total Industrial Demand			303	412	331	358	205	381	412	442
Industrial Existing Supply										
Colorado Basin		Ogallala			331	358	205	381	412	442
Total Industrial Existing Supply					331	358	205	381	412	442
Industrial Surplus/Shortage										
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0

Table 4-10
Projected Water Demands, Supplies, and Needs
Gaines County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Steam-Electric Existing Supply									
Colorado Basin				0	0	0	0	0	0
Total Steam-Electric Existing Supply				0	0	0	0	0	0
Steam-Electric Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage				0	0	0	0	0	0
Steam-Electric New Supply Need									
Colorado Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Colorado Basin		392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
Total Irrigation Demand		392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
Irrigation Supply									
Colorado Basin	Ogallala			355,323	336,817	319,275	302,647	286,885	271,943
Total Irrigation Supply				355,323	336,817	319,275	302,647	286,885	271,943
Irrigation Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Colorado Basin		3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
Total Mining Demand		3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
Mining Supply									
Colorado Basin	Ogallala			8,879	7,255	5,928	4,843	3,957	3,233
Total Mining Supply				8,879	7,255	5,928	4,843	3,957	3,233
Mining Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Colorado Basin		482	588	615	714	828	915	1,011	1,116
Total Beef Feedlot Livestock Demand		482	588	615	714	828	915	1,011	1,116
Beef Feedlot Livestock Supply									
Colorado Basin	Ogallala			615	714	828	915	1,011	1,116
Total Beef Feedlot Livestock Supply				615	714	828	915	1,011	1,116
Beef Feedlot Livestock Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Colorado Basin		322	336	347	368	390	415	443	473
Total Range & All Other Livestock Demand		322	336	347	368	390	415	443	473
Range & All Other Livestock Supply									
Colorado Basin	Local			347	368	390	415	443	473
Total Range & All Other Livestock Supply				347	368	390	415	443	473
Range & All Other Livestock Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
Industrial		303	412	331	358	205	381	412	442
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
Mining		3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
Beef Feedlot Livestock		482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock		322	336	347	368	390	415	443	473
Total County Demand		400,317	427,239	368,700	348,807	329,883	312,426	295,902	280,420

Table 4-10
Projected Water Demands, Supplies, and Needs
Gaines County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Supply									
Municipal				3,205	2,714	2,702	2,678	2,659	2,680
Industrial				331	358	205	381	412	442
Steam-Electric				0	0	0	0	0	0
Irrigation				355,323	336,817	319,275	302,647	286,885	271,943
Mining				8,879	7,255	5,928	4,843	3,957	3,233
Beef Feedlot Livestock				615	714	828	915	1,011	1,116
Range & All Other Livestock				347	368	390	415	443	473
Total County Supply				368,700	348,226	329,328	311,879	295,367	279,887
Total Surplus/Shortage									
Municipal				0	-581	-555	-547	-535	-533
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	-581	-555	-547	-535	-533
Total Basin Demand									
Colorado									
Municipal		2,920	2,928	3,205	3,295	3,257	3,225	3,194	3,213
Industrial		303	412	331	358	205	381	412	442
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
Mining		3,340	7,769	8,879	7,255	5,928	4,843	3,957	3,233
Beef Feedlot Livestock		482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock		322	336	347	368	390	415	443	473
Total Colorado Basin Demand		400,317	427,239	368,700	348,807	329,883	312,426	295,902	280,420
Total Basin Supply									
Colorado									
Municipal				3,205	2,714	2,702	2,678	2,659	2,680
Industrial				331	358	205	381	412	442
Steam-Electric				0	0	0	0	0	0
Irrigation				355,323	336,817	319,275	302,647	286,885	271,943
Mining				8,879	7,255	5,928	4,843	3,957	3,233
Beef Feedlot Livestock				615	714	828	915	1,011	1,116
Range & All Other Livestock				347	368	390	415	443	473
Total Colorado Basin Supply				368,700	348,226	329,328	311,879	295,367	279,887
Total Basin Surplus/Shortage									
Colorado									
Municipal				0	-581	-555	-547	-535	-533
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				0	-581	-555	-547	-535	-533

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-11
Projected Water Demands, Supplies, and Needs
Garza County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				4,502	4,502	4,502	4,502	4,502	4,502
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				4,502	4,502	4,502	4,502	4,502	4,502
	Dockum Aquifer				136	136	136	136	136	136
	Local Surface	Stock Tanks and Windmills			555	591	621	654	690	730
	Other Surface	White River Reservoir			1,021	1,021	1,021	1,021	1,021	1,021
	Total Supply				6,214	6,250	6,280	6,313	6,349	6,389
	Total Demand from Ogallala				4,502	4,502	4,168	3,792	3,462	3,169
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				23	23	23	23	23	23
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				23	23	23	23	23	23
	Local Surface	Stock Tanks and Windmills			0	0	0	0	0	0
	Other Surface				0	0	0	0	0	0
	Total Supply				23	23	23	23	23	23
	Total Demand from Ogallala				1	1	1	1	1	1
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				4,525	4,525	4,525	4,525	4,525	4,525
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				4,525	4,525	4,525	4,525	4,525	4,525
	Dockum Aquifer				136	136	136	136	136	136
	Local Surface	Stock Tanks and Windmills			555	591	621	654	690	730
	Other Surface	White River Reservoir			1,021	1,021	1,021	1,021	1,021	1,021
	Total Supply				6,237	6,273	6,303	6,336	6,372	6,412
	Total Demand from Ogallala				4,503	4,503	4,169	3,793	3,463	3,170
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Post			770	386	967	971	942	902	857	832
Rural			188	173	190	188	180	169	158	148
	Subtotal		958	559	1,157	1,159	1,122	1,071	1,015	980
Colorado Basin										
Rural			1	1	1	1	1	1	1	1
	Subtotal		1	1	1	1	1	1	1	1
Total Municipal Demand			959	560	1,158	1,160	1,123	1,072	1,016	981
Municipal Existing Supply										
Brazos Basin										
Post		White River Reservoir			1,021	1,021	1,021	1,021	1,021	1,021
Rural		Ogallala			154	152	144	133	122	112
		Dockum			36	36	36	36	36	36
Rural Subtotal					190	188	180	169	158	148
	Subtotal				1,211	1,209	1,201	1,190	1,179	1,169
Colorado Basin										
Rural		Ogallala			1	1	1	1	1	1
	Subtotal				1	1	1	1	1	1
Total Municipal Existing Supply					1,212	1,210	1,202	1,191	1,180	1,170
Municipal Surplus/Shortage										
Brazos Basin										
Post					54	50	79	119	164	189
Rural					0	0	0	0	0	0
	Subtotal				54	50	79	119	164	189
Colorado Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					54	50	79	119	164	189
Municipal New Supply Need										
Brazos Basin										
Post					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0

Table 4-11
Projected Water Demands, Supplies, and Needs
Garza County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Brazos Basin			2	2	2	3	3	4	5	5
Colorado Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			2	2	2	3	3	4	5	5
Industrial Existing Supply										
Brazos Basin		Ogallala			2	3	3	4	5	5
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					2	3	3	4	5	5
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
Colorado Basin			0	0	0	0	0	0	0	0
Total Irrigation Demand			4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
Irrigation Supply										
Brazos Basin		Ogallala			2,859	3,132	3,028	2,844	2,672	2,510
		Dockum			100	100	100	100	100	100
Brazos Basin Subtotal					2,959	3,232	3,128	2,944	2,772	2,610
Colorado Basin					0	0	0	0	0	0
Total Irrigation Supply					2,959	3,232	3,128	2,944	2,772	2,610
Irrigation Surplus/Shortage										
Brazos Basin					-570	-90	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					-570	-90	0	0	0	0
Mining Demand										
Brazos Basin			575	1,138	1,487	1,215	993	811	663	542
Colorado Basin			0	0	0	0	0	0	0	0
Total Mining Demand			575	1,138	1,487	1,215	993	811	663	542
Mining Supply										
Brazos Basin		Ogallala			1,487	1,215	993	811	663	542
Colorado Basin					0	0	0	0	0	0
Total Mining Supply					1,487	1,215	993	811	663	542

Table 4-11
Projected Water Demands, Supplies, and Needs
Garza County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		0	0	0	0	0	0	0	0
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		528	547	555	591	621	654	690	730
Colorado Basin		0	0	0	0	0	0	0	0
Total Range & All Other Livestock Demand		528	547	555	591	621	654	690	730
Range & All Other Livestock Supply									
Brazos Basin	Local			555	591	621	654	690	730
Colorado Basin	Local			0	0	0	0	0	0
Total Range & All Other Livestock Supply				555	591	621	654	690	730
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		959	560	1,158	1,160	1,123	1,072	1,016	981
Industrial		2	2	2	3	3	4	5	5
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
Mining		575	1,138	1,487	1,215	993	811	663	542
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		528	547	555	591	621	654	690	730
Total County Demand		6,447	12,772	6,731	6,291	5,868	5,485	5,146	4,868
Total Supply									
Municipal				1,212	1,210	1,202	1,191	1,180	1,170
Industrial				2	3	3	4	5	5
Steam-Electric				0	0	0	0	0	0
Irrigation				2,959	3,232	3,128	2,944	2,772	2,610
Mining				1,487	1,215	993	811	663	542
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				555	591	621	654	690	730
Total County Supply				6,215	6,251	5,947	5,604	5,310	5,057
Total Surplus/Shortage									
Municipal				54	50	79	119	164	189
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-570	-90	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-516	-40	79	119	164	189
Total Basin Demand									
Brazos									
Municipal		958	559	1,157	1,159	1,122	1,071	1,015	980
Industrial		2	2	2	3	3	4	5	5
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
Mining		575	1,138	1,487	1,215	993	811	663	542
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		528	547	555	591	621	654	690	730
Total Brazos Basin Demand		6,446	12,771	6,730	6,290	5,867	5,484	5,145	4,867

Table 4-11
Projected Water Demands, Supplies, and Needs
Garza County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado									
Municipal		0	0	1	1	1	1	1	1
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		0	0	0	0	0	0	0	0
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		0	0	0	0	0	0	0	0
Total Colorado Basin Demand		0	0	1	1	1	1	1	1
Total Basin Supply									
Brazos									
Municipal				1,211	1,209	1,201	1,190	1,179	1,169
Industrial				2	3	3	4	5	5
Steam-Electric				0	0	0	0	0	0
Irrigation				2,959	3,232	3,128	2,944	2,772	2,610
Mining				1,487	1,215	993	811	663	542
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				555	591	621	654	690	730
Total Brazos Basin Supply				6,214	6,250	5,946	5,603	5,309	5,056
Colorado									
Municipal				1	1	1	1	1	1
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Supply				1	1	1	1	1	1
Total Basin Surplus/Shortage									
Brazos									
Municipal				54	50	79	119	164	189
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-570	-90	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-516	-40	79	119	164	189
Colorado									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				0	0	0	0	0	0

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero
for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-12
Projected Water Demands, Supplies, and Needs
Hale County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				734	734	734	734	734	734
	Aquifer Storage[2]	Net Depletion			695	625	563	507	456	410
	Subtotal GW (Ogallala)[3]				1,429	1,359	1,297	1,241	1,190	1,144
	Local Surface	Stock Tanks and Windmills			1	1	1	1	1	1
	Other Surface				0	0	0	0	0	0
	Total Supply				1,430	1,360	1,298	1,242	1,191	1,145
	Total Demand from Ogallala				1,429	1,359	1,297	1,241	1,190	1,144
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				192,666	192,666	192,666	192,666	192,666	192,666
	Aquifer Storage[2]	Net Depletion			182,445	164,201	147,781	133,002	119,702	107,732
	Subtotal GW (Ogallala)[3]				375,111	356,867	340,447	325,668	312,368	300,398
	Other Ground	Ogallala (CRMWA - Roberts Co.)			1,476	1,476	1,476	1,476	1,476	1,476
	Local Surface	Stock Tanks and Windmills			227	247	265	284	304	328
	Other Surface	Lake Meredith (CRMWA)			2,805	2,805	2,805	2,805	2,805	2,805
	Reclaimed Water[4]				4,786	4,786	4,786	4,786	4,786	4,786
	Total Supply				384,405	366,181	349,779	335,019	321,739	309,793
	Total Demand from Ogallala				362,956	351,257	337,930	323,165	310,058	298,223
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				193,400	193,400	193,400	193,400	193,400	193,400
	Aquifer Storage[2]	Net Depletion			183,140	164,826	148,343	133,509	120,158	108,142
	Subtotal GW (Ogallala)[3]				376,540	358,226	341,743	326,909	313,558	301,542
	Other Ground	Ogallala (CRMWA - Roberts Co.)			1,476	1,476	1,476	1,476	1,476	1,476
	Local Surface	Stock Tanks and Windmills			228	248	266	285	305	329
	Other Surface	Lake Meredith (CRMWA)			2,805	2,805	2,805	2,805	2,805	2,805
	Reclaimed Water[4]				4,786	4,786	4,786	4,786	4,786	4,786
	Total Supply				385,835	367,541	351,076	336,261	322,930	310,938
	Total Demand from Ogallala				364,385	352,616	339,227	324,406	311,248	299,367
WATER DEMANDS										
Municipal Demand										
Red Basin										
Rural			6	10	7	7	7	8	8	8
	Subtotal		6	10	7	7	7	8	8	8
Brazos Basin										
Abernathy (part)			395	427	398	399	403	406	403	405
Hale Center			410	472	406	408	410	415	394	384
Petersburg			222	219	244	264	277	298	313	333
Plainview			4,421	4,431	4,505	4,416	4,320	4,267	4,074	3,939
Rural			921	1,583	1,061	1,123	1,173	1,233	1,299	1,375
	Subtotal		6,369	7,132	6,614	6,610	6,583	6,619	6,483	6,436
Total Municipal Demand			6,375	7,142	6,621	6,617	6,590	6,627	6,491	6,444
Municipal Existing Supply										
Red Basin										
Rural		Ogallala			7	7	7	8	8	8
	Subtotal				7	7	7	8	8	8
Brazos Basin										
Abernathy (part)		Ogallala			398	399	0	0	0	0
Hale Center		Ogallala			406	408	410	415	0	0
Petersburg		Ogallala			244	264	277	298	313	333
Plainview		Ogallala			224	135	39	0	0	0
		Lake Meredith (CRMWA)			2,805	2,805	2,805	2,805	2,805	2,805
		Ogallala (CRMWA - Roberts Co.)			1,476	1,476	1,476	1,476	1,476	1,476
Plainview Subtotal					4,505	4,416	4,320	4,281	4,281	4,281
Rural		Ogallala			1,061	1,123	1,173	1,233	1,299	1,375
	Subtotal				6,614	6,610	6,180	6,227	5,893	5,989
Total Municipal Existing Supply					6,621	6,617	6,187	6,235	5,901	5,997
Municipal Surplus/Shortage										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Abernathy (part)					0	0	-403	-406	-403	-405
Hale Center					0	0	0	0	-394	-384
Petersburg					0	0	0	0	0	0
Plainview					0	0	0	14	207	342
Rural					0	0	0	0	0	0
	Subtotal				0	0	-403	-392	-590	-447

Table 4-12

Projected Water Demands, Supplies, and Needs

Hale County

Llano Estacado Region

			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Total Municipal Surplus/Shortage					0	0	-403	-392	-590	-447

Table 4-12
Projected Water Demands, Supplies, and Needs
Hale County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Municipal New Supply Need										
Red Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Brazos Basin										
Abernathy (part)					0	0	403	406	403	405
Hale Center					0	0	0	0	394	384
Petersburg					0	0	0	0	0	0
Plainview					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	403	406	797	789
Total Municipal New Supply Need					0	0	403	406	797	789
Industrial Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
Total Industrial Demand			1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
Industrial Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin		Ogallala			1,643	1,774	1,904	2,028	2,238	3,739
Total Industrial Existing Supply					1,643	1,774	1,904	2,028	2,238	3,739
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			4,619	4,336	3,656	3,535	3,418	3,304	3,195	3,089
Brazos Basin			457,312	429,297	361,938	349,946	338,351	327,141	316,302	305,822
Total Irrigation Demand			461,931	433,633	365,594	353,481	341,769	330,445	319,497	308,911
Irrigation Supply										
Red Basin		Ogallala			1,422	1,352	1,290	1,233	1,182	1,136
Brazos Basin		Ogallala			357,152	345,160	331,916	316,820	303,647	289,994
		Reclaimed Water			4,786	4,786	4,786	4,786	4,786	4,786
Brazos Basin Subtotal					361,938	349,946	336,702	321,606	308,433	294,780
Total Irrigation Supply					363,360	351,298	337,992	322,839	309,615	295,916
Irrigation Surplus/Shortage										
Red Basin					-2,234	-2,183	-2,128	-2,071	-2,013	-1,953
Brazos Basin					0	0	-1,649	-5,535	-7,869	-11,042
Total Irrigation Surplus/Shortage					-2,234	-2,183	-3,777	-7,606	-9,882	-12,995
Mining Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			166	312	370	302	247	202	165	135
Total Mining Demand			166	312	370	302	247	202	165	135
Mining Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin		Ogallala			370	302	247	202	165	135
Total Mining Supply					370	302	247	202	165	135

Table 4-12
Projected Water Demands, Supplies, and Needs
Hale County
Llano Estacado Region

			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)

Table 4-12
Projected Water Demands, Supplies, and Needs
Hale County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Brazos Basin		1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
Total Beef Feedlot Livestock Demand		1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin	Ogallala			1,458	1,692	1,964	2,169	2,396	2,647
Total Beef Feedlot Livestock Supply				1,458	1,692	1,964	2,169	2,396	2,647
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		0	1	1	1	1	1	1	1
Brazos Basin		214	222	227	247	265	284	304	328
Total Range & All Other Livestock Demand		214	223	228	248	266	285	305	329
Range & All Other Livestock Supply									
Red Basin	Local			1	1	1	1	1	1
Brazos Basin	Local			227	247	265	284	304	328
Total Range & All Other Livestock Supply				228	248	266	285	305	329
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		6,375	7,142	6,621	6,617	6,590	6,627	6,491	6,444
Industrial		1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		461,931	433,633	365,594	353,481	341,769	330,445	319,497	308,911
Mining		166	312	370	302	247	202	165	135
Beef Feedlot Livestock		1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
Range & All Other Livestock		214	223	228	248	266	285	305	329
Total County Demand		471,380	444,936	375,914	364,114	352,740	341,756	331,092	322,205
Total Supply									
Municipal				6,621	6,617	6,187	6,235	5,901	5,997
Industrial				1,643	1,774	1,904	2,028	2,238	3,739
Steam-Electric				0	0	0	0	0	0
Irrigation				363,360	351,298	337,992	322,839	309,615	295,916
Mining				370	302	247	202	165	135
Beef Feedlot Livestock				1,458	1,692	1,964	2,169	2,396	2,647
Range & All Other Livestock				228	248	266	285	305	329
Total County Supply				373,680	361,931	348,560	333,758	320,620	308,763
Total Surplus/Shortage									
Municipal				0	0	-403	-392	-590	-447
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-2,234	-2,183	-3,777	-7,606	-9,882	-12,995
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-2,234	-2,183	-4,180	-7,998	-10,472	-13,442
Total Basin Demand									
Red									
Municipal		6	10	7	7	7	8	8	8
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		4,619	4,336	3,656	3,535	3,418	3,304	3,195	3,089
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		0	1	1	1	1	1	1	1
Total Red Basin Demand		4,625	4,347	3,664	3,543	3,426	3,313	3,204	3,098

Table 4-12
Projected Water Demands, Supplies, and Needs
Hale County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Brazos									
Municipal		6,369	7,132	6,614	6,610	6,583	6,619	6,483	6,436
Industrial		1,521	2,232	1,643	1,774	1,904	2,028	2,238	3,739
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		457,312	429,297	361,938	349,946	338,351	327,141	316,302	305,822
Mining		166	312	370	302	247	202	165	135
Beef Feedlot Livestock		1,173	1,394	1,458	1,692	1,964	2,169	2,396	2,647
Range & All Other Livestock		214	222	227	247	265	284	304	328
Total Brazos Basin Demand		466,755	440,589	372,250	360,571	349,314	338,443	327,888	319,107
Total Basin Supply									
Red									
Municipal				7	7	7	8	8	8
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				1,422	1,352	1,290	1,233	1,182	1,136
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				1	1	1	1	1	1
Total Red Basin Supply				1,430	1,360	1,298	1,242	1,191	1,145
Brazos									
Municipal				6,614	6,610	6,180	6,227	5,893	5,989
Industrial				1,643	1,774	1,904	2,028	2,238	3,739
Steam-Electric				0	0	0	0	0	0
Irrigation				361,938	349,946	336,702	321,606	308,433	294,780
Mining				370	302	247	202	165	135
Beef Feedlot Livestock				1,458	1,692	1,964	2,169	2,396	2,647
Range & All Other Livestock				227	247	265	284	304	328
Total Brazos Basin Supply				372,250	360,571	347,262	332,516	319,429	307,618
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-2,234	-2,183	-2,128	-2,071	-2,013	-1,953
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				-2,234	-2,183	-2,128	-2,071	-2,013	-1,953
Brazos									
Municipal				0	0	-403	-392	-590	-447
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	-1,649	-5,535	-7,869	-11,042
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				0	0	-2,052	-5,927	-8,459	-11,489

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] The value is the sum of reclaimed water from the City of Petersburg, City of Abernathy, City of Hale Center, City of Plainview, City of Edmonson, Excel Corp., John's Washout, Azteca Milling Co., Southern Cotton Oil Mill, Panhandle Processing Co., and Walker Brothers Produce. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated at 75 percent of the maximum waste discharge permit.

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Table 4-13
Projected Water Demands, Supplies, and Needs
Hockley County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				89,392	89,392	89,392	89,392	89,392	89,392
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				89,392	89,392	89,392	89,392	89,392	89,392
	Other Ground	Ogallala (CRMWA - Roberts Co.)			1,116	1,116	1,116	1,116	1,116	1,116
	Local Surface	Stock Tanks and Windmills			208	219	230	241	252	266
	Other Surface	Lake Meredith (CRMWA)			2,120	2,120	2,120	2,120	2,120	2,120
	Reclaimed Water[5]				1,486	1,486	1,486	1,486	1,486	1,486
	Total Supply				94,322	94,333	94,344	94,355	94,366	94,380
	Total Demand from Ogallala				88,087	88,047	84,152	80,469	77,015	73,699
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				17,922	17,922	17,922	17,922	17,922	17,922
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				17,922	17,922	17,922	17,922	17,922	17,922
	Local Surface	Stock Tanks and Windmills			41	44	45	47	49	52
	Reclaimed Water[5]				156	156	156	156	156	156
	Total Supply				18,119	18,122	18,123	18,125	18,127	18,130
	Total Demand from Ogallala				11,651	10,809	9,706	9,118	8,585	8,151
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				107,314	107,314	107,314	107,314	107,314	107,314
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				107,314	107,314	107,314	107,314	107,314	107,314
	Other Ground	Ogallala (CRMWA - Roberts Co.)			1,116	1,116	1,116	1,116	1,116	1,116
	Local Surface	Stock Tanks and Windmills			249	263	275	288	301	318
	Other Surface	Lake Meredith (CRMWA)			2,120	2,120	2,120	2,120	2,120	2,120
	Reclaimed Water[5]				1,642	1,642	1,642	1,642	1,642	1,642
	Total Supply				112,441	112,455	112,467	112,480	112,493	112,510
	Total Demand from Ogallala				99,738	98,856	93,858	89,587	85,600	81,850
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Anton			200	201	263	258	258	253	243	237
Levelland			2,377	1,954	2,518	2,479	2,401	2,311	2,176	2,099
Rural			771	896	895	891	867	830	791	732
	Subtotal		3,348	3,051	3,676	3,628	3,526	3,394	3,210	3,068
Colorado Basin										
Sundown			353	292	413	436	453	463	465	473
Rural			54	57	57	57	56	53	51	47
	Subtotal		407	349	470	493	509	516	516	520
Total Municipal Demand			3,755	3,400	4,146	4,121	4,035	3,910	3,726	3,588
Municipal Existing Supply										
Brazos Basin										
Anton		Ogallala			263	0	0	0	0	0
Levelland		Ogallala			0	0	0	0	0	0
		Lake Meredith (CRMWA)[4]			2,120	2,120	2,120	2,120	2,120	2,120
		Ogallala (CRMWA - Roberts Co.)[4]			1,116	1,116	1,116	1,116	1,116	1,116
Levelland Subtotal					3,236	3,236	3,236	3,236	3,236	3,236
Rural		Ogallala			895	891	867	830	791	732
	Subtotal				4,394	4,127	4,103	4,066	4,027	3,968
Colorado Basin										
Sundown		Ogallala			413	436	0	0	0	0
Rural		Ogallala			57	57	56	53	51	47
	Subtotal				470	493	56	53	51	47
Total Municipal Existing Supply					4,864	4,620	4,159	4,119	4,078	4,015
Municipal Surplus/Shortage										
Brazos Basin										
Anton					0	-258	-258	-253	-243	-237
Levelland					718	757	835	925	1,060	1,137
Rural					0	0	0	0	0	0
	Subtotal				718	499	577	672	817	900
Colorado Basin										
Sundown					0	0	-453	-463	-465	-473
Rural					0	0	0	0	0	0
	Subtotal				0	0	-453	-463	-465	-473
Total Municipal Surplus/Shortage					718	499	124	209	352	427

Table 4-13 Projected Water Demands, Supplies, and Needs Hockley County Llano Estacado Region											
			Total in	Total in	Projections						
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Municipal New Supply Need										
Brazos Basin										
Anton					0	258	258	253	243	237
Levelland					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	258	258	253	243	237
Colorado Basin										
Sundown					0	0	453	463	465	473
Rural					0	0	0	0	0	0
	Subtotal				0	0	453	463	465	473
Total Municipal New Supply Need					0	258	711	716	708	710
Industrial Demand										
Brazos Basin			67	55	82	98	117	138	161	188
Colorado Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			67	55	82	98	117	138	161	188
Industrial Existing Supply										
Brazos Basin		Ogallala			82	98	117	138	161	188
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					82	98	117	138	161	188
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			83,764	155,345	87,554	84,130	80,840	77,680	74,641	71,723
Colorado Basin			9,204	13,508	9,728	9,348	8,982	8,631	8,293	7,969
Total Irrigation Demand			92,968	168,853	97,282	93,478	89,822	86,311	82,934	79,692
Irrigation Supply										
Brazos Basin		Ogallala			81,796	82,644	79,354	76,194	73,155	70,237
		Reclaimed Water			1,486	1,486	1,486	1,486	1,486	1,486
Brazos Basin Subtotal					83,282	84,130	80,840	77,680	74,641	71,723
Colorado Basin		Ogallala			9,572	9,192	8,826	8,475	8,137	7,813
		Reclaimed Water			156	156	156	156	156	156
Colorado Basin Subtotal					9,728	9,348	8,982	8,631	8,293	7,969
Total Irrigation Supply					93,010	93,478	89,822	86,311	82,934	79,692
Irrigation Surplus/Shortage										
Brazos Basin					-4,272	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					-4,272	0	0	0	0	0
Mining Demand										
Brazos Basin			2,465	3,953	4,770	4,088	3,435	2,889	2,446	2,032
Colorado Basin			1,087	2,751	1,609	1,124	824	590	397	291
Total Mining Demand			3,552	6,704	6,379	5,212	4,259	3,479	2,843	2,323

Table 4-13
Projected Water Demands, Supplies, and Needs
Hockley County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Supply									
Brazos Basin	Ogallala			4,770	4,088	3,435	2,889	2,446	2,032
Colorado Basin	Ogallala			1,609	1,124	824	590	397	291
Total Mining Supply				6,379	5,212	4,259	3,479	2,843	2,323
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		331	269	281	326	379	418	462	510
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		331	269	281	326	379	418	462	510
Beef Feedlot Livestock Supply									
Brazos Basin	Ogallala			281	326	379	418	462	510
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				281	326	379	418	462	510
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		199	204	208	219	230	241	252	266
Colorado Basin		40	41	41	44	45	47	49	52
Total Range & All Other Livestock Demand		239	245	249	263	275	288	301	318
Range & All Other Livestock Supply									
Brazos Basin	Local			208	219	230	241	252	266
Colorado Basin	Local			41	44	45	47	49	52
Total Range & All Other Livestock Supply				249	263	275	288	301	318
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		3,755	3,400	4,146	4,121	4,035	3,910	3,726	3,588
Industrial		67	55	82	98	117	138	161	188
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		92,968	168,853	97,282	93,478	89,822	86,311	82,934	79,692
Mining		3,552	6,704	6,379	5,212	4,259	3,479	2,843	2,323
Beef Feedlot Livestock		331	269	281	326	379	418	462	510
Range & All Other Livestock		239	245	249	263	275	288	301	318
Total County Demand		100,912	179,526	108,419	103,498	98,887	94,544	90,427	86,619
Total Supply									
Municipal				4,864	4,620	4,159	4,119	4,078	4,015
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				93,010	93,478	89,822	86,311	82,934	79,692
Mining				6,379	5,212	4,259	3,479	2,843	2,323
Beef Feedlot Livestock				281	326	379	418	462	510
Range & All Other Livestock				249	263	275	288	301	318
Total County Supply				104,783	103,899	98,894	94,615	90,618	86,858
Total Surplus/Shortage									
Municipal				718	499	124	209	352	427
Industrial				-82	-98	-117	-138	-161	-188
Steam-Electric				0	0	0	0	0	0
Irrigation				-4,272	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-3,636	401	7	71	191	239

Table 4-13
Projected Water Demands, Supplies, and Needs
Hockley County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Demand									
Brazos									
Municipal		3,348	3,051	3,676	3,628	3,526	3,394	3,210	3,068
Industrial		67	55	82	98	117	138	161	188
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		83,764	155,345	87,554	84,130	80,840	77,680	74,641	71,723
Mining		2,465	3,953	4,770	4,088	3,435	2,889	2,446	2,032
Beef Feedlot Livestock		331	269	281	326	379	418	462	510
Range & All Other Livestock		199	204	208	219	230	241	252	266
Total Brazos Basin Demand		90,174	162,877	96,571	92,489	88,527	84,760	81,172	77,787
Colorado									
Municipal		407	349	470	493	509	516	516	520
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		9,204	13,508	9,728	9,348	8,982	8,631	8,293	7,969
Mining		1,087	2,751	1,609	1,124	824	590	397	291
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		40	41	41	44	45	47	49	52
Total Colorado Basin Demand		10,738	16,649	11,848	11,009	10,360	9,784	9,255	8,832
Total Basin Supply									
Brazos									
Municipal				4,394	4,127	4,103	4,066	4,027	3,968
Industrial				82	98	117	138	161	188
Steam-Electric				0	0	0	0	0	0
Irrigation				83,282	84,130	80,840	77,680	74,641	71,723
Mining				4,770	4,088	3,435	2,889	2,446	2,032
Beef Feedlot Livestock				281	326	379	418	462	510
Range & All Other Livestock				208	219	230	241	252	266
Total Brazos Basin Supply				93,017	92,988	89,104	85,432	81,989	78,687
Colorado									
Municipal				470	493	56	53	51	47
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				9,728	9,348	8,982	8,631	8,293	7,969
Mining				1,609	1,124	824	590	397	291
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				41	44	45	47	49	52
Total Colorado Basin Supply				11,848	11,009	9,907	9,321	8,790	8,359
Total Basin Surplus/Shortage									
Brazos									
Municipal				718	499	577	672	817	900
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-4,272	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-3,554	499	577	672	817	900
Colorado									
Municipal				0	0	-453	-463	-465	-473
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				0	0	-453	-463	-465	-473

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] The city's supply from CRMWA. Since the city's supply from CRMWA exceeds CRMWA's delivery capacity, the city must have terminal storage in order to use its full supply from CRMWA.

[5] Value is the sum of reclaimed water from the City of Anton, City of Levelland, Bowman Enterprises, City of Smyer, City of Ropesville, City of Sundown, and United Cotton Growers Coop & Whitharrel Water Supply Corp. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-14
Projected Water Demands, Supplies, and Needs
Lamb County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				214,919	214,919	214,919	214,919	214,919	214,919
	Aquifer Storage[2]	Net Depletion			96,139	86,525	77,873	70,085	63,077	56,769
	Subtotal GW (Ogallala)[3]				311,058	301,444	292,792	285,004	277,996	271,688
	Local Surface	Stock Tanks and Windmills			434	467	504	535	571	612
	Reclaimed Water[4]				5,651	5,651	5,651	5,651	5,651	5,651
	Total Supply				317,143	307,562	298,947	291,190	284,218	277,951
	Total Demand from Ogallala				306,420	295,538	291,174	280,696	271,098	266,929
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Amherst			147	152	155	140	124	112	106	102
Earth			312	277	320	325	326	331	334	343
Littlefield			1,010	1,430	1,165	1,175	1,164	1,158	1,156	1,172
Olton			457	513	585	598	598	606	610	617
Sudan			283	207	313	320	320	322	318	319
Rural			443	498	487	504	514	523	532	536
	Subtotal		2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
Total Municipal Demand			2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
Municipal Existing Supply										
Brazos Basin										
Amherst		Ogallala			155	140	124	0	0	0
Earth		Ogallala			320	325	326	0	0	0
Littlefield		Ogallala			1,165	1,175	1,164	1,158	1,156	1,172
Olton		Ogallala			585	598	0	0	0	0
Sudan		Ogallala			313	320	0	0	0	0
Rural		Ogallala			487	504	514	523	532	536
	Subtotal				3,025	3,062	2,128	1,681	1,688	1,708
Total Municipal Existing Supply					3,025	3,062	2,128	1,681	1,688	1,708
Municipal Surplus/Shortage										
Brazos Basin										
Amherst					0	0	0	-112	-106	-102
Earth					0	0	0	-331	-334	-343
Littlefield					0	0	0	0	0	0
Olton					0	0	-598	-606	-610	-617
Sudan					0	0	-320	-322	-318	-319
Rural					0	0	0	0	0	0
	Subtotal				0	0	-918	-1,371	-1,368	-1,381
Total Municipal Surplus/Shortage					0	0	-918	-1,371	-1,368	-1,381
Municipal New Supply Need										
Brazos Basin										
Amherst					0	0	0	112	106	102
Earth					0	0	0	331	334	343
Littlefield					0	0	0	0	0	0
Olton					0	0	598	606	610	617
Sudan					0	0	320	322	318	319
Rural					0	0	0	0	0	0
	Subtotal				0	0	918	1,371	1,368	1,381
Total Municipal New Supply Need					0	0	918	1,371	1,368	1,381
Industrial Demand										
Brazos Basin			753	448	711	655	593	593	593	593
Total Industrial Demand			753	448	711	655	593	593	593	593
Industrial Existing Supply										
Brazos Basin		Ogallala			711	655	593	593	593	593
Total Industrial Existing Supply					711	655	593	593	593	593

Table 4-14 Projected Water Demands, Supplies, and Needs Lamb County Llano Estacado Region									
		Total in	Total in	Projections					
Basin	Source	1990	1996	2000	2010	2020	2030	2040	2050
		(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Industrial Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Industrial Surplus/Shortage				0	0	0	0	0	0
Industrial New Supply Need									
Brazos Basin				0	0	0	0	0	0
Total Industrial New Supply Need				0	0	0	0	0	0
Steam-Electric Demand									
Brazos Basin		12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
Total Steam-Electric Demand		12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
Steam-Electric Existing Supply									
Brazos Basin	Ogallala			18,000	18,000	25,000	25,000	25,000	30,000
Total Steam-Electric Existing Supply				18,000	18,000	25,000	25,000	25,000	30,000
Steam-Electric Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage				0	0	0	0	0	0
Steam-Electric New Supply Need									
Brazos Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Brazos Basin		351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
Total Irrigation Demand		351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
Irrigation Supply									
Brazos Basin	Ogallala			282,719	271,593	260,895	250,610	240,722	231,216
	Reclaimed Water			5,651	5,651	5,651	5,651	5,651	5,651
Total Irrigation Supply				288,370	277,244	266,546	256,261	246,373	236,867
Irrigation Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Brazos Basin		76	125	138	107	97	94	92	95
Total Mining Demand		76	125	138	107	97	94	92	95
Mining Supply									
Brazos Basin	Ogallala			138	107	97	94	92	95
Total Mining Supply				138	107	97	94	92	95
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
Total Beef Feedlot Livestock Demand		1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
Beef Feedlot Livestock Supply									
Brazos Basin	Ogallala			1,827	2,121	2,461	2,718	3,003	3,317
Total Beef Feedlot Livestock Supply				1,827	2,121	2,461	2,718	3,003	3,317
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		400	423	434	467	504	535	571	612
Total Range & All Other Livestock Demand		400	423	434	467	504	535	571	612
Range & All Other Livestock Supply									
Brazos Basin	Local			434	467	504	535	571	612
Total Range & All Other Livestock Supply				434	467	504	535	571	612
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0

Table 4-14
Projected Water Demands, Supplies, and Needs
Lamb County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Demand									
Municipal		2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
Industrial		753	448	711	655	593	593	593	593
Steam-Electric		12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
Irrigation		351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
Mining		76	125	138	107	97	94	92	95
Beef Feedlot Livestock		1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
Range & All Other Livestock		400	423	434	467	504	535	571	612
Total County Demand		369,020	400,885	312,505	301,656	298,247	288,253	278,688	274,573
Total Supply									
Municipal				3,025	3,062	2,128	1,681	1,688	1,708
Industrial				711	655	593	593	593	593
Steam-Electric				18,000	18,000	25,000	25,000	25,000	30,000
Irrigation				288,370	277,244	266,546	256,261	246,373	236,867
Mining				138	107	97	94	92	95
Beef Feedlot Livestock				1,827	2,121	2,461	2,718	3,003	3,317
Range & All Other Livestock				434	467	504	535	571	612
Total County Supply				312,505	301,656	297,329	286,882	277,320	273,192
Total Surplus/Shortage									
Municipal				0	0	-918	-1,371	-1,368	-1,381
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	0	-918	-1,371	-1,368	-1,381
Total Basin Demand									
Brazos									
Municipal		2,652	3,077	3,025	3,062	3,046	3,052	3,056	3,089
Industrial		753	448	711	655	593	593	593	593
Steam-Electric		12,587	13,686	18,000	18,000	25,000	25,000	25,000	30,000
Irrigation		351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
Mining		76	125	138	107	97	94	92	95
Beef Feedlot Livestock		1,502	1,747	1,827	2,121	2,461	2,718	3,003	3,317
Range & All Other Livestock		400	423	434	467	504	535	571	612
Total Brazos Basin Demand		369,020	400,885	312,505	301,656	298,247	288,253	278,688	274,573
Total Basin Supply									
Brazos									
Municipal				3,025	3,062	2,128	1,681	1,688	1,708
Industrial				711	655	593	593	593	593
Steam-Electric				18,000	18,000	25,000	25,000	25,000	30,000
Irrigation				288,370	277,244	266,546	256,261	246,373	236,867
Mining				138	107	97	94	92	95
Beef Feedlot Livestock				1,827	2,121	2,461	2,718	3,003	3,317
Range & All Other Livestock				434	467	504	535	571	612
Total Brazos Basin Supply				312,505	301,656	297,329	286,882	277,320	273,192
Total Basin Surplus/Shortage									
Brazos									
Municipal				0	0	-918	-1,371	-1,368	-1,381
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				0	0	-918	-1,371	-1,368	-1,381

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from Southwestern Public Service Tolk, City of Littlefield, Plains Cotton Growers, City of Earth, Springlake-Earth ISD, City of Sudan, City of Olton, Southwestern Public Service Plant X, City of Springlake, and City of Amherst. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-15
Projected Water Demands, Supplies, and Needs
Lubbock County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				125,753	125,753	125,753	125,753	125,753	125,753
	Aquifer Storage[2]	Net Depletion			46,536	41,882	37,694	33,925	30,532	27,479
	Subtotal GW (Ogallala)[3]				172,289	167,635	163,447	159,678	156,285	153,232
	Other Ground	Ogallala (CRMWA - Roberts Co.)			15,453	15,453	15,453	15,453	15,453	15,453
	Local Surface	Stock Tanks and Windmills			587	819	894	978	1,081	1,192
	Other Surface	Lake Meredith (CRMWA)			29,362	29,362	29,362	29,362	29,362	29,362
	Other Surface	Lake Alan Henry			0	0	0	0	29,900	29,900
	Reclaimed Water (Lubbock-Electric Power)[4]				4,799	4,944	5,025	5,200	5,314	5,505
	Reclaimed Water (Lubbock-Irrigation)[4]				9,599	9,890	10,053	10,400	10,630	11,010
	Reclaimed Water[7]				3,173	3,173	3,173	3,173	3,173	3,173
	Total Supply				235,262	231,276	227,407	224,244	251,198	248,827
	Total Demand from Ogallala				152,826	144,002	134,209	125,974	118,603	111,362
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Abernathy (part)			109	133	149	159	168	177	184	195
Idalou			356	380	423	438	459	507	523	543
Lubbock			36,656	40,225	38,394	39,556	40,206	41,600	42,516	44,041
New Deal			96	105	106	104	100	102	105	110
Ransom Canyon			162	222	215	220	221	232	247	265
Reese AFB Community			657	750	662	638	615	610	606	603
Shallowater			325	352	364	377	397	438	448	468
Slaton			865	756	915	891	864	946	969	1,021
Wolfforth			337	375	391	402	421	467	476	494
Rural			2,779	4,587	2,619	2,562	2,495	2,328	2,222	1,945
	Subtotal		42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
Total Municipal Demand			42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
Municipal Existing Supply										
Brazos Basin										
Abernathy (part)		Ogallala			149	159	0	0	0	0
Idalou		Ogallala			423	438	0	0	0	0
Lubbock		Lake Meredith (CRMWA)[5]			27,712	27,712	27,712	27,712	27,712	27,712
		Ogallala (CRMWA - Roberts Co.)[5]			14,823	14,823	14,823	14,823	14,823	14,823
		Lake Alan Henry			0	0	0	0	29,900	29,900
		Ogallala (Bailey County)[6]			7,016	7,273	7,426	7,710	7,897	8,205
Lubbock Subtotal					49,551	49,808	49,961	50,245	80,332	80,640
New Deal		Ogallala			106	104	0	0	0	0
Ransom Canyon		Lubbock (Lake Meredith)			265	265	265	265	265	265
Reese Center		Lubbock (Ogallala)			662	638	615	610	606	603
Shallowater		Lubbock (Lake Meredith)			187	187	187	187	187	187
		Ogallala			177	190	0	0	0	0
Shallowater Subtotal					364	377	187	187	187	187
Slaton		Lake Meredith (CRMWA)[5]			1,198	1,198	1,198	1,198	1,198	1,198
		Ogallala (CRMWA - Roberts Co.)[5]			630	630	630	630	630	630
Slaton Subtotal					1,828	1,828	1,828	1,828	1,828	1,828
Wolfforth		Ogallala			391	402	0	0	0	0
Rural		Ogallala			2,619	2,562	2,495	2,328	2,222	1,945
	Subtotal				56,358	56,581	55,351	55,463	85,440	85,468
Total Municipal Existing Supply					56,358	56,581	55,351	55,463	85,440	85,468
Municipal Surplus/Shortage										
Brazos Basin										
Abernathy (part)					0	0	-168	-177	-184	-195
Idalou					0	0	-459	-507	-523	-543
Lubbock					11,157	10,252	9,755	8,645	37,816	36,599
New Deal					0	0	-100	-102	-105	-110
Ransom Canyon					50	45	44	33	18	0
Reese Center					0	0	0	0	0	0
Shallowater					0	0	-210	-251	-261	-281
Slaton					913	937	964	882	859	807
Wolfforth					0	0	-421	-467	-476	-494
Rural					0	0	0	0	0	0
	Subtotal				12,120	11,234	9,405	8,056	37,144	35,783
Total Municipal Surplus/Shortage					12,120	11,234	9,405	8,056	37,144	35,783

Table 4-15
Projected Water Demands, Supplies, and Needs
Lubbock County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Municipal New Supply Need										
Brazos Basin										
Abernathy (part)					0	0	168	177	184	195
Idalou					0	0	459	507	523	543
Lubbock					0	0	0	0	0	0
New Deal					0	0	100	102	105	110
Ransom Canyon					0	0	0	0	0	0
Reese Center					0	0	0	0	0	0
Shallowater					0	0	210	251	261	281
Slaton					0	0	0	0	0	0
Wolfforth					0	0	421	467	476	494
Rural					0	0	0	0	0	0
	Subtotal				0	0	1,358	1,504	1,549	1,623
Total Municipal New Supply Need					0	0	1,358	1,504	1,549	1,623
Industrial Demand										
Brazos Basin			1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
Total Industrial Demand			1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
Industrial Existing Supply										
Brazos Basin		Ogallala			1,704	2,071	2,106	2,230	2,572	2,923
Total Industrial Existing Supply					1,704	2,071	2,106	2,230	2,572	2,923
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
Total Steam-Electric Demand			1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
Steam-Electric Existing Supply										
Brazos Basin		Reclaimed Water (Lubbock)			4,799	4,944	5,025	5,200	5,314	5,505
Total Steam-Electric Existing Supply					4,799	4,944	5,025	5,200	5,314	5,505
Steam-Electric Surplus/Shortage										
Brazos Basin					2,799	2,944	25	200	314	505
Total Steam-Electric Surplus/Shortage					2,799	2,944	25	200	314	505
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
Total Irrigation Demand			230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
Irrigation Supply										
Brazos Basin		Ogallala			145,306	136,095	127,559	119,308	111,618	104,198
		Reclaimed Water (Lubbock)			9,599	9,890	10,053	10,400	10,630	11,010
		Reclaimed Water			3,173	3,173	3,173	3,173	3,173	3,173
Total Irrigation Supply					158,078	149,158	140,785	132,881	125,421	118,381
Irrigation Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					0	0	0	0	0	0
Mining Demand										
Brazos Basin			191	1,255	446	364	298	243	199	162
Total Mining Demand			191	1,255	446	364	298	243	199	162
Mining Supply										
Brazos Basin		Ogallala			446	364	298	243	199	162
Total Mining Supply					446	364	298	243	199	162

Table 4-15
Projected Water Demands, Supplies, and Needs
Lubbock County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		689	807	843	979	1,136	1,255	1,386	1,531
Total Beef Feedlot Livestock Demand		689	807	843	979	1,136	1,255	1,386	1,531
Beef Feedlot Livestock Supply									
Brazos Basin	Ogallala			843	979	1,136	1,255	1,386	1,531
Total Beef Feedlot Livestock Supply				843	979	1,136	1,255	1,386	1,531
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		503	562	587	819	894	978	1,081	1,192
Total Range & All Other Livestock Demand		503	562	587	819	894	978	1,081	1,192
Range & All Other Livestock Supply									
Brazos Basin	Local			587	819	894	978	1,081	1,192
Total Range & All Other Livestock Supply				587	819	894	978	1,081	1,192
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
Industrial		1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
Steam-Electric		1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
Irrigation		230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
Mining		191	1,255	446	364	298	243	199	162
Beef Feedlot Livestock		689	807	843	979	1,136	1,255	1,386	1,531
Range & All Other Livestock		503	562	587	819	894	978	1,081	1,192
Total County Demand		277,626	296,010	207,896	200,738	196,165	189,994	183,955	178,874
Total Supply									
Municipal				56,358	56,581	55,351	55,463	85,440	85,468
Industrial				1,704	2,071	2,106	2,230	2,572	2,923
Steam-Electric				4,799	4,944	5,025	5,200	5,314	5,505
Irrigation				158,078	149,158	140,785	132,881	125,421	118,381
Mining				446	364	298	243	199	162
Beef Feedlot Livestock				843	979	1,136	1,255	1,386	1,531
Range & All Other Livestock				587	819	894	978	1,081	1,192
Total County Supply				222,815	214,916	205,595	198,250	221,413	215,162
Total Surplus/Shortage									
Municipal				12,120	11,234	9,405	8,056	37,144	35,783
Industrial				0	0	0	0	0	0
Steam-Electric				2,799	2,944	25	200	314	505
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				14,919	14,178	9,430	8,256	37,458	36,288
Total Basin Demand									
Brazos									
Municipal		42,342	47,885	44,238	45,347	45,946	47,407	48,296	49,685
Industrial		1,469	1,797	1,704	2,071	2,106	2,230	2,572	2,923
Steam-Electric		1,715	1,171	2,000	2,000	5,000	5,000	5,000	5,000
Irrigation		230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
Mining		191	1,255	446	364	298	243	199	162
Beef Feedlot Livestock		689	807	843	979	1,136	1,255	1,386	1,531
Range & All Other Livestock		503	562	587	819	894	978	1,081	1,192
Total Brazos Basin Demand		277,626	296,010	207,896	200,738	196,165	189,994	183,955	178,874
Total Basin Supply									
Brazos									
Municipal				56,358	56,581	55,351	55,463	85,440	85,468
Industrial				1,704	2,071	2,106	2,230	2,572	2,923
Steam-Electric				4,799	4,944	5,025	5,200	5,314	5,505
Irrigation				158,078	149,158	140,785	132,881	125,421	118,381
Mining				446	364	298	243	199	162
Beef Feedlot Livestock				843	979	1,136	1,255	1,386	1,531
Range & All Other Livestock				587	819	894	978	1,081	1,192
Total Brazos Basin Supply				222,815	214,916	205,595	198,250	221,413	215,162

Table 4-15
Projected Water Demands, Supplies, and Needs
Lubbock County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Surplus/Shortage									
Brazos									
Municipal				12,120	11,234	9,405	8,056	37,144	35,783
Industrial				0	0	0	0	0	0
Steam-Electric				2,799	2,944	25	200	314	505
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				14,919	14,178	9,430	8,256	37,458	36,288

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Total supply of reclaimed water is estimated at 50 percent of projected municipal water use shown as municipal water demand. Reclaimed water is used for electric-power generation, with the remaineder used to irrigate about 6,000 acres of hay and forage crops. In the needs analysis, the quantity of reclaimed water used for irrigation is assumed to apply toward meeting the TWDB's projections of Lubbock and Lynn Counties irrigation water demand.

[5] The city's supply from CRMWA. Since the city's supply from CRMWA exceeds CRMWA's delivery capacity, the city must have terminal storage in order to use its full supply from CRMWA.

[6] The total groundwater supply available to Lubbock in Bailey County is 16,000 acft/yr, however, this analysis assumed the City of Lubbock will obtain 20 percent of their total supply from Bailey County, which increases from an estimated 7,678 acft/yr in 2000 to an estimated 8,808 acft/yr in 2050.

[7] Value is the sum of reclaimed water from the City of Idalou, City of Wolfforth, City of New Deal, Lubbock Power & Light, City of Slaton, City of Shallowater, SPS, Environmental Protection Services of Lubbock, Acid Delinting Inc., Texas Winery Inc., Town & Country Mobile Home Park, Paymaster Oil Mill, Lubbock Cooper ISD, Ransom Canyon, Plains Coop Oil Mill, and Gifford Hill American. The quantity of reclaimed water from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held constant throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

Table 4-16
Projected Water Demands, Supplies, and Needs
Lynn County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				35,642	35,642	35,642	35,642	35,642	35,642
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				35,642	35,642	35,642	35,642	35,642	35,642
	Edwards-Trinity (High Plains) Aquifer				4,944	4,160	3,580	2,802	2,335	2,065
	Other Ground	Ogallala (CRMWA - Roberts Co.)			184	184	184	184	184	184
	Local Surface	Stock Tanks and Windmills			251	272	288	306	325	348
	Other Surface	Lake Meredith (CRMWA)			350	350	350	350	350	350
	Reclaimed Water (Lubbock-Irrigation)[5]				4,799	4,944	5,025	5,200	5,314	5,505
	Reclaimed Water[6]				350	350	350	350	350	350
	Total Supply				46,520	45,902	45,419	44,834	44,500	44,444
	Total Demand from Ogallala				28,455	27,017	25,545	24,237	22,828	21,245
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				3,085	3,085	3,085	3,085	3,085	3,085
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				3,085	3,085	3,085	3,085	3,085	3,085
	Other Ground	Ogallala (CRMWA - Roberts Co.)			91	91	91	91	91	91
	Local Surface	Stock Tanks and Windmills			21	24	25	26	29	30
	Other Surface	Lake Meredith (CRMWA)			173	173	173	173	173	173
	Total Supply				3,370	3,373	3,374	3,375	3,378	3,379
	Total Demand from Ogallala				377	353	331	311	293	276
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				38,727	38,727	38,727	38,727	38,727	38,727
	Aquifer Storage[2]	Net Depletion			0	0	0	0	0	0
	Subtotal GW (Ogallala)[3]				38,727	38,727	38,727	38,727	38,727	38,727
	Edwards-Trinity (High Plains) Aquifer				4,944	4,160	3,580	2,802	2,335	2,065
	Other Ground	Ogallala (CRMWA - Roberts Co.)			275	275	275	275	275	275
	Local Surface	Stock Tanks and Windmills			272	296	313	332	354	378
	Other Surface	Lake Meredith			523	523	523	523	523	523
	Reclaimed Water (Lubbock-Irrigation)				4,799	4,944	5,025	5,200	5,314	5,505
	Reclaimed Water[6]				350	350	350	350	350	350
	Total Supply				49,890	49,275	48,793	48,209	47,878	47,823
	Total Demand from Ogallala				28,832	27,370	25,876	24,548	23,121	21,521
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Tahoka			488	483	517	527	527	519	495	483
Wilson			53	67	64	57	49	46	43	42
Rural			278	291	327	315	298	276	256	241
	Subtotal		819	841	908	899	874	841	794	766
Colorado Basin										
O'Donnell (part)			106	141	157	156	153	148	141	137
Rural			17	19	20	19	18	16	15	14
	Subtotal		123	160	177	175	171	164	156	151
Total Municipal Demand			942	1,001	1,085	1,074	1,045	1,005	950	917
Municipal Existing Supply										
Brazos Basin										
Tahoka		Ogallala			0	0	0	0	0	0
		Lake Meredith (CRMWA)[4]			350	350	350	350	350	350
		Ogallala (CRMWA - Roberts Co.)[4]			184	184	184	184	184	184
Tahoka Subtotal					534	534	534	534	534	534
Wilson		Ogallala			64	57	49	0	0	0
Rural		Ogallala			227	215	198	176	156	141
		Edwards-Trinity (High Plains)			100	100	100	100	100	100
Rural Subtotal					327	315	298	276	256	241
	Subtotal				925	906	881	810	790	775
Colorado Basin										
O'Donnell (part)		Lake Meredith (CRMWA)			173	173	173	173	173	173
		Ogallala (CRMWA - Roberts Co.)			91	91	91	91	91	91
O'Donnell (part) Subtotal					264	264	264	264	264	264
Rural		Ogallala			20	19	18	16	15	14
	Subtotal				284	283	282	280	279	278
Total Municipal Existing Supply					1,209	1,189	1,163	1,090	1,069	1,053
Municipal Surplus/Shortage										
Brazos Basin										
Tahoka					17	7	7	15	39	51
Wilson					0	0	0	-46	-43	-42
Rural					0	0	0	0	0	0

Table 4-16 Projected Water Demands, Supplies, and Needs Lynn County Llano Estacado Region											
			Total in	**Total in**	**Projections**						
Basin		**Source**	**1990**	**1996**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
			(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**
	Subtotal				17	7	7	-31	-4	9

Table 4-16
Projected Water Demands, Supplies, and Needs
Lynn County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado Basin										
O'Donnell (part)					107	108	111	116	123	127
Rural					0	0	0	0	0	0
	Subtotal				107	108	111	116	123	127
Total Municipal Surplus/Shortage					124	115	118	85	119	136
Municipal New Supply Need										
Brazos Basin										
Tahoka					0	0	0	0	0	0
Wilson					0	0	0	46	43	42
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	46	43	42
Colorado Basin										
O'Donnell (part)					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	46	43	42
Industrial Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			0	0	0	0	0	0	0	0
Industrial Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			39,616	55,264	38,108	36,057	34,117	32,282	30,545	28,902
Colorado Basin			372	1,070	346	327	310	293	277	262
Total Irrigation Demand			39,988	56,334	38,454	36,384	34,427	32,575	30,822	29,164
Irrigation Supply										
Brazos Basin		Ogallala			28,115	26,703	25,262	24,030	22,646	21,082
		Edwards-Trinity (High Plains)			4,844	4,060	3,480	2,702	2,235	1,965
		Reclaimed Water (Lubbock)			4,799	4,944	5,025	5,200	5,314	5,505
		Reclaimed Water			350	350	350	350	350	350
Brazos Basin Subtotal					38,108	36,057	34,117	32,282	30,545	28,902
Colorado Basin		Ogallala			346	327	310	293	277	262
Total Irrigation Supply					38,454	36,384	34,427	32,575	30,822	29,164
Irrigation Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					0	0	0	0	0	0

Table 4-16
Projected Water Demands, Supplies, and Needs
Lynn County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Demand									
Brazos Basin		116	219	49	42	36	31	26	22
Colorado Basin		0	8	11	7	3	2	1	0
Total Mining Demand		116	227	60	49	39	33	27	22
Mining Supply									
Brazos Basin	Ogallala			49	42	36	31	26	22
Colorado Basin	Ogallala			11	7	3	2	1	0
Total Mining Supply				60	49	39	33	27	22
Mining Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Brazos Basin		0	0	0	0	0	0	0	0
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		235	246	251	272	288	306	325	348
Colorado Basin		21	21	21	24	25	26	29	30
Total Range & All Other Livestock Demand		256	267	272	296	313	332	354	378
Range & All Other Livestock Supply									
Brazos Basin	Local			251	272	288	306	325	348
Colorado Basin	Local			21	24	25	26	29	30
Total Range & All Other Livestock Supply				272	296	313	332	354	378
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		942	1,001	1,085	1,074	1,045	1,005	950	917
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		39,988	56,334	38,454	36,384	34,427	32,575	30,822	29,164
Mining		116	227	60	49	39	33	27	22
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		256	267	272	296	313	332	354	378
Total County Demand		41,302	57,829	39,871	37,803	35,824	33,945	32,153	30,481
Total Supply									
Municipal				1,209	1,189	1,163	1,090	1,069	1,053
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				38,454	36,384	34,427	32,575	30,822	29,164
Mining				60	49	39	33	27	22
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				272	296	313	332	354	378
Total County Supply				39,995	37,918	35,942	34,030	32,272	30,617
Total Surplus/Shortage									
Municipal				124	115	118	85	119	136
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				124	115	118	85	119	136

Table 4-16
Projected Water Demands, Supplies, and Needs
Lynn County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Demand									
Brazos									
Municipal		819	841	908	899	874	841	794	766
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		39,616	55,264	38,108	36,057	34,117	32,282	30,545	28,902
Mining		116	219	49	42	36	31	26	22
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		235	246	251	272	288	306	325	348
Total Brazos Basin Demand		40,786	56,570	39,316	37,270	35,315	33,460	31,690	30,038
Colorado									
Municipal		123	160	177	175	171	164	156	151
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		372	1,070	346	327	310	293	277	262
Mining		0	8	11	7	3	2	1	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		21	21	21	24	25	26	29	30
Total Colorado Basin Demand		516	1,259	555	533	509	485	463	443
Total Basin Supply									
Brazos									
Municipal				925	906	881	810	790	775
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				38,108	36,057	34,117	32,282	30,545	28,902
Mining				49	42	36	31	26	22
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				251	272	288	306	325	348
Total Brazos Basin Supply				39,333	37,277	35,322	33,429	31,686	30,047
Colorado									
Municipal				284	283	282	280	279	278
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				346	327	310	293	277	262
Mining				11	7	3	2	1	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				21	24	25	26	29	30
Total Colorado Basin Supply				662	641	620	601	586	570
Total Basin Surplus/Shortage									
Brazos									
Municipal				17	7	7	-31	-4	9
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				17	7	7	-31	-4	9
Colorado									
Municipal				107	108	111	116	123	127
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				107	108	111	116	123	127

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] The city's supply from CRMWA. Since the city's supply from CRMWA exceeds CRMWA's delivery capacity, the city must have terminal storage in oder to use its full supply from CRMWA.

[5] Total supply of reclaimed water is estimated at 50 percent of projected municipal water use shown as municipal water demand. Reclaimed water is used for electric-power generation, with the remaineder used to irrigate about 6,000 acres of hay and forage crops. In the needs analysis, the quantity of reclaimed water used for irrigation is assumed to apply toward meeting the TWDB's projections of Lubbock and Lynn Counties irrigation water demand.

[6] Value is the sum of reclaimed water from the City of Wilson, City of Tahoka, and City of O'Donnell. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value is held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-17
Projected Water Demands, Supplies, and Needs
Motley County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				1,814	1,814	1,814	1,814	1,814	1,814
	Aquifer Storage[2]	Net Depletion			2,291	2,062	1,856	1,670	1,503	1,353
	Subtotal GW (Ogallala)[3]				4,105	3,876	3,670	3,484	3,317	3,167
	Seymour Aquifer				18,817	18,817	18,817	13,507	13,507	13,507
	Other Aquifer				227	208	185	168	151	131
	Local Surface	Stock Tanks and Windmills			653	703	753	807	866	932
	Other Surface				0	0	0	0	0	0
	Total Supply				23,802	23,604	23,425	17,966	17,841	17,737
	Total Demand from Ogallala				1,751	1,693	1,635	1,583	1,533	1,482
WATER DEMANDS										
Municipal Demand										
Red Basin										
Matador			221	209	227	208	185	168	151	131
Rural			81	117	99	89	76	67	60	52
	Subtotal		302	326	326	297	261	235	211	183
Total Municipal Demand			302	326	326	297	261	235	211	183
Municipal Existing Supply										
Red Basin										
Matador		Other Aquifer			227	208	185	168	151	131
Rural		Ogallala			99	89	76	67	60	52
	Subtotal				326	297	261	235	211	183
Total Municipal Existing Supply					326	297	261	235	211	183
Municipal Surplus/Shortage										
Red Basin										
Matador					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					0	0	0	0	0	0
Municipal New Supply Need										
Red Basin										
Matador					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Red Basin			0	2	4	4	5	6	7	8
Total Industrial Demand			0	2	4	4	5	6	7	8
Industrial Existing Supply										
Red Basin		Ogallala			4	4	5	6	7	8
Total Industrial Existing Supply					4	4	5	6	7	8
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0

Table 4-17
Projected Water Demands, Supplies, and Needs
Motley County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Irrigation Demand									
Red Basin		3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
Total Irrigation Demand		3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
Irrigation Supply									
Red Basin	Ogallala			1,622	1,574	1,527	1,482	1,438	1,394
	Seymour			2,065	2,003	1,943	1,885	1,828	1,774
Total Irrigation Supply				3,687	3,577	3,470	3,367	3,266	3,168
Irrigation Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Red Basin		23	24	26	26	27	28	28	28
Total Mining Demand		23	24	26	26	27	28	28	28
Mining Supply									
Red Basin	Ogallala			26	26	27	28	28	28
Total Mining Supply				26	26	27	28	28	28
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Red Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		609	640	653	703	753	807	866	932
Total Range & All Other Livestock Demand		609	640	653	703	753	807	866	932
Range & All Other Livestock Supply									
Red Basin	Local			653	703	753	807	866	932
Total Range & All Other Livestock Supply				653	703	753	807	866	932
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		302	326	326	297	261	235	211	183
Industrial		0	2	4	4	5	6	7	8
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
Mining		23	24	26	26	27	28	28	28
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		609	640	653	703	753	807	866	932
Total County Demand		4,817	5,126	4,696	4,607	4,516	4,443	4,378	4,319

Table 4-17
Projected Water Demands, Supplies, and Needs
Motley County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Supply									
Municipal				326	297	261	235	211	183
Industrial				4	4	5	6	7	8
Steam-Electric				0	0	0	0	0	0
Irrigation				3,687	3,577	3,470	3,367	3,266	3,168
Mining				26	26	27	28	28	28
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				653	703	753	807	866	932
Total County Supply				4,696	4,607	4,516	4,443	4,378	4,319
Total Surplus/Shortage									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	0	0	0	0	0
Total Basin Demand									
Red									
Municipal		302	326	326	297	261	235	211	183
Industrial		0	2	4	4	5	6	7	8
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
Mining		23	24	26	26	27	28	28	28
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		609	640	653	703	753	807	866	932
Total Red Basin Demand		4,817	5,126	4,696	4,607	4,516	4,443	4,378	4,319
Total Basin Supply									
Red									
Municipal				326	297	261	235	211	183
Industrial				4	4	5	6	7	8
Steam-Electric				0	0	0	0	0	0
Irrigation				3,687	3,577	3,470	3,367	3,266	3,168
Mining				26	26	27	28	28	28
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				653	703	753	807	866	932
Total Red Basin Supply				4,696	4,607	4,516	4,443	4,378	4,319
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	0	0	0

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-18
Projected Water Demands, Supplies, and Needs
Parmer County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				60,757	60,757	60,757	60,757	60,757	60,757
	Aquifer Storage[2]	Net Depletion			60,137	54,124	48,712	43,841	39,457	35,511
	Subtotal GW (Ogallala)[3]				120,894	114,881	109,469	104,598	100,214	96,268
	Local Surface	Stock Tanks and Windmills			354	388	423	462	507	554
	Reclaimed Water[4]				2,154	2,154	2,154	2,154	2,154	2,154
	Total Supply				123,402	117,423	112,046	107,214	102,875	98,976
	Total Demand from Ogallala				97,002	96,506	96,024	94,367	93,858	93,394
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				100,832	100,832	100,832	100,832	100,832	100,832
	Aquifer Storage[2]	Net Depletion			99,807	89,825	80,843	72,758	65,482	58,934
	Subtotal GW (Ogallala)[3]				200,639	190,657	181,675	173,590	166,314	159,766
	Local Surface	Stock Tanks and Windmills			683	750	821	893	969	1,057
	Reclaimed Water[4]				257	257	257	257	257	257
	Total Supply				201,579	191,664	182,753	174,740	167,540	161,080
	Total Demand from Ogallala				200,639	190,657	181,675	173,590	166,314	159,766
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				161,589	161,589	161,589	161,589	161,589	161,589
	Aquifer Storage[2]	Net Depletion			159,944	143,949	129,555	116,599	104,939	94,445
	Subtotal GW (Ogallala)[3]				321,533	305,538	291,144	278,188	266,528	256,034
	Local Surface	Stock Tanks and Windmills			1,037	1,138	1,244	1,355	1,476	1,611
	Reclaimed Water[4]				2,411	2,411	2,411	2,411	2,411	2,411
	Total Supply				324,981	309,087	294,799	281,954	270,415	260,056
	Total Demand from Ogallala				297,641	287,163	277,699	267,957	260,172	253,160
WATER DEMANDS										
Municipal Demand										
Red Basin										
Friona			912	816	939	994	1,029	1,056	1,090	1,137
Rural			138	156	136	130	122	113	99	91
	Subtotal		1,050	972	1,075	1,124	1,151	1,169	1,189	1,228
Brazos Basin										
Bovina			316	331	350	372	388	402	419	441
Farwell			410	273	429	461	486	507	531	562
Rural			472	345	486	473	456	436	405	386
	Subtotal		1,198	949	1,265	1,306	1,330	1,345	1,355	1,389
Total Municipal Demand			2,248	1,921	2,340	2,430	2,481	2,514	2,544	2,617
Municipal Existing Supply										
Red Basin										
Friona		Ogallala			939	994	1,029	0	0	0
Rural		Ogallala			136	130	122	113	99	91
	Subtotal				1,075	1,124	1,151	113	99	91
Brazos Basin										
Bovina		Ogallala			350	372	0	0	0	0
Farwell		Ogallala			429	461	0	0	0	0
Rural		Ogallala			486	473	456	436	405	386
	Subtotal				1,265	1,306	456	436	405	386
Total Municipal Existing Supply					2,340	2,430	1,607	549	504	477
Municipal Surplus/Shortage										
Red Basin										
Friona					0	0	0	-1,056	-1,090	-1,137
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	-1,056	-1,090	-1,137
Brazos Basin										
Bovina					0	0	-388	-402	-419	-441
Farwell					0	0	-486	-507	-531	-562
Rural					0	0	0	0	0	0
	Subtotal				0	0	-874	-909	-950	-1,003
Total Municipal Surplus/Shortage					0	0	-874	-1,965	-2,040	-2,140

Table 4-18
Projected Water Demands, Supplies, and Needs
Parmer County
Llano Estacado Region

			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Municipal New Supply Need										
Red Basin										
Friona					0	0	0	1,056	1,090	1,137
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	1,056	1,090	1,137
Brazos Basin										
Bovina					0	0	388	402	419	441
Farwell					0	0	486	507	531	562
Rural					0	0	0	0	0	0
	Subtotal				0	0	874	909	950	1,003
Total Municipal New Supply Need					0	0	874	1,965	2,040	2,140
Industrial Demand										
Red Basin			1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
Brazos Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
Industrial Existing Supply										
Red Basin		Ogallala			1,599	1,694	1,758	1,800	1,925	2,042
Brazos Basin					0	0	0	0	0	0
Total Industrial Existing Supply					1,599	1,694	1,758	1,800	1,925	2,042
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			137,750	130,070	94,236	93,235	92,245	91,266	90,297	89,338
Brazos Basin			337,250	318,446	230,715	228,265	225,842	223,444	221,072	218,725
Total Irrigation Demand			475,000	448,516	324,951	321,500	318,087	314,710	311,369	308,063
Irrigation Supply										
Red Basin		Ogallala			92,082	91,081	90,091	89,112	88,143	87,184
		Reclaimed Water			2,154	2,154	2,154	2,154	2,154	2,154
Red Basin Subtotal					94,236	93,235	92,245	91,266	90,297	89,338
Brazos Basin		Ogallala			196,282	185,763	177,055	168,555	160,829	153,768
		Reclaimed Water			257	257	257	257	257	257
Brazos Basin Subtotal					196,539	186,020	177,312	168,812	161,086	154,025
Total Irrigation Supply					290,775	279,255	269,557	260,078	251,383	243,363
Irrigation Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					-34,176	-42,245	-48,530	-54,632	-59,986	-64,700
Total Irrigation Surplus/Shortage					-34,176	-42,245	-48,530	-54,632	-59,986	-64,700

Table 4-18
Projected Water Demands, Supplies, and Needs
Parmer County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Demand									
Red Basin		0	0	0	0	0	0	0	0
Brazos Basin		0	0	0	0	0	0	0	0
Total Mining Demand		0	0	0	0	0	0	0	0
Mining Supply									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Supply				0	0	0	0	0	0
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		1,975	2,148	2,246	2,607	3,024	3,342	3,691	4,077
Brazos Basin		2,719	2,957	3,092	3,588	4,164	4,599	5,080	5,612
Total Beef Feedlot Livestock Demand		4,694	5,105	5,338	6,195	7,188	7,941	8,771	9,689
Beef Feedlot Livestock Supply									
Red Basin	Ogallala			2,246	2,607	3,024	3,342	3,691	4,077
Brazos Basin	Ogallala			3,092	3,588	4,164	4,599	5,080	5,612
Total Beef Feedlot Livestock Supply				5,338	6,195	7,188	7,941	8,771	9,689
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		322	344	354	388	423	462	507	554
Brazos Basin		622	667	683	750	821	893	969	1,057
Total Range & All Other Livestock Demand		944	1,011	1,037	1,138	1,244	1,355	1,476	1,611
Range & All Other Livestock Supply									
Red Basin	Local			354	388	423	462	507	554
Brazos Basin	Local			683	750	821	893	969	1,057
Total Range & All Other Livestock Supply				1,037	1,138	1,244	1,355	1,476	1,611
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		2,248	1,921	2,340	2,430	2,481	2,514	2,544	2,617
Industrial		1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		475,000	448,516	324,951	321,500	318,087	314,710	311,369	308,063
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		4,694	5,105	5,338	6,195	7,188	7,941	8,771	9,689
Range & All Other Livestock		944	1,011	1,037	1,138	1,244	1,355	1,476	1,611
Total County Demand		484,388	458,426	335,265	332,957	330,758	328,320	326,085	324,022
Total Supply									
Municipal				2,340	2,430	1,607	549	504	477
Industrial				1,599	1,694	1,758	1,800	1,925	2,042
Steam-Electric				0	0	0	0	0	0
Irrigation				290,775	279,255	269,557	260,078	251,383	243,363
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				5,338	6,195	7,188	7,941	8,771	9,689
Range & All Other Livestock				1,037	1,138	1,244	1,355	1,476	1,611
Total County Supply				301,089	290,712	281,354	271,723	264,059	257,182
Total Surplus/Shortage									
Municipal				0	0	-874	-1,965	-2,040	-2,140
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-34,176	-42,245	-48,530	-54,632	-59,986	-64,700
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-34,176	-42,245	-49,404	-56,597	-62,026	-66,840

Table 4-18
Projected Water Demands, Supplies, and Needs
Parmer County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Demand									
Red									
Municipal		1,050	972	1,075	1,124	1,151	1,169	1,189	1,228
Industrial		1,502	1,873	1,599	1,694	1,758	1,800	1,925	2,042
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		137,750	130,070	94,236	93,235	92,245	91,266	90,297	89,338
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		1,975	2,148	2,246	2,607	3,024	3,342	3,691	4,077
Range & All Other Livestock		322	344	354	388	423	462	507	554
Total Red Basin Demand		142,599	135,407	99,510	99,048	98,601	98,039	97,609	97,239
Brazos									
Municipal		1,198	949	1,265	1,306	1,330	1,345	1,355	1,389
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		337,250	318,446	230,715	228,265	225,842	223,444	221,072	218,725
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		2,719	2,957	3,092	3,588	4,164	4,599	5,080	5,612
Range & All Other Livestock		622	667	683	750	821	893	969	1,057
Total Brazos Basin Demand		341,789	323,019	235,755	233,909	232,157	230,281	228,476	226,783
Total Basin Supply									
Red									
Municipal				1,075	1,124	1,151	113	99	91
Industrial				1,599	1,694	1,758	1,800	1,925	2,042
Steam-Electric				0	0	0	0	0	0
Irrigation				94,236	93,235	92,245	91,266	90,297	89,338
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				2,246	2,607	3,024	3,342	3,691	4,077
Range & All Other Livestock				354	388	423	462	507	554
Total Red Basin Supply				99,510	99,048	98,601	96,983	96,519	96,102
Brazos									
Municipal				1,265	1,306	456	436	405	386
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				196,539	186,020	177,312	168,812	161,086	154,025
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				3,092	3,588	4,164	4,599	5,080	5,612
Range & All Other Livestock				683	750	821	893	969	1,057
Total Brazos Basin Supply				201,579	191,664	182,753	174,740	167,540	161,080
Total Basin Surplus/Shortage									
Red									
Municipal				0	0	0	-1,056	-1,090	-1,137
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	0	0	-1,056	-1,090	-1,137
Brazos									
Municipal				0	0	-874	-909	-950	-1,003
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-34,176	-42,245	-48,530	-54,632	-59,986	-64,700
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-34,176	-42,245	-49,404	-55,541	-60,936	-65,703

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Value is the sum of reclaimed water from Excel Corp., City of Friona, City of Farwell, City of Bovina, and Lazabuddie Utility & Water Supply. The quantity of reclaimed water available from municipal sources for reuse was estimated as the lesser of 50 percent of the TWDB municipal water use for the year 2000 or the maximum waste discharge permit quantity of the TNRCC waste discharge permit. This value was held level throughout the projection period. For all other entities, the quantity was calculated as 75 percent of the maximum waste discharge permit.

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Table 4-19
Projected Water Demands, Supplies, and Needs
Swisher County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Red Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				130,755	130,755	130,755	130,755	130,755	130,755
	Aquifer Storage[2]	Net Depletion			5,551	4,996	4,496	4,047	3,642	3,278
	Subtotal GW (Ogallala)[3]				136,306	135,751	135,251	134,802	134,397	134,033
	Dockum Aquifer (Santa Rosa Formation)				846	846	846	846	846	846
	Local Surface	Stock Tanks and Windmills			697	1,052	1,178	1,321	1,484	1,666
	Other Surface	Lake Mackenzie			417	417	417	417	417	417
	Total Supply				138,266	138,066	137,692	137,386	137,144	136,962
	Total Demand from Ogallala				88,155	88,075	85,128	88,138	88,158	88,237
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				17,637	17,637	17,637	17,637	17,637	17,637
	Aquifer Storage[2]	Net Depletion			749	674	607	546	491	442
	Subtotal GW (Ogallala)[3]				18,386	18,311	18,244	18,183	18,128	18,079
	Local Surface	Stock Tanks and Windmills			266	314	332	351	373	398
	Other Surface				0	0	0	0	0	0
	Total Supply				18,652	18,625	18,576	18,534	18,501	18,477
	Total Demand from Ogallala				18,386	18,311	18,244	18,183	18,128	18,079
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				148,392	148,392	148,392	148,392	148,392	148,392
	Aquifer Storage[2]	Net Depletion			6,300	5,670	5,103	4,593	4,133	3,720
	Subtotal GW (Ogallala)[3]				154,692	154,062	153,495	152,985	152,525	152,112
	Dockum Aquifer (Santo Rosa Formation)				846	846	846	846	846	846
	Local Surface	Stock Tanks and Windmills			963	1,366	1,510	1,672	1,857	2,064
	Other Surface	Lake Mackenzie			417	417	417	417	417	417
	Total Supply				156,918	156,691	156,268	155,920	155,645	155,439
	Total Demand from Ogallala				106,541	106,386	103,372	106,321	106,286	106,316
WATER DEMANDS										
Municipal Demand										
Red Basin										
Kress			101	87	95	84	72	65	61	59
Tulia			1,062	1,110	1,135	1,156	1,163	1,188	1,219	1,264
Rural			310	281	331	340	352	366	381	394
	Subtotal		1,473	1,478	1,561	1,580	1,587	1,619	1,661	1,717
Brazos Basin										
Rural			50	50	57	57	57	58	59	61
	Subtotal		50	50	57	57	57	58	59	61
Total Municipal Demand			1,523	1,528	1,618	1,637	1,644	1,677	1,720	1,778
Municipal Existing Supply										
Red Basin										
Kress		Ogallala			95	0	0	0	0	0
Tulia[4]		Ogallala			359	370	373	386	401	424
		Dockum (Santa Rosa Formation)			359	369	373	385	401	423
		Lake Mackenzie			417	417	417	417	417	417
Tulia Subtotal					1,135	1,156	1,163	1,188	1,219	1,264
Rural		Ogallala			331	340	352	366	381	394
	Subtotal				1,561	1,496	1,515	1,554	1,600	1,658
Brazos Basin										
Rural		Ogallala			57	57	57	58	59	61
	Subtotal				57	57	57	58	59	61
Total Municipal Existing Supply					1,618	1,553	1,572	1,612	1,659	1,719
Municipal Surplus/Shortage										
Red Basin										
Kress					0	-84	-72	-65	-61	-59
Tulia					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	-84	-72	-65	-61	-59
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal Surplus/Shortage					0	-84	-72	-65	-61	-59

Table 4-19
Projected Water Demands, Supplies, and Needs
Swisher County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Municipal New Supply Need										
Red Basin										
Kress					0	84	72	65	61	59
Tulia					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	84	72	65	61	59
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	84	72	65	61	59
Industrial Demand										
Red Basin			3	3	3	3	3	3	3	3
Brazos Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			3	3	3	3	3	3	3	3
Industrial Existing Supply										
Red Basin		Ogallala			3	3	3	3	3	3
Brazos Basin					0	0	0	0	0	0
Total Industrial Existing Supply					3	3	3	3	3	3
Industrial Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Red Basin			0	0	0	0	0	0	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Red Basin					0	0	0	0	0	0
Brazos Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Red Basin			79,600	118,082	84,376	83,894	80,377	82,939	82,465	81,994
Brazos Basin			60,050	50,606	63,678	63,315	60,660	62,593	62,236	61,880
Total Irrigation Demand			139,650	168,688	148,054	147,209	141,037	145,532	144,701	143,874
Irrigation Supply										
Red Basin		Ogallala			84,376	83,894	80,377	82,939	82,465	81,994
Brazos Basin		Ogallala			18,329	18,254	18,187	18,125	18,069	18,018
Total Irrigation Supply					102,705	102,148	98,564	101,064	100,534	100,012
Irrigation Surplus/Shortage										
Red Basin					0	0	0	0	0	0
Brazos Basin					-45,349	-45,061	-42,473	-44,468	-44,167	-43,862
Total Irrigation Surplus/Shortage					-45,349	-45,061	-42,473	-44,468	-44,167	-43,862
Mining Demand										
Red Basin			0	6	4	2	1	1	0	0
Brazos Basin			0	0	0	0	0	0	0	0
Total Mining Demand			0	6	4	2	1	1	0	0

Table 4-19
Projected Water Demands, Supplies, and Needs
Swisher County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Mining Supply									
Red Basin	Ogallala			4	2	1	1	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Supply				4	2	1	1	0	0
Mining Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Red Basin		2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
Brazos Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
Beef Feedlot Livestock Supply									
Red Basin	Ogallala			2,987	3,466	4,022	4,443	4,908	5,422
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				2,987	3,466	4,022	4,443	4,908	5,422
Beef Feedlot Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Red Basin		598	650	697	1,052	1,178	1,321	1,484	1,666
Brazos Basin		253	260	266	314	332	351	373	398
Total Range & All Other Livestock Demand		851	910	963	1,366	1,510	1,672	1,857	2,064
Range & All Other Livestock Supply									
Red Basin	Local			697	1,052	1,178	1,321	1,484	1,666
Brazos Basin	Local			266	314	332	351	373	398
Total Range & All Other Livestock Supply				963	1,366	1,510	1,672	1,857	2,064
Range & All Other Livestock Surplus/Shortage									
Red Basin				0	0	0	0	0	0
Brazos Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,523	1,528	1,618	1,637	1,644	1,677	1,720	1,778
Industrial		3	3	3	3	3	3	3	3
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		139,650	168,688	148,054	147,209	141,037	145,532	144,701	143,874
Mining		0	6	4	2	1	1	0	0
Beef Feedlot Livestock		2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
Range & All Other Livestock		851	910	963	1,366	1,510	1,672	1,857	2,064
Total County Demand		144,439	173,991	153,629	153,683	148,217	153,328	153,189	153,141
Total Supply									
Municipal				1,618	1,553	1,572	1,612	1,659	1,719
Industrial				3	3	3	3	3	3
Steam-Electric				0	0	0	0	0	0
Irrigation				102,705	102,148	98,564	101,064	100,534	100,012
Mining				4	2	1	1	0	0
Beef Feedlot Livestock				2,987	3,466	4,022	4,443	4,908	5,422
Range & All Other Livestock				963	1,366	1,510	1,672	1,857	2,064
Total County Supply				108,280	108,538	105,672	108,795	108,961	109,220
Total Surplus/Shortage									
Municipal				0	-84	-72	-65	-61	-59
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-45,349	-45,061	-42,473	-44,468	-44,167	-43,862
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-45,349	-45,145	-42,545	-44,533	-44,228	-43,921

Table 4-19
Projected Water Demands, Supplies, and Needs
Swisher County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Demand									
Red									
Municipal		1,473	1,478	1,561	1,580	1,587	1,619	1,661	1,717
Industrial		3	3	3	3	3	3	3	3
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		79,600	118,082	84,376	83,894	80,377	82,939	82,465	81,994
Mining		0	6	4	2	1	1	0	0
Beef Feedlot Livestock		2,412	2,856	2,987	3,466	4,022	4,443	4,908	5,422
Range & All Other Livestock		598	650	697	1,052	1,178	1,321	1,484	1,666
Total Red Basin Demand		84,086	123,075	89,628	89,997	87,168	90,326	90,521	90,802
Brazos									
Municipal		50	50	57	57	57	58	59	61
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		60,050	50,606	63,678	63,315	60,660	62,593	62,236	61,880
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		253	260	266	314	332	351	373	398
Total Brazos Basin Demand		60,353	50,916	64,001	63,686	61,049	63,002	62,668	62,339
Total Basin Supply									
Red									
Municipal				1,561	1,496	1,515	1,554	1,600	1,658
Industrial				3	3	3	3	3	3
Steam-Electric				0	0	0	0	0	0
Irrigation				84,376	83,894	80,377	82,939	82,465	81,994
Mining				4	2	1	1	0	0
Beef Feedlot Livestock				2,987	3,466	4,022	4,443	4,908	5,422
Range & All Other Livestock				697	1,052	1,178	1,321	1,484	1,666
Total Red Basin Supply				89,628	89,913	87,096	90,261	90,460	90,743
Brazos									
Municipal				57	57	57	58	59	61
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				18,329	18,254	18,187	18,125	18,069	18,018
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				266	314	332	351	373	398
Total Brazos Basin Supply				18,652	18,625	18,576	18,534	18,501	18,477
Total Basin Surplus/Shortage									
Red									
Municipal				0	-84	-72	-65	-61	-59
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Red Basin Surplus/Shortage				0	-84	-72	-65	-61	-59
Brazos									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-45,349	-45,061	-42,473	-44,468	-44,167	-43,862
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-45,349	-45,061	-42,473	-44,468	-44,167	-43,862

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] Tulia is obtaining a part of its municipal water from the Santa Rosa formation. Although studies in which the quantity of water available from the Santa Rosa have not been completed, the information available indicates that the aquifer can supply the quantities shown here for the projection period.

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Table 4-20
Projected Water Demands, Supplies, and Needs
Terry County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
					Projections					
WATER SUPPLIES										
	Brazos Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				2,724	2,724	2,724	2,724	2,724	2,724
	Aquifer Storage[2]	Net Depletion			787	597	418	248	87	0
	Subtotal GW (Ogallala)[3]				3,511	3,321	3,142	2,972	2,811	2,724
	Local Surface	Stock Tanks and Windmills			6	6	6	8	8	8
	Other Surface				0	0	0	0	0	0
	Total Supply				3,517	3,327	3,148	2,980	2,819	2,732
	Total Demand from Ogallala				3,511	3,321	3,142	2,972	2,811	2,724
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				83,122	83,122	83,122	83,122	83,122	83,122
	Aquifer Storage[2]	Net Depletion			23,813	18,077	12,647	7,510	2,648	0
	Subtotal GW (Ogallala)[3]				106,935	101,199	95,769	90,632	85,770	83,122
	Other Ground	Ogallala (CRMWA - Roberts Co.)			879	879	879	879	879	879
	Local Surface	Stock Tanks and Windmills			179	195	209	222	236	255
	Other Surface	Lake Meredith (CRMWA)			1,670	1,670	1,670	1,670	1,670	1,670
	Total Supply				109,663	103,943	98,527	93,403	88,555	85,926
	Total Demand from Ogallala				103,240	97,813	92,684	87,854	83,285	78,962
	County Total									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				85,846	85,846	85,846	85,846	85,846	85,846
	Aquifer Storage[2]	Net Depletion			24,600	18,674	13,065	7,758	2,735	0
	Subtotal GW (Ogallala)[3]				110,446	104,520	98,911	93,604	88,581	85,846
	Other Ground	Ogallala (CRMWA - Roberts Co.)			879	879	879	879	879	879
	Local Surface	Stock Tanks and Windmills			185	201	215	230	244	263
	Other Surface	Lake Meredith (CRMWA)			1,670	1,670	1,670	1,670	1,670	1,670
	Total Supply				113,180	107,270	101,675	96,383	91,374	88,658
	Total Demand from Ogallala				106,751	101,134	95,826	90,826	86,096	81,686
WATER DEMANDS										
Municipal Demand										
Brazos Basin										
Rural			21	23	23	24	23	24	24	23
	Subtotal		21	23	23	24	23	24	24	23
Colorado Basin										
Brownfield			1,481	1,738	1,655	1,712	1,750	1,805	1,853	1,935
Meadow			87	152	64	60	56	52	47	44
Rural			358	408	422	430	428	438	442	439
	Subtotal		1,926	2,298	2,141	2,202	2,234	2,295	2,342	2,418
Total Municipal Demand			1,947	2,321	2,164	2,226	2,257	2,319	2,366	2,441
Municipal Existing Supply										
Brazos Basin										
Rural		Ogallala			23	24	23	24	24	23
	Subtotal				23	24	23	24	24	23
Colorado Basin										
Brownfield		Ogallala			0	0	0	0	0	0
		Lake Meredith (CRMWA)[4]			1,670	1,670	1,670	1,670	1,670	1,670
		Ogallala (CRMWA - Roberts Co.)[4]			879	879	879	879	879	879
Brownfield Subtotal					2,549	2,549	2,549	2,549	2,549	2,549
Meadow		Ogallala			64	60	56	52	47	44
Rural		Ogallala			422	430	428	438	442	439
	Subtotal				3,035	3,039	3,033	3,039	3,038	3,032
Total Municipal Existing Supply					3,058	3,063	3,056	3,063	3,062	3,055
Municipal Surplus/Shortage										
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Colorado Basin										
Brownfield					894	837	799	744	696	614
Meadow					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				894	837	799	744	696	614
Total Municipal Surplus/Shortage					894	837	799	744	696	614
Municipal New Supply Need										
Brazos Basin										
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0

Table 4-20
Projected Water Demands, Supplies, and Needs
Terry County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Colorado Basin										
Brownfield					0	0	0	0	0	0
Meadow					0	0	0	0	0	0
Rural					0	0	0	0	0	0
	Subtotal				0	0	0	0	0	0
Total Municipal New Supply Need					0	0	0	0	0	0
Industrial Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	4	0	0	0	0	0	0
Total Industrial Demand			0	4	0	0	0	0	0	0
Industrial Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			0	0	0	0	0	0	0	0
Total Steam-Electric Demand			0	0	0	0	0	0	0	0
Steam-Electric Existing Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Existing Supply					0	0	0	0	0	0
Steam-Electric Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage					0	0	0	0	0	0
Steam-Electric New Supply Need										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Steam-Electric New Supply Need					0	0	0	0	0	0
Irrigation Demand										
Brazos Basin			6,595	8,884	5,343	5,069	4,809	4,563	4,329	4,107
Colorado Basin			125,306	139,177	101,517	96,312	91,374	86,689	82,245	78,028
Total Irrigation Demand			131,901	148,061	106,860	101,381	96,183	91,252	86,574	82,135
Irrigation Supply										
Brazos Basin		Ogallala			3,488	3,297	3,119	2,948	2,787	2,701
Colorado Basin		Ogallala			101,517	96,312	91,374	86,689	82,245	78,028
Total Irrigation Supply					105,005	99,609	94,493	89,637	85,032	80,729
Irrigation Surplus/Shortage										
Brazos Basin					-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Colorado Basin					0	0	0	0	0	0
Total Irrigation Surplus/Shortage					-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Mining Demand										
Brazos Basin			0	0	0	0	0	0	0	0
Colorado Basin			822	276	1,237	1,011	826	675	551	451
Total Mining Demand			822	276	1,237	1,011	826	675	551	451
Mining Supply										
Brazos Basin					0	0	0	0	0	0
Colorado Basin		Ogallala			1,237	1,011	826	675	551	451
Total Mining Supply					1,237	1,011	826	675	551	451
Mining Surplus/Shortage										
Brazos Basin					0	0	0	0	0	0
Colorado Basin					0	0	0	0	0	0
Total Mining Surplus/Shortage					0	0	0	0	0	0

Table 4-20
Projected Water Demands, Supplies, and Needs
Terry County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Beef Feedlot Livestock Demand									
Brazos Basin		0	0	0	0	0	0	0	0
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Brazos Basin		5	6	6	6	6	8	8	8
Colorado Basin		168	175	179	195	209	222	236	255
Total Range & All Other Livestock Demand		173	181	185	201	215	230	244	263
Range & All Other Livestock Supply									
Brazos Basin	Local			6	6	6	8	8	8
Colorado Basin	Local			179	195	209	222	236	255
Total Range & All Other Livestock Supply				185	201	215	230	244	263
Range & All Other Livestock Surplus/Shortage									
Brazos Basin				0	0	0	0	0	0
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,947	2,321	2,164	2,226	2,257	2,319	2,366	2,441
Industrial		0	4	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		131,901	148,061	106,860	101,381	96,183	91,252	86,574	82,135
Mining		822	276	1,237	1,011	826	675	551	451
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		173	181	185	201	215	230	244	263
Total County Demand		134,843	150,843	110,446	104,819	99,481	94,476	89,735	85,290
Total Supply									
Municipal				3,058	3,063	3,056	3,063	3,062	3,055
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				105,005	99,609	94,493	89,637	85,032	80,729
Mining				1,237	1,011	826	675	551	451
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				185	201	215	230	244	263
Total County Supply				109,485	103,884	98,590	93,605	88,889	84,498
Total Surplus/Shortage									
Municipal				894	837	799	744	696	614
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				-961	-935	-891	-871	-846	-792
Total Basin Demand									
Brazos									
Municipal		21	23	23	24	23	24	24	23
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		6,595	8,884	5,343	5,069	4,809	4,563	4,329	4,107
Mining		0	0	0	0	0	0	0	0
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		5	6	6	6	6	8	8	8
Total Brazos Basin Demand		6,621	8,913	5,372	5,099	4,838	4,595	4,361	4,138
Colorado									
Municipal		1,926	2,298	2,141	2,202	2,234	2,295	2,342	2,418
Industrial		0	4	0	0	0	0	0	0
Steam-Electric		0	0	0	0	0	0	0	0
Irrigation		125,306	139,177	101,517	96,312	91,374	86,689	82,245	78,028
Mining		822	276	1,237	1,011	826	675	551	451
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		168	175	179	195	209	222	236	255
Total Colorado Basin Demand		128,222	141,930	105,074	99,720	94,643	89,881	85,374	81,152

Table 4-20 Projected Water Demands, Supplies, and Needs Terry County Llano Estacado Region										
			Total in	Total in	Projections					
Basin		Source	1990	1996	2000	2010	2020	2030	2040	2050
			(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)

Table 4-20
Projected Water Demands, Supplies, and Needs
Terry County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Basin Supply									
Brazos									
Municipal				23	24	23	24	24	23
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				3,488	3,297	3,119	2,948	2,787	2,701
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				6	6	6	8	8	8
Total Brazos Basin Supply				3,517	3,327	3,148	2,980	2,819	2,732
Colorado									
Municipal				3,035	3,039	3,033	3,039	3,038	3,032
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				101,517	96,312	91,374	86,689	82,245	78,028
Mining				1,237	1,011	826	675	551	451
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				179	195	209	222	236	255
Total Colorado Basin Supply				105,968	100,557	95,442	90,625	86,070	81,766
Total Basin Surplus/Shortage									
Brazos									
Municipal				0	0	0	0	0	0
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Brazos Basin Surplus/Shortage				-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Colorado									
Municipal				894	837	799	744	696	614
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				894	837	799	744	696	614

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin.
In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

[4] The city's supply from CRMWA. Since the city's supply from CRMWA exceeds CRMWA's delivery capacity, the city must have terminal storage in order to use its full supply from CRMWA.

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Table 4-21
Projected Water Demands, Supplies, and Needs
Yoakum County
Llano Estacado Region

Basin		Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
WATER SUPPLIES										
	Colorado Basin									
	Aquifer Natural Recharge/Irrig. Recirculation[1]				91,702	91,702	91,702	91,702	91,702	91,702
	Aquifer Storage[2]	Net Depletion			52,535	48,199	44,217	40,517	37,124	32,669
	Subtotal GW (Ogallala)[3]				144,237	139,901	135,919	132,219	128,826	124,371
	Local Surface	Stock Tanks and Windmills			355	387	413	438	465	494
	Other Surface				0	0	0	0	0	0
	Total Supply				144,592	140,288	136,332	132,657	129,291	124,865
	Total Demand from Ogallala				96,343	91,088	85,754	79,828	75,594	71,667
WATER DEMANDS										
Municipal Demand										
Colorado Basin										
Denver City			1,079	764	1,198	1,298	1,357	1,458	1,544	1,657
Plains			438	309	410	438	457	477	486	501
Rural			298	281	312	328	335	342	344	353
	Subtotal		1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
Total Municipal Demand			1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
Municipal Existing Supply										
Colorado Basin										
Denver City		Ogallala			1,198	1,298	1,357	0	0	0
Plains		Ogallala			410	438	0	0	0	0
Rural		Ogallala			312	328	335	342	344	353
	Subtotal				1,920	2,064	1,692	342	344	353
Total Municipal Existing Supply					1,920	2,064	1,692	342	344	353
Municipal Surplus/Shortage										
Colorado Basin										
Denver City					0	0	0	-1,458	-1,544	-1,657
Plains					0	0	-457	-477	-486	-501
Rural					0	0	0	0	0	0
	Subtotal				0	0	-457	-1,935	-2,030	-2,158
Total Municipal Surplus/Shortage					0	0	-457	-1,935	-2,030	-2,158
Municipal New Supply Need										
Colorado Basin										
Denver City					0	0	0	1,458	1,544	1,657
Plains					0	0	457	477	486	501
Rural					0	0	0	0	0	0
	Subtotal				0	0	457	1,935	2,030	2,158
Total Municipal New Supply Need					0	0	457	1,935	2,030	2,158
Industrial Demand										
Colorado Basin			0	0	0	0	0	0	0	0
Total Industrial Demand			0	0	0	0	0	0	0	0
Industrial Existing Supply										
Colorado Basin					0	0	0	0	0	0
Total Industrial Existing Supply					0	0	0	0	0	0
Industrial Surplus/Shortage										
Colorado Basin					0	0	0	0	0	0
Total Industrial Surplus/Shortage					0	0	0	0	0	0
Industrial New Supply Need										
Colorado Basin					0	0	0	0	0	0
Total Industrial New Supply Need					0	0	0	0	0	0
Steam-Electric Demand										
Colorado Basin			0	0	2,200	2,200	2,200	2,200	2,200	2,200
Total Steam-Electric Demand			0	0	2,200	2,200	2,200	2,200	2,200	2,200

Table 4-21 Projected Water Demands, Supplies, and Needs Yoakum County Llano Estacado Region										
		Total in	Total in	Projections						
Basin	Source	1990	1996	2000	2010	2020	2030	2040	2050
		(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Steam-Electric Existing Supply									
Colorado Basin	Ogallala			2,200	2,200	2,200	2,200	2,200	2,200
Total Steam-Electric Existing Supply				2,200	2,200	2,200	2,200	2,200	2,200
Steam-Electric Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Steam-Electric Surplus/Shortage				0	0	0	0	0	0
Steam-Electric New Supply Need									
Colorado Basin				0	0	0	0	0	0
Total Steam-Electric New Supply Need				0	0	0	0	0	0
Irrigation Demand									
Colorado Basin		122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
Total Irrigation Demand		122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
Irrigation Supply									
Colorado Basin	Ogallala			84,925	80,861	76,990	73,305	69,797	66,456
Total Irrigation Supply				84,925	80,861	76,990	73,305	69,797	66,456
Irrigation Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Irrigation Surplus/Shortage				0	0	0	0	0	0
Mining Demand									
Colorado Basin		3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
Total Mining Demand		3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
Mining Supply									
Colorado Basin	Ogallala			7,298	5,963	4,872	3,981	3,253	2,658
Total Mining Supply				7,298	5,963	4,872	3,981	3,253	2,658
Mining Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Mining Surplus/Shortage				0	0	0	0	0	0
Beef Feedlot Livestock Demand									
Colorado Basin		0	0	0	0	0	0	0	0
Total Beef Feedlot Livestock Demand		0	0	0	0	0	0	0	0
Beef Feedlot Livestock Supply									
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Supply				0	0	0	0	0	0
Beef Feedlot Livestock Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Beef Feedlot Livestock Surplus/Shortage				0	0	0	0	0	0
Range & All Other Livestock Demand									
Colorado Basin		294	308	355	387	413	438	465	494
Total Range & All Other Livestock Demand		294	308	355	387	413	438	465	494
Range & All Other Livestock Supply									
Colorado Basin	Local			355	387	413	438	465	494
Total Range & All Other Livestock Supply				355	387	413	438	465	494
Range & All Other Livestock Surplus/Shortage									
Colorado Basin				0	0	0	0	0	0
Total Range & All Other Livestock Surplus/Shortage				0	0	0	0	0	0
Total Demand									
Municipal		1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation		122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
Mining		3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		294	308	355	387	413	438	465	494
Total County Demand		127,991	155,560	96,698	91,475	86,624	82,201	78,089	74,319

Table 4-21
Projected Water Demands, Supplies, and Needs
Yoakum County
Llano Estacado Region

Basin	Source	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Total Supply									
Municipal				1,920	2,064	1,692	342	344	353
Industrial				0	0	0	0	0	0
Steam-Electric				2,200	2,200	2,200	2,200	2,200	2,200
Irrigation				84,925	80,861	76,990	73,305	69,797	66,456
Mining				7,298	5,963	4,872	3,981	3,253	2,658
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				355	387	413	438	465	494
Total County Supply				96,698	91,475	86,167	80,266	76,059	72,161
Total Surplus/Shortage									
Municipal				0	0	-457	-1,935	-2,030	-2,158
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total County Surplus/Shortage				0	0	-457	-1,935	-2,030	-2,158
Total Basin Demand									
Colorado									
Municipal		1,815	1,354	1,920	2,064	2,149	2,277	2,374	2,511
Industrial		0	0	0	0	0	0	0	0
Steam-Electric		0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation		122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
Mining		3,473	6,795	7,298	5,963	4,872	3,981	3,253	2,658
Beef Feedlot Livestock		0	0	0	0	0	0	0	0
Range & All Other Livestock		294	308	355	387	413	438	465	494
Total Colorado Basin Demand		127,991	155,560	96,698	91,475	86,624	82,201	78,089	74,319
Total Basin Supply									
Colorado									
Municipal				1,920	2,064	1,692	342	344	353
Industrial				0	0	0	0	0	0
Steam-Electric				2,200	2,200	2,200	2,200	2,200	2,200
Irrigation				84,925	80,861	76,990	73,305	69,797	66,456
Mining				7,298	5,963	4,872	3,981	3,253	2,658
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				355	387	413	438	465	494
Total Colorado Basin Supply				96,698	91,475	86,167	80,266	76,059	72,161
Total Basin Surplus/Shortage									
Colorado									
Municipal				0	0	-457	-1,935	-2,030	-2,158
Industrial				0	0	0	0	0	0
Steam-Electric				0	0	0	0	0	0
Irrigation				0	0	0	0	0	0
Mining				0	0	0	0	0	0
Beef Feedlot Livestock				0	0	0	0	0	0
Range & All Other Livestock				0	0	0	0	0	0
Total Colorado Basin Surplus/Shortage				0	0	-457	-1,935	-2,030	-2,158

[1] Calculated as the TWDB estimated 1985 through 1995 average pumpage minus net depletion.

[2] Allocated between river basins on basis of percent of acreage of the county overlying the Ogallala Aquifer in each basin. In counties where water levels increased between 1985 and 1995, estimates of withdrawl from storage are held constant at zero for the projections period.

[3] Subtotal GW means quantity of water available from the aquifer; e.g. from groundwater source.

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Table 4-22
Projected Water Demands, Supplies, and Needs
River Basin and Llano Estacado Region Summaries
Llano Estacado Region

Basin	Total in 1990 (acft)	Total in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
Canadian Basin Demand								
Municipal	3	4	4	4	4	4	4	4
Industrial	0	0	0	0	0	0	0	0
Steam-Electric	0	0	0	0	0	0	0	0
Irrigation	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0
Beef Feedlot Livestock	0	0	0	0	0	0	0	0
Range & All Other Livestock	0	0	82	87	93	99	106	113
Total Canadian Basin Demand	3	4	86	91	97	103	110	117
Canadian Basin Supply								
Municipal			4	4	4	4	4	4
Industrial			0	0	0	0	0	0
Steam-Electric			0	0	0	0	0	0
Irrigation			0	0	0	0	0	0
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			82	87	93	99	106	113
Total Canadian Basin Supply			86	91	97	103	110	117
Canadian Basin Surplus/Shortage [1]								
Municipal			0	0	0	0	0	0
Industrial			0	0	0	0	0	0
Steam-Electric			0	0	0	0	0	0
Irrigation			0	0	0	0	0	0
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			0	0	0	0	0	0
Red Basin Demand								
Municipal	7,927	7,212	8,736	9,044	9,210	9,378	9,554	9,843
Industrial	2,395	3,410	2,615	2,833	2,979	3,094	3,355	3,609
Steam-Electric	0	0	0	0	0	0	0	0
Irrigation	730,231	808,302	640,957	623,447	603,478	590,136	574,291	558,963
Mining	344	350	372	353	357	366	373	382
Beef Feedlot Livestock	13,610	16,054	16,788	19,482	22,609	24,976	27,587	30,473
Range & All Other Livestock	4,491	4,773	4,904	5,619	6,101	6,627	7,212	7,858
Total Red Basin Demand	758,998	840,101	674,372	660,778	644,734	634,577	622,372	611,128
Red Basin Supply								
Municipal			8,736	8,960	9,138	5,741	5,807	5,930
Industrial			2,615	2,833	2,979	3,094	3,355	3,609
Steam-Electric			0	0	0	0	0	0
Irrigation			638,544	621,157	601,302	588,065	572,278	557,010
Mining			372	353	357	366	373	382
Beef Feedlot Livestock			16,788	19,482	22,609	24,976	27,587	30,473
Range & All Other Livestock			4,904	5,619	6,101	6,627	7,212	7,858
Total Red Basin Supply			671,959	658,404	642,486	628,869	616,612	605,262
Red Basin Surplus/Shortage [1]								
Municipal			0	-84	-72	-3,637	-3,747	-3,913
Industrial			0	0	0	0	0	0
Steam-Electric			0	0	0	0	0	0
Irrigation			-2,413	-2,290	-2,176	-2,071	-2,013	-1,953
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			0	0	0	0	0	0

Table 4-22 Projected Water Demands, Supplies, and Needs River Basin and Llano Estacado Region Summaries Llano Estacado Region								
	Total in	Total in	Projections					
Basin	1990	1996	2000	2010	2020	2030	2040	2050
	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Brazos Basin Demand								
Municipal	64,091	70,105	67,743	68,849	69,074	70,014	70,105	71,034
Industrial	5,752	6,314	6,409	7,228	7,678	8,242	9,269	11,595
Steam-Electric	14,302	14,857	20,000	20,000	30,000	30,000	30,000	35,000
Irrigation	2,226,798	2,673,812	1,818,110	1,757,220	1,696,435	1,642,481	1,588,390	1,536,364
Mining	4,207	7,684	8,090	6,919	5,894	5,050	4,368	3,764
Beef Feedlot Livestock	10,604	11,772	12,310	14,286	16,579	18,311	20,228	22,344
Range & All Other Livestock	4,949	5,231	6,589	7,360	7,955	8,567	9,243	9,999
Total Brazos Basin Demand	2,330,703	2,789,775	1,939,251	1,881,862	1,833,615	1,782,665	1,731,603	1,690,100
Brazos Basin Supply								
Municipal			80,776	80,825	76,529	74,296	103,220	103,003
Industrial			6,409	7,228	7,678	8,242	9,269	11,595
Steam-Electric			22,799	22,944	30,025	30,200	30,314	35,505
Irrigation			1,648,601	1,586,451	1,523,759	1,463,092	1,405,983	1,350,714
Mining			8,090	6,919	5,894	5,050	4,368	3,764
Beef Feedlot Livestock			12,310	14,286	16,579	18,311	20,228	22,344
Range & All Other Livestock			6,589	7,360	7,955	8,567	9,243	9,999
Total Brazos Basin Supply			1,785,574	1,726,013	1,668,419	1,607,758	1,582,625	1,536,924
Brazos Basin Surplus/Shortage [1]								
Municipal			13,033	11,976	7,455	4,282	33,115	31,969
Industrial			0	0	0	0	0	0
Steam-Electric			2,799	2,944	25	200	314	505
Irrigation			-169,509	-170,769	-172,676	-179,389	-182,407	-185,650
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			0	0	0	0	0	0
Colorado Basin Demand								
Municipal	9,586	9,749	10,874	11,204	11,246	11,356	11,426	11,648
Industrial	347	486	377	405	252	428	461	493
Steam-Electric	0	0	2,200	2,200	2,200	2,200	2,200	2,200
Irrigation	700,711	895,213	606,303	575,384	546,049	518,215	491,807	466,749
Mining	10,300	19,522	21,921	17,717	14,377	11,661	9,440	7,678
Beef Feedlot Livestock	482	588	615	714	828	915	1,011	1,116
Range & All Other Livestock	1,042	1,087	1,291	1,406	1,498	1,595	1,704	1,826
Total Colorado Basin Demand	722,468	926,645	643,581	609,030	576,450	546,370	518,049	491,710
Colorado Basin Supply								
Municipal			12,070	11,748	10,902	9,514	9,475	9,487
Industrial			377	405	252	428	461	493
Steam-Electric			2,200	2,200	2,200	2,200	2,200	2,200
Irrigation			606,303	575,384	546,049	518,215	491,807	466,749
Mining			21,921	17,717	14,377	11,661	9,440	7,678
Beef Feedlot Livestock			615	714	828	915	1,011	1,116
Range & All Other Livestock			1,291	1,406	1,498	1,595	1,704	1,826
Total Colorado Basin Supply			644,777	609,574	576,106	544,528	516,098	489,549
Colorado Basin Surplus/Shortage [1]								
Municipal			1,196	544	-344	-1,842	-1,951	-2,161
Industrial			0	0	0	0	0	0
Steam-Electric			0	0	0	0	0	0
Irrigation			0	0	0	0	0	0
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			0	0	0	0	0	0

Table 4-22 Projected Water Demands, Supplies, and Needs River Basin and Llano Estacado Region Summaries Llano Estacado Region									
	Total in	Total in	Projections						
Basin	1990	1996	2000	2010	2020	2030	2040	2050
	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)	(acft)
Llano Estacado Region Demand								
Municipal	81,607	87,070	87,357	89,101	89,534	90,752	91,089	92,529
Industrial	8,494	10,210	9,401	10,466	10,909	11,764	13,085	15,697
Steam-Electric	14,302	14,857	22,200	22,200	32,200	32,200	32,200	37,200
Irrigation	3,657,740	4,377,327	3,065,370	2,956,051	2,845,962	2,750,832	2,654,488	2,562,076
Mining	14,851	27,556	30,383	24,989	20,628	17,077	14,181	11,824
Beef Feedlot Livestock	24,696	28,414	29,713	34,482	40,016	44,202	48,826	53,933
Range & All Other Livestock	10,482	11,091	12,866	14,472	15,647	16,888	18,265	19,796
Total Llano Estacado Region Demand	3,812,172	4,556,525	3,257,290	3,151,761	3,054,896	2,963,715	2,872,134	2,793,055
Llano Estacado Region Supply								
Municipal			101,586	101,537	96,573	89,555	118,506	118,424
Industrial			9,401	10,466	10,909	11,764	13,085	15,697
Steam-Electric			24,999	25,144	32,225	32,400	32,514	37,705
Irrigation			2,893,448	2,782,992	2,671,110	2,569,372	2,470,068	2,374,473
Mining			30,383	24,989	20,628	17,077	14,181	11,824
Beef Feedlot Livestock			29,713	34,482	40,016	44,202	48,826	53,933
Range & All Other Livestock			12,866	14,472	15,647	16,888	18,265	19,796
Total Llano Estacado Region Supply			3,102,396	2,994,082	2,887,108	2,781,258	2,715,445	2,631,852
Llano Estacado Region Surplus/Shortage [1]								
Municipal			14,229	12,436	7,039	-1,197	27,417	25,895
Industrial			0	0	0	0	0	0
Steam-Electric			2,799	2,944	25	200	314	505
Irrigation			-171,922	-173,059	-174,852	-181,460	-184,420	-187,603
Mining			0	0	0	0	0	0
Beef Feedlot Livestock			0	0	0	0	0	0
Range & All Other Livestock			0	0	0	0	0	0

Notes:

[1] The values listed in this section of the table are not necessarily additive due to the fact that demands and supplies are not necessarily located in close proximity to each other.

It is important to note that the computations of supply and demand have been based upon county level data, and therefore show the county balance of shortage or surplus. This method of analysis may show a county or a user group within the county as having a surplus of water when individuals of user groups have shortages; i.e., the surplus water is not in a location nor an ownership such that it can be obtained by users who need it. This condition most likely applies to each user group of each county, and cannot be addressed unless plans are developed for each individual water user.

4.2 Water Needs Projections by Major Water Provider

For purposes of this regional planning project, and in accordance with TWDB Rules, water supply projections and needs projections are tabulated for each Major Water Provider identified by the Llano Estacado RWPG (Table 4-23).[2] For each Major Water Provider the water demands were brought forward from "Llano Estacado Regional Water Plan; Introduction, Description of the Planning Region (Task 1) and Population and Water Demand Projections (Task 2), Table 2-22; Llano Estacado Regional Water Planning Group, HDR Engineering, Inc., Lubbock, TX, October 1999."

Of the three Major Water Providers identified by the Llano Estacado RWPG, none are projected to have a water shortage during the planning period (Table 4-23).

[2] 31 Texas Administrative Code, Chapter 357, Regional Water Planning Guideline Rules, Texas Water Development Board, Austin, Texas, March 11, 1998.

Table 4-23.
Projected Water Demands, Supplies and Needs for Major Water Providers

	2000 (acft)	***2010 (acft)***	***2020 (acft)***	***2030 (acft)***	***2040 (acft)***	***2050 (acft)***
Canadian River Municipal Water Authority (CRMWA)						
Projected Supply						
Lake Meredith System	116,000	116,000	116,000	116,000	116,000	116,000
Total Projected Supply	116,000	116,000	116,000	116,000	116,000	116,000
Projected Demand[1]	91,893	101,239	101,846	102,277	101,887	101,614
Projected Surplus/Shortage	24,107	14,761	14,154	13,723	14,113	14,386
White River Municipal Water District (WRMWD)						
Projected Supply						
White River Reservoir	4,000	4,000	4,000	4,000	4,000	4,000
Total Projected Supply	4,000	4,000	4,000	4,000	4,000	4,000
Projected Demand[1]	1,927	1,869	1,771	1,659	1,591	1,552
Projected Surplus/Shortage	2,073	2,131	2,229	2,341	2,409	2,448
Mackenzie Municipal Water Authority (MMWA)						
Projected Supply						
Lake Mackenzie[2]	2,080	2,080	2,080	2,080	2,080	2,080
Total Projected Supply	2,080	2,080	2,080	2,080	2,080	2,080
Projected Demand[1]	868	868	869	869	869	869
Projected Surplus/Shortage	1,212	1,212	1,211	1,211	1,211	1,211

[1] See Section 2.10 (Table 2-22) for a more detailed description of how projected demands were calculated.
[2] Lake Mackenzie has a permit that shows firm yield of 5,200 acft/yr. However, the Mackenzie Municipal Water Authority indicates from recent experience that it can supply only about 40 percent of this, or 2,080 acft/yr, and since 1994 the lake has supplied only about 869 acft/yr.

4.3 Social and Economic Impacts of Not Meeting Projected Water Needs

Section 357.7(4) of the rules for implementing Senate Bill 1 require that the social and economic impact of not meeting regional water supply needs be evaluated by the Regional Water Planning Groups (RWPG). The Texas Water Development Board (TWDB) is required to provide technical assistance, upon request, to complete the evaluations. The Llano Estacado Regional Water Planning Group requested technical assistance of the TWDB to perform the required analyses. TWDB conducted the required analysis of the impacts of the identified needs for the Llano Estacado Region using the same methodology that was used for all other regions. The results of this analysis are presented for information purposes. These results give an indication of the significance of having an adequate water supply, and should be viewed by individuals and public policy makers in that light. The results of the social and economic impact analyses have not been used in any other way in the development of this water plan, since the TWDB Regional Water Planning Rules specified that the RWPG was to develop a water plan to meet the projected needs (shortages) of each water user group unless it was determined that it was not feasible to meet one or more of the projected needs.

The purpose of this element of Senate Bill 1 planning is to provide an estimate of the social and economic importance of meeting projected water needs, or conversely, provides estimates of potential costs of not meeting projected needs of each water user group. The social and economic effects of not meeting a projected water need can be viewed as the potential benefit to be gained from implementing a strategy to meet the particular need. The summation of all the impacts gives a view of the ultimate magnitude of the impacts caused by not meeting all of the projected needs.

The projected total water demands for the Llano Estacado Region decrease from 3.26 million acft in 2000 to 2.96 million acft in 2030, and 2.79 million acft in 2050 (Table 2-19). Under historic drought of record water supply conditions, and with no water management strategies in place, water shortages would amount to 172,000 acft/yr in 2000, increasing to 195,000 acft/yr in 2030 and to 202,000 acft/yr by 2050 (Table 4-24).

The water needs (shortages) of the region amount to about 6 percent of the projected demand by 2020, increasing to 7 percent of demand in 2040 and 2050. This means that by 2050 the region would be able to supply only 93 percent of the projected water demands unless supply development or other water management strategies are implemented.

The Llano Estacado Regional Water Planning Group identified 39 individual water user groups which showed an unmet need during drought-of-record supply conditions for each decade from 2000 to 2050 (Table 4-24). Of the 21 counties of the Llano Estacado Region, 17 have water user groups with projected water needs (shortages). The water user groups having projected water needs, together with the quantities of projected needs (shortages) are listed by county and river basin of location in the region (Table 4-24).[3] For example, the projected municipal needs for the City of Dimmitt of Castro County, in the Brazos River Basin are 1,250 acft/yr in 2030, 1,253 acft/yr in 2040, and 1,270 acft/yr in 2050 (Table 4-24). The projected

[3] If there is no water user group that has a projected water need (shortage) in a county, then that county is not listed in Table 4-24. The following counties of the Llano Estacado Region that did not have water user groups with projected water needs are Briscoe, Dawson, Dickens, and Motley.

needs for irrigation in Castro County in the Brazos River Basin are 39,261 acft/yr in 2000, 36,342 acft/yr in 2030, and 33,527 acft/yr in 2050(Table 4-24).

The water user groups having projected water needs (shortages) of Bailey, Castro, Cochran, Crosby, Deaf Smith, Floyd, Gaines, Garza, Hale, Hockley, Lamb, Lubbock, Lynn, Parmer, Swisher, Terry, and Yoakum Counties are shown in Table 4-24, with summaries by user group, river basin, and the entire region presented at the end of the Table. For example, the projected need (shortage) for the region is 194,721 acft/yr in 2030, of which 50,176 acft/yr is in the Red River Basin, 141,600 acft/yr is in the Brazos River Basin, and 2,945 acft/yr is in the Colorado River Basin (Table 4-24). Of the total projected need in 2030 of 194,721 acft/yr, 13,261 acft/yr is for municipal purposes, and 181,460 acft/yr is for irrigation (Table 4-24). The quantities for each county, and river basin are shown in Table 4-24, and will not be repeated in the text.

The detailed results of the social and economic analyses of not meeting the projected water needs (Shortages) are shown in Tables 4-24 through 4-28. Each water user group with a need is evaluated in terms of effects upon population, school enrollment, gross business, employment, and personal income. Both the direct and indirect social and economic impact on the region resulting from the shortage was calculated. The effects of shortages on population and school enrollment are the social variables of the analysis. Declining populations indicate a deprecation of social services in most cases, while declining school enrollment indicates loss of younger cohorts of the population and possibilities of strains on the tax bases, when combined with economic losses. Economic variables chosen by TWDB for this analysis include gross economic output (sales and business gross income), employment (number of jobs) and personal income (wages, salaries and proprietors net receipts).

The regional effects upon population, school enrollment, gross value of business, employment, and personal incomes are stated below. The values for individual water user groups, counties, and river basins are shown in Table 4-24 for population, Table 4-25 for school enrollment, Table 4-26 for gross business value, Table 4-27 for employment, and Table 4-28 for personal income.

Table 4-24.												
Projected Water Needs by Water User Group and Impacts of Not Meeting Water Needs Upon Population												
Llano Estacado Region												
	Projected Water Needs[1]						**Population Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Bailey County												
Brazos Basin												
Irrigation	7,278	6,463	5,350	4,014	2,431	925	49	37	40	28	20	7
County Total	7,278	6,463	5,350	4,014	2,431	925	49	37	40	28	20	7
Castro County												
Brazos Basin												
Dimmitt--Municipal				1,250	1,253	1,270				4,147	4,497	4,558
Hart--Municipal					302	310					741	760
Irrigation	39,261	39,143	38,621	36,342	34,894	33,527	267	279	287	251	257	248
County Total	39,261	39,143	38,621	37,592	36,449	35,107	267	279	287	4,398	5,495	5,566
Cochran County												
Brazos Basin												
Morton--Municipal			673	670	663	653			1,660	1,544	1,626	1,602
Whiteface--Municipal				80	75	74				185	206	216
Irrigation	13,181	12,046	10,275	9,118	8,098	7,129	90	70	76	64	66	63
County Total	13,181	12,046	10,948	9,868	8,836	7,856	90	70	1,736	1,793	1,898	1,881
Crosby County												
Red Basin												
Irrigation	179	107	48				2					
County Total	179	107	48	0	0	0	2	0	0	0	0	0
Deaf Smith County												
Red Basin												
Hereford--Municipal				2,516	2,596	2,717				7,651	8,542	8,940
County Total	0	0	0	2,516	2,596	2,717	0	0	0	7,651	8,542	8,940

Table 4-24 continued												
	Projected Water Needs[1]						**Population Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Floyd County												
Brazos Basin												
Lockney--Municipal				190	157	140				437	384	343
Irrigation	23,567	23,949	24,088	23,665	23,420	23,059	161	139	180	165	192	202
County Total	23,567	23,949	24,088	23,855	23,577	23,199	161	139	180	602	576	545
Gaines County												
Seagraves--Municipal	0	581	555	547	535	533		1,375	1,367	1,259	1,313	1,307
County Total	0	581	555	547	535	533	0	1,375	1,367	1,259	1,313	1,307
Garza County												
Brazos Basin												
Irrigation	570	90					4	0				
County Total	570	90	0	0	0	0	4	0	0	0	0	0
Hale County												
Red Basin												
Irrigation	2,234	2,183	2,128	2,071	2,013	1,953	15	12	16	15	15	16
Brazos Basin												
Abernathy--Municipal	0	0	403	406	403	405			993	936	988	994
Hale Center--Municipal	0	0	0	0	394	384					966	942
Irrigation	0	0	1,649	5,535	7,869	11,042			12	39	64	96
Hale County Totals												
Municipal	0	0	403	406	797	789	0	0	993	936	1,954	1,936
Irrigation	2,234	2,183	3,777	7,606	9,882	12,995	15	12	28	54	79	112
County Total	2,234	2,183	4,180	8,012	10,679	13,784	15	12	1,021	990	2,033	2,048

Table 4-24 continued												
	Projected Water Needs[1]						**Population Effects[2]**					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 Number**	**2010 Number**	**2020 Number**	**2030 Number**	**2040 Number**	**2050 Number**
Hockley County												
Brazos Basin												
Anton--Municipal	0	258	258	253	243	237		611	637	582	596	582
Irrigation	4,272	0	0	0	0	0	29					
Colorado Basin												
Sundown--Municipal	0	0	453	463	465	473			1,116	1,066	1,140	1,160
Hockley County Totals												
Municipal	0	258	711	716	708	710	0	611	1,753	1,648	1,736	1,742
Irrigation	4,272	0	0	0	0	0	29	0	0	0	0	0
County Total	4,272	258	711	716	708	710	29	611	1,753	1,648	1,736	1,742
Lamb County												
Brazos Basin												
Amherst--Municipal	0	0	0	112	106	102				259	259	249
Earth--Municipal	0	0	0	331	334	343				763	820	842
Olton--Municipal	0	0	598	606	610	617			1,475	1,397	1,497	1,513
Sudan--Municipal	0	0	320	322	318	319			788	742	780	782
County Total	0	0	918	1,371	1,368	1,381	0	0	2,263	3,161	3,356	3,386
Lubbock County												
Brazos Basin												
Abernathy--Municipal	0	0	168	177	184	195			414	407	451	479
Idalou--Municipal	0	0	459	507	523	543			1,130	1,168	1,283	1,333
New Deal--Municipal	0	0	100	102	105	110			247	234	257	269
Shallowater--Municipal	0	0	210	251	261	281			517	578	640	689
Wolfforth--Municipal	0	0	421	467	476	494			1,037	1,075	1,168	1,212
County Total	0	0	1,358	1,504	1,549	1,623	0	0	3,345	3,462	3,799	3,982

Table 4-24 continued												
	Projected Water Needs[1]						**Population Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Lynn County												
Brazos Basin												
Wilson--Municipal	0	0	0	46	43	42				107	117	122
County Total	0	0	0	46	43	42	0	0	0	107	117	122
Parmer County												
Red Basin												
Friona--Municipal	0	0	0	1056	1090	1137				3,503	3,912	4,081
Brazos Basin												
Bovina--Municipal	0	0	388	402	419	441			957	926	1,028	1,081
Farwell--Municipal	0	0	486	507	531	562			1,198	1,168	1,303	1,378
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	232	300	360	378	442	477
Parmer County Totals												
Municipal	0	0	874	1,965	2,040	2,140	0	0	2,155	5,597	6,243	6,540
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	232	300	360	378	442	477
County Total	34,176	42,245	49,404	56,597	62,026	66,840	232	300	2,515	5,975	6,685	7,017
Swisher County												
Red Basin												
Kress--Municipal	0	84	72	65	61	59		199	178	151	168	172
Irrigation	45,349	45,061	42,473	44,468	44,167	43,862	309	321	314	309	327	323
County Total	45,349	45,145	42,545	44,533	44,228	43,921	309	520	492	460	495	495
Terry County												
Brazos basin												
Irrigation	1,855	1,772	1,690	1,615	1,542	1,406	13	11	12	11	13	12
County Total	1,855	1,772	1,690	1,615	1,542	1,406	13	11	12	11	13	12

Table 4-24 continued												
	Projected Water Needs[1]						**Population Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Yoakum County												
Colorado Basin												
Denver City--Municipal	0	0	0	1,458	1,544	1,657				4,837	5,542	5,948
Plains--Municipal	0	0	457	477	486	501			1,126	1,099	1,192	1,230
County Total	0	0	457	1,935	2,030	2,158	0	0	1,126	5,936	6,734	7,178
Red Basin Totals												
Municipal	0	84	72	3,637	3,747	3,913	0	199	178	11,305	12,622	13,193
Irrigation	47,762	47,351	44,649	46,539	46,180	45,815	326	333	330	324	342	339
Total	47,762	47,435	44,721	50,176	49,927	49,728	326	532	508	11,629	12,964	13,532
Brazos Basin Totals												
Municipal	0	258	4,484	6,679	7,400	7,522	0	611	11,053	16,655	19,607	19,946
Irrigation	124,160	125,708	130,203	134,921	138,240	141,788	845	836	967	936	1,054	1,105
Total	124,160	125,966	134,687	141,600	145,640	149,310	845	1,447	12,020	17,591	20,661	21,051
Colorado Basin Totals												
Municipal	0	581	1,465	2,945	3,030	3,164	0	1,375	3,609	8,261	9,187	9,645
Irrigation	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	581	1,465	2,945	3,030	3,164	0	1,375	3,609	8,261	9,187	9,645

Table 4-24 concluded

County/Basin/Water User Group	Projected Water Needs[1] 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	Population Effects[2] 2000 Number	2010 Number	2020 Number	2030 Number	2040 Number	2050 Number
Llano Estacado Region												
Totals												
Municipal	0	923	6,021	13,261	14,177	14,599	0	2,185	14,840	36,221	41,416	42,784
Irrigation	171,922	173,059	174,852	181,460	184,420	187,603	1,171	1,169	1,297	1,260	1,396	1,444
Total	171,922	173,982	180,873	194,721	198,597	202,202	1,171	3,354	16,137	37,481	42,812	44,228
Percent of Totals												
Municipal	0.00	0.53	3.33	6.81	7.14	7.22	0.00	65.15	91.96	96.64	96.74	96.74
Irrigation	100.00	99.47	96.67	93.19	92.86	92.78	100.00	34.85	8.04	3.36	3.26	3.26
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Summary from Tables 4-1 through 4-21. Water needs are the differences between projected water supplies for an individual water user group and projected water demands for that water user group; i.e.; projected water shortages for that water user group. If the calculation of supply minus demand is positive, the water user group has a surplus, and consequently does not have a projected water need at the date for which the calculation is made. Only those water user groups having a calculated shortage (need) are included in this table.

[2] Computations were provided by the Texas Water Development Board in response to request of Llano Estacado Regional Water Planning Group.

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4.3.1 Population

The projected population growth of the region would be economically restricted by curtailed potential job creation. This would result in outmigration of some current population, reduced migration, and reduced future population growth. Compared to the baseline growth in population, the region could expect 3,000 fewer people in 2010, 37,000 fewer in 2030 and 44,000 fewer in 2050 (Table 4-24). The expected 2050 population under the unmet water need (shortage) conditions would be 7.5 percent lower than projected in the region's most likely growth projection.

4.3.2 School Enrollment

School enrollment is related to the size of the population of childbearing age, which, as mentioned above, is dependent upon employment. Failure to meet the projected water needs of the region, such that employment opportunities are affected, would result in lower population, and would result in reduced school enrollment. School enrollment estimates for the region are 818 less in 2010, 9,214 less in 2030, and 10,866 less in 2050 than if the projected water needs are met (Table 4-25).

4.3.3 Gross Business Value

The estimated effect of water shortages projected for the Llano Estacado Region upon gross value of business, which includes the direct and indirect effects are $140.7 million/yr in 2010, $1.4 billion/yr in 2030, and $1.6 billion/yr in 2050 (Table 4-26). The economic impact of unmet water needs varies depending on the Water User Group for which the shortage is projected. On a per acre-foot basis, the largest impacts result from shortages in municipal uses, while shortages for irrigation typically result in the smallest impact. Impacts for individual water user groups are shown in Table 4-26.

The largest percentage of the economic and social impacts of unmet water needs in the Llano Estacado Region result from municipal water shortages. In 2030, municipalities have unmet needs of 13,261 acre-feet, 6.8 percent of the total unmet needs. The economic impacts of this shortage (19,000 jobs, $1.36 billion in output, and $501.9 million of income) represent approximately 60 to 70 percent of the total impacts (Tables 4-27, 4-26, and 4-28, respectively). By 2050, unmet municipal needs total 14,599 acre-feet (7.2 percent of the total) resulting in

21,000 jobs not created, and reductions of $1.5 billion in potential output and $550.7 million in potential income (Tables 4-27, 4-26, and 4-28).

Unmet irrigation needs represent the largest category of need through 2050, but, due to the relatively small value of economic output added per acre-foot, the impacts of not meeting irrigation needs are considerably less. In 2010, irrigation has unmet needs of 173,000 acft, 99 percent of the total. The economic impacts of the shortage (645 direct and indirect jobs, $58.5 million in output, and $11.8 million in income) represent 30 to 40 percent of the total economic impact (Tables 4-27, 4-26, and 4-28, respectively).

If the water needs are left entirely unmet, the level of shortage in 2010 results in 1,788 fewer jobs than would be expected if the water needs of 2010 are fully met. The gap in job growth due to water shortages grows to 20,000 by 2030, and to 22,000 by 2050.

In the social and economic impact analyses summarized above, the emphasis has been upon the effects of not meeting projected water needs. However, is it very important that the reader understand fully the importance of a dependable supply of water the Llano Estacado 21-county region, which accounts for 60 percent of the state's cotton production, 16 percent of the state's grain sorghum production, 25 percent of the state's corn production, 75 percent of the state's peanut production, and 50 percent of the state's fed cattle for grocery store and restaurant sales of beef and beef products.

In the Llano Estacado Water Planning Region, where irrigation is used to supplement precipitation, irrigation is the farmer's drought management plan. If it does not rain, the farmer must apply irrigation water that is stored in the aquifer beneath the farmer's land to make up for the precipitation that did not occur. A shortage of water during the growing season could result in little or no crop production for the year. Irrigation farming is big, expensive business. Production costs range from $250 to $350 per acre. The average size farm in the region is about 2,000 acres, with production costs ranging from $500,000 to $700,00 per year. A water shortage to an irrigated farm of the region during periods of drought is severely detrimental to the economy of the region, as well as the state and the nation.

Livestock require more water during periods of drought, which generally occur during summer months when temperatures are above normal with very low relative humidity. A shortage of water available to livestock would result in death of livestock, sickness, loss of body weight, and reduced volumes of beef for local, state, and national markets.

Table 4-25.												
Projected Water Needs by Water User Group and Impacts of Not Meeting Water Needs Upon School Enrollment												
Llano Estacado Region												
	Projected Water Needs[1]						**School Enrollment Effects[2]**					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 Number**	**2010 Number**	**2020 Number**	**2030 Number**	**2040 Number**	**2050 Number**
Bailey County												
Brazos Basin												
Irrigation	7,278	6,463	5,350	4,014	2,431	925	11	6	8	6	6	2
County Total	7,278	6,463	5,350	4,014	2,431	925	11	6	8	6	6	2
Castro County												
Brazos Basin												
Dimmitt--Municipal				1,250	1,253	1,270				1,020	1,067	1,082
Hart--Municipal					302	310					187	192
Irrigation	39,261	39,143	38,621	36,342	34,894	33,527	60	70	68	62	65	63
County Total	39,261	39,143	38,621	37,592	36,449	35,107	60	70	68	1,082	1,319	1,337
Cochran County												
Brazos Basin												
Morton--Municipal			673	670	663	653			392	382	411	405
Whiteface--Municipal				80	75	74				40	62	66
Irrigation	13,181	12,046	10,275	9,118	8,098	7,129	20	11	16	14	20	19
County Total	13,181	12,046	10,948	9,868	8,836	7,856	20	11	408	436	493	490
Crosby County												
Red Basin												
Irrigation	179	107	48				0	0	0			
County Total	179	107	48	0	0	0	0	0	0	0	0	0
Deaf Smith County												
Red Basin												
Hereford--Municipal				2,516	2,596	2,717				1,881	2,028	2,122
County Total	0	0	0	2,516	2,596	2,717	0	0	0	1,881	2,028	2,122

Table 4-25 continued												
	Projected Water Needs[1]						**School Enrollment Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Floyd County												
Brazos Basin												
Lockney--Municipal				190	157	140				108	97	87
Irrigation	23,567	23,949	24,088	23,665	23,420	23,059	36	21	37	35	58	62
County Total	23,567	23,949	24,088	23,855	23,577	23,199	36	21	37	143	155	149
Gaines County												
Seagraves--Municipal	0	581	555	547	535	533		346	323	311	332	330
County Total	0	581	555	547	535	533	0	346	323	311	332	330
Garza County												
Brazos Basin												
Irrigation	570	90					1	0				
County Total	570	90	0	0	0	0	1	0	0	0	0	0
Hale County												
Red Basin												
Irrigation	2,234	2,183	2,128	2,071	2,013	1,953	3	2	3	3	5	5
Brazos Basin												
Abernathy--Municipal	0	0	403	406	403	405			235	231	250	251
Hale Center--Municipal	0	0	0	0	394	384					244	238
Irrigation	0	0	1,649	5,535	7,869	11,042			2	8	19	30
Hale County Totals												
Municipal	0	0	403	406	797	789	0	0	235	231	494	489
Irrigation	2,234	2,183	3,777	7,606	9,882	12,995	3	2	5	11	24	35
County Total	2,234	2,183	4,180	8,012	10,679	13,784	3	2	240	242	518	524

Table 4-25 continued												
	Projected Water Needs[1]						School Enrollment Effects[2]					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 Number**	**2010 Number**	**2020 Number**	**2030 Number**	**2040 Number**	**2050 Number**
Hockley County												
Brazos Basin												
Anton--Municipal		258	258	253	243	237		154	150	144	151	147
Irrigation	4,272						7					
Colorado Basin												
Sundown--Municipal			453	463	465	473			264	264	288	293
Hockley County Totals												
Municipal	0	258	711	716	708	710	0	154	414	408	439	440
Irrigation	4,272	0	0	0	0	0	7	0	0	0	0	0
County Total	4,272	258	711	716	708	710	7	154	414	408	439	440
Lamb County												
Brazos Basin												
Amherst--Municipal	0	0	0	112	106	102				64	66	63
Earth--Municipal	0	0	0	331	334	343				189	207	213
Olton--Municipal	0	0	598	606	610	617			348	345	378	382
Sudan--Municipal	0	0	320	322	318	319			186	184	197	198
County Total	0	0	918	1,371	1,368	1,381	0	0	534	782	848	856
Lubbock County												
Brazos Basin												
Abernathy--Municipal	0	0	168	177	184	195			98	101	114	121
Idalou--Municipal	0	0	459	507	523	543			267	289	324	337
New Deal--Municipal	0	0	100	102	105	110			58	58	65	68
Shallowater--Municipal	0	0	210	251	261	281			122	143	162	174
Wolfforth--Municipal	0	0	421	467	476	494			245	266	295	306
County Total	0	0	1,358	1,504	1,549	1,623	0	0	790	857	960	1,006

Table 4-25 continued												
	Projected Water Needs[1]						**School Enrollment Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Lynn County												
Brazos Basin												
Wilson--Municipal	0	0	0	46	43	42				23	36	37
County Total	0	0	0	46	43	42	0	0	0	23	36	37
Parmer County												
Red Basin												
Friona--Municipal	0	0	0	1056	1090	1137				861	929	969
Brazos Basin												
Bovina--Municipal	0	0	388	402	419	441			226	229	260	273
Farwell--Municipal	0	0	486	507	531	562			283	289	329	348
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	52	75	85	93	112	121
Parmer County Totals												
Municipal	0	0	874	1,965	2,040	2,140	0	0	509	1,379	1,518	1,590
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	52	75	85	93	112	121
County Total	34,176	42,245	49,404	56,597	62,026	66,840	52	75	594	1,472	1,630	1,711
Swisher County												
Red Basin												
Kress--Municipal	0	84	72	65	61	59		50	36	32	51	53
Irrigation	45,349	45,061	42,473	44,468	44,167	43,862	69	81	74	76	83	82
County Total	45,349	45,145	42,545	44,533	44,228	43,921	69	131	110	108	134	135
Terry County												
Brazos basin												
Irrigation	1,855	1,772	1,690	1,615	1,542	1,406	3	2	2	2	4	4
County Total	1,855	1,772	1,690	1,615	1,542	1,406	3	2	2	2	4	4

Table 4-25 continued												
	Projected Water Needs[1]						**School Enrollment Effects[2]**					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 Number**	**2010 Number**	**2020 Number**	**2030 Number**	**2040 Number**	**2050 Number**
Yoakum County												
Colorado Basin												
Denver City--Municipal	0	0	0	1,458	1,544	1,657				1,189	1,316	1,412
Plains--Municipal	0	0	457	477	486	501			266	272	301	311
County Total	0	0	457	1,935	2,030	2,158	0	0	266	1,461	1,617	1,723
Red Basin Totals												
Municipal	0	84	72	3,637	3,747	3,913	0	50	36	2,774	3,008	3,144
Irrigation	47,762	47,351	44,649	46,539	46,180	45,815	72	83	77	79	88	87
Total	47,762	47,435	44,721	50,176	49,927	49,728	72	133	113	2,853	3,096	3,231
Brazos Basin Totals												
Municipal	0	258	4,484	6,679	7,400	7,522	0	154	2,610	4,105	4,902	4,988
Irrigation	124,160	125,708	130,203	134,921	138,240	141,788	190	185	218	220	284	301
Total	124,160	125,966	134,687	141,600	145,640	149,310	190	339	2,828	4,325	5,186	5,289
Colorado Basin Totals												
Municipal	0	581	1,465	2,945	3,030	3,164	0	346	853	2,036	2,237	2,346
Irrigation	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	581	1,465	2,945	3,030	3,164	0	346	853	2,036	2,237	2,346

Table 4-25 concluded

County/Basin/Water User Group	Projected Water Needs[1] 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	School Enrollment Effects[2] 2000 Number	2010 Number	2020 Number	2030 Number	2040 Number	2050 Number
Llano Estacado Region												
Totals												
Municipal	0	923	6,021	13,261	14,177	14,599	0	550	3,499	8,915	10,147	10,478
Irrigation	171,922	173,059	174,852	181,460	184,420	187,603	262	268	295	299	372	388
Total	171,922	173,982	180,873	194,721	198,597	202,202	262	818	3,794	9,214	10,519	10,866
Percent of Totals												
Municipal	0.00	0.53	3.33	6.81	7.14	7.22	0.00	67.24	92.22	96.75	96.46	96.43
Irrigation	100.00	99.47	96.67	93.19	92.86	92.78	100.00	32.76	7.78	3.25	3.54	3.57
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Summary from Tables 4-1 through 4-21. Water needs are the differences between projected water supplies for an individual water user group and projected water demands for that water user group; i.e.; projected water shortages for that water user group. If the calculation of supply minus demand is positive, the water user group has a surplus, and consequently does not have a projected water need at the date for which the calculation is made. Only those water user groups having a calculated shortage (need) are included in this table.

[2] Computations were provided by the Texas Water Development Board in response to request of Llano Estacado Regional Water Planning Group.

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Table 4-26.

Projected Water Needs by Water User Group and Impacts of Not Meeting Water Needs Upon Gross Business

Llano Estacado Region

	Projected Water Needs[1]						Gross Business Effects--Millions of 1999 Dollars[2]					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 million$s**	**2010 million$s**	**2020 million$s**	**2030 million$s**	**2040 million$s**	**2050 million$s**
Bailey County												
Brazos Basin												
Irrigation	7,278	6,463	5,350	4,014	2,431	925	2.5	2.2	1.8	1.4	0.8	0.3
County Total	7,278	6,463	5,350	4,014	2,431	925	2.5	2.2	1.8	1.4	0.8	0.3
Castro County												
Brazos Basin												
Dimmitt--Municipal				1,250	1,253	1,270				151.5	151.8	153.9
Hart--Municipal					302	310					26.9	27.6
Irrigation	39,261	39,143	38,621	36,342	34,894	33,527	13.3	13.2	13.1	12.3	11.8	11.3
County Total	39,261	39,143	38,621	37,592	36,449	35,107	13.3	13.2	13.1	163.8	190.5	192.8
Cochran County												
Brazos Basin												
Morton--Municipal			673	670	663	653			59.9	59.6	59.0	58.1
Whiteface--Municipal				80	75	74				7.1	6.7	6.6
Irrigation	13,181	12,046	10,275	9,118	8,098	7,129	4.5	4.1	3.5	3.1	2.7	2.4
County Total	13,181	12,046	10,948	9,868	8,836	7,856	4.5	4.1	63.4	69.9	68.4	67.1
Crosby County												
Red Basin												
Irrigation	179	107	48				0.1	0.0	0.0			
County Total	179	107	48	0	0	0	0.1	0.0	0.0	0.0	0.0	0.0
Deaf Smith County												
Red Basin												
Hereford--Municipal				2,516	2,596	2,717				283.6	292.6	306.3
County Total	0	0	0	2,516	2,596	2,717	0.0	0.0	0.0	283.6	292.6	306.3

Table 4-26 continued												
	Projected Water Needs[1]						Gross Business Effects--Millions of 1999 Dollars[2]					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Floyd County												
Brazos Basin												
Lockney--Municipal				190	157	140				16.9	14.0	12.5
Irrigation	23,567	23,949	24,088	23,665	23,420	23,059	8.0	8.1	8.1	8.0	7.9	7.8
County Total	23,567	23,949	24,088	23,855	23,577	23,199	8.0	8.1	8.1	24.9	21.9	20.3
Gaines County												
Seagraves--Municipal	0	581	555	547	535	533		51.7	49.4	48.7	47.6	47.5
County Total	0	581	555	547	535	533	0.0	51.7	49.4	48.7	47.6	47.5
Garza County												
Brazos Basin												
Irrigation	570	90					0.2	0.0				
County Total	570	90	0	0	0	0	0.2	0.0	0.0	0.0	0.0	0.0
Hale County												
Red Basin												
Irrigation	2,234	2,183	2,128	2,071	2,013	1,953	0.8	0.7	0.7	0.7	0.7	0.7
Brazos Basin												
Abernathy--Municipal	0	0	403	406	403	405			35.9	36.1	35.9	36.1
Hale Center--Municipal	0	0	0	0	394	384					35.1	34.2
Irrigation	0	0	1,649	5,535	7,869	11,042			0.6	1.9	2.7	3.7
Hale County Totals												
Municipal	0	0	403	406	797	789	0.0	0.0	35.9	36.1	71.0	70.2
Irrigation	2,234	2,183	3,777	7,606	9,882	12,995	0.8	0.7	1.3	2.6	3.3	4.4
County Total	2,234	2,183	4,180	8,012	10,679	13,784	0.8	0.7	37.2	38.7	74.3	74.6

Table 4-26 continued												
	Projected Water Needs[1]						**Gross Business Effects--Millions of 1999 Dollars**[2]					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Hockley County												
Brazos Basin												
Anton--Municipal	0	258	258	253	243	237		23.0	23.0	22.5	21.6	21.1
Irrigation	4,272	0	0	0	0	0	1.4					
Colorado Basin												
Sundown--Municipal	0	0	453	463	465	473			40.3	41.2	41.4	42.1
Hockley County Totals												
Municipal	0	258	711	716	708	710	0.0	23.0	63.3	63.7	63.0	63.2
Irrigation	4,272	0	0	0	0	0	1.4	0.0	0.0	0.0	0.0	0.0
County Total	4,272	258	711	716	708	710	1.4	23.0	63.3	63.7	63.0	63.2
Lamb County												
Brazos Basin												
Amherst--Municipal	0	0	0	112	106	102				10.0	9.4	9.1
Earth--Municipal	0	0	0	331	334	343				29.5	29.7	30.5
Olton--Municipal	0	0	598	606	610	617			53.2	54.0	54.3	54.9
Sudan--Municipal	0	0	320	322	318	319			28.5	28.7	28.3	28.4
County Total	0	0	918	1,371	1,368	1,381	0.0	0.0	81.7	122.1	121.8	122.9
Lubbock County												
Brazos Basin												
Abernathy--Municipal	0	0	168	177	184	195			15.0	15.8	16.4	17.4
Idalou--Municipal	0	0	459	507	523	543			40.9	45.1	46.6	48.3
New Deal--Municipal	0	0	100	102	105	110			8.9	9.1	9.3	9.8
Shallowater--Municipal	0	0	210	251	261	281			18.7	22.3	23.2	25.0
Wolfforth--Municipal	0	0	421	467	476	494			37.5	41.6	42.4	44.0
County Total	0	0	1,358	1,504	1,549	1,623	0.0	0.0	120.9	133.9	137.9	144.5

Table 4-26 continued												
	Projected Water Needs[1]						**Gross Business Effects--Millions of 1999 Dollars[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Lynn County												
Brazos Basin												
Wilson--Municipal	0	0	0	46	43	42				4.1	3.8	3.7
County Total	0	0	0	46	43	42	0.0	0.0	0.0	4.1	3.8	3.7
Parmer County												
Red Basin												
Friona--Municipal	0	0	0	1056	1090	1137				128.0	132.1	137.8
Brazos Basin												
Bovina--Municipal	0	0	388	402	419	441			34.5	35.8	37.3	39.3
Farwell--Municipal	0	0	486	507	531	562			43.3	45.1	47.3	50.0
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	11.6	14.3	16.4	18.5	20.3	21.9
Parmer County Totals												
Municipal	0	0	874	1,965	2,040	2,140	0.0	0.0	77.8	208.9	216.7	227.1
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	11.6	14.3	16.4	18.5	20.3	21.9
County Total	34,176	42,245	49,404	56,597	62,026	66,840	11.6	14.3	94.2	227.4	236.9	248.9
Swisher County												
Red Basin												
Kress--Municipal	0	84	72	65	61	59		7.5	6.4	5.8	5.4	5.3
Irrigation	45,349	45,061	42,473	44,468	44,167	43,862	15.3	15.2	14.4	15.0	14.9	14.8
County Total	45,349	45,145	42,545	44,533	44,228	43,921	15.3	22.7	20.8	20.8	20.4	20.1
Terry County												
Brazos basin												
Irrigation	1,855	1,772	1,690	1,615	1,542	1,406	0.6	0.6	0.6	0.5	0.5	0.5
County Total	1,855	1,772	1,690	1,615	1,542	1,406	0.6	0.6	0.6	0.5	0.5	0.5

Table 4-26 continued												
	Projected Water Needs[1]						Gross Business Effects--Millions of 1999 Dollars[2]					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 million$s**	**2010 million$s**	**2020 million$s**	**2030 million$s**	**2040 million$s**	**2050 million$s**
Yoakum County												
Colorado Basin												
Denver City--Municipal	0	0	0	1,458	1,544	1,657				176.7	187.1	200.8
Plains--Municipal	0	0	457	477	486	501			40.7	42.5	43.3	44.6
County Total	0	0	457	1,935	2,030	2,158	0.0	0.0	40.7	219.1	230.4	245.4
Red Basin Totals												
Municipal	0	84	72	3,637	3,747	3,913	0.0	7.5	6.4	417.4	430.1	449.3
Irrigation	47,762	47,351	44,649	46,539	46,180	45,815	16.1	16.0	15.1	15.7	15.6	15.5
Total	47,762	47,435	44,721	50,176	49,927	49,728	16.1	23.5	21.5	433.1	445.7	464.8
Brazos Basin Totals												
Municipal	0	258	4,484	6,679	7,400	7,522	0.0	23.0	399.2	634.8	699.1	710.5
Irrigation	124,160	125,708	130,203	134,921	138,240	141,788	42.0	42.5	44.0	45.6	46.7	47.9
Total	124,160	125,966	134,687	141,600	145,640	149,310	42.0	65.5	443.2	680.4	745.8	758.4
Colorado Basin Totals												
Municipal	0	581	1,465	2,945	3,030	3,164	0.0	51.7	130.4	309.1	319.4	334.9
Irrigation	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0	581	1,465	2,945	3,030	3,164	0.0	51.7	130.4	309.1	319.4	334.9

Table 4-26 continued

County/Basin/Water User Group	Projected Water Needs[1]						Gross Business Effects--Millions of 1999 Dollars[2]					
	2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2000 million$s	2010 million$s	2020 million$s	2030 million$s	2040 million$s	2050 million$s
Llano Estacado Region												
Totals												
Municipal	0	923	6,021	13,261	14,177	14,599	0.0	82.2	536.0	1,361.2	1,448.6	1,494.7
Irrigation	171,922	173,059	174,852	181,460	184,420	187,603	58.1	58.5	59.1	61.3	62.3	63.4
Total	171,922	173,982	180,873	194,721	198,597	202,202	58.1	140.7	595.1	1,422.5	1,510.9	1,558.1
Percent of Totals												
Municipal	0.00	0.53	3.33	6.81	7.14	7.22	0.00	58.42	90.07	95.69	95.87	95.93
Irrigation	100.00	99.47	96.67	93.19	92.86	92.78	100.00	41.58	9.93	4.31	4.13	4.07
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Summary from Tables 4-1 through 4-21. Water needs are the differences between projected water supplies for an individual water user group and projected water demands for that water user group; i.e.; projected water shortages for that water user group. If the calculation of supply minus demand is positive, the water user group has a surplus, and consequently does not have a projected water need at the date for which the calculation is made. Only those water user groups having a calculated shortage (need) are included in this table.

[2] Computations were provided by the Texas Water Development Board in response to request of Llano Estacado Regional Water Planning Group.

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Table 4-27. Projected Water Needs by Water User Group and Impacts of Not Meeting Water Needs Upon Employment Llano Estacado Region												
	Projected Water Needs[1]						**Employment Effects[2]**					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 Number**	**2010 Number**	**2020 Number**	**2030 Number**	**2040 Number**	**2050 Number**
Bailey County												
Brazos Basin												
Irrigation	7,278	6,463	5,350	4,014	2,431	925	27	24	20	15	9	3
County Total	7,278	6,463	5,350	4,014	2,431	925	27	24	20	15	9	3
Castro County												
Brazos Basin												
Dimmitt--Municipal				1,250	1,253	1,270				2,266	2,271	2,302
Hart--Municipal					302	310					374	384
Irrigation	39,261	39,143	38,621	36,342	34,894	33,527	146	146	144	135	130	125
County Total	39,261	39,143	38,621	37,592	36,449	35,107	146	146	144	2,401	2,775	2,811
Cochran County												
Brazos Basin												
Morton--Municipal			673	670	663	653			834	830	821	809
Whiteface--Municipal				80	75	74				99	93	92
Irrigation	13,181	12,046	10,275	9,118	8,098	7,129	49	45	38	34	30	27
County Total	13,181	12,046	10,948	9,868	8,836	7,856	49	45	872	963	944	927
Crosby County												
Red Basin												
Irrigation	179	107	48				1	0	0			
County Total	179	107	48	0	0	0	1	0	0	0	0	0
Deaf Smith County												
Red Basin												
Hereford--Municipal				2,516	2,596	2,717				4,181	4,314	4,515
County Total	0	0	0	2,516	2,596	2,717	0	0	0	4,181	4,314	4,515

Table 4-27 continued

County/Basin/Water User Group	Projected Water Needs[1]						Employment Effects[2]					
	2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2000 Number	2010 Number	2020 Number	2030 Number	2040 Number	2050 Number
Floyd County												
Brazos Basin												
Lockney--Municipal				190	157	140				235	194	173
Irrigation	23,567	23,949	24,088	23,665	23,420	23,059	88	89	90	88	87	86
County Total	23,567	23,949	24,088	23,855	23,577	23,199	88	89	90	323	282	259
Gaines County												
Seagraves--Municipal	0	581	555	547	535	533		720	687	677	663	660
County Total	0	581	555	547	535	533	0	720	687	677	663	660
Garza County												
Brazos Basin												
Irrigation	570	90					2	0				
County Total	570	90	0	0	0	0	2	0	0	0	0	0
Hale County												
Red Basin												
Irrigation	2,234	2,183	2,128	2,071	2,013	1,953	8	8	8	8	7	7
Brazos Basin												
Abernathy--Municipal	0	0	403	406	403	405			499	503	499	502
Hale Center--Municipal	0	0	0	0	394	384					488	476
Irrigation	0	0	1,649	5,535	7,869	11,042			6	21	29	41
Hale County Totals												
Municipal	0	0	403	406	797	789	0	0	499	503	987	977
Irrigation	2,234	2,183	3,777	7,606	9,882	12,995	8	8	14	28	37	48
County Total	2,234	2,183	4,180	8,012	10,679	13,784	8	8	513	531	1,024	1,026

Table 4-27 continued												
	Projected Water Needs[1]						Employment Effects[2]					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Hockley County												
Brazos Basin												
Anton--Municipal	0	258	258	253	243	237		320	320	313	301	294
Irrigation	4,272	0	0	0	0	0	16					
Colorado Basin												
Sundown--Municipal	0	0	453	463	465	473			561	573	576	586
Hockley County Totals												
Municipal	0	258	711	716	708	710	0	320	881	887	877	879
Irrigation	4,272	0	0	0	0	0	16	0	0	0	0	0
County Total	4,272	258	711	716	708	710	16	320	881	887	877	879
Lamb County												
Brazos Basin												
Amherst--Municipal	0	0	0	112	106	102				139	131	126
Earth--Municipal	0	0	0	331	334	343				410	414	425
Olton--Municipal	0	0	598	606	610	617			741	751	756	764
Sudan--Municipal	0	0	320	322	318	319			396	399	394	395
County Total	0	0	918	1,371	1,368	1,381	0	0	1,137	1,698	1,694	1,710
Lubbock County												
Brazos Basin												
Abernathy--Municipal	0	0	168	177	184	195			208	219	228	242
Idalou--Municipal	0	0	459	507	523	543			568	628	648	673
New Deal--Municipal	0	0	100	102	105	110			124	126	130	136
Shallowater--Municipal	0	0	210	251	261	281			260	311	323	348
Wolfforth--Municipal	0	0	421	467	476	494			521	578	590	612
County Total	0	0	1,358	1,504	1,549	1,623	0	0	1,682	1,863	1,919	2,010

Table 4-27 continued												
	Projected Water Needs[1]						**Employment Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Lynn County												
Brazos Basin												
Wilson--Municipal	0	0	0	46	43	42				57	53	52
County Total	0	0	0	46	43	42	0	0	0	57	53	52
Parmer County												
Red Basin												
Friona--Municipal	0	0	0	1056	1090	1137				1,914	1,976	2,061
Brazos Basin												
Bovina--Municipal	0	0	388	402	419	441			481	498	519	546
Farwell--Municipal	0	0	486	507	531	562			602	628	658	696
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	127	157	181	203	223	241
Parmer County Totals												
Municipal	0	0	874	1,965	2,040	2,140	0	0	1,083	3,040	3,152	3,303
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	127	157	181	203	223	241
County Total	34,176	42,245	49,404	56,597	62,026	66,840	127	157	1,263	3,244	3,376	3,544
Swisher County												
Red Basin												
Kress--Municipal	0	84	72	65	61	59		104	89	81	76	73
Irrigation	45,349	45,061	42,473	44,468	44,167	43,862	169	168	158	166	165	163
County Total	45,349	45,145	42,545	44,533	44,228	43,921	169	272	247	246	240	236
Terry County												
Brazos basin												
Irrigation	1,855	1,772	1,690	1,615	1,542	1,406	7	7	6	6	6	5
County Total	1,855	1,772	1,690	1,615	1,542	1,406	7	7	6	6	6	5

Table 4-27 continued

County/Basin/Water User Group	Projected Water Needs[1]						Employment Effects[2]					
	2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2000 Number	2010 Number	2020 Number	2030 Number	2040 Number	2050 Number
Yoakum County												
Colorado Basin												
Denver City--Municipal	0	0	0	1,458	1,544	1,657				2,643	2,799	3,004
Plains--Municipal	0	0	457	477	486	501			566	591	602	621
County Total	0	0	457	1,935	2,030	2,158	0	0	566	3,234	3,401	3,624
Red Basin Totals												
Municipal	0	84	72	3,637	3,747	3,913	0	104	89	6,176	6,365	6,649
Irrigation	47,762	47,351	44,649	46,539	46,180	45,815	178	176	166	173	172	171
Total	47,762	47,435	44,721	50,176	49,927	49,728	178	280	255	6,349	6,537	6,820
Brazos Basin Totals												
Municipal	0	258	4,484	6,679	7,400	7,522	0	320	5,554	8,990	9,885	10,046
Irrigation	124,160	125,708	130,203	134,921	138,240	141,788	462	468	485	503	515	528
Total	124,160	125,966	134,687	141,600	145,640	149,310	462	788	6,039	9,493	10,400	10,574
Colorado Basin Totals												
Municipal	0	581	1,465	2,945	3,030	3,164	0	720	1,814	4,485	4,639	4,870
Irrigation	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	581	1,465	2,945	3,030	3,164	0	720	1,814	4,485	4,639	4,870

Table 4-27 concluded												
	Projected Water Needs[1]						**Employment Effects[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Llano Estacado Region												
Totals												
Municipal	0	923	6,021	13,261	14,177	14,599	0	1,143	7,457	19,650	20,889	21,565
Irrigation	171,922	173,059	174,852	181,460	184,420	187,603	640	645	651	676	687	699
Total	171,922	173,982	180,873	194,721	198,597	202,202	640	1,788	8,109	20,326	21,576	22,263
Percent of Totals												
Municipal	0.00	0.53	3.33	6.81	7.14	7.22	0.00	63.95	91.97	96.67	96.82	96.86
Irrigation	100.00	99.47	96.67	93.19	92.86	92.78	100.00	36.05	8.03	3.33	3.18	3.14
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Summary from Tables 4-1 through 4-21. Water needs are the differences between projected water supplies for an individual water user group and projected water demands for that water user group; i.e.; projected water shortages for that water user group. If the calculation of supply minus demand is positive, the water user group has a surplus, and consequently does not have a projected water need at the date for which the calculation is made. Only those water user groups having a calculated shortage (need) are included in this table.

[2] Computations were provided by the Texas Water Development Board in response to request of Llano Estacado Regional Water Planning Group.

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Table 4-28.												
Projected Water Needs by Water User Group and Impacts of Not Meeting Water Needs Upon Personal Income												
Llano Estacado Region												
	Projected Water Needs[1]						**Personal Income Effects--Millions of 1999 Dollars[2]**					
County/Basin/Water User Group	**2000 (acft)**	**2010 (acft)**	**2020 (acft)**	**2030 (acft)**	**2040 (acft)**	**2050 (acft)**	**2000 million$s**	**2010 million$s**	**2020 million$s**	**2030 million$s**	**2040 million$s**	**2050 million$s**
Bailey County												
Brazos Basin												
Irrigation	7,278	6,463	5,350	4,014	2,431	925	0.5	0.4	0.4	0.3	0.2	0.1
County Total	7,278	6,463	5,350	4,014	2,431	925	0.5	0.4	0.4	0.3	0.2	0.1
Castro County												
Brazos Basin												
Dimmitt--Municipal				1,250	1,253	1,270				58.3	58.4	59.2
Hart--Municipal					302	310					9.5	9.7
Irrigation	39,261	39,143	38,621	36,342	34,894	33,527	2.7	2.7	2.6	2.5	2.4	2.3
County Total	39,261	39,143	38,621	37,592	36,449	35,107	2.7	2.7	2.6	60.7	70.3	71.2
Cochran County												
Brazos Basin												
Morton--Municipal			673	670	663	653			21.1	21.0	20.8	20.5
Whiteface--Municipal				80	75	74				2.5	2.4	2.3
Irrigation	13,181	12,046	10,275	9,118	8,098	7,129	0.9	0.8	0.7	0.6	0.6	0.5
County Total	13,181	12,046	10,948	9,868	8,836	7,856	0.9	0.8	21.8	24.2	23.7	23.3
Crosby County												
Red Basin												
Irrigation	179	107	48				0.0	0.0	0.0			
County Total	179	107	48	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Deaf Smith County												
Red Basin												
Hereford--Municipal				2,516	2,596	2,717				107.2	110.6	115.8
County Total	0	0	0	2,516	2,596	2,717	0.0	0.0	0.0	107.2	110.6	115.8

Table 4-28 continued												
	Projected Water Needs[1]						**Personal Income Effects--Millions of 1999 Dollars[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Floyd County												
Brazos Basin												
Lockney--Municipal				190	157	140				6.0	4.9	4.4
Irrigation	23,567	23,949	24,088	23,665	23,420	23,059	1.6	1.6	1.6	1.6	1.6	1.6
County Total	23,567	23,949	24,088	23,855	23,577	23,199	1.6	1.6	1.6	7.6	6.5	6.0
Gaines County												
Seagraves--Municipal	0	581	555	547	535	533		18.2	17.4	17.2	16.8	16.7
County Total	0	581	555	547	535	533	0.0	18.2	17.4	17.2	16.8	16.7
Garza County												
Brazos Basin												
Irrigation	570	90					0.0	0.0				
County Total	570	90	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Hale County												
Red Basin												
Irrigation	2,234	2,183	2,128	2,071	2,013	1,953	0.2	0.1	0.1	0.1	0.1	0.1
Brazos Basin												
Abernathy--Municipal	0	0	403	406	403	405			12.7	12.8	12.7	12.7
Hale Center--Municipal	0	0	0	0	394	384					12.4	12.1
Irrigation	0	0	1,649	5,535	7,869	11,042			0.1	0.4	0.5	0.8
Hale County Totals												
Municipal	0	0	403	406	797	789	0.0	0.0	12.7	12.8	25.0	24.8
Irrigation	2,234	2,183	3,777	7,606	9,882	12,995	0.2	0.1	0.3	0.5	0.7	0.9
County Total	2,234	2,183	4,180	8,012	10,679	13,784	0.2	0.1	12.9	13.3	25.7	25.7

Table 4-28 continued												
	Projected Water Needs[1]						**Personal Income Effects--Millions of 1999 Dollars[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Hockley County												
Brazos Basin												
Anton--Municipal	0	258	258	253	243	237		8.1	8.1	7.9	7.6	7.4
Irrigation	4,272	0	0	0	0	0	0.3					
Colorado Basin												
Sundown--Municipal	0	0	453	463	465	473			14.2	14.5	14.6	14.9
Hockley County Totals												
Municipal	0	258	711	716	708	710	0.0	8.1	22.3	22.5	22.2	22.3
Irrigation	4,272	0	0	0	0	0	0.3	0.0	0.0	0.0	0.0	0.0
County Total	4,272	258	711	716	708	710	0.3	8.1	22.3	22.5	22.2	22.3
Lamb County												
Brazos Basin												
Amherst--Municipal	0	0	0	112	106	102				3.5	3.3	3.2
Earth--Municipal	0	0	0	331	334	343				10.4	10.5	10.8
Olton--Municipal	0	0	598	606	610	617			18.8	19.0	19.2	19.4
Sudan--Municipal	0	0	320	322	318	319			10.0	10.1	10.0	10.0
County Total	0	0	918	1,371	1,368	1,381	0.0	0.0	28.8	43.1	43.0	43.4
Lubbock County												
Brazos Basin												
Abernathy--Municipal	0	0	168	177	184	195			5.3	5.6	5.8	6.1
Idalou--Municipal	0	0	459	507	523	543			14.4	15.9	16.4	17.1
New Deal--Municipal	0	0	100	102	105	110			3.1	3.2	3.3	3.5
Shallowater--Municipal	0	0	210	251	261	281			6.6	7.9	8.2	8.8
Wolfforth--Municipal	0	0	421	467	476	494			13.2	14.7	14.9	15.5
County Total	0	0	1,358	1,504	1,549	1,623	0.0	0.0	42.6	47.2	48.6	51.0

Table 4-28 continued												
	Projected Water Needs[1]						Personal Income Effects--Millions of 1999 Dollars[2]					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Lynn County												
Brazos Basin												
Wilson--Municipal	0	0	0	46	43	42				1.4	1.4	1.3
County Total	0	0	0	46	43	42	0.0	0.0	0.0	1.4	1.4	1.3
Parmer County												
Red Basin												
Friona--Municipal	0	0	0	1056	1090	1137				49.2	50.8	53.0
Brazos Basin												
Bovina--Municipal	0	0	388	402	419	441			12.2	12.6	13.2	13.8
Farwell--Municipal	0	0	486	507	531	562			15.3	15.9	16.7	17.6
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	2.3	2.9	3.3	3.7	4.1	4.4
Parmer County Totals												
Municipal	0	0	874	1,965	2,040	2,140	0.0	0.0	27.4	77.8	80.6	84.5
Irrigation	34,176	42,245	48,530	54,632	59,986	64,700	2.3	2.9	3.3	3.7	4.1	4.4
County Total	34,176	42,245	49,404	56,597	62,026	66,840						
Swisher County												
Red Basin												
Kress--Municipal	0	84	72	65	61	59		2.6	2.3	2.0	1.9	1.9
Irrigation	45,349	45,061	42,473	44,468	44,167	43,862	3.1	3.1	2.9	3.0	3.0	3.0
County Total	45,349	45,145	42,545	44,533	44,228	43,921	3.1	5.7	5.2	5.1	4.9	4.9
Terry County												
Brazos basin												
Irrigation	1,855	1,772	1,690	1,615	1,542	1,406	0.1	0.1	0.1	0.1	0.1	0.1
County Total	1,855	1,772	1,690	1,615	1,542	1,406	0.1	0.1	0.1	0.1	0.1	0.1

Table 4-28 continued

County/Basin/Water User Group	Projected Water Needs[1] 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	Personal Income Effects--Millions of 1999 Dollars[2] 2000 million$s	2010 million$s	2020 million$s	2030 million$s	2040 million$s	2050 million$s
Yoakum County												
Colorado Basin												
Denver City--Municipal	0	0	0	1,458	1,544	1,657				67.9	72.0	77.2
Plains--Municipal	0	0	457	477	486	501			14.4	15.0	15.3	15.7
County Total	0	0	457	1,935	2,030	2,158	0.0	0.0	14.4	82.9	87.2	93.0
Red Basin Totals												
Municipal	0	84	72	3,637	3,747	3,913	0.0	2.6	2.3	158.5	163.3	170.6
Irrigation	47,762	47,351	44,649	46,539	46,180	45,815	3.3	3.2	3.1	3.2	3.2	3.1
Total	47,762	47,435	44,721	50,176	49,927	49,728	3.3	5.9	5.3	161.6	166.5	173.7
Brazos Basin Totals												
Municipal	0	258	4,484	6,679	7,400	7,522	0.0	8.1	140.8	228.8	251.4	255.5
Irrigation	124,160	125,708	130,203	134,921	138,240	141,788	8.5	8.6	8.9	9.2	9.4	9.7
Total	124,160	125,966	134,687	141,600	145,640	149,310	8.5	16.7	149.7	238.0	260.9	265.2
Colorado Basin Totals												
Municipal	0	581	1,465	2,945	3,030	3,164	0.0	18.2	46.0	114.6	118.6	124.6
Irrigation	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0	581	1,465	2,945	3,030	3,164	0.0	18.2	46.0	114.6	118.6	124.6

Table 4-28 concluded												
	Projected Water Needs[1]						**Personal Income Effects--Millions of 1999 Dollars[2]**					
County/Basin/Water User Group	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
	(acft)	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**(acft)**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**	**million$s**
Llano Estacado Region												
Totals												
Municipal	0	923	6,021	13,261	14,177	14,599	0.0	29.0	189.1	501.9	533.4	550.7
Irrigation	171,922	173,059	174,852	181,460	184,420	187,603	11.7	11.8	11.9	12.4	12.6	12.8
Total	171,922	173,982	180,873	194,721	198,597	202,202	11.7	40.8	201.0	514.3	546.0	563.5
Percent of Totals												
Municipal	0.00	0.53	3.33	6.81	7.14	7.22	0.00	71.02	94.06	97.59	97.69	97.72
Irrigation	100.00	99.47	96.67	93.19	92.86	92.78	100.00	28.98	5.94	2.41	2.31	2.28
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Summary from Tables 4-1 through 4-21. Water needs are the differences between projected water supplies for an individual water user group and projected water demands for that water user group; i.e.; projected water shortages for that water user group. If the calculation of supply minus demand is positive, the water user group has a surplus, and consequently does not have a projected water need at the date for which the calculation is made. Only those water user groups having a calculated shortage (need) are included in this table.

[2] Computations were provided by the Texas Water Development Board in response to request of Llano Estacado Regional Water Planning Group.

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Section 5
Water Management Strategies for the Llano Estacado Region and Llano Estacado Regional Water Plan

In previous sections, the Llano Estacado Region was described, population and water demand projections were presented, and water supplies and water needs were computed for each of the water user groups—municipal, industrial, steam-electric power, agricultural, irrigation, mining, and feedlot and range livestock. The analyses show some, but limited, opportunity for additional supplies through conventional means of groundwater and surface water development.[1] Therefore, the Llano Estacado Regional Water Planning Group (LERWPG) has identified conventional groundwater development strategies to meet specific short-term needs of cities from groundwater sources located within the Llano Estacado Region as near as possible to each respective city and an alternative groundwater source via pipeline from Region A to the north. In addition, the LERWPG has identified region-wide strategies to be evaluated for inclusion in the Llano Estacado Regional Water Plan to assist in meeting both short-term and, to some extent, long-term needs of the region. These strategies include precipitation enhancement, brush control, desalination of brackish groundwater, water conservation, wastewater reuse, irrigation application efficiency improvements, agricultural water conservation practices on farms, and recovery of capillary water from the dewatered sections of the Ogallala Formation.

These region-wide water management strategies would contribute to increasing the region's water supplies, and/or improve water use efficiency on a widespread scale by several water user groups, as opposed to being specifically applicable to an individual user group (e.g., municipalities). The drilling of additional wells to meet an individual city's needs is a specific, as opposed to a region-wide, strategy. The LERWPG believes that the procedures stated above will, to the extent possible, meet water needs of water user groups of the region in an equitable and consistent manner.

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[1] TWDB rules [31 TAC §357.5(e)(4)] require the RWPG to provide specific recommendations of water management strategies based upon identification, analysis, and comparison of all strategies the group determines to be potentially feasible so that the **cost effective water management strategies which are environmentally sensitive are considered and pursued**, where appropriate. In the case of municipalities having need (shortages), the nearest supply of available groundwater would be the most likely source of supply for the short term, and would be the lowest cost source. Since there is no other readily available source, there is no basis for comparison. Likewise, with respect to the region wide strategies, the RWPG has included those available. Thus, there is no basis for direct cost comparisons.

Strategies identified for consideration to meet long-term needs include interconnection of municipal systems, industries, and feedlots to efficiently distribute available supplies from Lake Alan Henry and the proposed Post Reservoir; importation of water from areas of surplus; and advanced treatment of reclaimed water for potable uses. The strategies are described and evaluated in Sections 5.1 and 5.2.

5.1 Short-term Water Management Strategies

5.1.1 Water Supply from Nearby Groundwater Sources for Cities Projected to Need Additional Municipal Supply

5.1.1.1 Description of Option

Most municipal water systems in the Llano Estacado Region obtain water from the Ogallala Aquifer for all or part of their supply. This source is strongly preferred since it is readily available at a comparatively reasonable cost, in most cases it is the only available local supply, and it is suitable as a public supply with minimal treatment (disinfection only). The water management strategy identified as one way to meet the needs of cities of the Llano Estacado Region that overlie the Ogallala and Dockum Aquifers is to obtain additional supplies from the aquifers beneath the area surrounding or near to the city. Using this water management strategy, the cities that need additional supplies would add new wells or well fields with new wells as the yields from their existing wells decline due to thinning of the saturated thickness of the water-bearing formation. This option is evaluated as to the approximate distance to additional water supplies; the dates at which additional supplies are projected to be needed; and the costs of land, wells, and conveyance facilities to obtain the needed supplies. The results are presented in Section 5.1.1.2.

5.1.1.2 Available Supply from the Ogallala Aquifer and/or Santa Rosa Formation to Meet Projected Needs of Cities

Staff members of the High Plains Underground Water Conservation District No. 1 (HPUWCD) made an analysis of the existing saturated thickness of the water-bearing formation of each city's well field(s) and the saturated thickness of the aquifer in areas surrounding each city. The volumes of groundwater in storage in each city's well field(s) in 1995 were calculated from saturated thickness maps. The HPUWCD compared the existing groundwater reserves to projected water demands for 77 towns and cities to determine when and how much, if any, additional water would be needed. Of the 41 cities in the Llano Estacado Region for which the

Texas Water Development Board has made water use projections and that are projected to obtain all or part of their water supply from the Ogallala Aquifer, 26 were projected to need additional water supplies during the planning period (Section 4 and Figure 5-1).[2] In addition, the City of Cotton Center, located in Hale County, which is not on the TWDB list, is projected to need additional water supplies during the planning period. For those cities obtaining water from both groundwater and surface water sources, the projected surface water supplies were estimated from water use data supplied by the respective surface water suppliers, and groundwater was used for the remaining supply to meet the total projected demand. As was determined in the analyses, in most cases adequate saturated formation exists within a 2 to 5-mile radius of the city to locate new well fields; although, in some cases, the distances are greater. The method of estimating costs and the data and assumptions used in evaluation of this water management strategy are presented in Section 5.1.1.4.

The new wells would be sized to meet the peak day demands of the city. As was done elsewhere in this study, calculations were based upon the assumption that the yields of new wells will decline 1 percent per year as the saturated thickness of the aquifer declines due to pumping. New wells would be located as close to the city as feasible.

5.1.1.3 Environmental Issues

The implementation of this option to supply cities with water to meet future needs is not expected to have significant, if any, adverse environmental effects. Wells will likely be located on property that has previously been altered by agriculture, and pipelines will be located in county and state road rights-of-way. In cases where these conditions are not met, field inspection of potential well sites and pipeline rights-of-way can be done, and well sites and pipeline routes can be selected to avoid any sensitive wildlife habitat, plant communities, and/or cultural resources.

[2] The Ogallala Aquifer northwest of Levelland has been contaminated with petroleum/refinery products, and if cleanup is not successful, Levelland may have a water need in a few years.

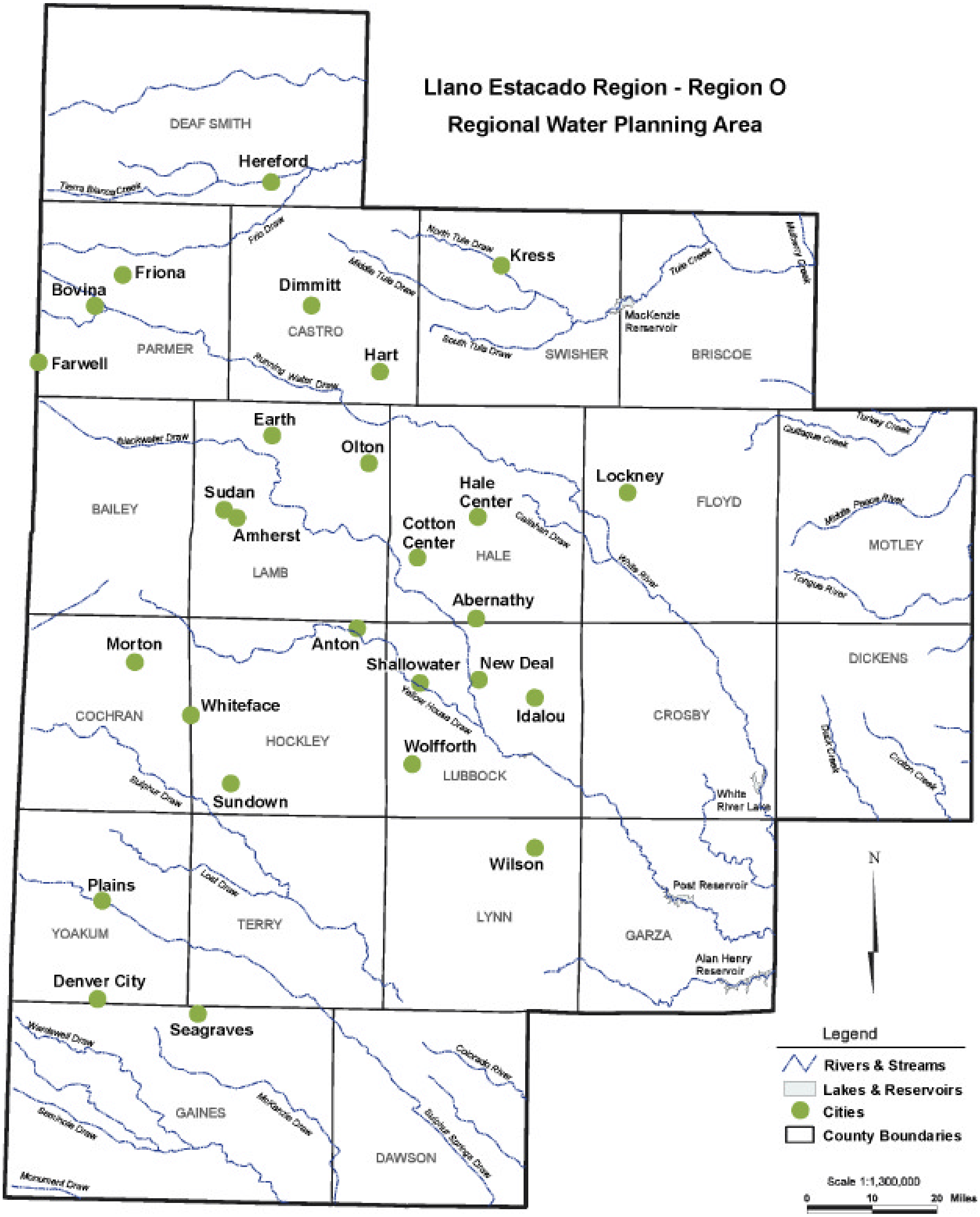

Figure 5-1. Cities Projected to Need Additional Water Supply

5.1.1.4 Engineering and Costing

A Llano Estacado Region representative set of costs for wells, pipelines, and land was developed (Table 5-1). For cost estimating purposes, it was assumed that well pumps would be sized to provide the needed pressure to move the water from the well to the distribution system without additional storage at the well site and without the need for booster pumps along the pipelines. It was estimated that the city would need to purchase 40 acres of land per well needed. In calculating pipeline costs, it was assumed that a single pipeline sized to carry all of the projected additional supply would be used to transport water from the well field to the city's distribution system, with smaller pipelines connecting individual wells to the main transmission pipeline. The final assumption for estimating costs was that all transmission pipelines would be located in existing rights-of-way along county roads, eliminating the costs of purchasing land for new rights-of-way.

Table 5-1.
Representative Costs
Llano Estacado Region

Item	*Cost*[1]
4-inch well and related equipment (Ogallala)	$50,000
6-inch well and related equipment (Ogallala)	$75,000
Well located in Santa Rosa Formation[2]	$160,000
4-inch PVC pipe	$12 per foot
6-inch PVC pipe	$18 per foot
8-inch PVC pipe	$24 per foot
10-inch PVC pipe	$30 per foot
12-inch PVC pipe	$35 per foot
14-inch PVC pipe	$40 per foot
16-inch PVC pipe	$45 per foot
Land[3]	$1,500 per acre

[1] All costs are in Second Quarter 1999 prices.
[2] Depth of wells is assumed to be 850 feet.
[3] Assumed 40 acres purchased per well needed.

Using the data and cost assumptions shown in Table 5-1, adding 10 percent of the total capital costs for engineering and contingencies, financing each new well and transmission pipeline for 30 years at 6 percent annual interest, and using a power cost of $0.06 per kWh, costs were computed for this water management strategy to meet the projected needs of each of the 26 cities of the region that can obtain additional water supply from the Ogallala Aquifer and Santa Rosa Formation of the Dockum Aquifer. A summary sheet is presented for each city that is estimated to need additional water supplies. The summary shows the approximate date at which new wells will be needed by each city, the distance to potentially available supply, the capacity needed, and the costs for land, wells and equipment, and pipelines. In addition, the costs are expressed as total capital costs, annual debt service, annual power costs, and cost per acre-foot and per 1,000 gallons of water (Tables 5-2 through 5-28). The individual city plans are provided on the following tables.

5.1.1.5 Implementation Issues

In order to obtain municipal water from nearby locations, as envisioned in this water plan, it will be necessary for cities to:

- Purchase land or water rights with sufficient saturated formation to supply the quantities of water needed;
- Obtain permits to drill wells from the underground water conservation district in whose jurisdiction the land is located;
- Obtain pipeline rights-of-way, through lease, purchase, or permission;
- Arrange financing to implement the project(s);
- Construct wells, pipelines, and storage facilities in accordance with standards required by the Texas Natural Resource Conservation Commission (TNRCC) for public supply, including wellhead protection of the aquifer; and
- Obtain approval from the TNRCC that the water supply meets state and federal requirements for public supply.

This water supply option has been compared to the plan development criteria, as shown in Table 5-29.

Table 5-29.
Evaluations of Local Groundwater to Meet Municipal Needs

Impact Category	*Comment(s)*
a. Quantity, reliability, and cost of treated water	• Adequate and dependable within ranges of known saturation thicknesses of local aquifers • Reasonable cost
b. Environmental factors	• None
c. State water resources	• No apparent negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• In some cases may use water that would have been used by irrigation farmers
e. Recreational	• None
f. Comparison and consistency equities	• Cost based upon comparable values
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• May reduce local irrigation uses and businesses, somewhat, but would be less than if municipality were short of water
i. Efficient use of existing water supplies and regional opportunities	• Most efficient from cost viewpoint
j. Effect on navigation	• None

Near the end of this planning effort, an alternative conceptual region-wide water supply alternative was identified, in which groundwater would be obtained from counties of region A to the north and piped to cities and feedlots in a large area of the Llano Estacado Region. This conceptual strategy is presented in Section 5.1.2.

5.1.2 Interconnect Cities and Feedlots (Source of Water to Include Hartley and Roberts Counties) – Maximum Delivery Rate of 52,000 acft/yr — Public/Private Partnership

5.1.2.1 Description of Option

This option could be a public/private partnership that would construct a regional pipeline that could potentially serve many cities in the western part of the Llano Estacado Region that are currently projected to have needs during the 50-year planning period. With this option, groundwater would be purchased in Hartley or Roberts Counties, and a well field would be developed. It is anticipated that an existing entity having authority to engage in the busines of providing public water supply to customers (or a new entity could be formed) would enter into binding contracts with water owners for the purchase or lease of water at the source, and in turn would provide water customers with supplies at rates adequate to pay the costs of the water supply system.

Water would be transported via a pipeline to Vega, Hereford, Friona, and Muleshoe (Figure 5-2) (see Appendix A for pipeline profile). The pipeline would then be connected to the existing City of Lubbock's Muleshoe pipeline, for which an appropriate user fee would be paid. Water transported in this pipeline would be utilized to augment the City of Lubbock's water supply, as well as supply water to several other cities along the pipeline route that are projected to have a shortage during the planning period, including Levelland if needed (see page 5-2). Additionally, lateral lines could be extended from the main pipeline to serve other cities in the region. Under the maximum delivery rate scenario, the new pipeline would supply water to the cities of Hereford, Dimmitt, Friona, Bovina, and Farwell. In addition to these cities, with this scenario the cities of Sudan and Amherst could be supplied water from the City of Lubbock's Muleshoe pipeline, and the City of Shallowater could increase its current supply from the City of Lubbock pipeline.

This additional water supply pipeline would reduce the demand on the Canadian River Municipal Water Authority (MWA) water supply pipeline extending from Amarillo to Lubbock

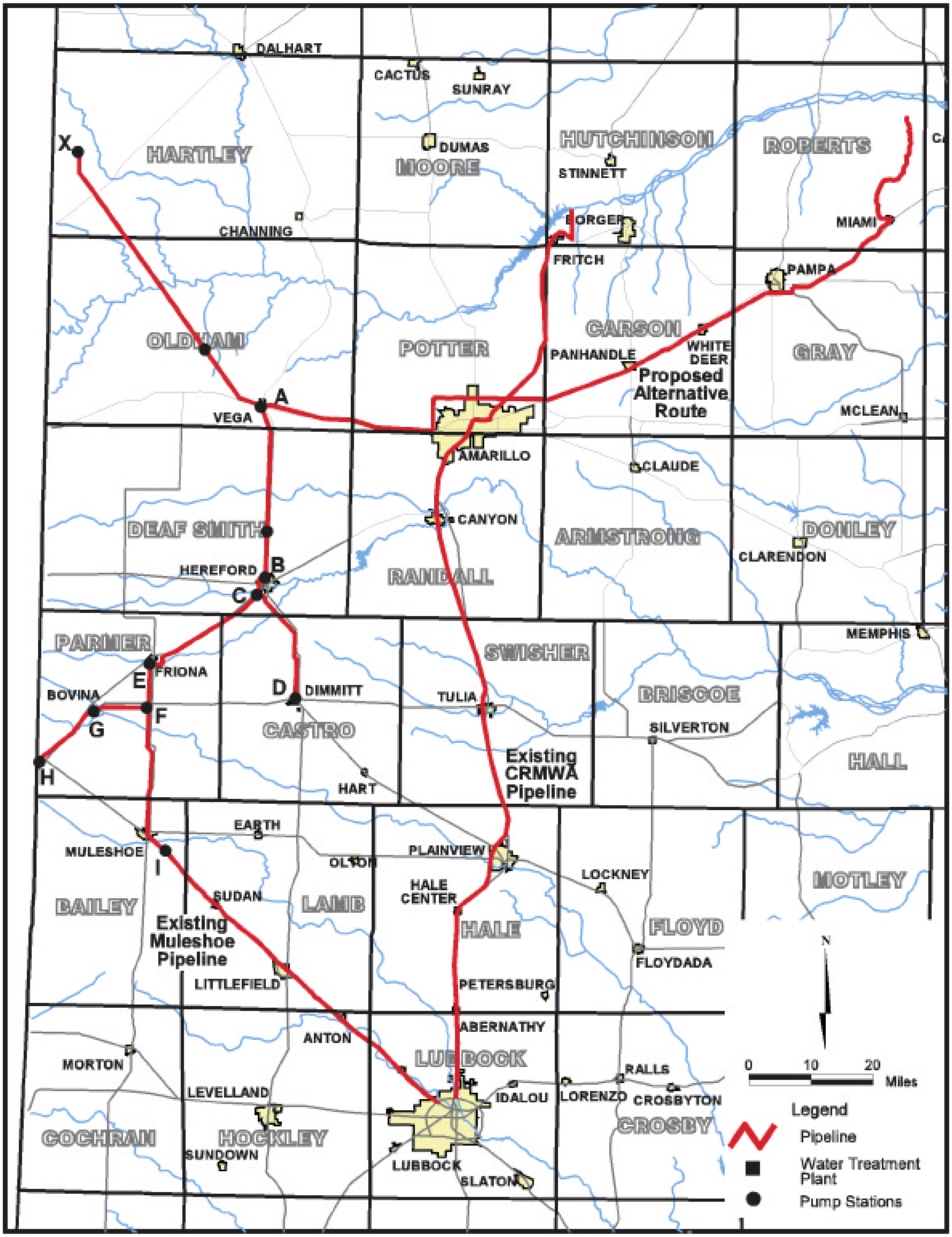

Figure 5-2. Regional Pipeline — Hartley and/or Roberts County (Public/Private Partnership)

and points beyond by supplementing Lubbock's supply from Canadian River MWA with water supplied by the new pipeline. Therefore, it would be possible to provide water from the Canadian River MWA pipeline to cities along and in the vicinity of the Canadian River MWA pipeline that are not currently obtaining water from this source. Under the maximum delivery rate scenario, it is assumed that the cities of Tulia, Kress, Hale Center, Abernathy, Idalou, and New Deal would obtain all of their water supply from the existing Canadian River MWA pipeline. Taking into consideration these cities' peaking factors, the City of Lubbock's water supply from the Canadian River MWA pipeline would be reduced by approximately 6,050 acft/yr. This reduction in supply from the Canadian River MWA pipeline would be made up with water supplied from the new regional pipeline. Lubbock would receive an equal supply of water from the new water source at the same price they pay for the other water they receive from the Canadian River MWA pipeline. Those who obtain water previously allocated to the City of Lubbock from this line would pay the price charged for water from the new supply.

Additionally, water from the proposed pipeline could be made available to serve feedlots in the vicinity of the proposed pipeline route. Feedlots could be regular customers of a publicly operated water supply system. This scenario assumes that 8,300 acft/yr could be made available to feedlots in the Hereford area, 8,359 acft/yr to feedlots in the Dimmitt area, 3,980 acft/yr to feedlots in the Friona area, and 5,505 acft/yr to feedlots in the Farwell area. Three pipelines extending about 9 miles from Hereford would distribute the additional water supply to feedlots in the Hereford area. The additional water supply to feedlots in the Dimmitt area would be distributed by one pipeline extending about 9 miles from the pipeline route. The additional water supply to feedlots in the Friona area would be distributed by one pipeline extending about 9 miles from the city. Two pipelines extending about 9 miles from the pipeline route would distribute the additional water supply to feedlots in the Farwell area. Individual feedlots would be responsible for extending water supply lines from these lateral lines to the feedlots.

5.1.2.2 Available Supply

A source of supply for this option is groundwater in Hartley County. The source of water would be from beneath rangeland or other lands that are not capable of being irrigated. Withdrawal rates would be within Region A's water management plan of not using more than 50 percent of current saturated thickness during the 2000–2050 period, and all well permits would be subject to local underground water conservation district rules. The estimated quantity available from this source, on a dependable basis, is 52,000 acft/yr. The quality of this water is very good, having less than 300mg/L of total dissolved solids.

5.1.2.3 Environmental Issues

This water management strategy involves drilling wells and constructing pipelines from the well fields to the water user groups. The siting of wells and the locations of pipelines can be done so as to avoid sensitive wildlife habitat and/or cultural resources.

5.1.2.4 Engineering and Costing

Costs for this option include a well field consisting of 64 wells, each rated at 500 gallons per minute (gpm), well costs, the raw water transmission pipeline, pump stations, storage facilities, and other project costs which include engineering costs, land acquisition, and interest during construction. The assumptions and conditions for this option are listed below.

- Well capacity for wells is 500 gpm;
- The well field is designed to deliver 52,000 acft/yr (31,983 gpm or 46.43 MGD). This includes all of the supply for those cities located along or near the proposed pipeline route, including their peaking demands;
- The well field could be constructed in either Hartley or Roberts Counties. Costs of this option are based upon the well field being constructed in Hartley County;
- Well depth is estimated to be 300 feet, with a drawdown of 50 feet;
- Cost of land for pipeline easements is $8,712 per acre. Cost of land for pump stations and storage tanks is $1,500 per acre;
- Power cost is $0.06 per kWh;
- Costs of water are calculated at $250 per acre of land;
- The costs given are for raw water in the pipeline and do not include treatment costs or upgrading the receiving city's current distribution system;
- The costs do not include lateral pipelines to new customers located along the City of Lubbock pipeline and the Canadian River MWA pipeline;
- Engineering, legal costs, and contingencies are calculated as 30 percent of the construction costs for pipelines and 35 percent for all other facilities;
- Environmental and archeological studies, mitigation, and permitting costs are calculated as 100 percent of the land cost; and
- Interest during construction is calculated with a 6 percent interest rate, with a 4 percent annual rate of return on funds for implementation, with a construction period of 4 years.

The total project cost for this option was estimated to be $293,128,000 (Table 5-30). Financing the project for 30 years at 6 percent annual interest results in an annual expense of $21,296,000 for debt service (Table 5-30). Annual operation and maintenance (O&M) costs total $1,894,000 (Table 5-30). The total annual cost, including debt service, O&M cost, and power cost, totals $35,360,000 (Table 5-30). For an annual delivery of 52,000 acft/yr, the resulting cost of raw water is $681 per acft (Table 5-30). This is the cost of raw water in the pipeline and does not include treatment costs or costs associated with upgrading any current distribution system.

5.1.2.5 Implementation Issues

Implementation will require agreements between the City of Amarillo, who owns the water rights, landowners on whose land the water is located, and the implementing agency. In addition, agreements and cooperation of the City of Lubbock and the Canadian River Municipal Water Authority, who own the existing pipelines of this option are needed. Permits to drill wells will need to be obtained from the North Plains Groundwater Conservation District, and rights-of-way for the pipeline acquired.

Table 5-30.
Estimated Costs for Hartley County Regional Pipeline
Llano Estacado Region
Second Quarter 1999 Prices

Item	***Estimated Cost for Facilities***
Capital Costs	
Pump Stations (10)	$26,038,000
Pump Station Power Connection Cost	3,358,000
Transmission Pipeline (54-inch diameter, 20.0 miles)	17,803,000
Transmission Pipeline (42-inch diameter, 60.2 miles)	39,463,000
Transmission Pipeline (36-inch diameter, 3.9 miles)	3,158,000
Transmission Pipeline (33-inch diameter, 18.6 miles)	8,746,000
Transmission Pipeline (27-inch diameter, 10.4 miles)	3,686,000
Transmission Pipeline (24-inch diameter, 15.5 miles)	5,361,000
Transmission Pipeline (20-inch diameter, 46.9 miles)	13,714,000
Transmission Pipeline (18-inch diameter, 14.3 miles)	3,888,000
Transmission Pipeline (14-inch diameter, 18.5 miles)	3,902,000
Transmission Pipeline (12-inch diameter, 57.8 miles)	10,683,000
Transmission Pipeline (10-inch diameter, 3.2 miles)	500,000
Transmission Pipeline (6-inch diameter, 3.2 miles)	300,000
Water Storage Tanks (10)	6,972,000
Wells (64 wells rated at 500 gpm)	6,112,000
Road and Rail Crossings	16,000
Total Capital Cost	**$153,700,000**
Engineering, Legal Costs and Contingencies	$47,059,000
Environmental Studies and Permitting	24,732,000
Land Acquisition and Surveying (65,141 acres)	27,205,000
Interest During Construction (4 years)	40,432,000
Total Project Cost	**$293,128,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$21,296,000
Operation and Maintenance:	
Pipeline, Storage Tank, and Well	1,243,000
Pump Station	651,000
Pumping Energy Costs (256,388,202 kWh @ $0.06 per kWh)	12,170,000
Total Annual Cost	**$35,360,000**
Available Project Yield (acft/yr)	**51,954**
Annual Cost of Water ($ per acft)[1]	**$681**
Annual Cost of Water ($ per 1,000 gallons)[1]	**$2.09**

[1] Reported Annual Cost of Water is for raw water in the pipeline and does not include costs associated with distribution within municipal systems.

Table 5-31.
Evaluation of Hartley County Pipeline to Meet Municipal and Feedlot Livestock Needs
Llano Estacado Region

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Adequate and dependable within ranges of known saturation thicknesses aquifer in Hartley County well field • Reasonable cost
b. Environmental factors	• Minor in well field and along pipeline route. Facilities would be located away from and/or routed around any environmental or cultural resources
c. State water resources	• No apparent negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• Since water is not being used at present and is located beneath lands that cannot be cultivated this option would not affect agricultural or natural resources
e. Recreational	• None
f. Comparison and consistency equities	• Cost based upon comparable values
g. Interbasin transfers	• Not applicable; this is groundwater
h. Third party social and economic impacts from voluntary redistribution of water	• No known negative impacts, however the use of the water may give rise to increased local employment and incomes
i. Efficient use of existing water supplies and regional opportunities	• Allows use of a source not presently being used, with comparable savings of other sources for use later
j. Effect on navigation	• None

5.1.3 Precipitation Enhancement

5.1.3.1 Description of Weather Modification to Enhance Precipitation

Weather modification, as it has been applied in Texas over the past 25 years, involves cloud seeding to either create rain when none would have occurred or to increase rain above what would have naturally occurred. The result of cloud seeding is referred to as precipitation enhancement. The concept of how this occurs is described below.

In natural rainfall, droplets are created from the presence of ice particles (crystals) in the cloud. These crystals are formed when freezing water contacts particles of dust, salt, or sand. The ice crystals form a nucleus around which water droplets attach to make the size of the droplet increase. When the size of a droplet increases sufficiently, it becomes a raindrop and falls from the cloud. Cloud seeding is thought to increase the number of "nuclei" available to take advantage of the moisture in the cloud to form raindrops that would not have otherwise formed. To be effective, seeding must be done at the correct time and in the correct manner.

As a cloud grows taller, the air temperature in the cloud cools and falls below the freezing point of water. This cooling effect means that the cloud droplets, which are much too small to fall as rain, are also cooled to a point where they respond to crystallization when contacted by an ice particle. Consequently, when there are fewer crystals to act as nuclei for raindrops, there will be less rain than would have been if more crystals were present. Although crude experiments to enhance rainfall were attempted in the United States as early as the mid-1800s, modern weather modification was begun in 1946 when it was found that silver iodide (AgI) almost exactly matches the chemical structure of ice crystals.[3] The other seeding chemical used when the cloud temperature is too warm for forming ice is sodium chloride (NaCl).

When silver iodide is introduced into a cloud, the number of ice crystals increases and the crystals contact water vapor, causing it to freeze to the crystal. Considerable heat is released to the atmosphere during the freezing and crystal formation phase. The released heat causes the cloud to grow taller and its vertical wind velocity (updraft) to increase. This results in the cloud being able to pull in more moist air and, thus, create more raindrops. However, not all clouds are potential rainmakers. Generally, cloud seeding is performed with a meteorologist working in tandem with pilots utilizing cloud seeding aircraft so that, with direction from the meteorologist, the pilots can target the most promising cloud(s).[4] The criteria used in Texas to find promising clouds is to locate "feeder" cells near developing cloud formations which have temperatures below 23^{o} F. The target cloud must also have sufficient moisture and airflow to be a candidate. About 20 or 30 minutes prior to the desired rainfall event, the candidate cloud is seeded when the airplane releases silver iodide particles in a plume, typically at the base of the cloud so the updraft can draw the particles upward and make more contact with water in the cloud. Seeding is believed to have another effect on large, potentially dangerous thunderstorms capable of causing hail. Seeding tends to mitigate the extreme freezing that results in forming large particles of ice (hail) and makes the moisture more likely to fall as rain.

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[3] Jensen, Ric, "Does Weather Modification Really Work?" Texas Water Resources, Summer 1994.
[4] Clouds may also be seeded using ground-based silver iodide dispensers. However, in this discussion, only the aircraft method is considered.

The criteria for cloud seeding based on experience in Texas since the early 1970s are the following:

- The cloud must be "convective," meaning that it displays instability in the atmosphere;
- Temperature at the top of the cloud must be 23^{o} F or less; and
- The base of the cloud must be lower than 12,000 feet elevation.

Clouds having the characteristics listed above exhibit a warm base, a strong updraft, and sufficient heat to carry water vapor to the cloud top.

A summary of recent cloud seeding experiments in Texas, Florida, Cuba, and Southeast Asia has been presented by the TNRCC in a public information document.[5] The TNRCC concludes the following:

- Cloud seeding with AgI increases rain generated by these clouds by extending the life of the clouds, by allowing the clouds to enlarge laterally so that they cover more area, and by slightly increasing the height of the clouds.
- Rain production of seeded clouds is more efficient than for non-seeded clouds.
- The timing of seeding and the selection of clouds are fundamental. These are such critical factors that "…seeding at the wrong time and in the wrong place(s) may actually decrease the rainfall."[6]

In order to engage in weather modification activities, an individual or organization must possess a weather modification license and a weather modification permit issued by the TNRCC (Texas Water Code: Section 18). The purpose of the weather modification license is to demonstrate competence in the field of meteorology necessary to engage in weather modification activities. The weather modification permit specifies the area to which the weather modification activity may be applied and any limitations or conditions to be observed. There are nine weather modification projects in operation in Texas, all of which use aircraft for seeding clouds (Table 5-32).

[5] Bomar, George, "Some Facts about Cloud Seeding from Recent Research on Rain Enhancement in Texas," Texas Natural Resource Conservation Commission (TNRCC), 1999.
[6] Bomar, George, Op. Cit., 1999.

Table 5-32.
Cloud Seeding Operations in Texas

Cloud Seeding Program	Counties Involved	Area (sq. miles)
Colorado River Municipal Water District	Bordon, Mitchell, and parts of Dawson, Howard, Sterling, Nolan, and Scurry	3,500
West Texas Weather Modification Association	Glasscock, Reagan, Crockett, Sutton, Schleicher, Irion and part of Tom Green	9,688
South Texas Weather Modification Association	Frio, Atascosa, McMullen, Live Oak, Bee, Karnes, Wilson	6,891
High Plains Underground Water Conservation District	Yoakum, Terry, Lynn, Cochran, Hockley, Gaines, Lubbock, Bailey, Lamb, Hale, Parmer, Castro, Floyd, and part of Armstrong, Deaf Smith, Potter, Randall, and Crosby	18,539
Texas Border Weather Modification Association	Val Verde, Kinney, and Maverick	5,922
Edwards Aquifer Authority	Medina, Bandera, Kerr, Kendall, Blanco, Hays, Caldwell, Comal, Guadalupe, Bexar, Uvalde, and part of Real	8,500
Southwest Rain Enhancement Association	Uvalde, Zavala, Dimmit, La Salle, and Webb	9,141
North Plains Groundwater Conservation District No.2	Sherman, Hansford, Ochiltree, Lipscomb, and parts of Dallam, Hartley, Moore, and Hutchinson	6,484
Panhandle Groundwater Conservation District No.3	Roberts, Carson, Gray, Wheeler, Armstrong, Donley, and parts of Hutchinson and Potter	5,469

5.1.3.1.1 Summaries of Results of Weather Modification Projects Performed in Texas

The findings of seven Texas cloud seeding projects are summarized below. The projects are listed in the order in which they were conducted, as follows: Colorado River Municipal Water District Program, Southwest Cooperative Program, Texas Experiment in Augmenting Rainfall through Cloud-Seeding Program, High Plains UWCD Program, Edwards Aquifer Authority Program, North Plains GWCD Program, and Panhandle GWCD Program. Each of these programs is described below, together with the results that are reported for their respective programs.

5.1.3.1.1.1 Colorado River Municipal Water District Program

Having been started in 1971, the Colorado River Municipal Water District (MWD) Program is the longest-running operational weather modification program in Texas. The target area is roughly the Upper Colorado River Basin up stream from Spence Reservoir, comprising some 3,600 square miles. The goals for the program have always been first, to increase water supplies to Lake Thomas and Spence Reservoir, and second, to increase rainfall to agricultural areas. The reported long-term results are that a 34 percent increase (above normal historic precipitation) in the seeded areas and a 13 percent increase in non-seeded areas occurred.[7,8]

5.1.3.1.1.2 Southwest Cooperative Program (SWCP)

The Southwest Cooperative Program (SWCP) was begun in 1986 as a cooperative effort between Oklahoma and Texas "…to develop a scientifically sound, environmentally sensitive, and socially acceptable applied weather modification technology for increasing water supplies…in the southern High Plains."[9] The area involved in Texas was 5,000 square miles located between Midland-Odessa and Lubbock. Random cloud seeding experiments were conducted in 1986, 1987, 1989, 1990, and 1994.

During the period 1987 through 1990, 183 experiments were made (93 seeded, 90 non-seeded). The criteria for selection were the following:

- Liquid water content had to be at least 0.5 gm/m^3 and updrafts had to be at least 1,000 ft/min.
- The target had to be a multiple-cell convective unit.
- No cloud or cell height could exceed 10 km (above ground level).
- Some of the tops had to have temperatures -10^{o} C or colder.

The results confirmed increased rainfall. Compared to the non-seeded cells, the seeded cells displayed an increase in maximum height of 7 percent, an increase in the coverage of the rainfall event of 43 percent, an increase in the storm duration of 36 percent, and an increase in rain volumes of 130 percent.[10]

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[7] Jones, R., "A Summary of the 1988 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield," Report 88-1 of the Colorado River Municipal Water District, 75 pages, 1988.
[8] Jones, R., "A Summary of the 1997 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield," Report 97-1 of the Colorado River Municipal Water District, 54 pages, 1997.
[9] Bomar, George, William L. Woodley, and Dale L. Bates, "The Texas Weather Modification Program: Objectives, Approach, and Progress," Journal of Weather Modification, Volume 31, April 1999.
[10] Rosenfeld, D. and W. L. Woodley, "Effects of Cloud Seeding in West Texas: Additional Results and New Insights," Journal of Applied Meteorology, Volume 32, pp. 1848-1866, 1993.

5.1.3.1.1.3 Texas Experiment in Augmenting Rainfall through Cloud Seeding

The State of Texas implemented the Texas Experiment in Augmenting Rainfall through Cloud Seeding (TEXARC) Program in 1994 and 1995 to investigate physical processes within large storms in the Big Spring-San Angelo area. This research was focused on understanding the best ways of seeding clouds to make them more efficient producers of water, rather than quantifying the results. The results showed that seeding must be within the super-cooled updraft region of the cloud to increase rainfall. From this research it was shown that the seeding agent must be carefully placed either directly in the top of the updraft or at the entrance to the updraft at the base of the cloud.

5.1.3.1.1.4 High Plains Underground Water Conservation District No.1 Program

The cloud seeding program operated by High Plains Underground Water Conservation District No. 1 (HPUWCD) was begun in 1997 and now covers 11,865,000 acres at a total cost of $850,000 per year, or 7.2 cents per acre per year. The present program includes the High Plains, Sandy Land, South Plains, and Llano Estacado Underground Water Conservation District areas in Texas, and Roosevelt and Curry Counties and the southwestern part of Quay County in New Mexico. The effectiveness of the program has been estimated by comparing average precipitation in the HPUWCD area for the 1945 to 1997 period prior to the program to the precipitation that occurred in 1997, 1998, and 1999, the 3 years during which the program has been in operation. Average annual precipitation for the HPUWCD area prior to weather modification was calculated as follows. A map showing the long-term average annual precipitation (1945 through 1997) for all the National Weather Service stations in the HPUWCD service area was secured, plotted, and contoured on a map of the Water District service area. The contoured map was planimetered, and the total volume of water represented by the average annual precipitation on the 6,869,910-acre HPUWCD area was calculated to be 10,475,488-acft. This indicates an annual average of 18.29 inches of precipitation over the Water District service area for the 1945 through 1997 time period.

Calculations were made by HPUWCD of average annual rainfall in each of the years during which cloud seeding was done. The total precipitation collected in each of the Water District's 400-plus rain gauges was plotted on a service area map, contoured, and planimetered. For 1997, the first year of the precipitation program, the total volume of water resulting from precipitation in the Water District service area was calculated at 11,313,527 acft. This equaled 19.76 inches per surface acre average, or 1.47 inches above the long-term (1945 to 1997) average.

In 1998, the total volume of water from precipitation was calculated at 8,303,145 acft. This equals 14.50 inches per surface acre, or 3.79 inches per acre below the long-term average. (1998 was the year that smoke from fires in Mexico glaciated the moisture in the clouds. The ice particles were so small that they would not fall as a result of the forces of gravity, nor could they be pulled together by seeding to cause them to fall as raindrops. After the smoke began to clear in mid-August the area began to get some rain.)

The total volume of water calculated to have occurred over the Water District service area in 1999 was 11,599,831 acft for an average of 20.26 inches per surface acre, or 1.97 inches per surface acre above the long-term average. The goal of this program is to increase rainfall in the target area an average of 2 inches annually over a 10-year period.

5.1.3.1.1.5 Edwards Aquifer Authority (EAA) Program

(Substantial portions of this program description were reproduced from the EAA web page, e-aquifer.com, and are presented here unedited)

"The Edwards Aquifer Authority board of directors voted in the Fall of 1997 to obtain a permit to conduct precipitation enhancement, or cloud seeding, from the TNRCC. The Authority contracted with Weather Modification, Inc. to complete and submit the permit application on the Authority's behalf and work with the TNRCC. The permit was granted by TNRCC in October 1998 and is valid for four years from January 1999 through December 2002. The permit allows the Authority to conduct precipitation enhancement any time during the year, including the traditional period of April through September. The Authority provided $500,000 for the 1999 program, with half the expenses reimbursed by the TNRCC.

"The target area of the program covers over 6 million acres at a total cost to the Authority and the State of Texas of 8 to 9 cents an acre." (Table 5-33).

Table 5-33.
Edwards Aquifer Authority Weather Modification Program Counties

Target Counties	***Operational Counties***	***SCTWAC Counties[1]***
Bandera, Bexar, Blanco, Caldwell, Comal, Guadalupe, Hays, Kendall, Kerr, Medina, Real (east of U.S. Highway 83), and Uvalde	Gillespie, portions of Atascosa, Burnet, Frio, Kimble, Llano, Real, Wilson, and Zavala	Calhoun, DeWitt, Goliad, Gonzales, Karnes, Nueces, Refugio, San Patricio, Victoria, Atascosa, Wilson, Uvalde, Medina, Bexar, Comal, Hays, Guadalupe, and Caldwell

[1] South Central Texas Water Advisory Committee (SCTWAC), as created by SB 1477.

"Each county in the target and South Central Texas Water Advisory Committee (SCTWAC) areas of the program can appoint a representative to sit on a Precipitation Enhancement Advisory Group. The group will work with the Authority in alerting the contractor about local conditions. The ways this committee has worked included communicating saturation conditions so that flights are suspended to avoid flood conditions and suspending flights during harvesting of crops.

"The first year of this program operated from April 15 to September 15, 1999. Consequently, no definitive results regarding estimated rainfall enhancement will be available for several months. The assumption for enhanced aquifer recharge was 10 percent above the recharge quantity that would occur without enhancement."

5.1.3.1.1.6 North Plains Groundwater Conservation District

The North Plains Groundwater Conservation District (GWCD) weather modification program was started in May 2000. The target area includes Sherman, Hansford, Ochiltree, Lipscomb, and parts of Dallam, Hartley, Moore, and Hutchinson Counties. The goal for the program is to increase rainfall in the target area by 15 to 20 percent.

5.1.3.1.1.7 Panhandle Groundwater Conservation District

The Panhandle Groundwater Conservation District (GWCD) weather modification program was started in May 2000. The target area includes Armstrong, Donley, Carson, Gray, Wheeler, Roberts, Carson, and parts of Potter and Hutchinson Counties. The goals of this program are to increase recharge to the Ogallala Aquifer in selected areas and to reduce irrigation water requirements from the Ogallala Aquifer.

5.1.3.2 Potential Quantities of Water Supply Resulting from Weather Modification in the Llano Estacado Regional Water Planning Area

The benefits resulting from cloud seeding in the Llano Estacado Regional Water Planning Area may include improvements in environmental and economic conditions. Potential improvements include increased crop production, increased livestock grazing, and increased ground and surface water supplies.

Performance data from cloud seeding programs typically focus on the rainfall event and parameters such as storm duration, cloud height, storm coverage (cloud area), and rainfall amount, rather than water supply parameters like increased stream flows and increased reservoir storage. Where water supply parameters have been measured in cloud seeding programs the results appear to be positive. For example, Colorado River MWD reservoir storage increased from 14,000 acft to 20,000 acft in Lake Spence and from 26,000 acft to 30,000 acft in Lake Thomas since the inception of cloud seeding in the Big Spring and Snyder areas.[11] Also, the Twin Buttes and Fisher Reservoirs increased from a combined 40,000 acft to a combined 230,000 acft during a cloud seeding program sponsored by the City of San Angelo between 1985 and 1989.[12]

Annual precipitation in the area seeded by the HPUWCD project was estimated to have been 1.47 and 1.97 inches more in 1997 and 1999, respectively, than the 1945 through 1997 long-term average of 18.29 inches (Figure 5-3). Data collected to date indicate that cloud seeding could materially contribute to the Llano Estacado Region's water supplies. For example, for the 20,294 square mile (12,988,160 acres) Llano Estacado Planning Region, an annual increase in precipitation of one and one-half inches would result in an increase of about 1,623,520 acft of water per year to the land surface. At a cost of 7.2 cents per acre, the cost per acre-foot of water is $0.57. Additional precipitation during the growing season, which is the period during which present cloud seeding projects are operated, would directly and immediately benefit both dryland and irrigated agriculture. Crop and grazing yields would be increased, irrigation water pumped from the Ogallala Aquifer could be reduced, and lawn irrigation could be reduced. The latter effect would contribute to meeting projected municipal water needs by reducing the quantities used per year from present supplies. Additional water would be provided

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[11] Jensen, Ric, Op. Cit., 1994.
[12] Jensen, Ric, Op. Cit., 1994.

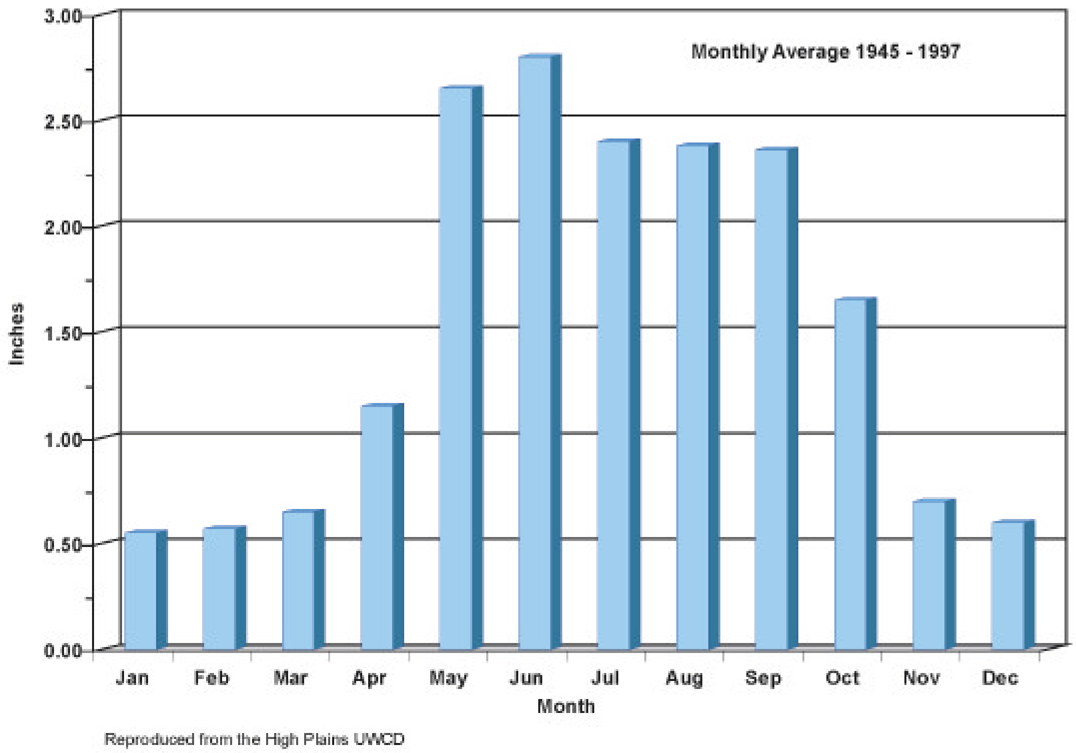

Figure 5-3. Rainfall Distribution

for surface water reservoirs used for public water supplies, and increased runoff into playa basins, some of which would recharge the aquifer as well as provide water for wildlife.

5.1.3.3 Potential Environmental Effects of Weather Modification

Although cloud seeding for weather modification is not a new technique, the effectiveness of weather modification has not been conclusively documented and efforts to quantify the effects continue. Since Texas established a permit procedure, administered by TNRCC, data have been collected for a more scientific evaluation of cloud seeding effectiveness and management. Originally conceived as a means to end droughts, experience shows that cloud seeding may work best during periods of normal rainfall. Weather modification is now considered a long-term water augmentation strategy for freshwater supplies.[13]

The amount of silver iodide and sodium chloride used during a seeding event is believed to be negligible and too widely dispersed to have a measurable effect on the environment. Safe

[13] Bomar, George, TNRCC Senior Meteorologist, Austin, Texas.

handling and storage of these materials prior to dispersal are a larger concern. Both are normally used in industrial applications and printing. Therefore, procedures for handling and storing silver iodide are well documented. There are no known environmental problems associated with this option.

5.1.3.4 Estimated Costs of Weather Modification

The cloud seeding program run by HPUWCD covers 11,865,000 acres at a total cost of about $850,000 per year, or 7.2 cents per acre per year.

5.1.3.5 Weather Modification Implementation Issues

In terms of a measurable and dependable regional water supply option, weather modification in the form of cloud seeding appears to be a beneficial, but somewhat uncertain, source of usable water. Although available data are not adequate to provide estimates of firm yield that can be depended upon during a drought, there are several potential benefits that could perhaps be realized. One important potential benefit of cloud seeding is that a part of the agricultural (irrigated and dryland crops, and rangelands) and municipal water needs could be met. For example, higher rainfall would lower the quantities of irrigation water that has to be withdrawn from the aquifers of the Llano Estacado Regional Water Planning Area for irrigation purposes, dryland production would benefit from increased rainfall, and municipal lawn irrigation could be reduced. Thus, for a relatively minor cost, cloud seeding could perhaps meet a part of the agricultural and municipal needs, as well as make significant contributions to aquifer recharge and streamflows of the region that collect in surface water reservoirs that are used to meet municipal and industrial water needs. This water management strategy is evaluated, to the extent possible, in Table 5-34 to provide an overall comparison with other regional options. The goal of this program is to increase rainfall in the target area an average of 2 inches annually over a 10-year period.

Table 5-34.
Evaluations of Weather Modification to Enhance Water Supplies
Llano Estacado Region

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Uncertain quantity and timing • Low cost
b. Environmental factors	• Increased precipitation would benefit native vegetation species; no expected negative effects
c. State water resources	• No apparent negative impacts on other water resources • Potential benefit to the Ogallala Aquifer water resource due to increased water for recharge • Potential benefit to farmers and ranchers through increased rainfall and reduced groundwater pumping
d. Threats to agriculture and natural resources in region	• Perhaps slight potential for flooding
e. Recreational	• Increased and improved wildlife habitat due to increased precipitation should increase opportunities for hunting and other outdoor recreational activities
f. Comparison and consistency equities	• Cost reported in annual unit area cost only. Have no information with which to compute unit cost of water
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over existing conditions
j. Effect on navigation	• None

5.1.4 Brush Control

5.1.4.1 Description of Brush Control for Increasing Water Supplies

The interest in brush control as a means to increase water supply has its roots in 1) the belief that Texas rangelands changed after settlement and use by Europeans from predominantly open grasslands to increasing domination of brush and 2) the significantly greater interception of water by brush than grasses. These views suggest the possibility of increasing aquifer recharge and streamflow by controlling and limiting growth of brush and trees in areas where grasslands would have naturally dominated. For this water management option, brush control methods will be described and estimates of cost and potential water supply effects will be presented.

Documentation by early European settlers[14] described Texas rangelands as grasslands. Prior to settlement by Europeans with its associated grazing, significant brush growth was inhibited due to several natural conditions. Tree seeds commonly die following germination in grass cover because they cannot compete with grasses for sunlight and moisture. Also, surviving seedlings are destroyed typically in periodic wildfires that occur in natural grasslands. Heavy grazing lessens the competitiveness of grass relative to brush and removes fuel (grass) for rangeland wildfires. The result of heavy grazing is the increased dominance of trees and brush in grasslands, with a resulting decrease in surface runoff and/or recharge to aquifers.[15]

Of the approximately 12.5 million acres of the Llano Estacado Region, about 30 percent is rangeland (3.8 million acres) (Table 5-35). The Natural Resources Conservation Service (NRCS) estimates that nearly 1.9 million acres of rangeland in the region have moderate-to-heavy canopy cover.[16] The most abundant species is mesquite (1.17 million acres), with shinnery oak next most abundant at 487,000 acres. Thus, nearly 87 percent of the moderate-to-heavy brush coverage is mesquite and shinnery oak. Other brush species in the region include sand sage, yucca, snake weed, juniper, and salt cedar.

Brush is important as food and cover for wildlife in the Llano Estacado Region. Rodents, small mammals, songbirds, and quail use the ripe Mesquite seeds. Deer utilize the leaves and twigs; they are also important nesting sites for larger birds such as hawks, ravens, and songbirds. Therefore, for brush control to be implemented while still providing food and cover for wildlife, certain guidelines need to be observed, as follows:

1. Brush Control should achieve the desired plant community of both herbaceous and woody species.
2. Brush Control should control target species and protect all desired species.
3. Scheduled follow-up treatment is mandatory when desired control is not achieved.
4. Mechanical methods that destroy all ground cover must be followed with revegetation of desired species.
5. An approved plan (patterns, strips, or motts) should be developed to assure that the proper percentage of brush is removed. All essential areas such as draws should be protected.

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[14] Smiens, F., S. Fuhlendorf, and C. Tayor, Jr., "Environmental and Land Use Changes: A Long-Term Perspective," Juniper Symposium Proceedings, Texas A & M Agricultural Experiment Station, Sonora, Texas, 1997.

[15] Thurow, T. L., "Assessment of Brush Management as a Strategy for Enhancing Water Yield," Proceedings of the 25th Water for Texas Conference, Texas Water Resources Institute, Texas A & M University, 1998.

[16] Bell, J.R. Natural Resources Conservation Service – Amarillo. December 6, 1999 letter to NRCS Lubbock.

6. Timing of treatment to minimize harm during wildlife nesting or breeding seasons is important.

All brush control should include protection of present and future land use values. The land value for aesthetics, recreation and wildlife uses is generally greater with some brush than with only herbaceous vegetation.

Table 5-35.
Approximate Range and Brush-Covered Areas
Llano Estacado Region

County	Range (acres)	Mesquite (acres)	Shinnery Oak (acres)	Sand Sage (acres)	Yucca (acres)	Snake Weed (acres)	Juniper (acres)	Salt Cedar (acres)
Bailey	108,300	42,000	52,000	10,000				
Briscoe	370,000	64,000					64,000	
Castro	106,000				8,700	20,000		
Crosby	221,500	65,000	20,000	2,000	2,000			500
Cochran	190,000	46,000	129,500	9,000				
Dawson	87,000	58,000	5,500					500
Deaf Smith	312,000	37,000				16,000		
Dickens	385,000	238,000	55,000					500
Floyd	117,000	35,000					5,000	
Gaines	162,000	40,000	85,000					
Garza	450,000	150,000	35,000				16,000	400
Hale	30,000	200			2,000	2,000		
Hockley	77,000	45,000	5,000					1,500
Lamb	100,000			18,000	1,500			
Lubbock	17,000	7,500						
Lynn	107,000	58,000	1,700					
Motley	500,000	230,000	25,000	5,000			8,000	500
Parmer	66,000				700	14,000		
Swisher	104,000	3,500			2,000			
Terry	71,000	30,000	20,000	5,000				2,000
Yoakum	197,000	20,000	50,000	5,000				
Totals	**3,787,800**	**1,169,000**	**487,000**	**54,000**	**16,900**	**52,000**	**93,000**	**5,900**

Source: J. R. Bell, Natural Resources Conservation Service Amarillo, December 8, 1999.

5.1.4.2 Potential Water Yield from Brush Control on Rangelands

In terms of water supply, for purposes of this water planning effort, yield is defined as the quantity of water available in a year for municipal, industrial, agricultural, and other uses, and is expressed as acre-feet per year. Firm yield is the quantity of water available during a critical drought. However, increasing the quantity of water that is not intercepted by brush on rangelands does not necessarily increase yield as defined above for water supply; e.g., there may be other factors that prevent this water from being available. For example, the water could enter the soil as deep percolation, or it could be captured in a rangeland impoundment.

The water balance stated below can be used to estimate the runoff and/or deep percolation from rangeland.[17]

Runoff + Deep Percolation = Precipitation – Evapotranspiration

and its variables are defined as follows:

Runoff is water that leaves the watershed through surface flow;

Deep Percolation is water that leaves the watershed by percolating through soil absent of roots (or below the rooting zone); and

Evapotranspiration is water vapor entering the atmosphere through both leaf tissue (transpiration) and the drying of wet soil or ponded water (evaporation).

According to the water balance, runoff and/or deep percolation can be increased by decreasing evapotranspiration, which can be accomplished by managing vegetation. There are large differences in interception loss (water in the canopy that can be evaporated) among the common brush (mesquite and juniper) and grasses. Interception losses in Texas range from 14 percent for grass to 73 percent for juniper.[18] Thus, a strategy of limiting brush cover and increasing grass cover would presumably increase runoff and/or deep percolation. There is anecdotal and other information concerning the rangelands of Texas that supports the contention than coverage of brush decreases soil percolation, runoff, and streamflow. For example, historical data on stream flow (USGS Station No. 08134000 at Carlsbad, Texas) and rainfall at the San Angelo weather station for the period from 1925 to 1996 show a reduction in average annual discharge from 38,617 acft to 8,358 acft between the periods 1925 to 1959 and 1960 to

[17] Thurow, T.L., Op. Cit., 1998.

1996, respectively. The declining recorded stream flow coincides with the increasing coverage of mesquite, juniper and other brush that occurred in the North Concho watershed between about 1900 and the 1950s, when coverage was essentially complete.[19]

In the Llano Estacado Region, about 60 percent of the area is cropland. Thus, row-crop cultivation in the region prevented the brush coverage that has occurred on the rangeland of the area. The areas of the region where significant concentrations of brush occur, and where brush management or control has potential to contribute to the region's water supplies, are in the east "caprock counties" and in the western counties. Information and discussion about the costs and potentials for contributions of brush control to the region's water supply are presented below.

The seasonal water use differences among trees, brush, and grasses common to the Llano Estacado Region are demonstrated in Table 5-36. The average unit water consumption for mesquite and Ashe Juniper is more than twice the average of the common grasses in the region. Thus, a reduction in brush species should result in more water for grass and increased quantities for stream flow and aquifer recharge.

Table 5-36.
Densities and Seasonal Water Use for Common Plant Species
Llano Estacado Region

Species	***Density***	***Seasonal Water Use[1] (acft)***
Mesquite[2]	307 plants/acre	0.93
Juniper (no grazing)	309 plants/acre	1.12
Juniper (goat grazing)	114 plants/acre	0.28
Sideoats grama grass[2]	890 pounds/acre	0.20
Kleingrass	1,525 pounds/acre	0.59
Buffalograss	1,340 pounds/acre	0.53

[1] The growing season of April through September.
[2] Common in Llano Estacado Region.

Source: Owens, M.K. and R.W. Knight, "Water Use on Rangelands," Water for South Texas, The Texas Agricultural Experiment Stations, pp. 1-13, October 1992.

[18] Thurow, T. L. and Hester, J. W., "How an Increase in Juniper Cover Alters Rangeland Hydrology," Proceedings Juniper Symposium, Texas A & M Agricultural Experiment Station Technical Report 97-1, 1997.

[19] Taylor, Charles, A. and Fred E. Smiens, "A History of Land Use of the Edwards Plateau and Its Effect on the Native Vegetation," 1994 Juniper Symposium, Texas A&M University Research Station at Sonora, 1994.

5.1.4.3 Areas in Llano Estacado Region Where Potential Yield Increase Exists

The areas of the region where significant concentrations of brush occur are in the east "caprock counties" and in the western counties. In addition, in the Llano Estacado Water Planning Region, there are approximately one million acres of land in the U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) on which perennial grass vegetation has been established.[20] This program was established to convert cropland to native or adapted vegetation, thereby reducing crop production in an effort to increase crop prices paid for the remaining crops marketed. As the current contracts with the USDA expire on these CRP areas and as the USDA programs change, some of the land may be returned to cultivated row crops; however, some acres are expected to remain in grass. If these grassland acres are not managed to prevent brush infestation, these areas could become brush covered, further contributing to the brush problem of the region.

Soil moisture management is critical to rangeland and pastureland production and is therefore very important to the potentials of brush management to increase water supplies of the region. Research and field trials have shown that as much as 60 percent of the precipitation runs off from poorly managed range and pastures.[21] Maximum opportunity time for infiltration into the soil cannot be achieved if ranges and pastures are grazed short. One trial in Oldham County, just north of the Llano Estacado Region, showed that with 1,350 pounds of grass cover per acre, runoff from rainfall was 35 percent. With 400 pounds of cover, runoff increased to 72 percent. The Llano Estacado Planning Region has three major soil types, which together with management practices determine the water production potentials of brush management. The soil types are (1) Sandy Soils of the south; (2) Sandy Loams and Loam Textured Soils of the central portion of the region; and (3) Clay Loam and Silty Clay Loam Soils of the north. The vegetation of each soil type is described below.

The sandier textured soils of the southwestern part of the region (Dawson, Gaines, Yoakum, Terry, and Lynn Counties, and parts of Cochran County) support taller grasses such as sand bluestem, little bluestem, sideoats grama, and dropseeds. The main woody plants present are mesquite, shinoak, and sand sagebrush. These brush species are present in moderate amounts

[20] USDA Economics and Statistics System. Conservation Reserve File Summary (96004). http\\usda.mannlib.cornell.edu/usda/

[21] Ibid.

on most of the rangeland of the region.[22] Their removal appears to offer significant potential for enhancement of water supplies and grazing.

The sandy loam and loam texture soils generally found through the central portion of the region (Bailey, Lamb, Hockley, Lubbock, and Crosby Counties) supported sideoats grama, blue grama, hairy grama, and sand dropseed and would best be described as a midgrass/shortgrass grassland. As overgrazing occurred, the percentage of these grasses decreased over time and now includes a higher percentage of lower quality grasses and woody species.[23] Mesquite is the most prevalent woody plant and is present on a majority of rangeland of the sandy loam and loam textured soils (Table 5-35). This part of the region offers promise for the brush control water management strategy.

The clay loam and silty clay loam texture soils found in the northern part of the region (Hale, Parmer, Castro, and Swisher Counties) supported short grasses, mainly blue grama, and buffalograss, with some occasional western wheatgrass along draws and drainages. As overgrazing occurred, the percentage of these grasses decreased over time and now includes a higher percentage of lower quality grasses and woody species. In this part of the region brush is less of a problem, although there is some presence of cholla, yucca, mesquite, and prickly pear; and brush control could perhaps make a contribution to local water supplies.[24]

In Crosby County, the watershed that drains into the White River Reservoir has a significant amount of brush. The NRCS performed a study to compare runoff under existing conditions to two hypothetical conditions. The existing condition is light brush coverage over about 70 percent of the 86,000-acre watershed. The hypothetical conditions are for 100 percent brush control in the watershed and no brush control (0 percent) in the watershed. The NRCS study suggested that considerably more runoff could be captured in the reservoir in either the existing condition (light brush on 70 percent of the watershed) or the 100-percent condition (brush control on 100 percent of the watershed), as compared to the condition where no brush control is practiced (Table 5-37). For example, for a 2-year frequency, 24-hour rainfall event (relatively often event), under existing brush conditions (70 percent of watershed covered), runoff to the reservoir is estimated at 5,054 acft. With no brush control, runoff is estimated at

[22] High Plains Underground Water Conservation District No. 1. Background material prepared for the Llano Estacado Regional Water Planning Group. December 10, 1999. Unpublished.
[23] Ibid.
[24] Ibid.

2,816 acft, while with 100 percent brush control, runoff is estimated at 6,498 acft, or 2.3 times that for no brush control (Table 5-37). For larger, or more intense, but less frequent storms (10-year frequency, 24-hour event), the estimated runoff into the reservoir is 2.6 to 3.4 times that for the 2-year, 24-hour event, depending upon level of brush control (Table 5-37).

Table 5-37.
Comparison of Water That Could be Collected in White River Reservoir for Varying Degrees of Brush Control
Llano Estacado Region

Rainfall Event	Runoff Volume Retained in White River Reservoir for Varying Percentages of Watershed with Brush Control		
	70% existing[1] (acft)	100% brush control[2] (acft)	0% brush control[2] (acft)
2-year frequency, 24-hour duration	5,054	6,498	2,816
5-year frequency, 24-hour duration	9,098	10,978	5,848
10-year frequency, 24-hour duration	13,935	16,246	9,748

[1] Approximates the existing condition in the watershed.
[2] Hypothetical brush control coverage in watershed, percent of total watershed.

Source: Natural Resources Conservation Service

The methods of brush control are described and costs of the leading methods used in the western parts of Texas are presented below.

5.1.4.4 Best Management Practices for Brush Control

The USDA Natural Resources Conservation Service has a conservation practice standard for brush control.[25] The standard includes biological, chemical, mechanical, and burning methods. The biological method describes the use of goats for specific vegetation goats eat. The method involves defoliation of brush systematically. Another standard is for the use of herbicides for brush control. A review of Texas Agricultural Extension Service on-line Expert System for Brush and Weed Control Technology Selection, Version 1.09 (Excel)[26] provided information on chemical agents for control of brush (Table 5-38).

The mechanical standard prescribes plowing, grubbing, chaining, and dozing as primary brush control methods. In most cases Natural Resources Conservation Service recommends burning to control sprouts. For control of mesquite and shinoak, the recommended methods

[25] Natural Resources Conservation Service, Conservation Practice Standard, Brush Management (Acre) Code 314.
[26] http://cnrit.tamu.edu/rsg/exsel/work/exsel.cgi

include root plowing, power grubbing, and hand grubbing. Control of these types of brush requires uprooting the plants. Because of the higher degree of ground disturbance with these methods, replanting grass is recommended. Replanting grass is done at the next applicable time following clearing. For example, if planting grass is planned for spring, brush clearing should be performed in early winter.[27]

Table 5-38.
Chemical Agents for Control of Brush

Brush	Chemical Agent	Control Level[1]
Ashe Juniper	Velpar L (hexazinone)	Very high control level
	Tordon 22K (picloram)	Very high control level
Blackjack Oak	Velpar L	Very high control level
	Spike 20P (tebuthiron)	Very high control level
	Crossbow	High control level
Live Oak	None recommended	
Mesquite	Remedy (triclopyr)	Very high control level
	Reclaim (clopyralid)	Very high control level
	Tordon 22K	Very high control level
	Velpar L	High control level
Post Oak	Velpar L	Very high control level
	Spike 20P	Very high control level
	Crossbow	High control level

[1] Very high means 76 to 100 percent of plants killed. High means 56 to 75 percent killed.

In 1985, the Texas Legislature authorized a brush control program for the state and placed planning and administration of the program with the Texas State Soil and Water Conservation Board (TSSWCB). The purpose of the program is to provide "selective control, removal, or reduction of noxious brush such as mesquite, salt cedar, or other brush species that consume water to a degree detrimental to water conservation." The Draft State Plan delineates a critical area in Texas for brush control. The counties in the area are those having 16 to 36 inches of precipitation per year. Cost of brush control in the draft plan is shared between landowners and the state. Local soil and water conservation districts determine the maximum and average

[27] NRCS Conservation Practice Standard Code 314 (http://okecs.ok.nrcs.usda.gov/stds/std314.htm)

costs for different control methods and the cost share rates. The methods of brush control that the TSSWCB can approve are those which:

1. Are proven effective and efficient for brush control,
2. Are cost effective,
3. Have beneficial impact on wildlife habitat,
4. Will maintain topsoil to prevent erosion or siltation, and
5. Will allow for revegetation of the area with plants that are beneficial to livestock and wildlife.[28]

Since the Texas brush control program is on a cost-sharing basis with the ranchers, an objective of the program is to equate rancher costs with rancher benefits. The benefit to ranchers would be the increases in income from cattle, sheep, and wildlife that result from brush control. Once the total cost of brush control is determined, then the difference between the total cost and the benefit to the rancher would be the cost that might be attributed to the additional water yield. Presumably, if the rancher receives no benefits, then the rancher would not be interested in engaging in the practices. In this case, brush control costs would have to be borne by the state or the water authority that would benefit from the increased water supply resulting from the practice. In the discussion below, estimates are presented of brush control costs.

5.1.4.5 Environmental Issues

Removal of woody species that compete with grasses for water and nutrients have been shown to increase runoff from treated areas. However, there are concerns that the techniques used to remove brush can adversely affect wildlife habitat, and if chemicals are used, concerns extend to their potential effects upon water quality.

A range management plan to protect species should be designed for this strategy. Chaining, cabling, disking, and other mechanical brush removal methods remove some wildlife habitat and expose soil surfaces to wind and water erosion. Therefore, low impact, hand techniques, or well controlled, selective mechanical methods that clear brush in a patchwork or strip fashion, leaving brush berms to control erosion and provide protection for wildlife are preferred.

The chemicals used to remove unwanted vegetation may be detected in surface water sources or may affect air quality, since they are sprayed from the air onto the brush covered areas

[28] Texas State Soil and Water Conservation Board, "Draft State Brush Control Plan," April 1, 1999.

to be treated. The chemical method of controlling brush can be implemented only after a very thorough evaluation is made, and plans are selected that will avoid chemical runoff into streams or percolation into aquifers.

5.1.4.6 Cost of Brush Control

The costs of brush control are estimated using information from brush control studies that have been done to determine brush control costs for rangelands in Texas.[29,30,31] Costs are presented on a present worth, uniform annual basis because brush control requires an initial

Table 5-39.
Initial and Interim Costs for Various Brush Control Methods

Brush Condition (method)	One Time Costs		Recurring Costs	
	Year 1 ($/acre)	Year 2 or 3 ($/acre)	Periodic Cost[1] ($/acre)	Frequency of Control (years)
Heavy mesquite (power grubber)	36.00	15.00	8.60	7
Heavy cedar (doze and burn)	70.00	0	8.60	6
Heavy cedar (2-way chain)	15.00	8.60	8.60	7
Moderate mesquite (chemical then prescribed burn)	15.00	0	8.60	6
Moderate cedar (chemical then prescribed burn)	20.00	0	8.60	6
Light mesquite (chemical then prescribed burn)	7.50	0	8.60	6
Light cedar (chemical then prescribed burn)	10.00	0	8.60	6

[1] Costs at intervals shown in column to the right (e.g.; heavy mesquite $8.60 per acre every 7 years).

Source: Bach, Joel P. and J. Richard Connor, "Economic Analysis of Brush Control Practices for Increased Water Yield: The North Concho River Example," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.

(year "1") investment, plus a periodic future outlay to maintain control (Table 5-39). The initial year, or front end, costs per acre for brush control range from $7.50 per acre for chemical applications to light mesquite, to $70 per acre to doze and burn heavy cedar (Table 5-39). The costs per acre, computed using 30 years as the project horizon, 6 percent interest, and the initial and periodic costs in Table 5-39, range from $1.08 per year for light mesquite to $4.88 per year for heavy mesquite, and $5.26 per year for heavy cedar (Table 5-40). Costs in Table 5-40

[29] Walker, J.W., F. B. Dugas, F. Baird, S. Bednarz, R. Muttiah, and R. Hicks, "Site Selection for Publicly Funded Brush Control to Enhance Water Yield," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.
[30] Bach, Joel P. and J. Richard Connor, "Economic Analysis of Brush Control Practices for Increased Water Yield: The North Concho River Example," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.
[31] Ethridge, D., B. Dahl, and R. Sosebee. Economic Evaluation of Chemical Mesquite Control Using 2,4,5-T. J. Range Management 37:152-156. 1984.

compare to costs reported from $8.90 to $29.54 per acre for chemical control of mesquite using 2,4,5-T in 1984.[32]

Table 5-40.
Present Worth and Uniform Annual Costs for
30-Year Brush Control Projects under Varying Brush Conditions

Brush Condition	Present Worth Per Acre (Second Quarter 1999 Costs)	Uniform Annual Cost (per acre)[1]
Heavy mesquite	$72.79	$4.88
Heavy cedar	$78.60	$5.26
Moderate mesquite	$23.60	$1.58
Moderate cedar	$28.60	$1.92
Light mesquite	$16.10	$1.08
Light cedar	$18.60	$1.25
[1] Amortized over 30 years at 6 percent interest.		

The following assumptions have been made to simplify the estimation of brush control cost in the Llano Estacado Region:

1. According to the NRCS, about 50 percent of the rangeland in the region has moderate to heavy brush.
2. The two most abundant species are mesquite and shinnery oak.
3. Based on the above facts, an estimated unit cost for brush control would be an average of the values in Table 5-40 for heavy mesquite and moderate mesquite. These unit values (per acre) would be $48.20 (rounded to $50) and $3.23 (rounded to $3.25) respectively, for present worth and annual cost.
4. All other brush listed in Table 5-40 would be assumed to require a cost comparable to light cedar, or $18.60 and $1.25, respectively for present worth and annual cost.
5. Brush control would only be applied to mesquite and shinnery oak in counties of the region having a combined total of 50,000 or more acres of these two species (Table 5-41). The reason for setting this acreage condition for the present cost estimation effort is that in counties having fewer than 50,000 acres of these brush species, the brush infested acreages are likely to be too widely dispersed to allow efficient brush control operations. However, this condition is not intended to be a limitation to a brush control effort by anyone who desires to conduct brush control projects.
6. Brush control would or could be applied to only 50 percent of the mesquite and shinnery oak acres of each county that meets the conditions specified in number 5 above. This condition is intended to give adequate latitude for selection of only the

[32] Ibid.

most appropriate acreages to which to apply brush control methods from both the wildlife habitat standpoints, and the water producing potentials.

Of the 21 counties of the Llano Estacado Region, 13 counties meet the condition of having 50,000 or more acres of mesquite and shinnery oak combined (Table 5-41). The counties located in the southwest corner of the region, and east, below the caprock, have the highest acreages of mesquite and shinnery oak and would be the places to apply brush control practices to increase water supplies for those parts of the region. The existing Alan Henry Reservoir and the proposed Post Reservoir are located in Garza County, which has over 185,000 acres of mesquite and shinnery oak. If brush control works to increase water supplies from reservoirs, then brush control projects on the watersheds of these two reservoirs could result in increased firm yields of both projects and contribute to the region's water supply.

Based upon the assumptions and costs listed above, the capital outlay to implement brush control upon 50 percent of the mesquite and shinnery oak infested acres in counties having 50,000 acres of these two species of brush is estimated at $39.2 million, with an annual cost of $2.55 million (Table 5-41). For example, if brush control on the Alan Henry Reservoir contributing watershed at an annual cost of $300,625 were to increase the yield of the reservoir by 10 percent, or 2,900 acft/yr, the cost per acft of raw water yield at the reservoir would be $104, or $0.31 per 1,000 gallons.

5.1.4.7 Implementation Issues

Several implementation issues pertain to this potential water supply option. *In situ* brush control studies are only available for catchment-level examples comprising an area 1,000 acres or less. A large-scale brush control program would require the cooperation of many landowners having different interests in their property. In a specific target watershed, there may be property owners who are not dependent on grazing income and therefore have limited interest in brush control. To ensure cooperation of ranch owners, additional incentives or other considerations may be required which could alter the cost estimates for brush control. Another issue is that most of the assumptions and results presented above are based on computer modeling rather than *in situ* examples that have the benefit of several years of performance to demonstrate results. It is recommended that results of current studies at specific sites be evaluated before public funds are invested in major projects in the LERWPA.

Table 5-41.
Estimated Cost of Brush Control
Llano Estacado Region

County	Mesquite (acres)	Shinnery Oak (acres)	Mesquite plus Shinnery Oak (acres)	Estimated Brush Control (acres)[1]	Initial Brush Control Capital Cost (dollars)[2]	Annual Brush Control Cost (dollars)[3]
Bailey	42,000	52,000	94,000	47,000	2,350,000	152,750
Briscoe	64,000		64,000	32,000	1,600,000	104,000
Castro						
Crosby	65,000	20,000	85,000	42,500	2,125,000	138,125
Cochran	46,000	129,000	175,000	87,500	4,375,000	284,375
Dawson	58,000	5,500	63,500	31,750	1,587,500	103,187
Deaf Smith	37,000		37,000			
Dickens	238,000	55,000	293,000	146,500	7,325,000	476,125
Floyd	35,000		35,000			
Gaines	40,000	85,000	125,000	62,500	3,125,000	203,125
Garza	150,000	35,000	185,000	92,500	4,625,000	300,625
Hale	200		200			
Hockley	45,000	5,000	50,000	25,000	1,250,000	81,250
Lamb						
Lubbock	7,500		7,500			
Lynn	58,000	1,700	59,700	29,500	1,475,000	95,875
Motley	230,000	25,000	255,000	127,500	6,375,000	414,375
Parmer						
Swisher	3,500		3,500			
Terry	30,000	20,000	50,000	25,000	1,250,000	81,250
Yoakum	20,000	50,000	70,000	35,000	1,750,000	113,750
Totals	1,169,000	487,000	1,656,000	784,250	39,212,500	2,548,812

[1] Estimated at 50 percent of total mesquite and shinnery oak acres.
[2] Calculated at $50 per acre.
[3] Calculated at $3.25 per acre.

One critical implementation issue is how the increase in runoff and/or recharge resulting from brush control would be related to usable water supply. Key questions that need answers are:

- How are the increased runoff and/or recharge verified?
- How much of the increased runoff and/or recharge results in yields of affected aquifers? and,
- How is the increased yield of the affected aquifers verified?

See Table 5-42 for evaluation of this water management strategy.

Table 5-42.
Evaluations of Brush Control to Enhance Water Supply Yield

Impact Category	***Comment(s)***
a. Quantity, reliability, and cost of treated water	• Indeterminate to low reliable quantity • Low cost
b. Environmental factors	• Brush control techniques may adversely affect existing wildlife populations, however, for Llano Estacado region, programs would be designed to enhance wildlife habitat • Chemical brush control methods may result in residual chemicals in aquifers and streams
c. State water resources	• No apparent negative impacts on other water resources • Potential benefit to Ogallala Aquifer water resources due to increased water for recharge and increased water for direct use, which would reduce need to withdraw water from aquifer
d. Threats to agriculture and natural resources in region	• Potential threats to habitat due to removal of brush, unless carefully designed to enhance wildlife habitat
e. Recreational	• Potentials to enhance hunting and other outdoor activities
f. Comparison and consistency equities	• Cost model for brush control is based on values reported in the literature; values appear to be comparable to those of other options • No estimate made for cost of water supply yield because data not adequate to estimate yields
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions
j. Effect on navigation	• None

5.1.5 Desalt Brackish Groundwater

5.1.5.1 Description of Option

The purpose of this option is to present estimates of the costs of desalination of brackish groundwater, the potential source of which is the Santa Rosa Aquifer of the Dockum Formation. The Dockum Formation underlies the entire area of the Llano Estacado Water Planning Region and crops out along the eastern edge of the caprock escarpment (Figure 5-4).[33] The primary water-bearing zone in the Dockum is commonly called the "Santa Rosa." The Santa Rosa section consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Water is under artesian conditions. Recharge is from rainfall on the outcrop, with the long-term average being estimated at less than 50,000 acft/yr (Figure 5-4).

Data currently available indicate that the quality of water in the Santa Rosa in the majority of the planning region is unsuitable for most uses without treatment, with the exception of parts of Deaf Smith, Swisher, Briscoe, Floyd, Crosby, Garza, Motley, and Dickens Counties, where the quality of water obtained from the Santa Rosa is adequate for some uses. Concentrations of dissolved solids (TDS) of this water range from less than 1,000 mg/L in the outcrop and downdip portion, to over 20,000 mg/L in the deeper parts of the formation near the center of the planning region (Figure 5-4). High sodium levels pose a salinity hazard for irrigation. Mixing Santa Rosa and Ogallala water reduces the salinity concentrations and is being done by some irrigators. Several municipalities are using water from the Santa Rosa, even though the water contains chlorides, sulfate, and dissolved solids that are near or in excess of safe drinking water standards.

In a part of the planning region where oil has been discovered, water from the Santa Rosa is being used for water flooding to recover oil. However, water from the Santa Rosa must be treated to make it compatible for use in water flooding, since the minerals of the Santa Rosa water are reported to cause flocculation to occur when injected into oil bearing formations that have water of a different mineral content.

[33] Bureau of Economic Geology, The University of Texas at Austin, 1967.

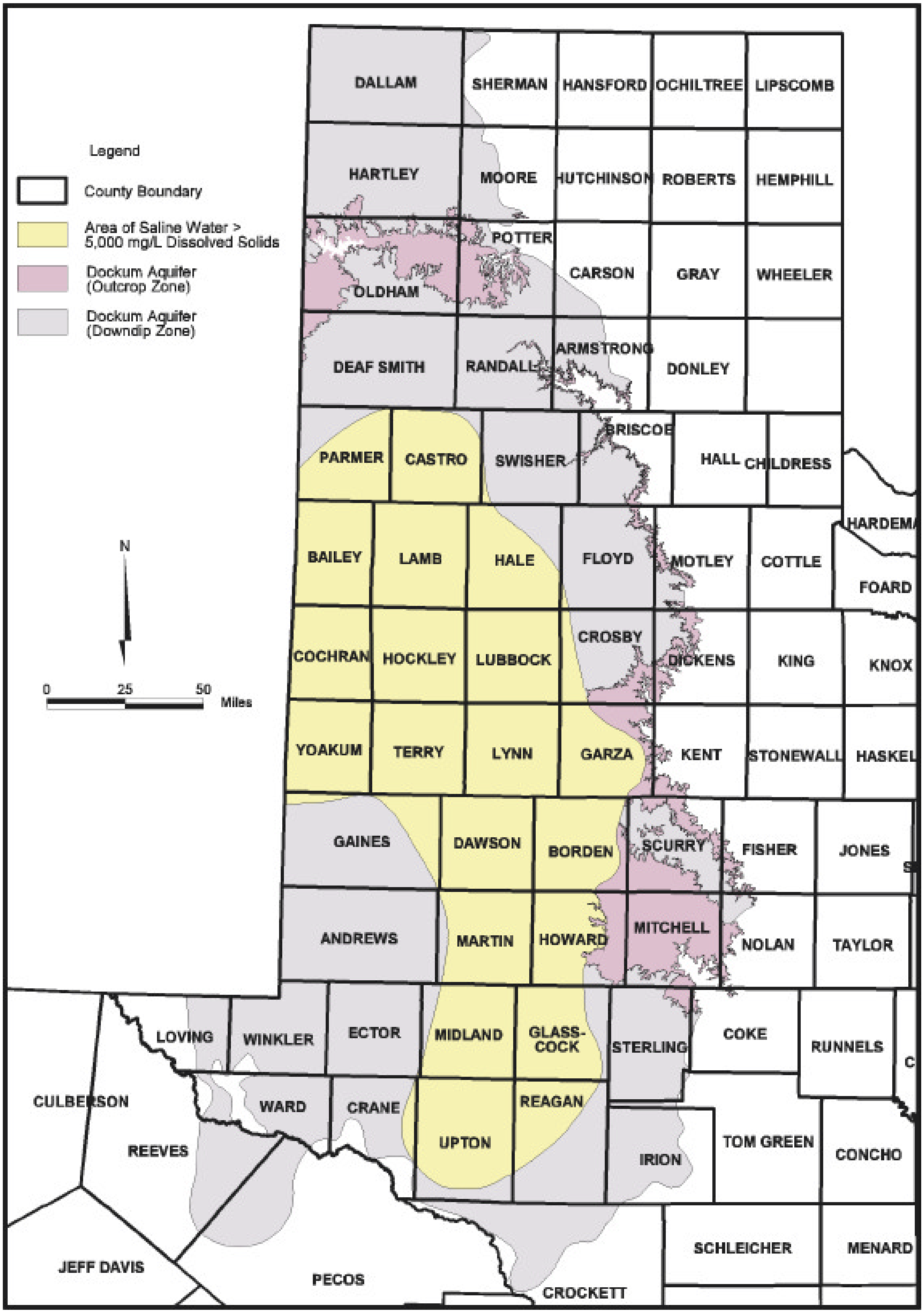

Figure 5-4. Santa Rosa Formation of the Dockum Aquifer

5.1.5.1.1 General Desalination Background

The commercially available processes that are currently used to desalt seawater and brackish groundwater to produce potable water are:

- Distillation (thermal) Processes; and
- Membrane (non-thermal) Processes.

Each of these processes is described below.

5.1.5.1.1.1 Distillation (Thermal) Processes

Distillation processes produce purified water by vaporizing a portion of the saline feedstock to form steam. Since the salts dissolved in the feedstock are nonvolatile, they remain unvaporized and the steam formed is captured as a pure condensate. Distillation processes are normally very energy-intensive, quite expensive, and are generally used for large-scale desalination of seawater. Heat is usually supplied by steam produced by boilers or from a turbine power cycle used for electric power generation. Distillation plants are commonly dual-purpose facilities that produce purified water and electricity.

In general, for a specific plant capacity the equipment in distillation plants tends to be much larger than membrane desalination equipment. However, distillation plants do not have the stringent feedwater quality requirements of membrane plants. Due to the relatively high temperatures required to evaporate water, distillation plants have high energy requirements, making energy a large factor in the cost of water.

The three main distillation processes in use today are Multistage Flash Evaporation (MSF), Multiple Effect Distillation (MED), and Vapor Compression (VC). All three of these processes utilize an evaporator vessel that vaporizes and condenses the feedstock. The three processes differ in the design of the heat exchangers in the vessels and in the method of heat introduction into the process. Since seawater is not available in the Llano Estacado Region, distillation does not seem appropriate and will not be considered here. However, there are membrane desalination operations in Texas, from which information relevant to the Llano Estacado Region can be obtained. The following discussion and analyses present this information.

5.1.5.1.1.2 Membrane (Non-thermal) Processes

The two types of membrane processes use either pressure, as in RO, or electrical charge, as in electrodialysis reversal, to reduce the mineral content of water. Both processes use semi-permeable membranes that allow selected ions to pass through while other ions are blocked. Electrodialysis reversal (EDR) uses direct electrical current applied across a vessel to attract the dissolved salt ions to their opposite electrical charges. EDR can desalt brackish water with total dissolved solids (TDS) up to several thousand mg/L.

Reverse Osmosis (RO) utilizes a semi-permeable membrane that limits the passage of salts from the saltwater side to the freshwater side of the membrane. Electric motor driven pumps or steam turbines (in dual-purpose installations) provide the 800 to 1,200 psi pressure to overcome the osmotic pressure and drive the freshwater through the membrane, leaving a waste stream of brine/concentrate. The basic components of an RO plant include pre-treatment, high-pressure pumps, membrane assemblies, and post-treatment. Pre-treatment is essential because feedwater must pass through very narrow membrane passages during the process and suspended materials, biological growth, and some minerals can foul the membrane. As a result, virtually all suspended solids must be removed and the feedwater must be pre-treated so precipitation of minerals or growth of microorganisms does not occur on the membranes. Various levels of filtration and the addition of various chemical additives and inhibitors normally accomplish this. Post-treatment of product water is usually required prior to distribution to reduce its corrosivity and to improve its aesthetic qualities. Specific treatment is dependent on product water composition.

Depending upon TDS levels of the feed-water, a "single-pass/stage" RO plant can produce water with a TDS of 300 to 500 mg/L, most of which is sodium and chloride. The product water will be corrosive, but this may be acceptable if a source of blending water is available. If not, and if post-treatment is required, the various post-treatment additives may cause the product water to exceed the desired TDS levels. In such cases, or when better water quality is desired, a "two-pass/stage" RO system is used to produce water typically in the 200 mg/L TDS range. In a two-pass RO system, the product water from the first RO pass/stage is further desalted in a second RO pass/stage, and the water from the second pass is blended with water from the first pass.

Recovery rates up to 45 percent are common for a two-pass/stage RO facility. RO plants, which comprise about 31 percent of the world's desalting capacity, range from a few gallons per day (gpd) to 15 million gallons per day (MGD). The largest RO seawater plant in the United States is the 6.7-MGD plant in Santa Barbara, California. The largest RO plant in operation in Texas is a groundwater desalt plant at Kenedy with a capacity of 2.86 MGD (Table 5-43). The current domestic and worldwide trend seems to be for the adoption of RO when a single purpose seawater desalting plant is to be constructed. RO membranes have been improved significantly over the past two decades (i.e., the membranes have been improved with respect to efficiency, longer life, and lower prices).

Table 5-43. Municipal Use Desalt Plants in Texas (>25,000 gpd and as of December 1998)

Location	Source	Total Capacity (MGD)	Desalt Capacity (MGD)	Membrane Type[1]
Bayside, City of	Groundwater	0.15	0.15	RO
Dell City, City of	Groundwater	0.11	0.11	EDR
Ft. Stockton, City of	Groundwater	6.5	3	RO
Granbury, City of	Lake Water	0.35	0.35	EDR
Haciendas del Norte (El Paso)	Groundwater	0.133	0.133	RO
Homestead MUD (El Paso)	Groundwater	0.1	0.1	RO
Kenedy, City of	Groundwater	2.86	0.72	RO
Lake Granbury	Lake Water	3.5	3.5	EDR
Robinson, City of	River	2	2	RO
Seadrift, City of	Groundwater	0.24	0.17	RO
Sherman, City of	Lake Water	6.0	6.0	EDR
Sportsman's Paradise	Lake Water	0.1	0.1	RO
Texas Resort Co.	Lake Water	0.144	0.144	EDR

[1] RO = Reverse Osmosis EDR = Electrodialysis Reversal

5.1.5.1.1.3 Example of Relevant Existing Desalt Projects

Seadrift, Texas: In 1996, Seadrift (population 1,890) was dependent upon the Gulf Coast Aquifer for its water supply. Total dissolved solids and chlorides had reached unacceptable levels of 1,592 mg/L and 844 mg/L, respectively. These values exceeded the primary drinking water standard for TDS (1,000 mg/L) and the secondary drinking water standard for chlorides (300 mg/L). Since the community was not located near an adequate quantity of freshwater or a wholesaler of drinking water, the decision was made to install RO to treat this slightly brackish groundwater. The city installed pressure filters, two RO units, antiscalent chemical feed equipment, and a chlorinator. The capital cost for the system was $1.2 million and the annual O&M cost is $56,000, resulting in a total debt service plus O&M cost of about $0.88 per 1,000 gallons treated by RO. The capital cost included the cost of facilities in addition to the RO units and their appurtenant equipment. Product water from the RO units is blended with groundwater to meet an acceptable quality level. About 60 percent of the total is from the desalt units.

5.1.5.2 Quantity of Supply Available

The best way to evaluate the Santa Rosa is to compare it with the Ogallala. The first consideration is the physical location of the respective aquifers. The Ogallala lies near the land surface; the Santa Rosa lies below the Ogallala and is several hundred feet below land surface in most of the planning area. The greater the depth of the formation, the greater the cost to drill, complete, equip, and operate wells to obtain water. A well completed in the Santa Rosa in Deaf Smith County costs approximately $100,000 in 1999, while wells drilled and completed in the Ogallala in the same area, producing comparable yields, costs between $20,000 and $30,000.

The coefficient of storage in the Ogallala is about 0.15, or about 15 percent. The coefficient of storage of the Santa Rosa is about 0.0001. This indicates that at least 100 times more water can be recovered from 100 feet of saturated Ogallala material than could be recovered from 100 feet of decline in the artesian head (water level) of the Santa Rosa. The permeability of the Ogallala is about 400 gallons per day per square foot (gpd/sf), as compared to the 250 gpd/sf for the Santa Rosa.

The decline in feet from the static water level when a well located in the center of a grid of nine wells evenly spaced 440 yards apart, is pumped at a rate of 600 gpm from the Ogallala Aquifer, with a permeability of 400 gpd/sf, a coefficient of storage of 0.15 percent, and a saturated thickness of 100 feet, would be about 31 feet after 15 days of continuous pumping, 41 feet after 30 days of continuous pumping, 58 feet after 60 days of continuous pumping, and 73 feet after 90 days of continuous pumping. This example assumes that all nine wells are being pumped for the time periods stated. An example is given below of the results of comparable pumping for the Santa Rosa Formation. The decline in feet from the static water level when a well is pumped that is located in the center of a grid of nine wells evenly spaced 440 yards apart, pumping 600 gpm from the Santa Rosa Aquifer, with a transmissibility of 22,000 gpd/f, and a coefficient of storage of 0.0001, would be about 215 feet after 15 days of continuous pumping, 234 feet after 30 days of continuous pumping, 254 feet after 60 days of continuous pumping, and 265 feet after 90 days of continuous pumping. This example assumes that all nine wells are being pumped for the time periods stated. Recommended spacing for Santa Rosa wells is one mile.

In summary, the quantity of useable quality water (less than 5,000 mg/L of TDS) in storage in the Santa Rosa Aquifer in the planning region in 2000 is estimated to be about 3.2 million acft. The estimated volume of usable quality water in storage in the Ogallala Aquifer in the planning region in 2000 is about 108 million acft. Due to the poor quality of water in the Santa Rosa Aquifer in a large part of the Llano Estacado Planning Region, demineralization would be necessary for municipal and industrial uses. Therefore, estimates of costs of desalination are presented, since such estimates may be useful to local communities that need additional municipal water supply (e.g., may need supply that can be blended with existing sources or supply that can be used directly).

5.1.5.3 Environmental Issues

As freshwater is extracted from brackish water, a more concentrated brackish water is produced as a waste product. Concentrated brackish water created from the desalination process is about triple the level of TDS of the brackish aquifer water and must be disposed of properly. For this option, it has been assumed that the brine concentrate will be discharged into the city's wastewater collection and treatment system.

5.1.5.4 Cost Estimates

The cost of desalting brackish groundwater depends upon the concentration levels of minerals in the feedwater to be treated (Table 5-44). For purposes of this analysis, cost estimates are presented for two levels of feedwater salinity—3,000 mg/L and 10,000 mg/L, and four water treatment plant sizes--0.1 MGD, 0.5 MGD, 1.0 MGD, and 3.0 MGD (Tables 5-45 and 5-46).

The cost per acre-foot for a 0.1 MGD plant to desalt 3,000 mg/L water is estimated at $773, or $2.37 per 1,000 gallons, while the cost for the same size plant to desalt 10,000 mg/L water is estimated at $878/acre-foot, or $2.69 per 1,000 gallons (Tables 5-45 and 5-46).

Table 5-44.
Engineering Assumptions for Brackish Groundwater Desalination

Parameter	Assumption	Description
Raw water salinity	3,000 mg/L & 10,000 mg/L	Range from 1,200 to 1,500 mg/L
Finished water chlorides	Less than 500 mg/L	
RO Feedwater Pressure	300 psi & 400 psi	300 psi for 3,000 mg/L and 400 psi for 10,000 mg/L
Treatment capacity	Varies	
WTP storage	0	Use existing tanks
Booster pumps	0	Use existing tanks
Land for plant	0	Use existing city property
Pipeline friction factor	C = 140	C-900 PVC pipe

At larger water treatment plants, the costs are lower. For example, for a 0.5 MGD plant the cost to desalt 3,000 mg/L water is estimated at $397/acre-foot, or $1.22 per 1,000 gallons; the cost to desalt 10,000 mg/L water is estimated at $472/acre-foot, or $1.45 per 1,000 gallons (Tables 5-45 and 5-46). A 3.0 MGD size plant is estimated to have a desalt cost of $281/acre-foot, or $0.86 per 1,000 gallons for water with 3,000 mg/L of salts, and for water with 10,000 mg/L of salts, the cost is $342/acre-foot, or $1.05 per 1,000 gallons (Tables 5-45 and 5-46).

Table 5-45.
Cost Estimate for Brackish Groundwater Desalt (3,000 mg/L TDS)

Item	Estimated Costs (0.1 MGD)	Estimated Costs (0.5 MGD)	Estimated Costs (1 MGD)	Estimated Costs (3 MGD)
Capital Costs				
Source Water Supply				
Water Treatment Plant	$478,000	$1,077,000	$1,823,000	$3,946,000
Concentrate Disposal				
Distribution				
Total Capital Cost	**$478,000**	**$1,077,000**	**$1,823,000**	**$3,946,000**
Engineering, Legal Costs and Contingencies (35%)	$167,000	$377,000	$638,000	$1,381,000
Environmental & Archaeology Studies and Mitigation				
Surveying				
Interest During Construction (1 year)	29,000	65,000	109,000	237,000
Total Project Cost	**$674,000**	**$1,519,000**	**$2,570,000**	**$5,564,000**
Annual Costs				
Debt Service (6 percent for 30 years)	$49,000	$110,000	$187,000	$404,000
Operation and Maintenance:				
Source Water Supply				
Water Treatment Plant	37,544	112,103	209,522	541,840
Concentrate Disposal				
Distribution				
Total Annual Cost	**$86,544**	**$222,103**	**$396,522**	**$945,840**
Available Project Yield (acft/yr)	**112**	**560**	**1,120**	**3,360**
Annual Cost of Water ($ per acft)	**$773**	**$397**	**$354**	**$281**
Annual Cost of Water ($ per 1,000 gallons)	**$2.37**	**$1.22**	**$1.09**	**$0.86**

Table 5-46.
Brackish Groundwater (10,000 mg/L TDS)
Cost Estimate Summary

Item	*Estimated Costs (0.1 MGD)*	*Estimated Costs (0.5 MGD)*	*Estimated Costs (1 MGD)*	*Estimated Costs (3 MGD)*
Capital Costs				
Source Water Supply				
Water Treatment Plant	$534,000	$1,216,000	$2,031,000	$4,409,000
Concentrate Disposal				
Distribution				
Total Capital Cost	**$534,000**	**$1,216,000**	**$2,031,000**	**$4,409,000**
Engineering, Legal Costs and Contingencies (35%)	$187,000	$426,000	$711,000	$1,543,000
Environmental & Archaeology Studies and Mitigation				
Surveying				
Interest During Construction (1 year)	32,000	73,000	122,000	265,000
Total Project Cost	**$753,000**	**$1,715,000**	**$2,864,000**	**$6,217,000**
Annual Costs				
Debt Service (6 percent for 30 years)	$55,000	$125,000	$208,000	$452,000
Operation and Maintenance:				
Source Water Supply				
Water Treatment Plant	43,319	139,592	262,131	695,634
Concentrate Disposal				
Distribution				
Total Annual Cost	**$98,319**	**$264,592**	**$470,131**	**$1,147,634**
Available Project Yield (acft/yr)	**112**	**560**	**1,120**	**3,360**
Annual Cost of Water ($ per acft)	**$878**	**$472**	**$420**	**$342**
Annual Cost of Water ($ per 1,000 gallons)	**$2.69**	**$1.45**	**$1.29**	**$1.05**

5.1.5.5 Implementation Issues

Implementation of small community water supply from brackish groundwater sources includes financial and technological issues. For a municipal water demand of about 500,000 gpd, desalination could improve the quality of a backup supply or could perhaps replace a more vulnerable freshwater supply as the primary source. However, the estimated cost, while comparable to conventional treatment, is much higher than communities experience when they do not have to treat their groundwater, except to disinfect. Therefore, the best applications may be for small, remotely located systems where freshwater supplies are readily available nearby. Then desalination may compete economically with projects transporting fresh raw water or treated water over a distance of several miles.

There are two technological issues confronting a small utility that might consider desalination. The first is how to make the more centralized desalt plant compatible with a distribution system that is likely constructed to be compatible with two or more wells. Normally, this would be resolved in the design engineering process.

The second technological issue is the relative complexity of desalination compared to the relative simplicity of a fresh groundwater supply, requiring only extraction from the ground, storage, disinfection and distribution. Desalt plants encounter scaling, corrosion, and chemical challenges that require relatively highly trained and experienced treatment staff. Therefore, the smaller communities might consider contract operations rather than developing in-house expertise to operate desalt plants.

This water supply option has been compared to the plan development criteria, as shown in Table 5-47.

Table 5-47.
Evaluation of Brackish Groundwater Desalination

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Unknowns regarding extent and yields of brackish aquifer • Moderately high treatment cost
b. Environmental factors	• Disposal of concentrated brine created from process • Typically in low recharge rate aquifers or confined aquifers; use could lead to the depletion of aquifers • Extracted brackish water possibly replaced by freshwater from a higher strata aquifer, thereby removing and contaminating accessible freshwater
c. State water resources	• In case of brackish aquifer, improves state water resources • For freshwater aquifer having brackish lower zone, potentially contaminates fresh groundwater
d. Threats to agriculture and natural resources in region	• None
e. Recreational	• None
f. Comparison and consistency equities	• Same cost model used to estimate total costs
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Increases
j. Effect on navigation	• Not applicable

5.1.6 Use of Reclaimed Water

5.1.6.1 Description of Option

Reclaimed water is treated wastewater. This reclaimed wastewater can be used for non-potable purposes as a replacement for potable water supply. Examples of the use of reclaimed municipal and feedlot wastewater include the irrigation of golf courses and other public lands, and irrigation of agricultural land near to or adjacent to the town or city or feedlot from which the water is obtained. In the Llano Estacado Region, the primary use of reclaimed municipal wastewater is to irrigate farmland. The primary use of reclaimed feedlot wastewater is also to irrigate farmland. The irrigating entity or entities using the reclaimed water are, in effect, adding a new source of water supply to their existing supplies. In the Llano Estacado Region, approximately 95 percent of all the water obtained from the Ogallala Aquifer is used for irrigation purposes. By substituting water pumped from the Ogallala Aquifer with reclaimed water, the amount of groundwater withdrawal can be decreased.

5.1.6.2 Quantity of Supply Available

In the Llano Estacado Region, reclaimed water supplies from municipal and other sources are included in the current and projected water supplies and needs analysis. The quantity of reclaimed water available for irrigation use from municipal sources was estimated as the lesser of 50 percent of the TWDB projected municipal water use for the year 2000, or the maximum waste discharge permit quantity of the TNRCC waste discharge permit (Table 5-48).[34] The total quantity of the municipal wastewater discharge permits for the Llano Estacado Region is 48,850 acft/yr. The estimated quantity of treated municipal effluent available for reuse from the cities of the region is 12,570 acft/yr (Table 5-48). This value was held constant throughout the projection period, with the estimated total quantity of reclaimed water added to the available supply of irrigation water in the county where the reclaimed water is located. If the county had a surplus of irrigation supply, the reclaimed water was used to offset an equal quantity of irrigation water that would have been pumped from the aquifer. However, information about the quantities of feedlot wastewater was not available and therefore could not be included in the calculations. The quantities are important to the farms that use them and should be considered where possible.

5.1.6.3 Environmental Issues

This practice is regulated through state and federal water quality protection laws, and has been used in the Llano Estacado Region for many years without adverse environmental effects. It does not appear that there are significant environmental issues of concern.

5.1.6.4 Costing

Inasmuch as facilities to carry out this water management strategy are already in place, no further costing is appropriate at this time. If facilities need to be extended the costs will include pipelines, pumps, and pump stations.

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[34] For the City of Lubbock, the amount of reclaimed water was estimated as 50 percent of the projected municipal water use shown as municipal water demand. Reclaimed water from the City of Lubbock is used for electric-power generation, with the remainder used to irrigate about 6,000 acres of hay and forage crops. In the water needs analysis, the quantity of reclaimed water from Lubbock is included in the irrigation water supply for Lubbock and Lynn Counties to meet projected irrigation water demand.

Table 5-48.
Summary of Reuse of Municipal Effluent
Llano Estacado Region

County/City	Maximum Waste Discharge Permit Quantity[1] (acft/yr)	Estimated Quantity of Reclaimed Water Available for Use[2] (acft/yr)
Bailey County		
City of Muleshoe	538	538
Subtotal	**538**	**538**
Castro County		
City of Dimmitt	840	572
City of Hart	202	123
Subtotal	**1,042**	**695**
Cochran County		
City of Morton	200	200
City of Whiteface	39	39
Subtotal	**239**	**239**
Crosby County		
City of Crosbyton	296	195
City of Lorenzo	190	133
City of Ralls	290	159
Subtotal	**776**	**486**
Deaf Smith County		
City of Hereford	2,240	2,213
Subtotal	**2,240**	**2,213**
Floyd County		
City of Floydada	560	311
City of Lockney	224	187
Subtotal	**784**	**498**
Hale County		
City of Abernathy	426	274
City of Edmonson	22	22
City of Hale Center	274	203
City of Petersburg	112	112
City of Plainview	3,697	2,253
Subtotal	**4,531**	**2,863**

Table 5-48 (continued)

County/City	Maximum Waste Discharge Permit Quantity[1] (acft/yr)	Estimated Quantity of Reclaimed Water Available for Use[2] (acft/yr)
Hockley County		
City of Anton	112	112
City of Levelland	2,016	1,259
City of Ropesville	43	32
City of Smyer	90	67
City of Sundown	165	124
Subtotal	**2,426**	**1,594**
Lamb County		
City of Amherst	137	78
City of Earth	224	160
City of Littlefield	1,960	583
City of Olton	280	280
City of Springlake	10	8
City of Sudan	118	118
Subtotal	**2,729**	**1,226**
Lubbock County		
City of Idalou	280	212
City of Lubbock	29,964	
City of New Deal	118	53
City of Shallowater	325	182
City of Slaton	1,019	458
City of Wolfforth	459	196
Subtotal	**32,165**	**1,100**
Lynn County		
City of O'Donnell	134	90
City of Tahoka	403	259
City of Wilson	2	2
Subtotal	**540**	**350**
Parmer County		
City of Bovina	134	134
City of Farwell	165	165
City of Friona	542	470
Subtotal	**841**	**769**
Regional Total	**48,850**	**12,570**

[1] Source: Texas Natural Resource Conservation Commission.
[2] Quantity included as supply available for use as irrigation water.

5.1.6.5 Implementation Issues

In order for municipal effluent to be reused, regulatory requirements of federal, state, and local governments must be met. The primary issue of federal concern in developing a reclaimed water system involves potential applicability of Section 404 of the Clean Water Act for discharge of dredge and fill materials into waters of the United States. This regulation applies primarily in cases where a pipeline is used to transport the reclaimed water and that pipeline must cross a stream.

However, there are several regulatory considerations at the state level. The State of Texas closely regulates the use of reclaimed water. This is primarily to assure public health, but also to assure the appropriateness of reclaimed water use with respect to water quality effects and existing surface water rights. The TNRCC promulgated rules in 1997 addressing the use of reclaimed water. These rules apply to the reclaimed water producer, provider, and user. In general, these rules apply only to the beneficial use of treated effluent, which is considered any use that would offset the need for other freshwater supplies. However, the rules do not apply to irrigation if it is primarily intended as a means to dispose of wastewater.

As part of this authority, these rules also require that application to the TNRCC and a use determination be made before contracting and supplying individual new reclaimed water customers. A primary emphasis in this review is to assure that such reclaimed water contracts are for “on demand” service and not “take or pay.” The concern here is to minimize the potential for and discharge of unused reclaimed water.

In addition to these regulations there may also be local development restrictions that need to be considered before a new reclaimed water project is started.

There are two general qualities of treated wastewater allowed for reclaimed water use under State regulation in TNRCC rules, Chapter 210. These are grouped and defined as Type I and Type II uses.

Broadly defined, Type I reclaimed water quality is required where contact between humans and the reclaimed water is likely. Type I reclaimed water uses could generally be:

- Residential irrigation;
- Urban irrigation for parks, golf courses with unrestricted public access, school yards or athletic fields;
- Fire protection;

- Irrigation of food crops where the reclaimed water may have direct contact with the edible part of the crop;
- Irrigation of pastures for milking animals;
- Maintenance of water bodies where recreation may occur;
- Toilet or urinal flushing; and
- Other similar activities where unintentional human exposure may occur.[35]

Type I water can also be used for all Type II uses listed below.

Type II water quality is where such human contact is unlikely. The types of water uses that would generally be considered as eligible for Type II reclaimed water are:

- Irrigation of sod farms, silvaculture, limited access highway rights-of-way, and other areas where human access is restricted (restricted access can include remote sites, fenced or walled borders with controlled access, or the site not being used by the public when normal irrigation operations are in progress);
- Irrigation of food crops where the reclaimed water is not likely to have direct contact with the edible part of the crop;
- Irrigation of animal feed crops, other than pasture for milking animals;
- Maintenance of water bodies where direct human contact is unlikely;
- Certain soil compaction or dust control uses;
- Cooling tower makeup water;
- Irrigation or other non-potable uses of reclaimed water at a wastewater treatment facility; and
- Any eligible Type I water uses.[36]

At a minimum, the TNRCC requires that the reclaimed water will be of the quality specified in their standards (Table 5-49).

[35] Source: Texas Natural Resource Conservation Commission (TNRCC), 1997.
[36] Source: TNRCC, 1997.

Table 5-49.
Quality Standards for Using Reclaimed Water
(30-day Average)

Type I	
BOD_5 or $CBOD_5$	5 mg/L
Turbidity	3 NTU
Fecal Coliform	20 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	75 CFU/100 ml (single grab sample)
Type II Pond System	
BOD_5	20 mg/L
or $CBOD_5$	15 mg/L
Fecal Coliform	200 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	800 CFU/100 ml (single grab sample)
Type II Other Systems	
BOD	30 mg/L
Fecal Coliform	20 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	75 CFU/100 ml (single grab sample)

Source: TNRCC, 1997.

This water supply option has been compared to the plan development criteria, as shown in Table 5-50.

Table 5-50.
Evaluation of Use of Reclaimed Water

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Quantity is relatively steady on a daily basis and increases as municipal populations increase • Cost is comparatively low in relation to other water sources
b. Environmental factors	• Must be treated to regulatory standards and if managed according to regulatory requirements has no negative effects
c. State water resources	• Contributes to overall supply since in Llano Estacado Region very little is discharged to streams
d. Threats to agriculture and natural resources in region	• None. Is positive with respect to overall supply
e. Recreational	• None
f. Comparison and consistency equities	• Same cost methods used to estimate costs
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Increases
j. Effect on navigation	• Not applicable

5.1.7 Municipal Water Conservation

5.1.7.1 Description of Option

Municipal water is freshwater that meets drinking water standards. Such water is supplied by both public and private utilities; and in areas not served by water utilities, it is obtained from privately owned wells for individual households. Water utilities supply municipal water to private individuals for direct use by people in and around their homes. Municipal water is also supplied to businesses, commercial establishments, and public entities for direct and indirect use by people within commercial and business establishments such as restaurants, offices, laundries, car washes, schools, churches, theaters, sports arenas, hospitals, hotels, motels, and other places of business. Municipal water is used by government agencies for fire protection, sanitation, and recreation, including public swimming pools and irrigation of parks and public areas. A key parameter of water use within a typical city or water supply service area is the number of gallons per person per day (per capita water use). The objective of municipal water conservation programs is to reduce the per capita water use parameter without adversely affecting the quality of life of the people involved. This can be achieved through:

- Use of plumbing fixtures (e.g., toilets, shower heads, and faucets) that are designed for low quantities of flow per unit of use;
- The selection and use of more efficient water using appliances (e.g., clothes washers and dishwashers);
- Modifying and/or installing lawn and landscaping systems to use grass and plants that require less water;
- Repair of plumbing and water using appliances to reduce leaks;
- Leak detection and repair of water distribution lines; and
- Modification of personal behavior that controls the use of plumbing fixtures, appliances, and lawn watering methods.

5.1.7.2 Water Conservation Methods and Potential Effects of Water Conservation upon Quantities of Municipal Water Use

The types of plumbing fixtures in place in both private and public places and the manner and method of how these fixtures are operated by those who use them significantly affect the quantity of water used in the municipal water user group. The present legislation that governs the types of plumbing fixtures that can be sold in Texas and the principal water conservation methods that can be used in the Llano Estacado Region are presented and described below.

In 1991, the Texas Legislature enacted legislation (Senate Bill 587) that established minimum standards for plumbing fixtures sold within Texas.[37] The bill became effective on January 1, 1992 and allowed for wholesalers and retailers to clear existing inventories of pre-standards plumbing fixtures by January 1, 1993. The standards for new plumbing fixtures, as specified by Senate Bill 587, are shown in Table 5-51. The TNRCC has promulgated rules requiring the labeling of both plumbing fixtures and water-using appliances sold in Texas. The labels must specify the rates of flow for plumbing fixtures and lawn sprinklers and the amounts of water used per cycle for clothes washers and dishwashers.[38]

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[37] Senate Bill 587, Texas Legislature, Regular Session, 1991, Austin, Texas.
[38] Chapter 290, 30 TAC Sections 290.251, 290.253 - 290.256, 290.260, 290.265, 290.266, Water Hygiene, Texas Register, Page 9935, December 24, 1993.

Table 5-51.
Standards for New Plumbing Fixtures

Fixture	Standard
Wall Mounted Flushometer Toilets	2.00 gallons per flush
All Other Toilets	1.60 gallons per flush
Shower Heads	2.75 gallons per minute at 80 psi
Urinals	1.00 gallons per flush
Faucet Aerators	2.20 gallons per minute at 80 psi
Drinking Water Fountains	Shall be self-closing

The TWDB has estimated that the effect of the new plumbing fixtures in dwellings, offices, and public places will be a reduction in per capita water use of 18 gallons per person per day in comparison to what would have occurred with the previous generations of plumbing fixtures.[39] The estimated water conservation effect of 18 gallons per capita per day (gpcd) was obtained using the data found in Table 5-52.

Table 5-52.
Water Conservation Potentials of
Low-Flow Plumbing Fixtures[1]

Plumbing Fixture	Water Savings (gpcd)
Toilets – 1.6 gallons per flush	11.5
Shower Heads – 2.75 gallons per minute	4.0
Faucet Aerators – 2.2 gallons per minute	2.0
Urinals – 1.0 gallons per minute	0.3
Drinking Fountains (self-closing)	0.1
Total	17.9 (18 gpcd)

[1] Texas Water Development Board, 1992.

The TWDB estimates that beginning in 1993, the use of the new plumbing fixtures in new construction and in normal replacement of fixtures in existing structures will phase in this

[39] "Water Conservation Impacts on Per Capita Water Use," Unpublished Water Planning Information, Texas Water Development Board, Austin, Texas 1992.

conservation effect within Texas by the year 2020. The per capita conservation effects in new construction and normal replacements, when averaged over the entire population, would result in one-third of the savings being realized by year 2000, two-thirds being realized by year 2010, and the final one-third being realized by 2020. The TWDB further assumed that efficient water-using appliances would be used in new construction and in replacement of existing appliances. The water savings rates mentioned in Table 5-52, together with the estimated effects of water conservation through efficient water-using appliances, were factored into the TWDB "average conservation case" municipal water demand projections presented in Section 2 of the area description and report (Tasks 1 and 2).[40] For example, without the new plumbing fixtures required by Senate Bill 587, the municipal water demand projections of Section 2.2 would have been 6 gpcd higher in year 2000, 12 gpcd higher in 2010, and 18 gpcd higher in 2020, 2030, 2040, and 2050.

The principal water conservation methods are: (1) public information and education; (2) incentive programs; (3) conservation pricing; (4) leak detection; (5) conservation landscaping; (6) lawn watering; (7) retrofit plumbing fixtures; and (8) gray water use for watering lawns and landscaping. Each of these methods is described below.

(1) Public Information and Education: An important and key element to accomplishing water conservation is to inform water users about ways to save water inside homes and other structures, in landscaping and lawn watering, and in recreation uses. Among the methods for communication of water conservation information are television, radio, newspaper announcements and advertisements, public displays, bill inserts, brochures, pamphlets, and public and private school curricula to teach conservation to each generation of students.

Public information and education can work in two ways to accomplish water conservation. One way is to inform and convince water users to obtain and use water-efficient plumbing fixtures and appliances, to adopt low water use landscaping plans and plants, to find and repair plumbing leaks, to use gray water for permissible uses (e.g., lawn and shrubbery watering where regulations allow), and to take advantage of water conservation incentives where available.

A second way public information and education can work to conserve water is to inform water users of ways to manage and operate existing and new fixtures and appliances so that less

[40] Llano Estacado Regional Water Plan, Tasks 1 and 2, Section 2, High Plains Underground Water Conservation District No. 1, Lubbock , Texas, October 1999.

water is used. This includes ideas and practices such as washing full loads of clothes and dishes; using a pail of water instead of a flowing hose to wash automobiles; turning the water off while brushing one's teeth, washing one's hands, or shaving; and watering lawns, gardens, and shrubs during evening hours rather than daytime hours.

It is estimated that water conservation information programs that communicate to the public through news media and "advertising efforts" and through the schools has the potential to reduce water use by 1.5 gpcd.[41] The costs of such programs usually run about $0.75 per person per year.

(2) Conservation Incentives: Conservation incentives include factors such as rebates to water customers to replace existing plumbing fixtures with low-flow fixtures and to replace present landscapes and lawn grasses with more drought tolerant plants and turf grasses. The potential water savings and costs of these conservation measures are incorporated into the retrofit and conservation landscaping measures described below.

(3) Conservation Pricing: The consumer demand for water for municipal purposes is influenced by a number of factors including the price of water and the income levels of the consumers. Over certain ranges of water use, as price increases, the quantity of water used is expected to decline for a given level of income, while other items such as plumbing fixtures and landscaping arrangements remain unchanged. In a 1991 TWDB study, price and income elasticities of water demand were estimated for each of the 28 Metropolitan Statistical Areas (MSAs) of Texas.[42] For the Lubbock MSA, price elasticity of demand for municipal water use was estimated at -0.068, which means that a 10 percent increase in the price of water would cause a 0.068 percent reduction in use of water, other things such as income held constant. Income elasticity of demand for municipal water in the Lubbock MSA was estimated at 0.244, which means that for a 1 percent increase in income, municipal water use would increase 0.24 percent. From this analysis, it can be concluded that the demand for municipal water is fairly inelastic with respect to price (e.g., price can be increased by a small percentage and quantity of municipal water use will be reduced by a smaller percentage).

(4) Leak Detection and Repair: An important water conservation method is to find and repair leaks in the water distribution system, and in the residential, commercial, and institutional

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[41] "Hays County Water and Wastewater Study," Hays Co. Water Development Board, San Marcos, Texas, May 1989.
[42] Holloway, M.L., and Bob S. Ball, "Understanding Trends in Texas Per Capita Water Consumption," Southwest Econometrics, Austin, Texas, 1991.

structures. Where dripping faucets and leaking showers are found replacement of valve seats and washers or, if necessary, replacement of leaking parts will reduce per capita water use. Where toilets are flowing because flapper valves are worn or fail to seat properly, replacement of the faulty parts will also save water. The savings from repairing leaks inside the home are estimated at 2.2 gpcd.[43] The savings from repairing leaks in the distribution system can be as much as 10 to 20 percent of total water diverted from the source.

(5) Conservation Landscaping: Replacement of existing lawns and landscaping with more drought tolerant species, (i.e., using Buffalo Grass instead of Bermuda) can reduce per capita water use.[44] The use of water efficient landscaping is estimated to reduce lawn water use by 30 percent.[45]

(6) Lawn Watering: Scheduling lawn watering during evening and early morning hours, watering only when needed, and watering thoroughly, but less often, is an important municipal water conservation method. In addition to saving water, this practice can improve the appearance of the landscape. A well-scheduled watering program can save as much as 30 to 50 percent of lawn irrigation water in some parts of Texas.[46]

(7) Retrofit Plumbing Fixtures: The principal elements of retrofitting plumbing fixtures are the addition of faucet aerators, replacement of shower heads with low-flow fixtures, replacement of existing toilets in homes and public places with 1.6 gallon per flush units, and replacement of urinals in public buildings with 1.0 gallon per flush units. The combined savings of retrofitting these fixtures are a reduction in per capita water use of 17.9 gallons (Table 5-52) at an estimated per person cost of $154 (Table 5-53).

(8) Use of Reclaimed Water for Watering Lawns and Landscaping and for Industrial Purposes: The use of reclaimed water requires separate plumbing systems for irrigation and industrial applications. The technique is being used successfully in unincorporated areas, but is not approved by regulatory agencies for individual household use in cities. In the Llano Estacado Region, municipal effluent has been used to irrigate livestock feed crops for many

[43] "City of Austin Report for Water Conservation Plan", Montgomery Watson, Austin, Texas, March 1993.
[44] There are two varieties of Buffalo Grass -- 609 Buffalo Grass or Prairie Buffalo Grass.
[45] Ibid.
[46] "San Antonio Pilot Study finds that turf thrives on deficit irrigation," Texas Water Savers, vol. 5 No. 2, Spring 1999, Texas Water Resources Institute, Texas Agricultural Experiment Station, College Station, Texas, Spring, 1999.

decades; and in this plan, this source of supply has been included in the supply for the agricultural irrigation water use group where the practice is now being used (Subsection 5.1.6).

Table 5-53.
Estimated Costs to Retrofit
Plumbing Fixtures of a Typical Residence
Llano Estacado Region

Items	Quantity	Costs (Second Quarter 1999)	
		Unit[1,2]	Total
Showers and Lavatories			
Low-Flow Showerheads	2	\$9.89[3]	\$19.78
Faucet Aerators	3	1.55[4]	4.66
Adm./Labor/Info.	1	9.43[5]	9.43
Subtotal	—	—	33.87
Toilet Replacements			
Commodes	2	116.28[6]	232.57
Promotion/Info.	1	11.10[5]	11.10
Disposal	2	11.10	22.20
Adm./Labor/Info.	1	99.90	99.90
Subtotal	—	—	365.77
Total	—	—	\$399.64
Cost per Person	—	—	\$154.00

1 Number of Persons per unit is the Llano Estacado Average of 2.6.
2 Includes sales tax at 8 percent.
3 Retail prices range from \$3.00 to \$15.40 per unit. The price chosen is for a chrome fixture, judged to be suitable for most settings.
4 Retail prices range from \$1.32 to \$1.78 per unit. The mid-priced fixture was chosen.
5 "Assessment of Water Savings from Best Management Practices," Metropolitan Water District of Southern California, Brown and Caldwell, February 1991 (San Jose, California experience).
6 Retail prices range from \$85.00 to \$320.00 per unit without the seat. It is assumed that seats from existing units can be transferred to new units.

(9) Municipal Water Conservation Potential for the Llano Estacado Region: The possibilities for additional municipal water conservation in the Llano Estacado Region are limited. The per capita municipal water demand projections for average and "additional" water conservation are shown in Table 5-54 for cities and rural areas of each county and parts of counties located in each river basin of the region. In addition, the per capita water use reductions of the TWDB projections are shown in percentage of reduction from year 2000 to 2050 (Table 5-54). The projected per capita water use reductions for average water conservation for the period

2000 to 2030 for the Canadian River Basin area is 22.50 percent, and for the period 2000 to 2050 is 26.19 percent (Table 5-54).

For the Red River Basin area, the average water conservation effect for the 2000 to 2030 period is 11.60 percent, and for the 2000 to 2050 period is 12.71 percent (Table 5-54). Within the Red River Basin, for the 2000 to 2030 period, the projected conservation effect ranges from a low of 9.72 percent for Quitaque to a high of 21.67 percent for rural Crosby County. For the 2000 to 2050 period, the low rate is 11.34 percent for Quitaque, with a high rate of 24.68 percent for rural Crosby County (Table 5-54).

For the Brazos Basin, the average conservation effect for the 2000 to 2030 period is 12.00 percent, and for the 2000 to 2050 period is 14.32 percent (Table 5-54). Within the Brazos Basin, for the 2000 to 2030 period, the projected conservation effect ranges from a low of 9.69 percent for rural Parmer County to a high of 18.24 percent for rural Bailey County (Table 5-54).

For the Colorado Basin area of the Llano Estacado Region, the projected water conservation effect for 2000 to 2030 is 12.82 percent, and for 2000 to 2050 is 15.08 percent (Table 5-54).

The projected average conservation for the Llano Estacado Region for 2000 to 2030 is 12.02 percent, and for 2000 to 2050 is 14.18 percent (Table 5-54). However, visual inspection of the per capita water use rates listed in Table 5-54 shows that with average conservation, 19 municipalities of the region have projected water use rates that range from over 200 gpcd in year 2000, trending downward for future years to rates in the 170 gpcd and 180 gpcd range (Table 5-54). These 19 individual cities that are considered to have additional water conservation potential are marked in Table 5-54 with 5 asterisks (*****). For these 19 entities, calculations were made of the potentials for additional water conservation to that already included in the TWDB water demand projections. Additional conservation is shown in percent, with 50 percent estimated to be accomplished by 2010 and 100 percent accomplished by 2020 (Table 5-54).

The estimated additional water conservation for individual cities, counties, and river basin areas of the Llano Estacado Region is shown in Table 5-54 and will not be verbalized individually here. The estimated totals for the Red River Basin are 147 acft/yr in 2010, 293 acft/yr in 2030, and 289 acft/yr in 2050 (Table 5-55). The estimated additional water conservation for the Brazos River Basin is 500 acft/yr in 2010, 962 acft/yr in 2030, and 939 acft/yr in 2050 (Table 5-55). The estimates for the Colorado Basin are 383 acft/yr in 2010, 767 acft/yr in 2030, and 791 acft/yr in 2050 (Table 5-55). The estimated additional municipal water conservation for the Llano Estacado Region are 1,030 acft/yr in 2010, 2,022 acft/yr in 2030, and 2,018 acft/yr in 2050 (last page of Table 5-55).

In the Llano Estacado Region, per capita water use in the municipal sector for dry weather conditions was projected at 164 gallons per person per day (gpcd) in the year 2000, and is projected to be reduced by 14 percent by 2050 to 141 gpcd, with average water conservation efforts including the use of low flow plumbing fixtures. The potentials for additional municipal water conservation are about 2,000 acft/yr or 2.2 percent of the projected 2050 municipal demand (Table 5-55). Although the potential is modest, it is very important that municipal water conservation continue to be emphasized through active public information and education programs in the public schools, through the media, and at the individual water utility levels. With respect to the latter, it is suggested that each water utility of the region measure its water distribution system leaks and unaccounted for water and set goals to bring this parameter into the 12 to 15 percent range.

5.1.7.3 Environmental Issues

Municipal water conservation operates to reduce the quantities of water required for a given population and thereby reduces the quantities of land and other resources needed to supply the population of an individual city with water. For this reason, this water management strategy has little, if any adverse effects upon fish and wildlife habitat and cultural resources which might otherwise be impacted by development and delivery of the larger quantities of water that would be needed for the lower conservation scenario. However, a potential environmental impact of municipal water conservation might result from reduced quantities of reclaimed water available for established uses or discharge to streams in the short term. In the Llano Estacado

Table 5-55.
Projected Municipal Water Demand
With Average and Additional Water Conservation
Llano Estacado Region
Selected Cities*

Basin/County/City/Rural	Total in 1990 (gpcd)	Total in 1996 (gpcd)	Projections 2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)
Red Basin (part)								
Briscoe (all)								
Quitaque								
With average conservation	129	120	115	109	96	94	95	91
With additional conservation	129	120	115	98	77	75	76	73
Additional Conservation	0	0	0	11	19	19	19	18
Motley (all)								
Matador								
With average conservation	221	209	227	208	185	168	151	131
With additional conservation	221	209	227	176	129	117	106	91
Additional Conservation	0	0	0	32	56	51	45	40
Parmer (part)								
Friona								
With average conservation	912	816	939	991	1,029	1,056	1,090	1,137
With additional conservation	912	816	939	944	926	948	983	1,024
Additional Conservation	0	0	0	47	103	108	107	113
Swisher (part)								
Tulia								
With average conservation	1,062	1,110	1,135	1,156	1,163	1,188	1,219	1,264
With additional conservation	1,062	1,110	1,135	1,099	1,040	1,072	1,098	1,146
Additional Conservation	0	0	0	57	123	116	121	118
Red Basin Total	**0**	**0**	**0**	**147**	**300**	**293**	**293**	**289**
Brazos Basin (part)								
Bailey (all)								
Muleshoe								
With average conservation	1,073	910	1,078	1,064	1,016	850	643	489
With additional conservation	1,073	910	1,078	1,008	915	768	580	441
Additional Conservation	0	0	0	56	101	82	63	48
Castro (part)								
Dimmitt								
With average conservation	894	1,050	1,144	1,206	1,239	1,250	1,253	1,270
With additional conservation	894	1,050	1,144	1,145	1,112	1,126	1,127	1,141
Additional Conservation	0	0	0	61	127	124	126	129

Table 5-55 (continued)

Basin/County/City/Rural	Total in 1990 (gpcd)	Total in 1996 (gpcd)	Projections					
			2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)
Cochran (part)								
Morton								
With average conservation	631	546	656	676	673	670	663	653
With additional conservation	631	546	656	642	605	605	597	588
Additional Conservation	0	0	0	34	68	65	66	65
Whiteface								
With average conservation	117	127	115	102	89	80	75	74
With additional conservation	117	127	115	97	80	72	68	67
Additional Conservation	0	0	0	5	9	8	7	7
Crosby (part)								
Lorenzo								
With average conservation	227	221	265	249	231	209	202	199
With additional conservation	227	221	265	237	208	188	182	179
Additional Conservation	0	0	0	12	23	21	20	20
Dickens (part)								
Dickens								
With average conservation	99	105	91	86	81	80	78	76
With additional conservation	99	105	91	77	65	64	62	61
Additional Conservation	0	0	0	9	16	16	16	15
Garza (part)								
Post								
With average conservation	770	386	967	971	942	902	857	832
With additional conservation	770	386	967	874	753	722	688	667
Additional Conservation	0	0	0	97	189	180	169	165
Lamb (all)								
Amherst								
With average conservation	147	152	155	140	124	112	106	102
With additional conservation	147	152	155	136	118	106	101	97
Additional Conservation	0	0	0	4	6	6	5	5
Earth								
With average conservation	312	277	320	325	326	331	334	343
With additional conservation	312	277	320	292	261	264	267	274
Additional Conservation	0	0	0	33	65	67	67	69
Olton								
With average conservation	457	513	585	598	598	606	610	617
With additional conservation	457	513	585	538	477	485	488	494
Additional Conservation	0	0	0	60	121	121	122	123
Sudan								
With average conservation	283	207	313	320	320	322	318	319
With additional conservation	283	207	313	272	224	225	223	222
Additional Conservation	0	0	0	48	96	97	95	97

Table 5-55 (continued)

Basin/County/City/Rural	Total in 1990 (gpcd)	Total in 1996 (gpcd)	Projections 2000 (gpcd)	2010 (gpcd)	2020 (gpcd)	2030 (gpcd)	2040 (gpcd)	2050 (gpcd)
Lubbock (all)								
Ransom Canyon								
With average conservation	162	222	215	220	221	232	247	265
With additional conservation	162	222	215	209	198	209	222	238
Additional Conservation	0	0	0	11	23	23	25	27
Parmer (part)								
Farwell								
With average conservation	410	273	429	461	486	507	531	562
With additional conservation	410	273	429	390	340	355	372	393
Additional Conservation	0	0	0	71	146	152	159	169
Brazos Basin Total	0	0	0	500	990	962	941	939
Colorado Basin (part)								
Gaines (all)								
Seagraves								
With average conservation	555	495	559	581	555	547	535	533
With additional conservation	555	495	559	550	496	491	483	481
Additional Conservation	0	0	0	31	59	56	52	52
Seminole								
With average conservation	1,676	1,688	1,945	2,034	2,047	2,056	2,080	2,123
With additional conservation	1,676	1,688	1,945	1,726	1,433	1,440	1,458	1,485
Additional Conservation	0	0	0	308	614	616	622	638
Yoakum (all)								
Plains								
With average conservation	438	309	410	438	457	477	486	501
With additional conservation	438	309	410	394	366	381	389	400
Additional Conservation	0	0	0	44	91	96	97	101
Colorado Basin Total	0	0	0	383	763	767	771	791
Llano Estacado Region Total	0	0	0	1,030	2,053	2,022	2,004	2,018
River and Coastal Basins Summary								
Canadian	0	0	0	0	0	0	0	0
Red	0	0	0	147	300	293	293	289
Brazos	0	0	0	500	990	962	941	939
Colorado	0	0	0	383	763	767	771	791
Llano Estacado Region Total	0	0	0	1,030	2,053	2,022	2,004	2,018

* Those cities with per capita water use in excess of 200 gallons per person per day for average conservation.

Region, where a large part of the wastewater effluent is being used for agricultural irrigation, increased municipal water conservation would slightly reduce the quantities of water available for use by the irrigation user group. Since very little municipal wastewater effluent is discharged to streams in the Region, municipal water conservation would have little or no effect upon stream flows.

5.1.7.4 Costing

Cost estimates for municipal water conservation include about $0.75 per person per year for public information and education. The one-time costs of retrofitting plumbing fixtures are estimated at $154 per person (Table 5-53).

5.1.7.5 Implementation Issues

The major implementation issues are public acceptance and willingness of water users to change their habits insofar as operation of water using appliances is concerned. From the water utility's viewpoint, a significant factor affecting the rate and extent of water conservation effort is the potential reduction in revenues in the immediate future; e.g., if debt has been incurred in the development of the water supply and water rates have been set based upon historic per capita water use rates, then water conservation programs could lower the utility's income by reducing the quantity of water sold at the established rate and necessitate rate increases to produce enough income to meet debt service and other fixed payments.

This water supply option has been compared to the plan development criteria, as shown in Table 5-56.

5.1.8 Irrigation Water Conservation

5.1.8.1 Description of Option

Irrigation water is freshwater that is pumped from aquifers and/or diverted from streams and lakes of the study area and applied directly to grow crops, orchards, and hay and pasture in the study area. In the case of groundwater, the irrigation wells are usually located within the fields to be irrigated. The irrigation water is taken directly from the wells and applied to the land by: (1) flowing or flooding water down the furrows; and (2) sprinklers. In the case of surface water from study area streams and lakes water is diverted from the source and conveyed by canals and pipelines to the fields where it is then applied by: (1) flowing or flooding water down the furrows; and (2) sprinklers. In the Llano Estacado Region there is practically no

Table 5-56.
Evaluation of Municipal Water Conservation

Impact Category	***Comment(s)***
a. Quantity, reliability, and cost of treated water	• In this case, potential quantity is low • Costs are low in comparison to cost of adding supply
b. Environmental factors	• Reduction in quantities of reclaimed water
c. State water resources	• Reduces pressures upon all sources of supply
d. Threats to agriculture and natural resources in region	• Limited reductions in quantities of reclaimed water for irrigation, in short run
e. Recreational	• Not applicable
f. Comparison and consistency equities	• Based upon factors comparable to other strategies
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• May adversely affect water supplies for irrigators who are using reclaimed water, but would be minor, since these quantities are relatively low in Llano Estacado Region
i. Efficient use of existing water supplies and regional opportunities	• Increases by reducing quantity of supply per unit served
j. Effect on navigation	• Not applicable

surface water supply for irrigation, except that which is pumped from the playas that are located on the farms. In both the use of groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation, evaporation, and evapotranspiration between the originating points (wells in the case of groundwater and stream or lake diversion points in the case of surface water) and the irrigated crops in the fields. Thus, the focus is upon investments in irrigation application equipment, instruments, and conveyance facility improvements to reduce seepage losses, deep percolation, and evaporation of water between the originating points of the water and the destination locations within the irrigated fields. Principal methods of irrigation water conservation are (1) low-pressure sprinklers (LESA); (2) low-energy precision application systems (LEPA); (3) surge irrigation; and (4) furrow diking. In comparison to the irrigation method (furrow or flood irrigation) of releasing the water into the furrows at the ends of the rows and allowing it to flow across the fields until each furrow has been saturated throughout its entire length, the use of sprinklers, LEPA, surge valves, furrow diking, land leveling, and irrigation scheduling improves application efficiency within the irrigated fields and thereby reduces the total quantity of water needed to produce an irrigated crop.

5.1.8.2 Irrigation Water Needs and Quantity of Supply Available through Irrigation Water Conservation

Given that irrigators of the Llano Estacado Region have been installing and using highly efficient irrigation application methods for many years and that the TWDB has already incorporated potential water conservation effects into the irrigation water demand projections for the Llano Estacado Region, the potentials for additional conservation are somewhat limited. For example, the TWDB estimates of irrigation water use in the 21 counties of the Region was 3,657,740 acft/yr in 1990, with projections of irrigation water demand in 2030 of 2,750,832 acft/yr, and in 2050 of 2,562,076 acft/yr (Table 5-57). For the Llano Estacado Region, the irrigation projections show a reduction in water use of 906,908 acft/yr, or 25 percent by 2030, and a reduction in water use of 1,095,664 acft/yr, or 30 percent, by 2050 (Table 5-57).

In order to accomplish the maximum potential irrigation conservation, it will be necessary to install low-energy precision application (LEPA and/or LESA) systems that discharge water directly into the furrows or in a spray near the ground at low pressure. When used in conjunction with furrow dikes, which hold both precipitation and sprinkler applied water behind small mounds of earth within the furrows, LEPA systems are the most efficient irrigation application systems available to irrigators of the region for row crop production, with the possible exception of drip irrigation.[47] Even though drip irrigation uses less water, this method is not yet economically feasible for most irrigators to utilize. Thus, LEPA and LESA are the methods of choice and will be evaluated for the regional water plan.

[47] Furrow dikes are constructed by towing the furrow-diking implement behind planters or cultivators when these operations are performed. The furrow dikes hold water in place within the furrows, allowing it to infiltrate the soil profile as opposed to allowing the water to flow down the furrows and exiting the fields. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland.

Table 5-57.
Irrigation Water Demand Projections
Individual Counties*
Llano Estacado Region

	County	Use In 1990 (acft)	Use in 1996 (acft)	Projections 2000 (acft)	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)
1	Bailey	220,775	250,175	172,269	168,136	164,136	160,166	156,324	152,573
2	Briscoe	39,592	20,934	32,584	31,401	30,262	29,164	28,105	27,085
3	Castro	351,189	519,038	306,595	294,840	283,537	272,665	262,212	252,158
4	Cochran	32,679	165,163	50,969	49,001	47,111	45,293	43,544	41,863
5	Crosby	105,634	138,358	88,163	84,611	81,203	77,931	74,791	71,779
6	Dawson	39,097	143,326	36,475	34,418	32,478	30,646	28,919	27,289
7	Deaf Smith	285,459	282,026	251,112	243,156	235,454	227,994	220,771	231,777
8	Dickens	4,779	8,551	3,792	3,679	3,569	3,463	3,360	3,259
9	Floyd	131,706	224,791	148,304	142,397	136,726	131,280	126,051	121,029
10	Gaines	392,950	415,206	355,323	336,817	319,275	302,647	286,885	271,943
11	Garza	4,383	10,525	3,529	3,322	3,128	2,944	2,772	2,610
12	Hale	461,931	433,633	365,594	353,481	341,769	330,445	319,497	308,911
13	Hockley	92,968	168,853	97,282	93,478	89,822	86,311	82,934	79,692
14	Lamb	351,050	381,379	288,370	277,244	266,546	256,261	246,373	236,867
15	Lubbock	230,717	242,533	158,078	149,158	140,785	132,881	125,421	118,381
16	Lynn	39,988	56,334	38,454	36,384	34,427	32,575	30,822	29,164
17	Motley	3,883	4,134	3,687	3,577	3,470	3,367	3,266	3,168
18	Parmer	475,000	448,516	324,951	321,500	318,087	314,710	311,369	308,063
19	Swisher	139,650	168,688	148,054	147,209	141,037	145,532	144,701	143,874
20	Terry	131,901	148,061	106,860	101,381	96,183	91,252	86,574	82,135
21	Yoakum	122,409	147,103	84,925	80,861	76,990	73,305	69,797	66,456
	Total	3,659,730	4,379,323	3,067,370	2,958,061	2,845,962	2,752,862	2,656,528	2,582,126
	Reductions from 1990			592,370	701,689	811,778	906,908	1,003,252	1,095,664
	% reductions from 1990			16%	19%	22%	25%	27%	30%
	Add'l Potential(acft/yr)[1]			355,451	319,906	287,914	259,123	233,212	209,892
	Additional Potential(%)[1]			9.7%	8.7%	7.8%	7.1%	6.4%	5.7%

* As specified in Texas Water Development Board (TWDB) Rules, 31 Texas Administrative Code, Regional Water Planning Areas, March 11, 1998; Taken from "Llano Estacado Region Water Plan, Task 1—Description of the Planning Region: Task 2—Population and Water Demand Projections, October 1999, Table 2-8.

Source: TWDB; 1996 Consensus Water Plan, Most Likely Case, below normal rainfall, aggressive adoption of irrigation technology, and reduction in federal farm programs by one-half, as revised January 21, 1999.

In the Llano Estacado Planning Region in 1998, the most recent date for which data are available, 16,420 center pivots were in operation. Of the 3,107,166 reported irrigated acres in the region in 1998, it is estimated that 2,267,345 acres were irrigated with these 16,420 center pivots (Table 5-58).[48] It is estimated that in the region there are about 2,980,826 acres, or 95 percent of the 3,107,166 acres irrigated in 1998, that could be irrigated with center pivot systems (Table 5-58).[49] The goal of this option is to bring the number of acres irrigated by low energy precision application (LEPA for row crops and LESA for drilled crops) systems to 95 percent of the total irrigated acres (row crops and drilled and broadcast crops) for each county within the region by the year 2020. In 1998, six counties (Cochran, Dawson, Gaines, Motley, Terry, and Yoakum) had center pivot systems on 95 percent of the irrigated acreage (Table 5-58).[50] If each county in the Llano Estacado Region increased its use of LEPA systems to 95 percent of the total irrigated acreage, an additional 716,925 acres could be irrigated with LEPA systems instead of other irrigation methods, resulting in approximately 355,451 acft/yr of irrigation water savings due to lower irrigation water application rates (Table 5-58).

5.1.8.3 Environmental Issues

The methods of this water management strategy were developed and tested through public and private sector research and have been adopted widely in the Llano Estacado Region. Thousands of LEPA systems have been installed and are in operation today. Experience has shown that there are not any environmental issues associated with this water management strategy, i.e., this method improves water use efficiency without making changes to wildlife habitat. LEPA center pivot irrigation application systems apply irrigation water directly into the furrows. This method of application, when coupled with furrow dikes, reduces runoff of both applied irrigation water and rainfall. The results are reduced transport of sediment and any

[48] Although not all of the operational center pivots are LEPAs, a large proportion are.

[49] The center pivot acreage and irrigated acreage data are obtained from different sources; and although they are the most complete and best available, the reports and surveys are not necessarily consistent with respect to definition and concept; e.g., some surveys may respond for double crops, while others may not. In addition, some respondents may report hailed out acres and also report the same acres on which catch crops or second plantings in the same year are made. Thus, the reported irrigated acreage may contain some double cropping without so noting. The result is that reported pivot irrigated acreage may exceed the total reported irrigated acreage of an individual county.

[50] Note: Gaines, Lynn, Motley, Terry, and Yoakum counties reported a higher number of center pivot irrigated acres in 1998 than total irrigated acres in 1998. For these counties it was assumed that their current usage of LEPA systems exceeded 95percent of all irrigated acres, and no new LEPAs are included for these counties.

Table 5-58.
Irrigation Water Conservation
Irrigation Data[1]
Llano Estacado Region

County	Center Pivot Irrigation[2]				Total Irrigated Acres[3] (1998)	Difference in Pivot Irrigated Acres and Total Irrigated Acres	Estimated % Irrigated via Center Pivot
	Center Pivots (1995)	Center Pivots (1998)	Increase (1995 to 1998)	Pivot Irrigated Acres (1998)			
Bailey	794	877	83	108,228	115,961	7,733	93.3%
Briscoe	21	92	71	13,101	37,245	24,144	35.2%
Castro	1,003	1,261	258	190,089	259,943	69,854	73.1%
Cochran	493	590	97	76,140	79,055	2,915	96.3%
Crosby	336	509	173	73,674	149,095	75,421	49.4%
Dawson	367	483	116	66,192	67,190	998	98.5%
Deaf Smith	624	781	157	118,554	169,042	50,488	70.1%
Dickens	13	39	26	5,511	7,805	2,294	70.6%
Floyd	210	385	175	65,205	201,168	135,963	32.4%
Gaines	1,660	2,107	447	290,516	290,516	0	100.0%
Garza	24	41	17	5,400	11,891	6,491	45.4%
Hale	990	1,298	308	188,577	331,812	143,235	56.8%
Hockley	731	884	153	110,874	149,257	38,383	74.3%
Lamb	1,459	1,709	250	212,706	244,972	32,266	86.8%
Lubbock	539	778	239	111,759	222,700	110,941	50.2%
Lynn	308	493	185	65,637	74,809	9,172	87.7%
Motley	27	45	18	5,892	5,906	14	99.8%
Parmer	1,556	1,719	163	218,934	247,575	28,641	88.4%
Swisher	89	301	212	55,230	156,098	100,868	35.4%
Terry	1,138	1,319	181	174,513	174,513	0	100.0%
Yoakum	549	709	160	110,613	110,613	0	100.0%
Total	12,931	16,420	3,489	2,267,345	3,107,166	839,821	73.0%

1 These irrigation and center pivot data were obtained from different sources; and although are the most complete and best available, they are not necessarily consistent with respect to definition. For example, some respondents may report double crops while others do not; and some respondents may report acreages that were hailed out, as well as the same acreages that were planted to a catch crop after the hail. Thus, total center pivot acreages may exceed the total reported irrigated acreages in some counties.
2 High Plains Underground Water Conservation District No.1.
3 TWDB 1998 On-farm Irrigation Water Use Survey.

fertilizers or other chemicals that have been applied to the crops. Thus, the proposed conservation practices do not have potential adverse effects; and in fact have potential beneficial environmental effects.

5.1.8.4 Costing

Assuming a cost of $360 per acre to install LEPA systems, it would cost $258.1 million to install LEPA systems on the remaining applicable acres within the Llano Estacado Region (Table 5-59). The cost per county varies from a high of $45.6 million in Hale County to a low of $685,400 in Dickens County (Table 5-59).

Loans for LEPA systems have been made at about 6 percent interest rate and farmers have been repaying the loans in 7 to 10 years. For purposes of this analysis, calculations have been made based upon interest rates of 6 percent per year, with repayment schedules of 8 years. However, it is estimated that the useful life of LEPA Systems is 25 years.[51] Thus, in order to obtain estimates of cost per acre foot of water saved, it was necessary to express the loan repayments on a 25 year basis, even though repayment is done in fewer years, and in the present case in 8 years (Table 5-59, Column 10). Calculating cost per acre-foot of water saved must also take into account the condition that as the saturated section of the aquifer thins due to withdrawal of water, the quantity of water that can be pumped per well will decline. Therefore, the potential quantity of water that can be saved per LEPA System will also decline in future years. In this planning project, it has been estimated that well yields will decline one percent per year due to thinning of the saturated section of the aquifer (Section 3, Table 3-1), and that water conservation potentials will also decline one percent per year in future years simply because the water cannot be pumped and therefor is not available to conserve (Table 5-59 Continued, Columns 2 through 7).

The method of calculating cost per acre-foot of water saved is listed below, using totals for the region.

- The estimated total cost to install LEPA on 716,925 acres is $258,093,126.
- The annual payment to retire a $258,093,126 loan at 6% interest in 8 years is $41,492,443.
- Total dollars repaid at this rate for 8 years is $41,492,443 x 8 = $331,939,540.
- Average repayment for the 25 year useful life of LEPA Systems is $331,939,540 divided by 25 = $13,277,582.
- Average cost per acre foot of water saved in year 2000 is $13,277,582 divided by 355,451 = $37.35. (Table 5-59 Continued, Column 9, Total Row).

[51] For purposes of this analysis it is assumed that LEPA Systems will be replaced at the end of their useful life of 25 years, and continued in operation for the remainder of the 50 year planning horizon. Therefore, at 2nd quarter 1999 prices, annual costs will not change and the calculations described in the text are appropriate.

- Average cost per acre foot of water saved in year 2010 is $13,277,582 divided by 319,906 = $41.50. (Table 5-59 Continued, Column 10, Total Row).
- Average cost per acre foot of water saved in year 2030 is $13,277,582 divided by 259,124 = $51.24. (Table 5-59 Continued, Column 12, Total Row).
- Average cost per acre foot of water saved in year 2050 is $13,277,582 divided by 209,892 = $51.24. (Table 5-59 Continued, Column 14, Total Row).

The calculations for each county are shown in Tables 5-59 and 5-59 Continued. For example, for Bailey County, estimated water conservation in 2000 is 1,319 acft/yr, declining to 962 acft/yr in 2030 and 779 acft/yr in 3050. Cost per acft saved in 2000 is estimated at 27.21, in 2030 is $37.31, and in 2050 is $$46.05 (Table 5-59 Continued). Values for the other counties of the region can be seen in Table 5-59 Continued and will not be repeated here.

5.1.8.5 Implementation Issues

The water needs analysis, in which projected irrigation water demands were compared to projected irrigation water supplies (Task 4; Table 4-1 through Table 4-21), showed that 11 counties (Bailey, Castro, Cochran, Crosby, Floyd, Garza, Hale, Hockley, Parmer, Swisher, and Terry) have projected irrigation water shortages or needs, e.g., the individual county's projected irrigation water demands exceeded the county's projected irrigation water supplies (Table 5-60).[52] The irrigation water conservation strategy described above could result in enough water being saved within the county to offset or meet the projected needs in five of the 11 counties. The five counties where projected irrigation conservation could save enough water to meet the projected needs at the county level are Crosby, Floyd, Garza, Hale, and Hockley, leaving Bailey, Castro, Cochran, Parmer, Swisher, and Terry with projected unmet irrigation needs (Table 5-60). Thus, the irrigation conservation management strategy, if adopted and used, will meet a part of the projected irrigation user group's needs. It cannot meet all of the projected irrigation need. However, the LERWPG finds that at this time it is not economically feasible to meet all of the projected irrigation needs, since the cost of the water management strategy with enough water supply to meet the needs far exceeds the ability of irrigators to pay for the water. The water management strategy under consideration is "Importation from East Texas and Central

[52] Although the comparison of projected irrigation water demands with projected irrigation water supplies at the county level shows 11 counties with shortages, no doubt there will be individual farms within most, if not all, of the region's counties where shortages will occur.

Arkansas," which has a Second Quarter 1999 price tag of over $865 per acre-foot of water

Table 5-60.
Projected Irrigation Water Supply Needs*
Individual Counties
Llano Estacado Region

County	2000 (acft/yr)	2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)
Bailey County						
Projected Irr. Surplus/Shortage**	-7,278	-6,463	-5,350	-4,014	-2,431	-925
Additional Conservation***	1,319	1,187	1,068	962	865	779
Surplus/Shortage w/ Cons.	-5,959	-5,276	-4,282	-3,052	-1,566	-146
Briscoe County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	6,814	6,133	5,519	4,967	4,471	4,024
Surplus/Shortage w/ Cons.	6,814	6,133	5,519	4,967	4,471	4,024
Castro County						
Projected Irr. Surplus/Shortage	-39,261	-39,143	-38,621	-36,342	-34,894	-33,527
Additional Conservation	47,358	42,622	38,360	34,524	31,072	27,964
Surplus/Shortage w/ Cons.	8,097	3,479	-261	-1,818	-3,822	-5,563
Cochran County						
Projected Irr. Surplus/Shortage	-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	-13,181	-12,046	-10,275	-9,118	-8,098	-7,129
Crosby County						
Projected Irr. Surplus/Shortage	-179	-107	-48	0	0	0
Additional Conservation	27,400	24,660	22,194	19,975	17,977	16,179
Surplus/Shortage w/ Cons.	27,221	24,553	22,146	19,975	17,977	16,179
Dawson County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	0	0	0	0	0	0
Deaf Smith County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	23,775	21,398	19,258	17,332	15,599	14,039
Surplus/Shortage w/ Cons.	23,775	21,398	19,258	17,332	15,599	14,039

Table 5-60 (continued)

County	2000 (acft/yr)	2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)
Dickens County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	763	687	618	556	501	451
Surplus/Shortage w/ Cons.	763	687	618	556	501	451
Floyd County						
Projected Irr. Surplus/Shortage	-23,567	-23,949	-24,088	-23,665	-23,420	-23,059
Additional Conservation	59,112	53,201	47,881	43,093	38,783	34,905
Surplus/Shortage w/ Cons.	35,545	29,252	23,793	19,428	15,363	11,846
Gaines County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	0	0	0	0	0	0
Garza County						
Projected Irr. Surplus/Shortage	-570	-90	0	0	0	0
Additional Conservation	3,120	2,808	2,527	2,274	2,047	1,842
Surplus/Shortage w/ Cons.	2,550	2,718	2,527	2,274	2,047	1,842
Hale County						
Projected Irr. Surplus/Shortage	-2,234	-2,183	-3,777	-7,606	-9,882	-12,995
Additional Conservation	60,063	54,056	48,651	43,786	39,407	35,467
Surplus/Shortage w/ Cons.	57,829	51,873	44,874	36,180	29,525	22,472
Hockley County						
Projected Irr. Surplus/Shortage	-4,272	0	0	0	0	0
Additional Conservation	13,324	11,992	10,792	9,713	8,742	7,868
Surplus/Shortage w/ Cons.	9,052	11,992	10,792	9,713	8,742	7,868
Lamb County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	12,237	11,013	9,912	8,921	8,029	7,226
Surplus/Shortage w/ Cons.	12,237	11,013	9,912	8,921	8,029	7,226
Lubbock County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	45,156	40,640	36,576	32,919	29,627	26,664
Surplus/Shortage w/ Cons.	45,156	40,640	36,576	32,919	29,627	26,664

Table 5-60 (concluded)

County	2000 (acft/yr)	2010 (acft/yr)	2020 (acft/yr)	2030 (acft/yr)	2040 (acft/yr)	2050 (acft/yr)
Lynn County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	2,763	2,487	2,238	2,014	1,813	1,632
Surplus/Shortage w/ Cons.	2,763	2,487	2,238	2,014	1,813	1,632
Motley County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	0	0	0	0	0	0
Parmer County						
Projected Irr. Surplus/Shortage	-34,176	-42,245	-48,530	-54,632	-59,986	-64,700
Additional Conservation	12,538	11,284	10,156	9,140	8,226	7,404
Surplus/Shortage w/ Cons.	-21,638	-30,961	-38,374	-45,492	-51,760	-57,296
Swisher County						
Projected Irr. Surplus/Shortage	-45,349	-45,061	-42,473	-44,468	-44,167	-43,862
Additional Conservation	39,709	35,738	32,164	28,948	26,053	23,448
Surplus/Shortage w/ Cons.	-5,640	-9,323	-10,309	-15,520	-18,114	-20,414
Terry County						
Projected Irr. Surplus/Shortage	-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	-1,855	-1,772	-1,690	-1,615	-1,542	-1,406
Yoakum County						
Projected Irr. Surplus/Shortage	0	0	0	0	0	0
Additional Conservation	0	0	0	0	0	0
Surplus/Shortage w/ Cons.	0	0	0	0	0	0
Llano Estacado Region						
Projected Irr. Surplus/Shortage	-171,922	-173,059	-174,852	-181,460	-184,420	-187,603
Additional Conservation	355,451	319,906	287,914	259,124	233,212	209,892
Surplus/Shortage w/ Cons.	183,529	146,847	113,062	77,664	48,792	22,289

* Needs are equal to shortages.

** Negative values are shortages, or needs.

*** Additional conservation is assumed to be reduced by 1 percent per year due to reduced well yields because of thinning of the aquifer. This is the same estimate used in the water supply computations.

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delivered from the source to a central location near Lubbock, Texas, and does not include the cost of distributing imported water to irrigation farms (Section 5.2.2). At today's and projected future farm commodity prices, the estimated ability of irrigation farmers to pay for water from a source other than beneath their respective farms is on the order of $20 to maybe $60 per acre foot. ***Thus, the conclusion is that at the present time it is not economically feasible to meet all of the projected irrigation water needs of the Llano Estacado Region.***

It is important to note, and is hereby emphasized, that the irrigation water conservation strategy, which has been in operation within the region for many years, is reducing the quantity of irrigation water withdrawn annually from the aquifer in the short term. These annual water savings now are contributing to extending the life of the existing supplies for use later, when the supply from this source would have otherwise been exhausted. The proposed expansion of the irrigation water conservation strategy in this water plan will meet a part of the projected irrigation needs in those counties of the region where further irrigation conservation opportunity exists. For example, in 11 of the region's counties (Briscoe, Crosby, Deaf Smith, Dickens, Floyd, Garza, Hale, Hockley, Lamb, Lubbock, and Lynn) where additional conservation potential exists, irrigation conservation is estimated to make the same kind of positive contribution to future irrigation water supplies as was described above, by reducing the quantity of water withdrawn for irrigation during the next 50 years, leaving it in the aquifer for use later (Table 5-60).

Although implementation of this strategy requires comparatively large capital investments for irrigation farmers, it has been widely accepted. The Texas Water Plan Legislation of 1985, as amended, established a low interest loan program for agricultural water conservation equipment.[53] This program is widely used within the Llano Estacado and other regions of Texas, and together with private sector financing is adequate to implement this water management strategy in the region.

This water supply option has been compared to the plan development criteria, as shown in Table 5-61.

[53] 31 TAC Section 367.1 et seq.

Table 5-61.
Evaluation of Irrigation Water Conservation as a Water Management Strategy
Llano Estacado Region

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Quantity directly dependent upon degree of acceptance and implementation • Among the lowest cost strategies
b. Environmental factors	• None
c. State water resources	• No apparent negative impacts on other water resources; reduces quantities needed for given condition
d. Threats to agriculture and natural resources in region	• None; Enhances agriculture and natural resources
e. Recreational	• None
f. Comparison and consistency equities	• Win-win for all involved
g. Interbasin transfers	• Not applicable
h. Third party social and economics impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Very high
j. Effect on navigation	• None

5.1.9 Agricultural Water Conservation Practices on Farms

These are region-wide or regional water management strategies applicable to individual irrigators that have been applied to about 75 percent of irrigated acreage of the region and have significantly benefited the economy of the entire region. Approximately 25 percent of the irrigated acreage needs additional conservation applied. The water management strategies described below are useful to both agriculture and the maintenance of wildlife habitat and aquifer recharge, and to the extent data are available, the strategies are evaluated according to TWDB Rules, Section 357.7.

5.1.9.1 Description of Option

In the Llano Estacado Region, both irrigation and non-irrigated, or dryland farming, is practiced. Of the total 7.8 million acres of cropland in production, approximately 60 percent are farmed without irrigation and 40 percent is irrigated. For the most part, the irrigated acreages are those that have saturated sections of the Ogallala Formation underlying them that are thick enough to provide an adequate quantity of water to justify drilling, equipping, and pumping irrigation wells. Such wells supply water that is used to supplement precipitation for crop production. In 1998 in the Llano Estacado Region, approximately 3.1 million acres were reported to have received some irrigation water.[54]

Dryland and irrigation farmers in the area attempt to maximize the use of the precipitation they receive on their farms. Precipitation will support a few crops (dryland cotton, dryland grain sorghum, and dryland wheat) resulting in yields adequate to return a profit in about six of ten years. With increased precipitation or supplemental irrigation, yields of these crops can be increased by 30 percent to more than 300 percent and other crops can be produced, i.e., cotton requires about 5 inches of water to grow the plant, then for each additional inch of water the cotton plants will produce from 30 to 50 pounds of lint per acre depending on soil fertility and the timing of the receipt of additional water. Grain sorghum and wheat also require a similar amount of water to grow the plant, and the yields produced have a direct relationship to the total amount of water available during the growing season. The water supply can be a combination of stored soil moisture and precipitation or irrigation water received during the growing season.

Irrigation application methods have been the subject of research and development since irrigation became possible in the Llano Estacado Region in the 1930s, and in recent decades there have been significant improvements in irrigation application methods as compared to methods available in the beginning. For example, during the 1940s, 1950s, 1960s, 1970s, and into the 1980s, the method of "furrow irrigation" was used to apply water to row crops, such as cotton, corn, grain sorghum, and vegetables; and this method is still in use in the region to some limited extent. However, this is the least efficient irrigation method, since water is siphoned from open, unlined ditches or released into furrows from pipes and allowed to flow down the furrow until the entire furrow length is wetted. To wet the entire length of the furrow water must be kept flowing into the head of the furrow until the flow reaches the other end, at which time water already in the furrow will most likely continue flowing on out the end of the row and be lost from the irrigated fields as irrigation tailwater. In addition, this method results in deep

[54] Texas Water development Board, 1998 Irrigation Survey, Austin, Texas, 1998.

percolation below the root zone from the wetted furrows, since the water receiving ends of the furrows are required to be kept full of water until flow reaches the opposite end of the fields.

Surge valves introduced in the area in the early 1980s have been used to increase the water application efficiency of furrow irrigation by 20 to 40 percent, depending on soil type, slope, and length of the furrows. Surge valves are used on the majority of the fields currently being furrow irrigated. The following irrigation applications and water management practices are currently being utilized in the planning region: (1) Subsurface Drip Irrigation—SDI, (2) Low Energy Precision Application—LEPA pivot, (3) Low Elevation Spray Applicator/Low Pressure in Canopy—LESA/LPIC, (4) Surge Valves, (5) Pipelines, (6) Lay Flat Tubing, (7) Furrow Diking, (8) Soil Moisture Monitoring, and (9) Irrigation Scheduling (See Appendix B). These methods and practices are presented and described below.

Subsurface Drip Irrigation (SDI) delivers water to plants by means of buried, small diameter, plastic tubes with small orifices or holes spaced to allow the release of water near the plant roots. This method has the potential for irrigation efficiencies of 90 to 98 percent, since it ensures a minimum loss of water through evaporation or deep percolation into the ground. Yields have been increased from 500 to 1,500 pounds of lint cotton per acre on some drip irrigation tracts. The method is adaptable to most soils, but has limited acceptance because installation costs are high--$700 to $1,400 per acre.

Low-Energy Precision Application (LEPA) systems use a center-pivot piping and transport system, but instead of spraying water into the atmosphere, the water is delivered through drop lines extending from the overhead transport frame to a few inches above the land surface between crop rows. Some LEPA systems are equipped with socks and others with drag hoses or lines. LEPA systems have application efficiency potentials of 90 to 95 percent. The advantages of LEPA systems are that they require low pressure to operate, little evaporation occurs from the application process, and they provide the opportunity to control the volume of delivered irrigation water. Also, they can be used with furrow dikes that hold both precipitation and applied irrigation water in the furrows until it soaks into the ground. More uniform and timely applications of irrigation water results in higher yields (uniform production over the entire field). Less water is pumped, which reduces energy cost, and labor cost is lowered as compared to furrow irrigation. Cost to convert from older, high pressure types of sprinkler systems to

LEPA are in the range of $25 to $50 per acre, and installation of new LEPA systems costs approximately $300 per acre.

Low Elevation Spray Applicator/Low Pressure in Canopy (LESA/LPIC) application systems are alternate row sprays with low drift nozzles placed one to four feet above the ground. Once the crop canopy is established, evaporation losses due to wind drift and heat are reduced. These systems are applicable to slopes greater than 1 percent and have application efficiency potentials of 80 to 90 percent. Cost of LESA/LPIC conversions from older, high-pressure systems is about $100 per acre and a new system costs about $250 per acre.

Surge Valves are a variation of furrow irrigation in which gated pipes are used to release irrigation water into the furrows being irrigated. The gates of the pipes are spaced to deliver a stream of water into a set of furrows. The surge method uses a time-controlled valve placed between two sets of gated pipe. The system alternately waters two sets of furrows in a series of timed “surges,” with each cycle supplying only enough water to flow a part of the length of the field. During the off period of the cycle, the water in the furrow infiltrates into the soil and creates a surface sealing effect that reduces infiltration in that section of furrow when the valve recycles to the set. During the next surge, water flows down the previously wetted section of the furrow more rapidly, reducing deep percolation at the top end of the field. The cycle continues until enough water has been discharged into each set to wet the soil uniformly throughout the field. Surge irrigation improves irrigation efficiency in comparison to the standard furrow method by 10 to about 40 percent and is low cost in terms of capital investment. Surge valves cost between $1,000 and $1,500 each and can be moved from field to field during the irrigation season.

Pipelines that replace open ditches to convey water from the irrigation wells to the crops to be irrigated can reduce water losses from 10 to 30 percent per 1,000 feet depending on soil type. Plastic pipelines costing from $1.00 to $5.00 per foot (depending on size) are suitable for most areas of the Llano Estacado Region.

Lay Flat Tubing, a thin wall polyethylene tube, is a usable temporary replacement for open ditches and can be used to transport irrigation water for furrow irrigation systems. Lay Flat Tubing can reduce water losses from 10 to 30 percent per 1,000 feet, depending on soil type, when used instead of open ditches. It is disposable and usually lasts for 1 or 2 years.

Furrow Dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve (capture) as much as 100 percent of rainfall runoff, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. This maintains high irrigation uniformity and increases irrigation application efficiencies. Capturing and holding precipitation that would have drained from the fields replaces required irrigation water on irrigated fields; and on dryland cropland it maximizes the benefits of precipitation for use by dryland crops. In addition, furrow diking may help increase recharge to the Ogallala Aquifer during periods when rainfall is in excess of the plant root zone soil water holding capacity. Furrow diking requires special tillage equipment and costs $3.00 to $5.00 per acre to install.

Soil Moisture Monitoring is the periodic measurement of soil moisture content. Its purpose is to indicate when and how much irrigation water needs to be applied to meet crop needs. Soil moisture information is used by irrigators to apply the correct amount of water at the correct time, thus reducing over or under irrigation. Soil Moisture Monitoring is most effective when used with an irrigation-scheduling program. The cost of Soil Moisture Monitoring is initially high because of the cost of the instruments; but annual costs are then usually low.

Irrigation Scheduling is the practice of applying irrigation water to crops in quantities that the crop can efficiently use, when the crop needs it, and in amounts that are not in excess of the soil water holding capacity. Proper Irrigation Scheduling also maintains a storage deficit in the soil profile to make room available for rainfall when it occurs, thus maximizing the utilization of rainfall as well as irrigation water. Irrigation Scheduling requires additional and higher levels of management from the irrigator than is the case without Irrigation Scheduling. Costs associated with Irrigation Scheduling are generally labor costs related to the time spent scheduling, subscriber costs to a PET network, or consultant fees.

There is an estimated 14,000 playa basins located within the Llano Estacado Region. These playas serve a variety of purposes, including as wildlife habitat. In turn, the playas are affected by agricultural production practices and especially by irrigation and water management practices.

Studies have estimated that from 20 to 80 percent of the water collected on the floor of playas during normal years moved into the subsurface to recharge the Ogallala Aquifer.[55] Other studies surveying frequency of significant recharge to the Ogallala Aquifer from precipitation runoff into playa basins found that 27 to 43 percent of the precipitation runoff that collected in the playas was recharged to the Ogallala Aquifer.[56] White and others in 1946 provided extensive data from five wells in close proximity to playa lakes in Deaf Smith, Floyd, Hale, and Lubbock Counties that illustrated the direct response of aquifer levels to the recharge from playa lakes after local rainfall events.[57]

One of the greatest threats to playa ecosystems is sedimentation from the playa watersheds. Sedimentation impacts the hydrology of the playa basin, reducing the length of time that the playa holds water after flooding. Restoration and enhancement of watersheds and uplands surrounding playa lakes can drastically slow the siltation of playa basins. Enhancement through cropping and grazing management can improve habitat for nesting, migrating and wintering birds, and other wildlife in the area.

Well-planned, efficient water management practices on playa watersheds ensures that during rainfall, they serve as catchment basins and provide valuable habitat for wildlife, as well as enhancing their natural function as a source of recharge to the Ogallala Aquifer.

5.1.9.2 Potential Quantities of Water from Water Management Practices

In the description of the water management strategies in Subsection 5.1.9.1, a range of potential percentages of water use efficiency improvements was indicated. The potentials range from a low of 40 percent to 98 percent for general consideration (Table 5-62). These estimates give an indication of results that can be expected if applied in the field (Section 5.1.8.2). Of the 3,107,166 reported irrigated acres in the region in 1998, it is estimated that 2,267,345 acres were irrigated with 16,420 center pivot systems, which is about 73 percent of the total irrigated acres. If each county in the Llano Estacado Regional Water Planning Region increased the acreage

[55] Havens, J.S., 1966, Recharge Studies on the High Plains in Northern Lea County, New Mexico: U.S. Geological Survey-Water Supply Paper 1819-F, 52 p.
[56] Claborn, B.J., Urban, L.V., and Oppel, S.E. 1985, Frequency of Significant Recharge to the Ogallala Aquifer from Playa Lakes: Texas Tech University, Water Resources Center, Final Report, Project Number G-935-03, 24 p.
[57] White, W.N., Broadhurst, W.L., and Lang, J.W., 1946, Ground Water in the High Plains of Texas: U.S. Geological Survey Water-Supply Paper 889-F, p. 381-420.

irrigated with center pivots to 95 percent, an additional 716,925 acres could be irrigated in this way, resulting in water savings of about 355,451 acft/yr (Table 5-59).

5.1.9.3 Environmental Issues

There are no known environmental issues associated with the irrigation practices of this water management strategy. For example, the essence of the strategy is to increase the efficiencies of existing water uses without changes to wildlife habitats. In effect, the use of the water management practices described above have reduced the rates of withdrawal of water from the Ogallala and other aquifers, may have increased recharge, and have reduced the quantities of energy used to pump and apply irrigation water. They have contributed to water supply sustainability by lengthening the economic life of the existing water supply of the region.

Table 5-62.
List of Irrigation Systems and Efficiency of Each
Llano Estacado Region

Irrigation Systems	*Range of Application Efficiency (percent)*
Drip Irrigation	90 to 98%
LEPA Center Pivots	90 to 95%
Low Elevation Spray Applicator	80 to 90%
Surge Valves with Furrow Application	50 to 70%
Pipelines with Furrow Application	45 to 75%
Lay Flat Tubing with Furrow Application	45 to 65%
Furrow with Open Ditch	40 to 60%

Source: High Plains Underground Water Conservation District

5.1.9.4 Costing

The unit costs of the water management practices are included in the description above (Subsection 5.1.9.1) and are summarized below (Table 5-63). However, as in the case of estimation of quantities of water involved, costs per unit of water cannot be estimated since these are water management practices that can be used by individual irrigators on their respective irrigation operations. If applied in large numbers to large acreages, the results will be beneficial to those who use them; and in the aggregate they will be extremely beneficial to the region. However, data are not available with which to make estimates for the region.

5.1.9.5 Implementation Issues

Adoption and use of equipment to improve irrigation application efficiencies was begun in the late 1970s and has continued at a rapid pace to the present. As an example, in 1995, 12,931 center pivot systems were in place. This increased to 16,420 systems by 1998, an increase of about 8.3 percent per year since 1995. The TWDB inventory of irrigated acres in the Llano Estacado Region (averaged from 1985 to 1998) is 3,031,293 acres. In 1998, 2,297,406 acres were irrigated with center pivot systems, which is about 75 percent of the total irrigated acres.

Table 5-63.
List of Irrigation Practices and Unit Cost of Each
Llano Estacado Region

Irrigation Systems	*Cost Per Unit (dollars)*
Drip Irrigation	700 to 1,400/acre
LEPA Center Pivots	150 to 360/acre
Low Elevation Spray Applicator	150 to 300/acre
Surge Valves with Furrow Application	1,000 to 1,500/valve*
Pipelines with Furrow Application	1.00 to 5.00/foot
Lay Flat Tubing with Furrow Application	1.00 to 2.00/foot
Furrow with Open Ditch	Not Applicable
Furrow Diking	3.00 to 5.00/acre

* Can use on more than one field.

Source: High Plains Underground Water Conservation District

The principal issues pertaining to implementation of the water management practices included in this option are:

- Information about the costs and potential returns to individual irrigators,
- Expected profitability of irrigation farming in the immediate future, and
- Source of financing.

With public information programs and low interest loans through the underground water conservation districts, the water management practices included here can be fully implemented within less than 10 years.

This water supply option has been compared to the plan development criteria, as shown in Table 5-64.

Table 5-64.
Evaluation of Water Management Practices as a Water Management Strategy
Llano Estacado Region

Impact Category	Comment(s)
a. Quantity, reliability, and cost of treated water	• Quantity directly dependent upon degree of acceptance and implementation • Among the lowest cost strategies
b. Environmental factors	• None
c. State water resources	• No apparent negative impacts on other water resources; reduces quantities needed for given condition
d. Threats to agriculture and natural resources in region	• None; Enhances agriculture and natural resources
e. Recreational	• None
f. Comparison and consistency equities	• Win-win for all involved
g. Interbasin transfers	• Not applicable
h. Third party social and economics impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Very high
j. Effect on navigation	• None

5.1.10 Recovery of Capillary Water[58]

5.1.10.1 Description of Option

Capillary water is the water that is retained in the formation by capillary forces following gravity drainage. Capillary forces are the result of the molecular attraction between formation particles and water. The method of implementing this option is to inject air under pressure into the dewatered layers of the formation to release water held by capillary forces and allow it to drain to the water table and become available to wells. Three field tests have been conducted to determine if the injection of air under pressure will result in the release of water being held by capillary forces, allowing it to drain down by the forces of gravity to the current water table where it can be recovered by wells. All three of the field tests yielded positive results. Additional field tests are needed to determine how to design air injection wells that will provide the opportunity to release the maximum quantity of capillary water at the least cost per unit of water from the Ogallala Formation, which consists of multi-layers of different types of material (i.e., sand, gravel, silts, and clays).

Laboratory and field tests indicate that the injection of about 250 cubic feet per minute of air with a pressure head of 10 to 12 pounds per square inch will result in the release of significant quantities of capillary water. The centrifugal compressor that was used in the last test conducted would produce 376 cubic feet of air per minute at 18 pounds per square inch and required 18 brake horsepower operating at 3,000 revolutions per minute. The quantity of capillary water released on one of the field tests was estimated to be 13 gallons per cubic foot of air injected. If this rate of release can be maintained, then injecting 250 cubic feet per minute should result in the release of 3,250 gallons of water per minute. When the capillary water is released it will drain by the forces of gravity down to the water table. The time required for gravity drainage to occur may be several months. The rate of movement of the water will depend on the number and thickness of clay lenses in the formation. The following pages (Figures 5-5, 5-6, and 5-7) illustrate how to construct an air injection well. Additional field demonstrations and tests will likely result in refining the technology to make it more efficient and cost-effective.

[58] Contributed by Wyatt, A. Wayne, Manager, High Plains Underground Water Conservation District No. 1, Lubbock, Texas.

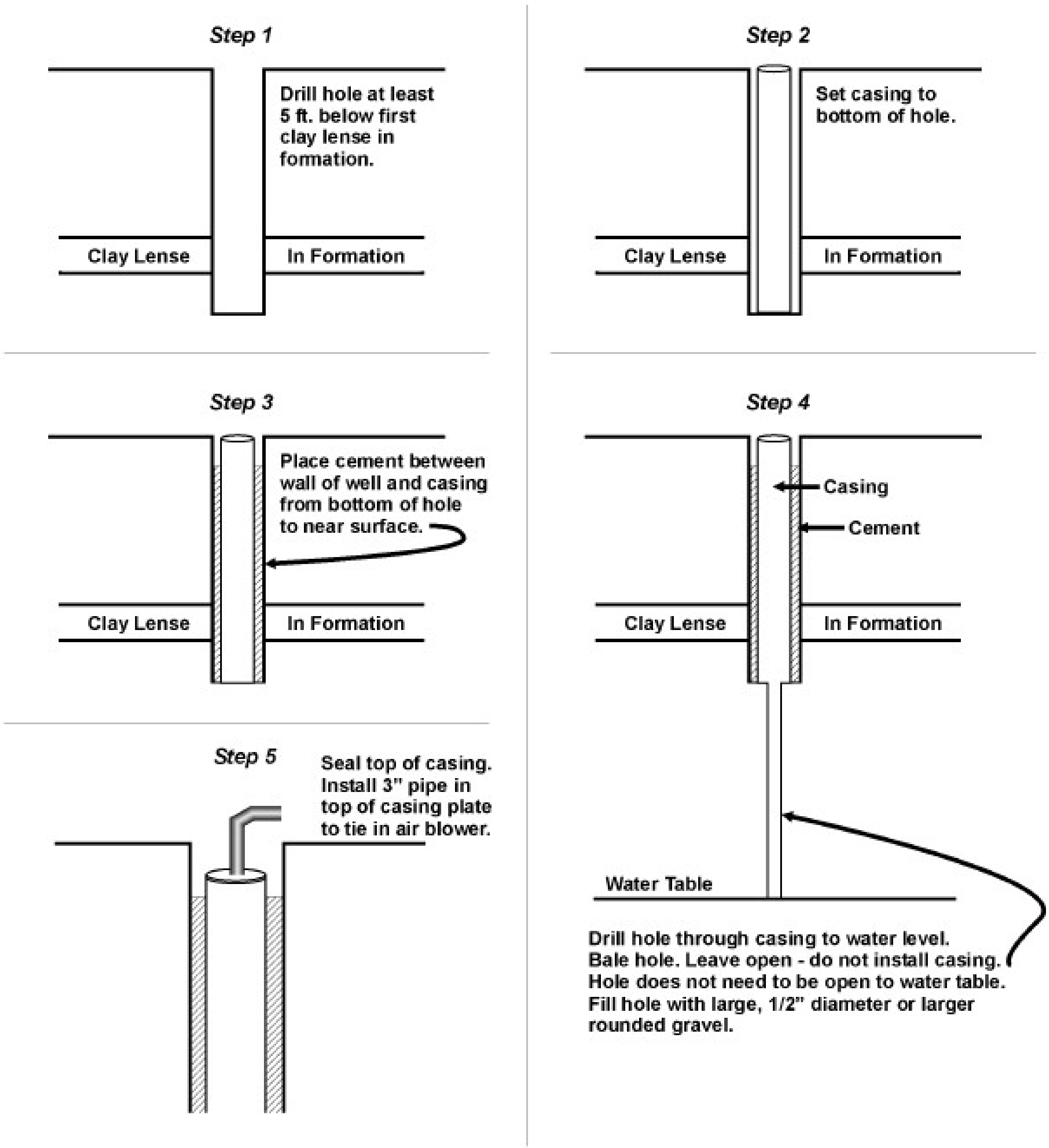

Figure 5-5. Air Injection Well for Capillary Water Recovery

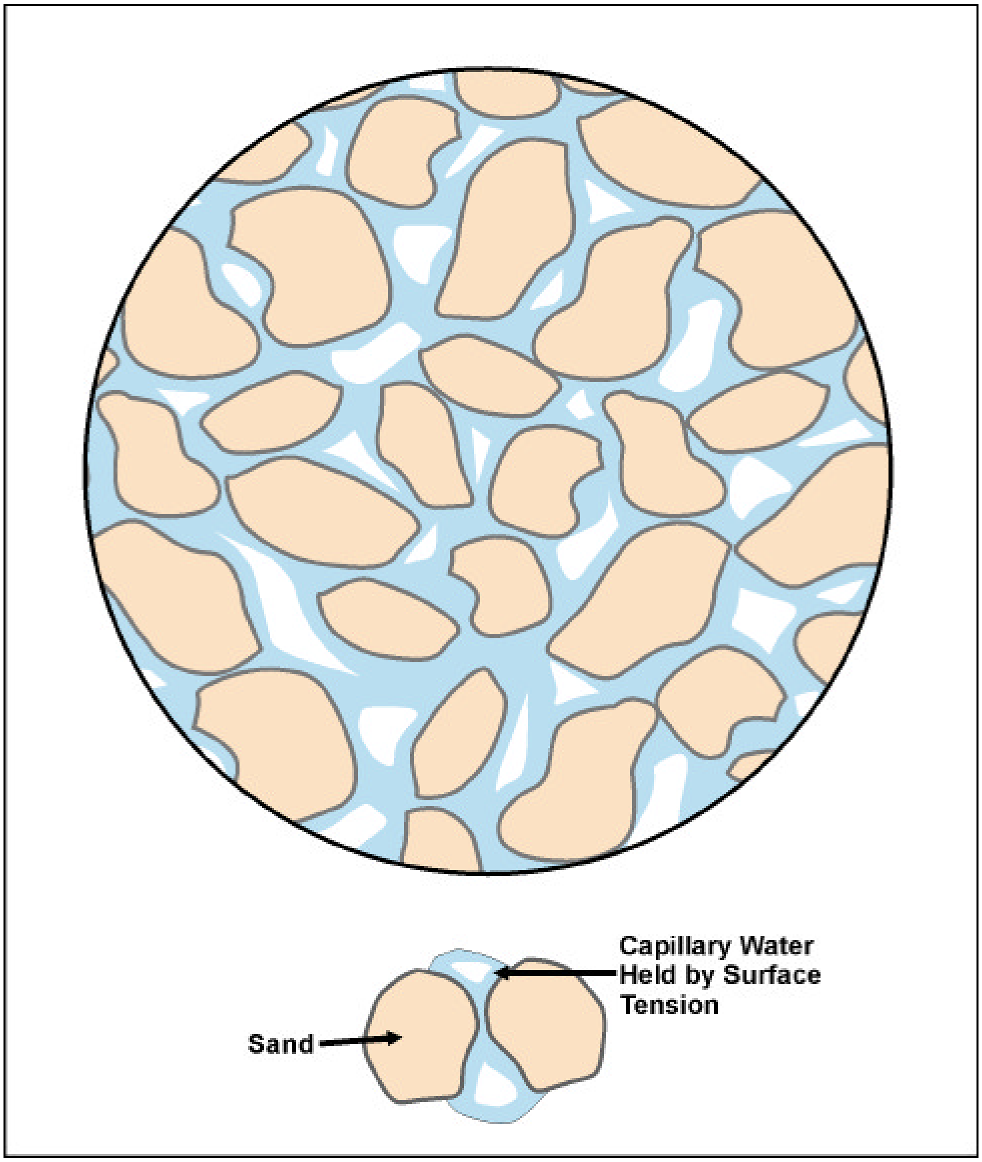

Figure 5-6. Conceptual Illustration of Capillary Water Held in Storage

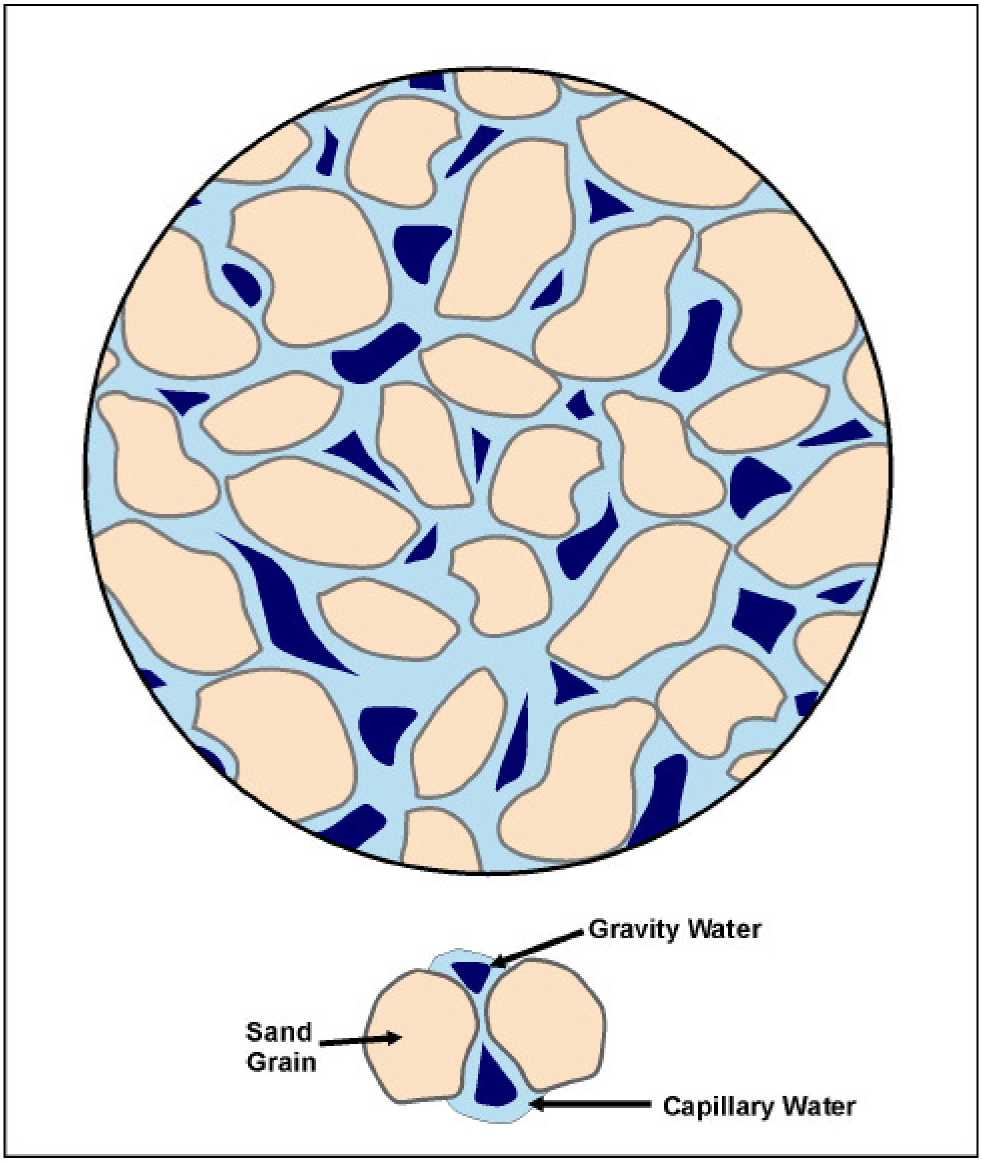

Figure 5-7. Conceptual Illustration of Water Held in Storage under Saturated Conditions

5.1.10.2 Estimated Volume of Capillary Water in Storage

Test hole drilling and core analyses indicate that the moisture content of the formation material from 10 feet below land surface to the water table ranged from 10 to 40 percent by volume with an average of 25 percent. Using the average value of 25 percent, the 1,443,876,691 acft of currently unsaturated material in the Ogallala Formation would contain approximately 360 million acft of capillary water. The amount of capillary water which may remain when the current saturated portion is drained (about 750 million acft of saturated material containing about 108 million acft of gravity water in 2000) would equal about 187 million acft of capillary water, for a total potential of 547 million acft of capillary water in the 21-county Llano Estacado Regional Water Planning Area.

The volume of unsaturated formation material from 10 feet below land surface to the level of the water table in 1980 was calculated by subtracting the difference in elevations from a regional U.S. Geological Survey land surface topographic map and a map constructed by the Texas Department of Water Resources (currently the Texas Water Development Board) illustrating the elevation of the 1980 water table. The values where the contour lines crossed were noted on the overlay map. These values were then contoured. The volume area in acres between the contour lines was calculated by using a planimeter. The feet of formation material between each contour were multiplied by the number of acres within each contour interval. The volume of material for all contour intervals was totaled, providing a value for each county. The volume in acft of unsaturated formation material calculated for each county in 1980 in the Llano Estacado Region is as follows:

Gaines	65,952,370	Motley	8,708,093
Dawson	37,234,308	Floyd	122,904,106
Garza	6,302,774	Hale	102,562,720
Lynn	24,090,306	Lamb	69,203,926
Terry	44,230,828	Bailey	41,098,009
Yoakum	41,042,305	Parmer	139,658,917
Cochran	68,785,316	Castro	109,137,254
Hockley	64,084,398	Swisher	81,232,198
Lubbock	65,936,069	Briscoe	33,963,077
Crosby	96,604,284	Deaf Smith	176,911,492
Dickens	18,584,241	**Total**	1,443,876,691

The net change in the volume of water in storage in the same 21-county area between 1985 and 1995 was calculated to be 2,565,583 acft. Using a specific gravity yield of 15 percent, 17,100,000 acft of saturated material would have yielded 2,656,000 acft of water. A further assumption was made that the volume of saturated formation material that was drained of gravity water between 1980 and 1985 should equal about 50 percent of the volume of drained material that was calculated for the period between 1985 and 1995, which added 8,550,000 acft to the estimate.

Therefore, the estimated volume of unsaturated formation material from 10 feet below the land surface to the 1995 water table is calculated as follows:

1,418,226,691	acft of unsaturated formation material in 1980
8,550,000	acft of dewatered formation material between 1980 and 1985
17,100,000	acft of dewatered formation material between 1985 and 1995
1,443,876,691	Total

5.1.10.3 Environmental Issues

This water management strategy will have to be implemented by individual landowners on their own properties. Since the only structural changes will be the drilling and completion of air injection wells on land that has already been subjected to crop production, water well drilling, and irrigation, there are not any known environmental issues.

5.1.10.4 Costing

The release of capillary water will cost approximately $50.00 per acft. An air compressor and electrical motor can be utilized on multiple locations reducing the per unit cost. Approximately one air injection well per 40 acres should yield the maximum release of capillary water (see Section 5.1.10.1 above for description of tests from which this estimate was obtained).

5.1.10.5 Implementation Issues

Implementation is a matter of choice by individual landowners. There are no known issues at this time.

5.1.11 Cistern Well Construction[59]

5.1.11.1 Description of Option

A cistern well is a well that can produce a small quantity of water for domestic and/or range livestock use in areas where the saturated thickness of the Ogallala Formation or alluvium are thin or the formation will not yield large enough quantities of water to support a pump and/or a windmill. A water well construction technique that can be used to install a cistern well is described below.

[59] Contributed by Wyatt, A. Wayne, Manager, High Plains Underground Water Conservation District, Lubbock, Texas.

5.1.11.2 Quantity of Water Available

The Ogallala Formation in the Llano Estacado Regional Water Planning area varies in thickness from a few inches to more than 500 feet. The saturated portion of the formation also varies in thickness from a few inches to more than 200 feet. In those areas where the saturated thickness of the formation is thin, it is sometimes difficult to complete a well that will yield enough water to support a rural residence and/or provide an adequate water supply for grazing livestock. The purpose of this discussion is to provide an example of a well construction technique that can be used to harvest enough water from a thin saturated section to support a rural residence and/or range livestock. In addition to areas that have thin layers of saturated material, often times the saturated formation material has a very low permeability rate. Permeability is a measure of the ease of fluid flow through formation material. Formation materials such as gravel, large grain-sized sand, or a mixture of the two generally have a high rate of permeability. Formation materials, such as fine sands, silts, and clays (or a mixture thereof) usually have a low rate of permeability. If the pore size of the saturated formation material is large, the water will flow fairly rapidly. If the pore size is small, the water will flow at a very slow rate. The forces of gravity are also a very important factor that contribute to the rate of flow of the water through the formation material. The gravitational factor which influences the rate that water will move into the well is the weight of the water in the formation above the low point of the water in the well when it is pumped or bailed. The weight of the water in the formation provides a pressure gradient to push the water through the formation material into the well when water from the well is pumped or bailed.

Conventional wells are drilled to the base of the formation, which in most instances are the red beds. The driller determines the depth in feet below the land surface that water is encountered (the water level). The driller will also record the type of formation materials, such as clay, sand, silt, and gravel, and particle size of the material encountered between the water table and the red beds. Based on experience, the driller can usually provide a fairly reliable estimate of the potential yield of the well. The estimate can be confirmed by bailing the well dry and recording the time it takes for the hole to fill up with water to the depth of the top of the water level (i.e., if a 10-inch diameter hole has been drilled, the driller knows it will hold approximately 4 gallons of water per foot). If it takes 40 minutes to fill five feet of hole with water, this will indicate the formation is yielding one-half gallon per minute (4 gallons times

5 feet equals 20 gallons divided by 40 minutes equals one-half gallon per minute). If the water in the well rises 5 feet in 20 minutes, this indicates the formation will yield one gallon per minute. In this example, the half-gallon per minute yield will be used, which should be a worst-case scenario.

If the driller is advised that the construction of a cistern well is desired, this puts a new perspective on the evaluation of the prospective well (Figure 5-8). The driller can confirm the earlier estimate of the well's potential yield by bailing the well. If an 8-inch bailing bucket is used, it will hold 2.61 gallons per foot. If the well has only 5 feet of water, the bailing bucket can only be filled with 5 feet of water on the first bailing trip, which will remove 13 gallons of water. Therefore it would require 26 minutes for the hole to refill to collect another 13 gallons of water. If it fills back to the 5-foot level in less than 26 minutes, this will indicate the formation will produce more than one-half gallon per minute. Bailing the well cleans the drilling mud/fluids from the formation, which generally will increase the yield of the water from the formation into the well. When the volume of water versus time stabilize then the well can be designed to fit the needs.

A cistern well is drilled through the water-bearing geologic section past the base of the aquifer, which is generally the red bed, to a pre-determined depth to create a holding reservoir for water. A casing is installed in the well with perforations located between the water level and the base of the aquifer. The casing extending into the red beds will serve as a reservoir or cistern to collect water that drains from the aquifer 24 hours per day. If the saturated portion of the formation will yield one-half gallon per minute, 720 gallons can be collected in a cistern well in a 24-hour period. Average daily water use in the urban communities in the Llano Estacado Regional Water Planning area is about 165 gallons per person. A 1,000-pound ranch cow needs about 10 gallons of water per day. A 400 to 500 gallon cistern well should provide an adequate water supply for a family of four for all inside the house uses, plus some limited outside use. Water will drain from the formation into the cistern well every minute of every day (1,440 minutes). Table 5-65 illustrates the quantities of water various sizes of casing will hold per foot of depth for one foot, 10 feet, and by multiples of 10 to 100 feet. As an example, one hundred feet of 10-inch casing will hold 408 gallons of water.

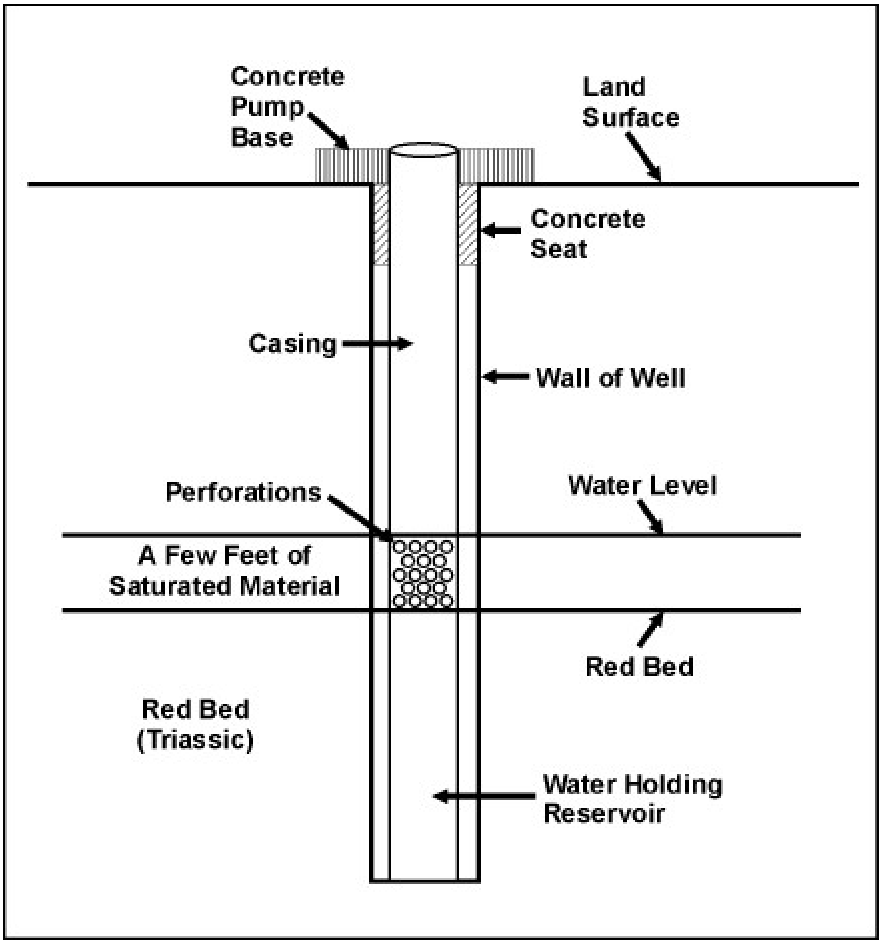

Figure 5-8. A Typical Cistern Well

Table 5-65.
Volumes of Water in Gallons for Specified Casing Diameters
Llano Estacado Region

Inside Diameter of Casing (Inches)	Volumes (gallons per linear foot)	Feet of Standing Water in Casing									
		10	20	30	40	50	60	70	80	90	100
3.0	0.037	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3	37.0
3.5	0.500	5.0	10.0	15.0	20.0	25.0	30.0	25.0	40.0	45.0	50.0
4.0	0.650	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5	65.0
4.5	0.740	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6	74.0
5.0	1.020	10.2	20.4	30.6	40.8	51.0	61.2	71.4	81.6	91.8	102.0
5.5	1.230	12.3	24.6	36.9	49.2	61.5	73.8	86.1	98.4	110.7	123.0
6.0	1.470	14.7	29.4	44.1	58.8	73.5	88.2	102.9	117.6	132.3	147.0
7.0	2.000	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0	200.0
8.0	2.610	26.1	52.2	78.3	104.4	130.5	156.6	182.7	208.8	234.9	261.0
10.0	4.080	40.8	81.6	122.4	163.2	204.0	244.8	285.6	326.4	367.2	408.0
12.0	5.880	58.8	117.6	176.4	235.2	294.0	352.8	411.6	470.4	529.2	588.0
14.0	8.000	80.0	160.0	240.0	320.0	400.0	480.0	560.0	640.0	720.0	800.0
16.0	10.000	100.0	200.0	300.0	400.0	500.0	600.0	700.0	800.0	900.0	1000.0
18.0	13.220	132.2	264.4	396.6	528.8	661.0	793.2	925.4	1057.6	1189.8	1322.0
20.0	16.320	163.2	326.4	489.6	652.8	816.0	979.2	1142.4	1305.6	1468.8	1632.0

If the yield test indicates that the saturated portion of the formation will yield an adequate quantity of water to supply the cistern well, then the well can be designed to specify the size of the hole, the number of feet and size of casing to install. The values provided in Table 5-65 should assist in making these decisions. Once these decisions have been made, the next step is to drill the hole to the desired depth. As an example, assume that the original well was drilled to a depth of 105 feet, the water level was encountered at 95 feet, and the red bed was reached at 100 feet below the surface. Should it be decided that 100 feet of 10-inch casing is needed to store 408 gallons of water, the driller will likely need to drill a 12-inch diameter hole to a total depth of 200 feet to satisfy this need. Ten inch inside diameter thick wall plastic casing can be used. The top of the hole will likely need to be reamed out to a 12-inch hole if a smaller hole was originally drilled. After it is reamed out and bailed clean, the driller will drill out the remaining 95 feet of hole using a 12-inch drill bit, assuming a rotary drill is used. The geological formation material (red beds) into which drilling is being done is a clay material. The clay will create a mudpack on the wall of the well as it is being drilled. This mudpack may block or restrict the movement of the water from the formation into the well. Prior to the casing being installed, four to six rows of perforations per foot need to be cut. The perforations should be at least one-eighth inch wide and at least a foot long in that portion of the casing that will be set in the hole where the formation is saturated. The perforations in the casing should be set one foot above the water level and extend one foot below the bottom of the saturated thickness of the formation (94 feet to 101 feet in this example well). Measuring from the bottom of the well, the first 99 feet of casing should be blank with no perforations. The next 7 feet should be perforated (from 94 feet to 101 feet), and from 94 feet to the surface should be blank. After the casing is set, a high-pressure water jet attached to the end of the drill stem should be used to wash the mud pack off and out of the saturated portion of the geologic section. The jet can be used to get the water through the perforations as the driller rotates the drill stem and moves it up and down in the area that the casing is perforated. Clean water should be used for jetting. A small amount of surfactant (soap) can also be added to reduce the size of the water molecules, which helps in the cleaning of the fine particles of mud from geologic formation. Once the water jetting process is completed the drilling mud and geologic material washed into the casing should be removed by bailing. The well should be bailed dry. To determine if the formation has been opened up and will yield the desired volume of water to the well, the water level in the well should be measured at timed intervals after the casing is bailed dry. If the well is producing one-half gallon per minute, the water level in the well should rise one foot every 8 minutes in the 10-inch casing used in the example. If the rate of rise in the water level were significantly less, additional time using the water jet would be in order. After the well is completed, the bottom of the pump should be set within 2 feet of the bottom of the well. A pressure tank should be used to regulate the water pressure in the house. If the pump is to be used to pump into a livestock holding tank, a time clock should be used and set so that the total amount of water pumped in a 24-hour period will not exceed the total holding capacity of the cistern well.

5.1.11.3 Environmental Issues

This water management strategy will have to be implemented by individual landowners on their own properties. Since the only structural changes will be the drilling and completion of wells, there are not any known environmental issues.

5.1.11.4 Costing

The cost of drilling and equipping a cistern well is estimated at about $20 per foot. For depths of 100 feet, the cost of a well is estimated at $2,000, and for a 450 foot well the cost would about $9,000.

5.1.11.5 Implementation Issues

Implementation is a matter of choice by individual landowners. There are no known implementation issues at this time.

5.1.12 Post Reservoir—Raw Water at the Reservoir

5.1.12.1 Description of Option

The proposed Post Reservoir Project is located on the North Fork of the Double Mountain Fork of the Brazos River northeast of Post, Texas in Garza County (Figure 5-9). Preliminary data pertinent to the project was obtained from the September 1968 report entitled "Feasibility Report on Post Reservoir Site."[60] The proposed project includes a 5,800-ft rolled embankment dam with a 2,000-ft emergency spillway for passing the probable maximum flood (PMF). The project also includes a morning glory type service spillway to pass storm flows up to the 100-year return period.

5.1.12.2 Available Supply of Water

The conservation pool would provide approximately 56,000 acft of storage (neglecting sedimentation) and 37,000 acft (including sedimentation) with a surface area of 2,280 acres. The 1968 reservoir analysis indicates that the proposed reservoir will have a firm yield of approximately 9,500 acft/yr in the year 2020 considering runoff, depletion, and sedimentation.

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[60] Freese, Nichols and Endress, 1968, "Feasibility Report on Post Reservoir Site," prepared for White River Municipal Water District, September. The 1968 cost estimate was $2.2 million.

5.1.12.3 Environmental Issues

The construction of Post Reservoir would result in the change of an estimated 3,320 acres of land from ranching to that of a reservoir site, inundating about 2,280 acres. It is estimated that the entire 3,320 acres would require wildlife habitat mitigation for which costs have been included in Section 5.1.12.4.

5.1.12.4 Costing

The following assumptions and conditions were applied in the updating of the costs of this water management strategy:

- Capital costs were updated from 1968 to the Second Quarter of 1999 using the Engineering News Record Construction Cost Index (CCI). The CCI ratio was increased by an additional 15 percent to account for more stringent requirements related to construction activities.
- Engineering, legal costs, and contingencies are calculated as 35 percent of the total capital costs associated with construction of the dam. Environmental studies, mitigation and permitting costs are calculated as 100 percent of the land acquisition cost.
- Land acquisition and survey costs were based on the inundated area during PMF. Land cost was assumed as $1,500/ac for the site.
- Interest during construction is calculated considering a 6 percent interest rate, with a 4 percent return on investments over a 4-year construction period.
- The annual cost for debt service is based on a 6 percent interest rate over a 40-year period.
- O&M costs are calculated as 1.5 percent of the estimated construction costs for the dam and reservoir.

Costs for this option include construction costs and other project costs, which include engineering costs, land acquisition for the reservoir and dam site, and interest during construction. The total project cost for this option was estimated to be $28,200,000 (Table 5-66). Financing the project for 40 years at 6 percent annual interest results in an annual expense of $1,874,000 for debt service (Table 5-66). Annual operating and maintenance costs total $158,000 (Table 5-66). The total annual cost, including debt service and O&M cost, totals $2,032,000 (Table 5-66). For an annual firm yield of 9,500 acft/yr, the resulting cost of raw water at the reservoir is $214 per acft, or $0.66 per 1,000 gallons (Table 5-66). This is the cost of raw water at the reservoir and does not include transmission pipeline, water treatment, or distribution system costs.

Table 5-66.
Cost Estimate Summary for Post Reservoir
Llano Estacado Region
Second Quarter 1999 Prices

Item	*Estimated Cost for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool of 56,000 acft, 2,280 acres, 2,430 ft msl)	
Preparation of Site	$180,000
Core Trench Excavation (74,300 cubic yards)	156,000
Wetted and Rolled Embankment (2,317,400 cubic yards)	4,997,000
Riprap (62,400 cubic yards)	2,243,000
Blanket (25,900 cubic yards)	931,000
Service Spillway and Outlet	1,498,000
Mulching (22 acres)	92,000
Irrigation for Downstream Slope	90,000
Relocation[1]	320,000
Total Capital Cost	**$10,507,000**
Engineering, Legal Costs and Contingencies (35% of Total Capital Cost)	$3,677,000
Environmental & Archaeology Studies, Mitigation, and Permitting	4,980,000
Land Acquisition and Surveying (3,320 acres)	5,146,000
Interest During Construction (4 years)	3,890,000
Total Project Cost	**$28,200,000**
Annual Costs	
Debt Service (6 percent for 40 years)	$1,874,000
Operation and Maintenance	158,000
Total Annual Cost	**$ 2,032,000**
Available Project Firm Yield (acft/yr)	**9,500**
Annual Cost of Raw Water at the Reservoir ($ per acft)	**$214**
Annual Cost of Raw Water at the Reservoir ($ per 1,000 gallons)	**$0.66**
[1] The bridge at FM 651 may need to be raised, widened, or relocated.	

5.1.12.5 Implementation Issues

The development of the Post Reservoir will require a local sponsor and customers willing to purchase water at prices adequate to retire the debt and pay operating costs, including water treatment and conveyance to locations of use. Implementation will require the following permits and studies.

1. Permits
   a. Texas Natural Resource Conservation Commission (TNRCC) Water Rights and Storage Permit.
   b. U. S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs and pipelines impacting wetlands or navigable waters of the U. S.
   c. Texas Parks and Wildlife Department (TPWD) Sand, Gravel, and Marl permit for construction in state owned streambeds.
   d. National Pollution Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan.
   e. General Land Office (GLO) easement for use of the state-owned streambed; and
   f. Section 404 certification from the Texas Natural Resource Conservation Commission (TNRCC) required by the clean water act.
2. Studies to Support Permit Application
   a. Assessment of changes in stream flows.
   b. Habitat mitigation plan.
   c. Environmental surveys.
   d. Cultural resources surveys, studies, and mitigation.
3. Land will have to be acquired either by negotiation or condemnation.

5.1.13 Research and Development of Drought Tolerant Crops and New Technology

This is a region-wide or regional water management strategy, since it is applicable to individual irrigation and dryland farmers and ranchers. The strategy is described but cannot be evaluated according to TWDB Rules, Section 357.7, because of lack of data.

5.1.13.1 Description of Option

Both public and private agricultural research organizations are presently engaged in plant crop breeding, plant nutrition, and cultural practices to improve the productivity, quality, and other characteristics of crops that can be produced in the Llano Estacado and other regions of Texas, the United States, and other countries of the world. The LERWPG recommends that funding be continued in adequate levels for research and development of new and improved technology in the fields of drought tolerant strains of crops, new or alternative crops for arid and semiarid regions, plant nutrition, irrigation application methods, brush control, weather modification, aquifer recharge, and development of better information about the aquifers and other water resources of the region.

5.1.13.2 Quantity of Water

Not possible to make evaluation.

5.1.13.3 Environmental Issues

Not possible to make evaluation.

5.1.13.4 Costing

Not possible to make evaluation.

5.1.13.5 Implementation

Not possible to make evaluation.

5.2 Long-term Water Management Strategies

5.2.1 Interconnect Cities and Industries (Sources of Water to Include Lake Alan Henry and Post Reservoir)

5.2.1.1 Description of Option

This option would include the construction of a pipeline from Lake Alan Henry, which has a firm yield of 29,900 acft/yr, to the City of Lubbock (Figure 5-10). A second pipeline would be constructed from the proposed Post Reservoir, which would have a firm yield of approximately 9,500 acft/yr, and tie into the pipeline from Lake Alan Henry to Lubbock (Figure 5-10). A new 36-MGD surface water treatment plant would need to be constructed to treat this new supply (Figure 5-10). For purposes of this evaluation, the water treatment is assumed to be located near the southeast corner of Lubbock. The treated water could be utilized by the City of Lubbock as an additional source, or the city could sell this water to its existing customers or new customers within the Lubbock general area. This pipeline could be interconnected with the Mackenzie Municipal Water Authority distribution line and/or the White River Municipal Water District distribution line, in which case the water treatment plant would need to be located at the lakes. However, for this option the pipeline is assumed to terminate at a new water treatment plant near Lubbock.

5.2.1.2 Quantity of Water Available

The quantity available for this option is the sum of the yields of Lake Alan Henry and the proposed Post Reservoir, which is 38,500 acft/yr (29,000 + 9,500).

5.2.1.3 Environmental Issues

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

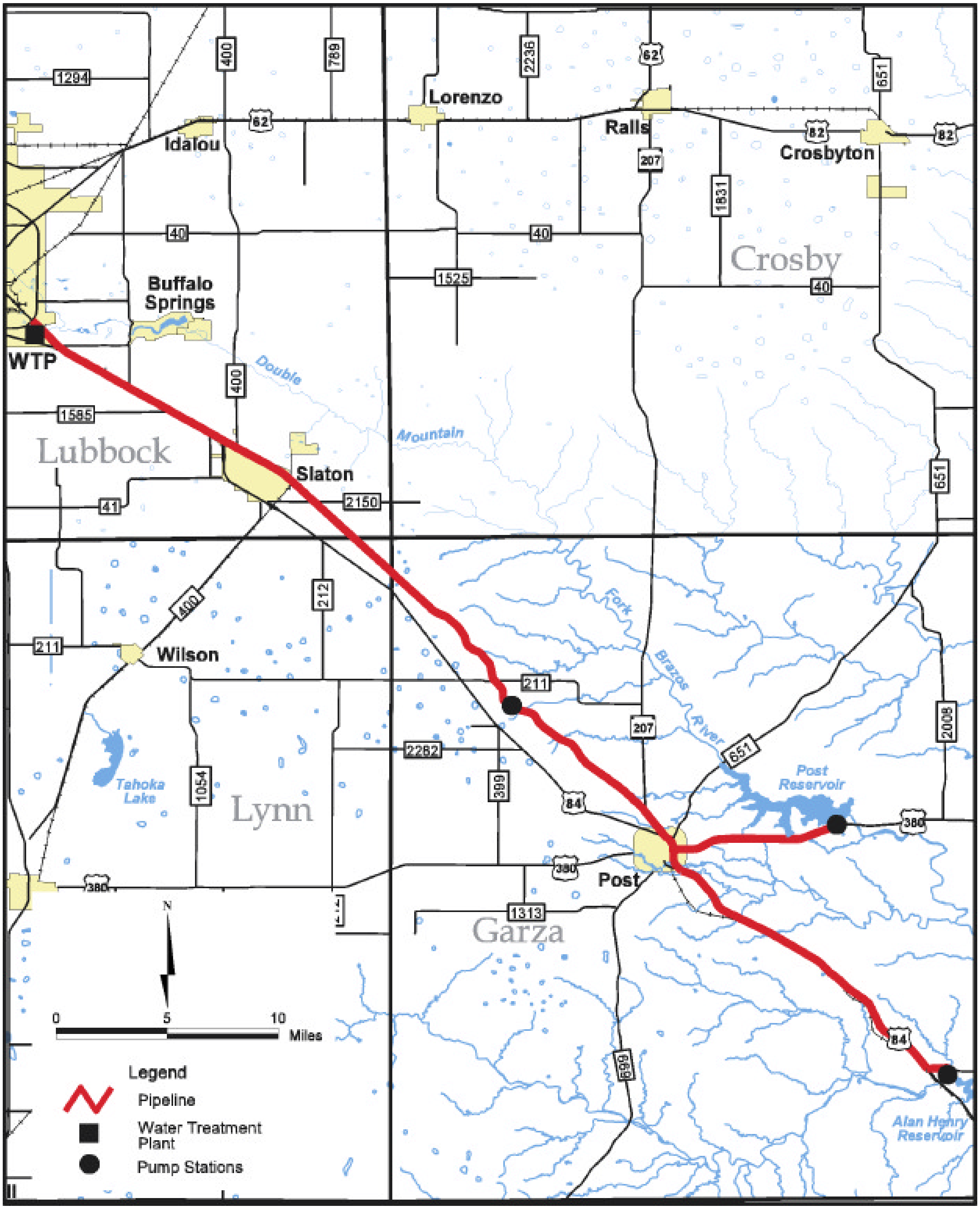

Figure 5-10. Lake Alan Henry/Post Reservoir Pipeline

5.2.1.4 Costing

Costs for this option include the raw water transmission pipeline, surface water treatment plant, and other project costs that include engineering costs, land acquisition, and interest during construction. The following assumptions and conditions were used in the costing of this option.

- The firm yield of Lake Alan Henry is 29,000 acft. The pipeline from Lake Alan Henry to near Post Reservoir is sized to transport the full firm yield amount.
- The firm yield of the proposed Post Reservoir is approximately 9,500 acft/yr. The pipeline from Post Reservoir to the Lake Alan Henry pipeline is sized to transport the full firm yield amount.
- The new surface water treatment plant has a capacity of 36 MGD (sized to treat the firm yield of both reservoirs).
- Cost of land for pipeline easements is $8,712 per acre. Cost of land for pump stations, storage tanks, and a water treatment plant is $1,500 per acre.
- The costs given are for treated water at the new water treatment plant and do not include costs associated with transporting the treated water from the water treatment plant to the end users.
- The costs for raw water from Lake Alan Henry are $148 per acft.
- The costs for raw water from Post Reservoir are $214 per acft.
- Engineering, legal costs, and contingencies are calculated as 30 percent of the construction costs for pipelines and 35 percent for all other facilities.
- Environmental and archeological studies, mitigation, and permitting costs are calculated as 100 percent of the land cost.
- Interest during construction is calculated with a 6 percent interest rate and a 4 percent annual rate of return for a period of 5 years.

The total project cost for this option was estimated at $117,248,000 (Table 5-67). Financing the project for 30 years at 6 percent annual interest results in an annual expense of $8,518,000 for debt service (Table 5-67). Annual O&M costs total $14,871,000 (Table 5-67). The total annual cost, including debt service, raw water cost, O&M cost, and power cost, totals $23,389,000 (Table 5-67). For an annual delivery of 39,400 acft/yr, the resulting cost of treated water at the water treatment plant is $594 per acft (Table 5-67). This is the cost of treated water at the water treatment plant and does not include costs associated with transporting the water from the water treatment plant.

Table 5-67.
Cost Estimate Summary for
Lake Alan Henry and Post Reservoir Regional Pipeline (39,400 acft/yr)
Llano Estacado Region

Item	Estimated Cost for Facilities (2nd quarter 1999)
Capital Costs	
Pump Stations (4)	$13,450,000
Pump Station Power Connection Cost	1,621,000
Intake Stations (2)	2,282,000
Transmission Pipeline (48 in dia, 47.5 miles)	19,076,000
Transmission Pipeline (42 in dia, 41.0 miles)	15,922,000
Transmission Pipeline (20 in dia, 33.0 miles)	1,830,000
Water Treatment Plant (36 MGD)	15,146,000
Water Storage Tanks (4)	3,249,000
Road Crossings	13,000
Total Capital Cost	**$72,589,000**
Engineering, Legal Costs and Contingencies	$23,565,000
Environmental Studies and Permitting	2,344,000
Land Acquisition and Surveying (284 acres)	2,578,000
Interest During Construction (4 years)	16,172,000
Total Project Cost	**$117,248,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$8,518,000
Pipeline and Storage Tank Operation and Maintenance	401,000
Pump Station Operation and Maintenance	336,000
Water Treatment Plant Operation and Maintenance	2,590,000
Purchase of Water (39,400 acft/yr)[1]	6,458,000
Pumping Energy Costs (84,761,700 kW-hr @ $0.06/kW-hr)	5,086,000
Total Annual Cost[1]	**$23,389,000**
Available Project Yield (acft/yr)	**39,400**
Annual Cost of Water ($ per acft)[2]	**$594**
Annual Cost of Water ($ per 1,000 gallons)[2]	**$1.82**

[1] Cost of raw water at Lake Alan Henry is $148 per acft, and at Post Reservoir is $214 per acft.
[2] Reported Annual Cost of Water is for treated water at the water treatment plant and does not include costs associated with distribution within municipal systems.

5.2.1.5 Implementation Issues

Implementation of this option will require the development of a regional water supply system, including customers and terms and conditions between customers and the regional supplier. The regional supplier will need to arrange financing, secure the water from the owners of the reservoirs, obtain rights-of-way and sites for facilities, secure state and federal permits for stream crossings, perform environmental and cultural resources studies, and provide mitigation for any environmental and cultural resources that might be affected.

5.2.2 Import Water[61]

5.2.2.1 Description of Option

This option would divert water from as many as six sources located in Arkansas and Texas and transport this water via an open canal to a terminal storage facility located on the White River in Blanco Canyon about five miles south of U.S. Highway 82 near Crosbyton, Texas.[62] The proposed pipeline alignment is shown in Figure 5-11. Four of the potential water supply sources are located in Arkansas (White River at Clarendon, Arkansas River at Pine Bluff, Ouachita River at Camden, and the Red River at Fulton) and two potential water supply sources are located in Texas (Sabine River at Tatum and the Sulphur River at Darden). This water would primarily be used as a new source of irrigation supply for parts of Texas, New Mexico, and Oklahoma. The amount of water needed by each state to restore and maintain lands that would go out of irrigated production between 1977 and 2020 due to a declining water level in the Ogallala Aquifer was used as a target delivery rate for this option. The states of Texas, New Mexico, and Oklahoma have a combined quantity of 1.16 million acft/yr needed to restore and maintain those irrigation lands which would go out of production by 2020.

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[61] This report section is a summary of information contained in the "Six-State High Plains-Ogallala Aquifer Regional Resources Study – A Report to the U.S. Department of Commerce and the High Plains Study Council" conducted by Camp Dresser & McKee, Inc., Black & Veatch, and Arthur D. Little, Inc., March 1982.

[62] Mr. Fred Kuntz, of Dimmitt, Texas has identified an import strategy that would move water from Toledo Bend Reservoir of the Sabine River Basin to the Llano Estacado Region. However, this strategy has not been analyzed due to lack of technical data needed to make cost, environmental, and implementation analyses.

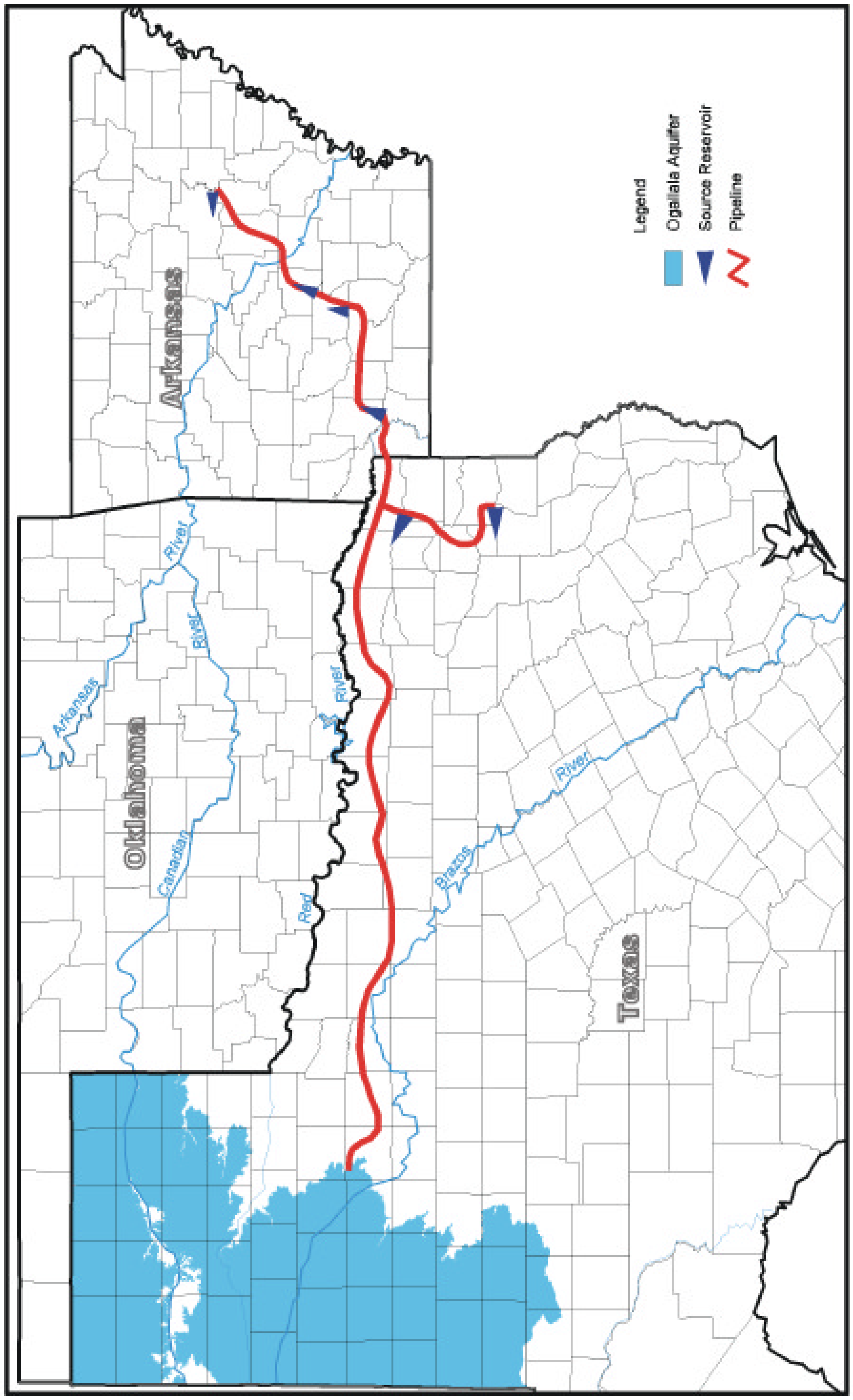

Figure 5-11. Pipeline Alignment for Water Import Option

5.2.2.2 Quantity of Water Considered

The maximum delivery rate scenario would divert 10.91 million acft/yr from the six potential sources in order to deliver approximately 8.7 million acft/yr to lands in the High Plains. This quantity exceeds the amounts identified as necessary to restore and maintain irrigated land in all six of the High Plains States (Texas, New Mexico, Oklahoma, Colorado, Kansas, and Nebraska). However, because the minimum delivery rate is adequate to supply the projected irrigation needs of the Llano Estacado Region, only the minimum delivery rate scenario will be described in this option.

The minimum delivery rate of this option is 1.55 million acft/yr utilizing only the Red and Sulphur Rivers as diversion locations. It is important to note that approximately 2 million acft/yr would have to be diverted from these sources because of losses in transfer. The minimum quantity is more than sufficient to supply the water necessary to restore and maintain irrigated lands going out of production by 2020 in New Mexico, Oklahoma, and Texas. The minimum delivery rate option would divert 1.3 million acft/yr from the Red River only at times when the base flow exceeds 5,000 cfs. The water would then be transported by a canal to near the Bodcau Reservoir site where it would be pumped into the reservoir for continuous release to the main canal at a rate of 1,800 cfs. The canal would carry the water westward where it would cross the Red River by siphon. From the Red River, the canal would continue along the divide between the Red and Sulphur Rivers to about four miles west of DeKalb, Texas where it would be enlarged to accommodate the flows diverted from the Sulphur River. Water would be withdrawn from the Sulphur River at the Marvin Nichols site when flows exceed 1,000 cfs. A total of 0.66 million acft/yr would be pumped from the site at a rate of 910 cfs to a canal that would transport the water northward to near DeKalb. The combined channel with a capacity of 3,200 cfs would be constructed along the south divide of the Red River and would carry the water westward and to the terminal storage area in Crosby County. The minimum delivery rate scenario would require 21 pump stations and 565 miles of open channel.

5.2.2.3 Environmental Issues

This would be a very large construction effort, including reservoirs on navigable streams of the U.S., pipelines and siphons to cross navigable streams, canals, pumping plants, and terminal storage reservoirs. The environmental assessment of these potential facilities is voluminous and cannot be included here.[63]

5.2.2.4 Costing

The unit cost of water delivered using the minimum delivery rate scenario is approximately $865 per acft. This is the cost of water delivered to the terminal storage facility near Crosbyton and does not include the distribution cost of transporting the water from this facility to farms or other users.

5.2.2.5 Implementation Issues

Implementation of this option would require an extensive effort, including federal and state legislation. The implementation effort is too lengthy and involved to be described here.[64]

5.2.3 Reuse of Municipal Effluent for Potable Water Supply

This is a water management strategy for the municipal water user group. The strategy is described, but cannot be evaluated according to TWDB Rules, Section 357.7, because of lack of data.

5.2.3.1 Description of Option

Of the total quantities of water used for municipal purposes, approximately 45 percent to 65 percent are returned to the respective municipal wastewater treatment plants for treatment and disposal. In the Llano Estacado Water Planning Region a large percentage of this treated effluent, or reclaimed water, is used for irrigation of open spaces, golf courses, and neighboring farmland. However, the quantity is between 45 and 65 percent of the quantity of municipal use and can be a significant source of municipal supply in the future if treatment levels can be increased to the extent that the use of such water does not pose a health risk. As a source of

[63] Six-State High Plains Ogallala Regional Resources Study, Water Transfer Element, Appendices A through D, Southwestern Division, U.S. Army Corps of Engineers, Dallas, Texas, September 1982.

municipal supply, reclaimed water is already at or very near the point of use and would not have to be transported to the city, as other sources would have to be. In addition, this water exists, whereas equivalent quantities may not be readily available, if available at all.

5.2.3.2 Quantity of Water

Not possible to make evaluation.

5.2.3.3 Environmental Issues

Must be studied and treatment technology improved enough to be acceptable by the public and regulatory agencies.

5.2.3.4 Costing

Not possible to make evaluation.

5.2.3.5 Implementation

Requires further research.

5.2.4 Stormwater Capture, Treatment, and Use

This is a water management strategy for the municipal water user group. The strategy is described, but cannot be evaluated according to TWDB Rules, Section 357.7, because of lack of data.

5.2.4.1 Description of Option

In some cities of the Llano Estacado Water Planning Region disposal of stormwater has become a serious problem. Lubbock is one of the cities having this problem. Therefore, in this water-short region, it has become desirable to evaluate the possibility to capture, treat, and use this water as a source of supply for non-potable as well as potable uses. Although it is expected that water treatment technology, such as membranes, can handle the treatment requirements, evaluations are needed of ways to successfully integrate flood protection, storage of this stormwater, and treatment of this water for useful purposes.

[64] Six-state High Plains—Ogallala Aquifer Regional Resources Study; Water Transfer Element, Appendices A-D; Southwestern Division, U.S. Army Corps of Engineers, Dallas, Texas, September 1992.

5.2.4.2 Quantity of Water

Not possible to make evaluation.

5.2.4.3 Environmental Issues

Must be studied and treatment technology demonstrated to be acceptable by the public and regulatory agencies.

5.2.4.4 Costing

Not possible to make evaluation.

5.2.4.5 Implementation

Requires further research.

5.3 Llano Estacado Regional Water Plan

In Section 1, the Llano Estacado Region was described. In Section 2 projections of population and water demand were presented. In Section 3, existing water supplies were tabulated. In Section 4, the projected water demands of Section 2 were compared with the existing water supplies of Section 3 and shortages or needs for additional supplies were calculated. In Sections 5.1 and 5.2, water management strategies were identified, described, and evaluated. The information from Sections 1, 2, 3, 4, and 5 mentioned above is used in the development of the following water plan for the region.

In subsections 5.1 and 5.2, short-term and long-term water management strategies for the Llano Estacado Region were presented. Water management strategies included in the plan to meet the needs of specific water user groups include local groundwater development for municipalities and irrigation water conservation for irrigators, while strategies that are not specific to a particular water user group, but instead are region-wide strategies include weather modification and brush management.

The proposed plan to meet the specific short-term needs of cities located within the region is to develop additional groundwater supplies located as near as possible to each respective city. Each city with a projected need will need to gradually expand or replace their existing wells or well fields with new wells. If the new wells or well fields are located on private property, the city will need to purchase that property or purchase water rights.

The proposed plan includes the irrigation water conservation strategy to meet as much as possible of the projected irrigation needs of the region. Individual irrigators who have not already installed efficient irrigation systems will need to do so as soon as possible to conserve their current water supplies.

Non-specific strategies would contribute to increasing the region's water supplies on a widespread scale for all water user groups, as opposed to being specifically applicable to an individual user group. These include weather modification and brush control. Both weather modification and brush control have been and should continue to be carried out by underground water conservation districts or soil and water conservation districts.

The water management strategies are intended to assist in meeting the water needs of the region during all types of weather, but are especially directed at meeting needs during drought.

In addition, these strategies were selected to contribute to sustainability of present supplies of groundwater. The detailed plans for each of the 21 counties of the Llano Estacado Planning Region are presented in alphabetic order below. In each county plan, each water user group of the county is listed, and if the user group has a need (shortage) during the planning horizon, a water management strategy to meet the need is included, except in the case of irrigated agriculture, for which it has been determined that it is not economically feasible to meet all of the projected needs at this time. The strategies selected are those that are estimated to be the lowest cost by virtue of the fact that they are the strategies located nearest to the location of need.

The LERWPG hereby recognizes the individual cities "Demand Management and Drought Contingency Plans" required to be on file with the TNRCC. The surface water supplies of this plan are included only at the firm yield quantities and the groundwater supplies are included at the quantities believed to be available through existing facilities and aquifer capabilities. Therefore, the LERWPG depends upon water users to follow their respective drought management plans and to implement any additional water conservation needed during droughts that may affect existing and planned water management strategies.

5.3.1 Bailey County Water Supply Plan

Table 5-68 lists each water user group in Bailey County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

5.3.1.1 Irrigation

5.3.1.1.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 164,991 acft/yr in 2000 declining to 151,648 acft/yr in 2050.

Table 5-68.
Bailey County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Muleshoe	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-4,014	-925	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-1, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.1.1.2 Options Considered

Table 5-69 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-69.
Water Management Strategies Considered for Irrigation—Bailey County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	1,319	$35,888	$27.21[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.1.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet a portion of the projected irrigation shortages through 2050 in Bailey County. However, the Llano Estacado Regional Water Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of the county nor the region at this time (Section 5.1.8.5).

- Irrigation water conservation by individual farmers to supply an additional 1,319 acft/yr in 2000, declining to 779 acft/yr in 2050.

5.3.1.1.4 Costs

Costs of the recommended plan for irrigation to meet a part of the 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $696,582
   - Annual Cost: $35,888; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-70).

Table 5-70.
Recommended Plan Costs by Decade for Irrigation—Bailey County

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Irrigation Water Conservation						
Projected Shortage (acft/yr)	-7,278	-6,463	-5,350	-4,014	-2,431	-925
Quantity Available (acft/yr)	1,319	1,187	1,068	962	865	779
Annual Cost ($/yr)	$35,888	$35,888	$35,888	$35,888$	$35,888	$35,888
Unit Cost ($/acft)	$27.21	$30.23	$33.60	$37.31	$41.49	$46.07

5.3.2 Briscoe County Water Supply Plan

Table 5-71 lists each water user group in Briscoe County and their corresponding surplus or shortage in years 2030 and 2050. There are no projected shortages for any water user groups in this county; and consequently, no recommended water management plans are needed for Briscoe County.

Table 5-71.
Briscoe County Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Quitaque	0	0	No projected surplus/shortage
City of Silverton[2]	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected demand
Mining	0	0	No projected demand
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-2, Section 4.1 – Water Needs Projections by Water User Group.
[2] The City of Silverton is projected to obtain 85 acft/yr from MMWA with the remainder of the City's demand being met from its own groundwater supplies.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.3 Castro County Water Supply Plan

Table 5-72 lists each water user group in Castro County and their corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

5.3.3.1 The City of Dimmitt

5.3.3.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2024, at which time additional supplies will be needed

5.3.3.1.2 Options Considered

Table 5-73 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Dimmitt.

Table 5-72.
Castro County Surplus/Shortage

Water User Group	*Surplus/Shortage[1]* 2030 (acft/yr)	*Surplus/Shortage[1]* 2050 (acft/yr)	*Comment*
City of Dimmitt	-1,250	-1,270	Projected shortage – see plan below
City of Hart	0	-310	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected demand
Irrigation	-36,342	-33,527	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-3, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

Table 5-73.
Water Management Strategies Considered for the City of Dimmitt

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	1,319	$114,912[4]	$87[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	1,270	$864,870	$681[5]
Municipal Water Conservation (Sec. 5.1.7)	129		$23

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-8 and 5-74 for annual and unit costs for each decade.
[5] Source of Cost Estimate: Section 5.1.2.

5.3.3.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Dimmitt through 2050.

- Local groundwater development beginning in 2017 needed to supply an additional 1,319 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately 11 miles from the City of Dimmitt into which the city could locate new municipal water supply wells.

5.3.3.1.4 Costs

Costs of the recommended plan for the City of Dimmit to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-8
   - Date to be Implemented: 2017
   - Total Project Cost: $3,306,336
   - Annual Cost: See Table 5-74 for a cost summary of this option.

Table 5-74.
Recommended Plan Costs by Decade for the City of Dimmitt

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-1,250	-1,253	-1,270
Quantity Available (acft/yr)	0	0	883	1,627	1,465	1,319
Annual Cost ($/yr)	-	-	$253,903	$325,945	$325,945	$114,912
Unit Cost ($/acft)	-	-	$288	$200	$222	$87

5.3.3.2 City of Hart

5.3.3.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2038, at which time additional supplies will be needed

5.3.3.2.2 Options Considered

Table 5-75 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Hart.

Table 5-75.
Water Management Strategies Considered for the City of Hart

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	366	$55,589[4]	$152[4]

[1] The project's estimated yield in 2050.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-13 and 5-76 for annual and unit costs for each decade.

5.3.3.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Hart through 2050:

- Local groundwater development beginning in 2033 needed to supply an additional 366 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Hart into which the city could locate new municipal water supply wells.

5.3.3.2.4 Costs

Costs of the recommended plan for the City of Hart to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-13
   - Date to be Implemented: 2033
   - Total Project Cost: $458,936
   - Annual Cost: See Table 5-76 for a cost summary of this option.

Table 5-76.
Recommended Plan Costs by Decade for the City of Hart

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	0	-302	-310
Quantity Available (acft/yr)	0	0	0	0	407	366
Annual Cost ($/yr)	-	-	-	-	$55,589	$55,589
Unit Cost ($/acft)	-	-	-	-	$137	$152

5.3.3.3 Irrigation

5.3.3.3.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water.
- **Current Supply:** 267,334 acft/yr in 2000, declining to 218,631 acft/yr in 2050.

5.3.3.3.2 Options Considered

Table 5-77 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-77.
Water Management Strategies Considered for Irrigation—Castro County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	47,358	$1,054,535	$22.27[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.3.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 for irrigation in Castro County. However, the Llano Estacado Regional Water Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of Castro County nor the region at this time (Section 5.1.8.5).

- Irrigation water conservation by individual farmers to supply an additional 47,358 acft/yr in 2000, declining to 27,964 acft/yr in 2050.

5.3.3.3.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $20,468,466
   - Annual Cost: Annual Cost: $1,054,535; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-78).

Table 5-78.
Recommended Plan Costs by Decade for Irrigation—Castro County

Plan Element	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
Irrigation Water Conservation						
Projected Shortage (acft/yr)	-39,262	-39,143	-38,621	-36,343	-34,894	-33,528
Quantity Available (acft/yr)	47,358	42,622	38,360	34,524	31,072	27,964
Annual Cost ($/yr)	$1,054,053	$1,054,053	$1,054,053	$1,054,053	$1,054,053	$1,054,053
Unit Cost ($/acft)	$22.27	$24.74	$27.49	$30.54	$33.94	$37.71

5.3.4 Cochran County Water Supply Plan

Table 5-79 lists each water user group in Cochran County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-79.
Cochran County Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Morton	-670	-653	Projected shortage – see plan below
City of Whiteface	-80	-74	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-9,118	-7,129	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-4, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.4.1 The City of Morton

5.3.4.1.1 Description of Supply

- **Source:** Ogallala Aquifer.
- **Current Supply:** Adequate to meet demands until approximately 2014, at which time additional supplies will be needed.

5.3.4.1.2 Options Considered

Table 5-80 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Morton.

Table 5-80.
Water Management Strategies Considered for the City of Morton

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	732	$53,013[4]	$72[4]
Municipal Water Conservation (Sec. 5.1.7)	65		$25

1 The project's estimated yield in 2050.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-18 and 5-81 for annual and unit costs for each decade.

5.3.4.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Morton through 2050:

- Local groundwater development beginning in 2007 needed to supply an additional 732 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Morton into which the city could locate new municipal water supply wells.

5.3.4.1.4 Costs

Costs of the recommended plan for the City of Morton to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-18
   - Date to be Implemented: 2007
   - Total Project Cost: $1,027,840
   - Annual Cost: See Table 5-81 for a cost summary of this option

Table 5-81.
Recommended Plan Costs by Decade for the City of Morton

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-673	-670	-663	-653
Quantity Available (acft/yr)	0	437	1,003	903	813	732
Annual Cost ($/yr)	-	$70,199	$127,685	$127,685	$78,921	$53,013
Unit Cost ($/acft)	-	$161	$127	$141	$97	$72

5.3.4.2 City of Whiteface

5.3.4.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2028, at which time additional supplies will be needed.

5.3.4.2.2 Options Considered

Table 5-82 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Whiteface.

Table 5-82.
Water Management Strategies Considered for the City of Whiteface

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	329	$55,589[4]	$169[4]
Municipal Water Conservation (Sec. 5.1.7)	7		$38

[1] The project's estimated yield in 2050.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-26 and 5-83 for annual and unit costs for each decade.

5.3.4.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Whiteface through 2050:

- Local groundwater development beginning in 2023 needed to supply an additional 329 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Whiteface into which the city could locate new municipal water supply wells.

5.3.4.2.4 Costs

Costs of the recommended plan for the City of Whiteface to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-26
   - Date to be Implemented: 2023
   - Total Project Cost: $485,936
   - Annual Cost: See Table 5-83 for a cost summary of this option.

Table 5-83.
Recommended Plan Costs by Decade for the City of Whiteface

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-80	-75	-74
Quantity Available (acft/yr)	0	0	0	407	366	329
Annual Cost ($/yr)	-	-	-	$55,589	$55,589	$55,589
Unit Cost ($/acft)	-	-	-	$137	$152	$169

5.3.4.3 Irrigation

5.3.4.3.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 37,788 acft/yr in 2000, declining to 34,734 acft/yr in 2050.

5.3.4.3.2 Options Considered

Table 5-84 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-84.
Water Management Strategies Considered for Irrigation—Cochran County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Irrigation Water Conservation (Sec. 5.1.8)	0	-	-[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.4.3.3 Water Supply Plan

Considering the option analyses for irrigation water conservation, there does not appear to be any additional water available for irrigation from this source However, the Llano Estacado Regional Water Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of Cochran County nor the region at this time (Section 5.1.8.5).

5.3.5 Crosby County Water Supply Plan

Table 5-85 lists each water user group in Crosby County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-85.
Crosby County Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Crosbyton	83	95	Projected surplus
City of Lorenzo	0	0	No projected surplus/shortage
City of Ralls	91	109	Projected surplus
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-179	0	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-5, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.5.1 Irrigation

5.3.5.1.1 Description of Supply

- **Source:** Ogallala Aquifer, Seymour Aquifer and Reclaimed Water
- **Current Supply:** 87,984 acft/yr in 2000 declining to 71,779 acft/yr in 2050.

5.3.5.1.2 Options Considered

Table 5-86 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-86.
Water Management Strategies Considered for Irrigation—Crosby County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	27,400	$1,260,584	$46.01[4]

1 The project's estimated yield in 2000.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
3 Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
4 Source of Cost Estimate: Section 5.1.8.

5.3.5.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected irrigation shortages through 2050:

- Irrigation water conservation by individual farmers to supply an additional 27,400 acft/yr in 2000, declining to 16,179 acft/yr in 2050.

5.3.5.1.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $24,467,850
   - Annual Cost: $1,260,584; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-87).

Table 5-87.
Recommended Plan Costs by Decade for Irrigation—Crosby County

Plan Element	2000	2010	2020	2030	2040	2050
Irr. Water Conservation						
Projected Shortage (acft/yr)	-179	-107	-48	0	0	0
Quantity Available (acft/yr)	27,400	24,660	22,194	19,975	17,977	16,179
Annual Cost ($/yr)	1,260,584	1,260,584	1,260,584	1,260,584	1,260,584	1,260,584
Unit Cost ($/acft)	$46.01	$51.12	$56.80	$63.11	$70.12	$77.91

5.3.6 Dawson County Water Supply Plan

Table 5-88 lists each water user group in Dawson County and its corresponding surplus or shortage in years 2030 and 2050. There are no projected shortages for any of the water user groups in this county; and consequently, no recommended water management plans are needed for Dawson County.

Table 5-88.
Dawson County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Lamesa	215	239	Projected surplus
City of O'Donnell (part)	28	23	Projected surplus
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-6, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.7 Deaf Smith County Water Supply Plan

Table 5-89 lists each water user group in Deaf Smith County and their corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-89.
Deaf Smith County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Hereford	-2,516	-2,717	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected demand
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-7, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.7.1 The City of Hereford

5.3.7.1.1 Description of Supply

- **Source:** Ogallala Aquifer and Dockum (Santa Rosa) Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2017, after which time additional supplies will be needed.

5.3.7.1.2 Options Considered

Table 5-90 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Hereford.

Table 5-90.
Water Management Strategies Considered for the City of Hereford

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	2,753	$670,253[4]	$243[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	5,433	$3,699,873	$681[5]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-14 and 5-91 forannual and unit costs for each decade.
[5] Source of Cost Estimate: Section 5.1.2.

5.3.7.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Hereford:

- Local groundwater development beginning in 2013 needed to supply an additional 2,753 acft/yr in 2050. There appears to be adequate saturated thickness of the Dockum/Santa Rosa Formation near the City of Hereford's existing wells into which the city could locate new municipal water supply wells.

5.3.7.1.4 Costs

Costs of the recommended plan for the City of Hereford to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-14
   - Date to be Implemented: 2013
   - Total Project Cost: $3,302,816
   - Annual Cost: See Table 5-91 for a cost summary of this option.

Table 5-91.
Recommended Plan Costs by Decade for the City of Hereford

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-2,516	-2,596	-2,717
Quantity Available (acft/yr)	0	0	1,450	2,817	3,059	2,753
Annual Cost ($/yr)	-	-	$348,977	$679,809	$785,446	$670,253
Unit Cost ($/acft)	-	-	$241	$241	$257	$243

5.3.8 Dickens County Water Supply Plan

Table 5-92 lists each water user group in Dickens County and its corresponding surplus or shortage in years 2030 and 2050. There are no projected shortages for any of the water user groups in this county; and consequently, no recommended water management plans are needed for Dickens County.

Table 5-92.
Dickens County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Dickens	0	0	No projected surplus/shortage
City of Spur	154	162	Projected surplus
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-8, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.9 Floyd County Water Supply Plan

Table 5-93 lists each water user group in Floyd County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-93.
Floyd County Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Floydada[2]	0	0	No projected surplus/shortage
City of Lockney[3]	-190	-140	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-23,665	-23,059	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-9, Section 4.1 – Water Needs Projections by Water User Group.
[2] The City of Floydada is projected to obtain 212 acft/yr from MMWA with the remainder of the City's demand being met from its own groundwater supplies.
[3] The City of Lockney is projected to obtain 150 acft/yr from MMWA with the remainder of the City's demand being met from its own groundwater supplies until approximately 2015 at which time the City will need to develop additional groundwater supplies to meet its projected demands.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.9.1 The City of Lockney

5.3.9.1.1 Description of Supply

- **Source:** Ogallala Aquifer and Mackenzie Municipal Water District (Lake Mackenzie)
- **Current Supply:** Adequate to meet demands until approximately 2020, at which time additional supplies will be needed.

5.3.9.1.2 Options Considered

Table 5-94 lists the water management strategies, references to the report section detailing the strategy, total project cost, and unit costs that were considered for the City of Lockney.

Table 5-94.
Water Management Strategies Considered for the City of Lockney

Option	Yield (acft/yr)[1]	Approximate Cost[2] Annual Cost[3]	Approximate Cost[2] Unit ($/acft)
Local Groundwater (Section 5.1.1)	304	$20,286[4]	$67[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-17 and 5-95 for annual and unit costs for each decade.

5.3.9.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Lockney:

- Local groundwater development beginning in 2015 needed to supply an additional 304 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Lockney into which the city could locate new municipal water supply wells.

5.3.9.1.4 Costs

Costs of the recommended plan for the City of Lockney to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-17
   - Date to be Implemented: 2015
   - Total Project Cost: 485,936
   - Annual Cost: See Table 5-95 for a cost summary of this option.

Table 5-95.
Recommended Plan Costs by Decade for the City of Lockney

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-190	-157	-140
Quantity Available (acft/yr)	0	0	415	374	337	304
Annual Cost ($/yr)	-	-	$55,589	$55,589	$55,589	$20,286
Unit Cost ($/acft)	-	-	$134	$149	$165	$67

5.3.9.2 Irrigation

5.3.9.2.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 124,737 acft/yr in 2000, decreasing to 97,970 acft/yr in 2050.

5.3.9.2.2 Options Considered

Table 5-96 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-96.
Water Management Strategies Considered for Irrigation—Floyd County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	59,112	$2,335,178	$39.50[4]

[1] The projects estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: 5.1.8.

5.3.9.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of irrigation:

- Irrigation water conservation by individual farmers to supply an additional 59,112 acft/yr in 2000, declining to 34,905 acft/yr in 2050.

5.3.9.2.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $45,325,656
   - Annual Cost: $1,260,584; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-97).

Table 5-97.
Recommended Plan Costs by Decade for Irrigation—Floyd County

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Irr. Water Conservation						
Projected Shortage (acft/yr)	-23,567	-23,949	-24,088	-23,665	-23,419	-23,060
Quantity Available (acft/yr)	59,112	53,201	47,881	43,093	38,783	34,905
Annual Cost ($/yr)	2,335,178	2,335,178	2,335,178	2,335,178	2,335,178	2,335,178
Unit Cost ($/acft)	$39.50	$43.89	$48.77	$54.19	$60.21	$66.90

5.3.10 Gaines County Water Supply Plan

Table 5-98 lists each water user group in Gaines County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-98.
Gaines County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Seagraves	-547	-533	Projected shortage – see plan below
City of Seminole	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-10, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.10.1 The City of Seagraves

5.3.10.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2009, at which time additional supplies will be needed.

5.3.10.1.2 Options Considered

Table 5-99 lists the water management strategies, references to the report section detailing the strategy, total project cost, and unit costs that were considered for the City of Seagraves.

Table 5-99.
Water Management Strategies Considered for the City of Seagraves

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	546	$41,721[4]	$76[4]
Municipal Water Conservation (Sec. 5.1.7)	52		$27

[1] The project's estimated average yield in 2050. However, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-22 and 5-100 for annual and unit costs for each decade.

5.3.10.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Seagraves:

- Local groundwater development beginning in 2002 needed to supply an additional 546 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of Seagraves into which the city could locate new municipal water supply wells.

5.3.10.1.4 Costs

Costs of the recommended plan for the City of Seagraves to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-22
   - Date to be Implemented: 2002
   - Total Project Cost: $1,157,156
   - Annual Cost: See Table 5-100 for a cost summary of this option.

Table 5-100.
Recommended Plan Costs by Decade for the City of Seagraves

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	-581	-555	-547	-535	-533
Quantity Available (acft/yr)	0	830	748	674	606	546
Annual Cost ($/yr)	-	$125,788	$125,788	$125,788	$41,721	$41,721
Unit Cost ($/acft)	-	$152	$168	$187	$69	$76

5.3.11 Garza County Water Supply Plan

Table 5-101 lists each water user group in Garza County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-101.
Garza County Surplus/Shortage

Water User Group	*Surplus/Shortage[1]* 2030 (acft/yr)	*Surplus/Shortage[1]* 2050 (acft/yr)	*Comment*
City of Post	119	189	Projected surplus
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	Projected shortage (2000 and 2010) – see plan below
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

1 From Table 4-11, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.11.1 Irrigation

5.3.11.1.1 Description of Supply

- **Source:** Ogallala Aquifer and Dockum Aquifer
- **Current Supply:** 2,959 acft/yr in 2000, decreasing to 2,610 acft/yr in 2050.

5.3.11.1.2 Options Considered

Table 5-102 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-102.
Water Management Strategies Considered for Irrigation—Garza County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	3,120	$109,363	$35.05

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.11.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of irrigation:

- Irrigation water conservation by individual farmers to supply an additional 3,120 acft/yr in 2000, declining to 1,842 acft/yr in 2050.

5.3.11.1.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $2,122,722
   - Annual Cost: $109,363; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-103).

Table 5-103.
Recommended Plan Costs by Decade for Irrigation—Garza County

Plan Element	2000	2010	2020	2030	2040	2050
Irr. Water Conservation						
Projected Shortage (acft/yr)	-570	-90	0	0	0	0
Quantity Available (acft/yr)	3,120	2,808	2,527	2,274	2,047	1,842
Annual Cost ($/yr)	$109,363	$109,363	$109,363	$109,363	$109,363	$109,363
Unit Cost ($/acft)	$35.05	$38.95	$43.28	$48.09	$53.43	$59.37

5.3.12 Hale County Water Supply Plan

Table 5-104 lists each water user group in Hale County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-104.
Hale County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Abernathy[2]	-583	-600	Projected shortage – see plan below
City of Hale Center	0	-384	Projected shortage – see plan below
City of Petersburg	0	0	No projected surplus/shortage
City of Plainview	14	342	Projected surplus
County Other[3]	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-7,606	-12,995	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-12, Section 4.1 – Water Needs Projections by Water User Group.
[2] A portion of the City of Abernathy is located in Lubbock County. However, the city's total projected shortage is shown here.
[3] Although County-Other is not projected with a shortage, the City of Cotton Center will need replacement wells – see plan below.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.12.1 The City of Abernathy

5.3.12.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2014, at which time additional supplies will be needed.

5.3.12.1.2 Options Considered

Table 5-105 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Abernathy.

Table 5-105.
Water Management Strategies Considered for the City of Abernathy

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	768	$62,037[4]	$81[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	600	$408,600	$681[5]

[1] The project's estimated average yield in 2050. However, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-2 and 5-106 for annual and unit costs for each decade..
[5] Source of Cost Estimate: Section 5.1.2.

5.3.12.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Abernathy:

- Local groundwater development beginning in 2007 needed to supply an additional 768 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately 10 miles from the City of Abernathy into which the city could locate new municipal water supply wells.

5.2.12.1.4 Costs

Costs of the recommended plan for the City of Abernathy to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-2
   - Date to be Implemented: 2007
   - Total Project Cost: $2,486,792
   - Annual Cost: See Table 5-106 for a cost summary of this option.

Table 5-106.
Recommended Plan Costs by Decade for the City of Abernathy

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-571	-583	-587	-600
Quantity Available (acft/yr)	0	206	790	711	853	768
Annual Cost ($/yr)	-	$145,519	$209,914	$209,914	$96,003	$62,037
Unit Cost ($/acft)	-	$706	$266	$295	$113	$81

5.3.12.2 City of Hale Center

5.3.12.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2034, at which time additional supplies will be needed.

5.3.12.2.2 Options Considered

Table 5-107 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Hale Center.

Table 5-107.
Water Management Strategies Considered for Hale Center

Option	*Yield (acft/yr)*[1]	*Approximate Cost*[2]	
		Annual Cost[3]	*Unit ($/acft)*
Local Groundwater (Sec. 5.1.1)	536	$82,117[4]	$153[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	415	$282,615	$681[5]

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-12 and 5-106 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.12.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Hale Center:

- Local groundwater development beginning in 2029 needed to supply an additional 536 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Hale Center into which the city could locate new municipal water supply wells.

5.3.12.2.4 Costs

Costs of the recommended plan for the City of Hale Center to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-12
   - Date to be Implemented: 2029
   - Total Project Cost: $711,480
   - Annual Cost: See Table 5-108 for a cost summary of this option.

Table 5-108.
Recommended Plan Costs by Decade for the City of Hale Center

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	0	-394	-384
Quantity Available (acft/yr)	0	0	0	211	595	536
Annual Cost ($/yr)	-	-	-	$39,187	$82,117	$82,117
Unit Cost ($/acft)	-	-	-	$186	$138	$153

5.3.12.3 County-Other (Cotton Center)

5.3.12.3.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2011, at which time additional supplies will be needed.

5.3.12.3.2 Options Considered

Table 5-109 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for Cotton Center.

Table 5-109.
Water Management Strategies Considered for Cotton Center

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	274	$20,286[4]	$74[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-6 and 5-110 for annual and unit costs for each decade.

5.3.12.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of Cotton Center through 2050:

- Local groundwater development beginning in 2006 needed to supply an additional 274 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from Cotton Center into which the city could locate new municipal water supply wells.

5.3.12.3.4 Costs

Costs of the recommended plan for Cotton Center to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-6
   - Date to be Implemented: 2006
   - Total Project Cost: $485,936
   - Annual Cost: See Table 5-110 for a cost summary of this option.

Table 5-110.
Recommended Plan Costs by Decade for Cotton Center

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-57	-57	-64	-71
Quantity Available (acft/yr)	0	416	375	338	304	274
Annual Cost ($/yr)	-	$55,589	$55,589	$55,589	$20,286	$20,286
Unit Cost ($/acft)	-	$134	$148	$164	$67	$74

5.3.12.4 Irrigation

5.3.12.4.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 363,360 acft/yr in 2000, decreasing to 295,916 acft/yr in 2050.

5.3.12.4.2 Options Considered

Table 5-111 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-111.
Water Management Strategies Considered for Irrigation—Hale County

Option	*Yield (acft/yr)*[1]	*Approximate Cost*[2]	
		Annual Cost[3]	*Unit ($/acft in 2000)*
Irrigation Water Conservation (Sec. 5.1.8)	60,063	$2,348,899	$39.11[4]

1 The project's estimated yield in 2000.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
3 Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
4 Source of Cost Estimate: Section 5.1.8.

5.3.12.4.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected irrigation shortages through 2050:

- Irrigation water conservation by individual farmers to supply an additional 60,063 acft/yr in 2000, decreasing to 35,467 acft/yr in 2050.

5.3.12.4.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $45,591,984
   - Annual Cost: $2,348,899; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-112).

Table 5-112.
Recommended Plan Costs by Decade for Irrigation—Hale County

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Irr. Water Conservation						
Projected Shortage (acft/yr)	-2,234	-2,183	-3,777	-7,606	-9,882	-12,995
Quantity Available (acft/yr)	60,063	54,056	48,651	43,786	39,407	35,467
Annual Cost ($/yr)	$2,348,899	$2,348,899	$2,348,899	$2,348,899	$2,348,899	$2,348,899
Unit Cost ($/acft)	$39.11	$43.45	$48.28	$53.64	$59.61	$66.23

5.3.13 Hockley County Water Supply Plan

Table 5-113 lists each water user group in Hockley County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-113.
Hockley County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Anton	-253	-237	Projected shortage – see plan below
City of Levelland[2]	925	1,137	Projected surplus[2]
City of Sundown	-463	-473	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	Projected shortage (in 2000) – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-13, Section 4.1 – Water Needs Projections by Water User Group.
[2] The Ogallala Aquifer northwest of Levelland has been contaminated with petroleum/refinery products, and if cleanup is not successful, Levelland may have a water need in a few years.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.13.1 The City of Anton

5.3.13.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2003, at which time additional supplies will be needed.

5.3.13.1.2 Options Considered

Table 5-114 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Anton.

Table 5-114.
Water Management Strategies Considered for the City of Anton

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Section 5.1.1)	382	$30,429[4]	$80[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-4 and 5-115 for annual and unit costs for each decade.

5.3.13.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Anton:

- Local groundwater development beginning in 2001 needed to supply an additional 382 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of Anton into which the city could locate new municipal water supply wells.

5.3.13.1.4 Costs

Costs of the recommended plan for the City of Anton to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-4
   - Date to be Implemented: 2001
   - Total Project Cost: $963,840
   - Annual Cost: See Table 5-115 for a cost summary of this option.

Table 5-115.
Recommended Plan Costs by Decade for the City of Anton

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	-258	-258	-253	-243	-237
Quantity Available (acft/yr)	0	586	528	472	424	382
Annual Cost ($/yr)	-	$102,371	$102,371	$102,371	$30,429	$30,429
Unit Cost ($/acft)	-	$175	$194	$217	$72	$80

5.3.13.2 City of Sundown

5.3.13.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2013, at which time additional supplies will be needed.

5.3.13.2.2 Options Considered

Table 5-116 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Sundown.

Table 5-116.
Water Management Strategies Considered for the City of Sundown

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	565	$41,721[4]	$74[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-25 and 5-116 for annual and unit costs for each decade.

5.3.13.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Sundown:

- Local groundwater development beginning in 2006 needed to supply an additional 565 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Sundown into which the city could locate new municipal water supply wells.

5.3.13.2.4 Costs

Costs of the recommended plan for the City of Sundown to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-25
   - Date to be Implemented: 2006
   - Total Project Cost: $808,676
   - Annual Cost: See Table 5-117 for a cost summary of this option.

Table 5-117.
Recommended Plan Costs by Decade for the City of Sundown

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-453	-463	-465	-473
Quantity Available (acft/yr)	0	641	775	697	627	565
Annual Cost ($/yr)	-	$79,006	$100,471	$100,471	$53,043	$41,721
Unit Cost ($/acft)	-	$123	$130	$144	$85	$74

5.3.13.3 Irrigation

5.3.13.3.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 93,010 acft/yr in 2000 decreasing to 79,692 acft/yr in 2050.

5.3.13.3.2 Options Considered

Table 5-118 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-118.
Water Management Strategies Considered for Irrigation—Hockley County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Irrigation Water Conservation (Sec. 5.1.8)	13,324	$573,482	$43.04[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.13.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected irrigation shortages through 2050:

- Irrigation water conservation by individual farmers to supply an additional 13,324 acft/yr in 2000, declining to 7,868 acft/yr in 2050.

5.3.13.3.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $11,131,254
   - Annual Cost: $573,482; including debt service, and averaged over the 25 year useful life of LEPA Systems.

Table 5-119.
Recommended Plan Costs by Decade for Irrigation—Hockley County

Plan Element	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
Irr. Water Conservation						
Projected Shortage (acft/yr)	-4,272	0	0	0	0	0
Quantity Available (acft/yr)	13,324	11,992	10,792	9,713	8,742	7,868
Annual Cost ($/yr)	$573,482	$573,482	$573,482	$573,482	$573,482	$573,482
Unit Cost ($/acft)	$43.04	$47.82	$53.14	$59.04	$65.60	$72.89

5.3.14 Lamb County Water Supply Plan

Table 5-120 lists each water user group in Lamb County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-120.
Lamb County Surplus/Shortage

Water User Group	Surplus/(Shortage)[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Amherst	-112	-102	Projected shortage – see plan below
City of Earth	-331	-343	Projected shortage – see plan below
City of Littlefield	0	0	No projected surplus/shortage
City of Olton	-606	-617	Projected shortage – see plan below
City of Sudan	-322	-319	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected surplus/shortage
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-14, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.14.1 The City of Amherst

5.3.14.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2022, at which time additional supplies will be needed.

5.3.14.1.2 Options Considered

Table 5-121 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Amherst.

Table 5-121.
Water Management Strategies Considered for the City of Amherst

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Section 5.1.1)	308	$31,608[4]	$103[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	155	$105,555	$681[5]
Municipal Water Conservation (Sec. 5.1.7)	5		$65

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-3 and 5-121 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.14.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of the City of Amherst:

- Local groundwater development beginning in 2017 needed to supply an additional 308 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately five miles from the City of Amherst into which the city could locate new municipal water supply wells.

5.3.14.1.4 Costs

Costs of the recommended plan for the City of Amherst to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-3
   - Date to be Implemented: 2017

- Total Project Cost: $799,568
- Annual Cost: See Table 5-122 for a cost summary of this option.

Table 5-122.
Recommended Plan Costs by Decade for the City of Amherst

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-112	-106	-102
Quantity Available (acft/yr)	0	0	207	382	343	308
Annual Cost ($/yr)	-	-	$56,909	$78,374	$78,374	$31,608
Unit Cost ($/acft)	-	-	$275	$205	$228	$103

5.3.14.2 The City of Earth

5.3.14.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2027, at which time additional supplies will be needed.

5.3.14.2.2 Options Considered

Table 5-123 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Earth.

Table 5-123.
Water Management Strategies Considered for the City of Earth

Option	*Yield (acft/yr)*[1]	*Approximate Cost*[2]	
		Annual Cost[3]	*Unit ($/acft)*
Local Groundwater (Sec. 5.1.1)	517	$92,244[4]	$178[4]
Municipal Water Conservation (Sec. 5.1.7)	69		$12

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-9 and 5-124 for annual and unit costs for each decade.

5.3.14.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Earth through 2050 of the City of Earth:

- Local groundwater development beginning in 2022 needed to supply an additional 517 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Earth into which the city could locate new municipal water supply wells.

5.3.14.2.4 Costs

Costs of the recommended plan for the City of Earth to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-9
   - Date to be Implemented: 2022
   - Total Project Cost: $850,872
   - Annual Cost: See Table 5-124 for a cost summary of this option.

Table 5-124.
Recommended Plan Costs by Decade for the City of Earth

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-331	-334	-343
Quantity Available (acft/yr)	0	0	0	403	575	517
Annual Cost ($/yr)	-	-	-	$70,779	$92,244	$92,244
Unit Cost ($/acft)	-	-	-	$176	$160	$178

5.3.14.3 The City of Olton

5.3.14.3.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2019, at which time additional supplies will be needed.

5.3.14.3.2 Options Considered

Table 5-125 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Olton.

Table 5-125.
Water Management Strategies Considered for the City of Olton

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	771	$53,013[4]	$69[4]
Municipal Water Conservation (Sec. 5.1.7)	123		$11

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-20 and 5-126 for annual and unit costs for each decade.

5.3.14.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Olton through 2050:

- Local groundwater development beginning in 2012 needed to supply an additional 771 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Olton into which the city could locate new municipal water supply wells.

5.3.14.3.4 Costs

Costs of the recommended plan for the City of Olton to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-20
   - Date to be Implemented: 2012
   - Total Project Cost: $1,027,840
   - Annual Cost: See Table 5-126 for a cost summary of this option.

Table 5-126.
Recommended Plan Costs by Decade for the City of Olton

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-598	-606	-610	-617
Quantity Available (acft/yr)	0	0	1,057	952	857	771
Annual Cost ($/yr)	-	-	$127,685	$127,685	$127,685	$53,013
Unit Cost ($/acft)	-	-	$121	$134	$149	$69

5.3.14.4 The City of Sudan

5.3.14.4.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2011, at which time additional supplies will be needed.

5.3.14.4.2 Options Considered

Table 5-127 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Sudan.

Table 5-127.
Water Management Strategies Considered for the City of Sudan

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	426	$31,578[4]	$74[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	322	$219,282	$681[5]
Municipal Water Conservation (Sec. 5.1.7)	97		$12

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-24 and 5-128 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.14.4.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Sudan through 2050:

- Local groundwater development beginning in 2006 needed to supply an additional 426 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of Sudan into which the city could locate new municipal water supply wells.

5.3.14.4.4 Costs

Costs of the recommended plan for the City of Sudan to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-24
   - Date to be Implemented: 2006
   - Total Project Cost: $861,916
   - Annual Cost: See Table 5-128 for a cost summary of this option.

Table 5-128.
Recommended Plan Costs by Decade for the City of Sudan

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-320	-322	-318	-319
Quantity Available (acft/yr)	0	432	583	525	473	426
Annual Cost ($/yr)	-	$72,731	$94,196	$94,196	$42,900	$31,578
Unit Cost ($/acft)	-	$168	$162	$174	$91	$74

5.3.15 Lubbock County Water Supply Plan

Table 5-129 lists each water user group in Lubbock County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-129.
Lubbock County Surplus/Shortage

Water User Group	***Surplus/Shortage[1]***		***Comment***
	2030 (acft/yr)	***2050 (acft/yr)***	
City of Abernathy			See Hale County
City of Idalou	-507	-543	Projected shortage – see plan below
City of Lubbock	9,255	37,202	Projected surplus
City of New Deal	-102	-110	Projected shortage – see plan below
City of Ransom Canyon	33	0	Projected surplus
City of Reese Center	0	0	No projected surplus/shortage
City of Shallowater	-251	-281	Projected shortage – see plan below
City of Slaton	882	807	Projected surplus
City of Wolfforth	-467	-494	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	200	505	Projected surplus
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-15, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.15.1 The City of Abernathy (See Hale County)

5.3.15.2 The City of Idalou

5.3.15.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2019, at which time additional supplies will be needed.

5.3.15.2.2 Options Considered

Table 5-130 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Idalou.

Table 5-130.
Water Management Strategies Considered for the City of Idalou

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	619	$51,894[4]	$83[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	543	$369,783	$681[5]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-15 and 5-131 for annual and unit costs for each decade.
[5] Source of Cost Estimate: Section 5.1.2.

5.3.15.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Idalou through 2050:

- Local groundwater development beginning in 2012 needed to supply an additional 619 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of Idalou into which the city could locate new municipal water supply wells.

5.3.15.2.4 Costs

Costs of the recommended plan for the City of Idalou to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):

- Cost Source: Section 5.1.1, Table 5-15
- Date to be Implemented: 2012
- Total Project Cost: $1,285,504
- Annual Cost: See Table 5-131 for a cost summary of this option.

Table 5-131.
Recommended Plan Costs by Decade for the City of Idalou

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-459	-507	-523	-543
Quantity Available (acft/yr)	0	0	612	764	688	619
Annual Cost ($/yr)	-	-	$112,498	$133,963	$133,963	$51,894
Unit Cost ($/acft)	-	-	$183	$175	$195	$83

5.3.15.3 The City of New Deal

5.3.15.3.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2013, at which time additional supplies will be needed.

5.3.15.3.2 Options Considered

Table 5-132 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of New Deal.

Table 5-132.
Water Management Strategies Considered for the City of New Deal

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	281	$20.286[4]	$72[4]
Hartley County Regional Pipeline (Sec. 5.1.2)[5]	110	$74,910	$681[6]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-19 and 5-133 for annual and unit costs for each decade.
[5] On August 17, 1990, Mr. Ches Carthel of Lubbock reported to the LERWPG that Lubbock has agreed to supply water to New Deal and that delivery facilities are under construction.
[6] Source of Cost Estimate: Section 5.1.2.

5.3.15.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of New Deal through 2050:

- Local groundwater development beginning in 2008 needed to supply an additional 281 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of New Deal into which the city could locate new municipal water supply wells.
- On August 17, 1990, Mr. Ches Carthel of Lubbock reported to the LERWPG that Lubbock has agreed to supply water to New Deal and that delivery facilities are under construction.

5.3.15.3.4 Costs

Costs of the recommended plan for the City of New Deal to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-19
   - Date to be Implemented: 2008
   - Total Project Cost: $695,024
   - Annual Cost: See Table 5-133 for a cost summary of this option.

Table 5-133.
Recommended Plan Costs by Decade for the City of New Deal

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-100	-102	-105	-110
Quantity Available (acft/yr)	0	209	386	347	312	281
Annual Cost ($/yr)	-	$49,314	$70,779	$70,779	$31,171	$20,286
Unit Cost ($/acft)	-	$236	$183	$204	$100	$72

5.3.15.4 The City of Shallowater

5.3.15.4.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2011, at which time additional supplies will be needed.

5.3.15.4.2 Options Considered

Table 5-134 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Shallowater.

Table 5-134.
Water Management Strategies Considered for the City of Shallowater

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	426	$31,578[4]	$74[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	468	$318,708	$681[5]

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-23 and 5-135 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.15.4.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Shallowater through 2050:

- Local groundwater development beginning in 2006 needed to supply an additional 426 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Shallowater into which the city could locate new municipal water supply wells.

5.3.15.4.4 Costs

Costs of the recommended plan for the City of Shallowater to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-23
   - Date to be Implemented: 2006
   - Total Project Cost: $583,132
   - Annual Cost: See Table 5-135 for a cost summary of this option.

Table 5-135.
Recommended Plan Costs by Decade for the City of Shallowater

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-210	-251	-261	-281
Quantity Available (acft/yr)	0	432	583	525	473	426
Annual Cost ($/yr)	-	$52,477	$73,942	$73,942	$42,900	$31,578
Unit Cost ($/acft)	-	$121	$127	$141	$91	$74

5.3.15.5 The City of Wolfforth

5.3.15.5.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2018, at which time additional supplies will be needed

5.3.15.5.2 Options Considered

Table 5-136 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Wolfforth.

Table 5-136.
Water Management Strategies Considered for the City of Wolfforth

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)[4]	599	$41,721[5]	$70[5]

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 On August 17, 1990, Mr. Ches Carthel of Lubbock reported to the LERWPG that Lubbock has agreed to supply water to New Deal and that Lubbock is negotiating with Wolfforth to supply water.
5 Cost is for 2050. See Tables 5-28 and 5-137 for annual and unit costs for each decade.

5.3.15.5.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Wolfforth through 2050:

- Local groundwater development beginning in 2011 needed to supply an additional 599 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Wolfforth into which the city could locate new municipal water supply wells.
- On August 17, 1990, Mr. Ches Carthel of Lubbock reported to the LERWPG that Lubbock has agreed to supply water to New Deal and that Lubbock is negotiating with Wolfforth to supply water.

5.3.15.5.4 Costs

Costs of the recommended plan for the City of Wolfforth to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-28
   - Date to be Implemented: 2011
   - Total Project Cost: $808,676

- Annual Cost: See Table 5-137 for a cost summary of this option.

Table 5-137.
Recommended Plan Costs by Decade for the City of Wolfforth

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-421	-467	-476	-494
Quantity Available (acft/yr)	0	0	821	739	665	599
Annual Cost ($/yr)	-	-	$100,471	$100,471	$100,471	$41,721
Unit Cost ($/acft)	-	-	$122	$136	$151	$70

5.3.16 Lynn County Water Supply Plan

Table 5-138 lists each water user group in Lynn County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-138.
Lynn County Surplus/Shortage

Water User Group	*Surplus/Shortage[1]*		*Comment*
	2030 (acft/yr)	*2050 (acft/yr)*	
City of O'Donnell (part)	116	127	Projected surplus
City of Tahoka	15	51	Projected surplus
City of Wilson	-46	-42	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-16, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.16.1 The City of Wilson

5.3.16.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2024, at which time additional supplies will be needed.

5.3.16.1.2 Options Considered

Table 5-139 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Wilson.

Table 5-139.
Water Management Strategies Considered for the City of Wilson

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	316	$31,608[4]	$100[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-27 and 5-140 for annual and unit costs for each decade.

5.3.16.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Wilson through 2050:

- Local groundwater development beginning in 2019 needed to supply an additional 316 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately two miles from the City of Wilson into which the city could locate new municipal water supply wells.

5.3.16.1.4 Costs

Costs of the recommended plan for the City of Wilson to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-27
   - Date to be Implemented: 2019
   - Total Project Cost: $485,936
   - Annual Cost: See Table 5-140 for a cost summary of this option.

Table 5-140.
Recommended Plan Costs by Decade for the City of Wilson

Plan Element	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-46	-43	-42
Quantity Available (acft/yr)	0	0	211	390	351	316
Annual Cost ($/yr)	-	-	$34,124	$55,589	$55,589	$31,608
Unit Cost ($/acft)	-	-	$162	$143	$158	$100

5.3.17 Motley County Water Supply Plan

Table 5-141 lists each water user group in Motley County and their corresponding surplus or shortage in years 2030 and 2050. Although data for Motley County are not as complete as for counties of the groundwater conservation districts, the data provided by the TWDB shows that there are no projected shortages for any of the water user groups in the county; and consequently, no recommended water management plans are presented for Motley County at this time. It is anticipated that more specific data will be obtained for the future update of the regional water plan.

Table 5-141.
Motley County Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
City of Matador	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-17, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.18 Parmer County Water Supply Plan

Table 5-142 lists each water user group in Parmer County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-142.
Parmer County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Bovina	-402	-441	Projected shortage – see plan below
City of Farwell	-507	-562	Projected shortage – see plan below
City of Friona	-1,056	-1,137	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected demand
Irrigation	-54,632	-64,700	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-18, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.18.1 The City of Bovina

5.3.18.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2013, at which time additional supplies will be needed.

5.3.18.1.2 Options Considered

Table 5-143 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Bovina.

Table 5-143.
Water Management Strategies Considered for the City of Bovina

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	611	$51,894[4]	$85[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	441	$300,321	$681[5]

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-5 and 5-144 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.18.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Bovina through 2050:

- Local groundwater development beginning in 2006 needed to supply an additional 611 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Bovina into which the city could locate new municipal water supply wells.

5.3.18.1.4 Costs

Costs of the recommended plan for the City of Bovina to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-5
   - Date to be Implemented: 2006
   - Total Project Cost: $1,111,264
   - Annual Cost: See Table 5-144 for a cost summary of this option.

Table 5-144.
Recommended Plan Costs by Decade for the City of Bovina

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-388	-402	-419	-441
Quantity Available (acft/yr)	0	418	575	518	679	611
Annual Cost ($/yr)	-	$78,374	$99,839	$99,839	$63,216	$51,894
Unit Cost ($/acft)	-	$187	$174	$193	$93	$85

5.3.18.2 The City of Farwell

5.3.18.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2017, at which time additional supplies will be needed.

5.3.18.2.2 Options Considered

Table 5-145 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Farwell.

Table 5-145.
Water Management Strategies Considered for the City of Farwell

Option	*Yield (acft/yr)*[1]	*Approximate Cost*[2]	
		Annual Cost[3]	*Unit ($/acft)*
Local Groundwater (Sec. 5.1.1)	609	$51,894[4]	$85[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	562	$382,722	$681[5]
Municipal Water Conservation (Sec. 5.1.7)	169		$7

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-10 and 5-146 for annual and unit costs for each decade.
[5] Source of Cost Estimate: Section 5.1.2.

5.3.18.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Farwell through 2050:

- Local groundwater development beginning in 2010 needed to supply an additional 609 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Farwell into which the city could locate new municipal water supply wells.

5.3.18.2.4 Costs

Costs of the recommended plan for the City of Farwell to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-10
   - Date to be Implemented: 2010
   - Total Project Cost: $1,111,264
   - Annual Cost: See Table 5-146 for a cost summary of this option.

Table 5-146.
Recommended Plan Costs by Decade for the City of Farwell

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-486	-507	-531	-562
Quantity Available (acft/yr)	0	213	599	752	677	609
Annual Cost ($/yr)	-	$56,909	$99,839	$121,304	$74,538	$51,894
Unit Cost ($/acft)	-	$267	$167	$161	$110	$85

5.3.18.3 The City of Friona

5.3.18.3.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2021, at which time additional supplies will be needed.

5.3.18.3.2 Options Considered

Table 5-147 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Friona.

Table 5-147.
Water Management Strategies Considered for the City of Friona

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	1,304	$100,326[4]	$77[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	1,137	$774,297	$681[5]
Municipal Water Conservation (Sec. 5.1.7)	113		$9

1 The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
2 Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
3 Includes debt service at 6% annual interest for 30 years.
4 Cost is for 2050. See Tables 5-11 and 5-148 for annual and unit costs for each decade.
5 Source of Cost Estimate: Section 5.1.2.

5.3.18.3.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Friona through 2050:

- Local groundwater development beginning in 2016 needed to supply an additional 1,304 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately four miles from the City of Friona into which the city could locate new municipal water supply wells.

5.3.18.3.4 Costs

Costs of the recommended plan for the City of Friona to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-11
   - Date to be Implemented: 2016
   - Total Project Cost: $1,680,096

- Annual Cost: See Table 5-148 for a cost summary of this option.

Table 5-148.
Recommended Plan Costs by Decade for the City of Friona

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	0	-1,056	-1,090	-1,137
Quantity Available (acft/yr)	0	0	1,323	1,610	1,449	1,304
Annual Cost ($/yr)	-	-	$171,778	$207,799	$207,799	$100,326
Unit Cost ($/acft)	-	-	$130	$129	$143	$77

5.3.18.5 Irrigation

5.3.18.5.1 Description of Supply

- **Source:** Ogallala Aquifer and Reclaimed Water
- **Current Supply:** 290,775 acft/yr in 2000, decreasing to 243,363 acft/yr in 2050.

5.3.18.5.2 Options Considered

Table 5-149 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-149.
Water Management Strategies Considered for Irrigation—Parmer County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft in 2000)
Irrigation Water Conservation (Sec. 5.1.8)	12,538	$301,619	$24.06[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.18.5.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 of irrigation in Parmer County. However, this option will not meet all of the projected shortage However, the Llano Estacado Regional Water Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of Parmer County nor the region at this time (Section 5.1.8.5).

Irrigation water conservation by individual farmers to supply an additional 12,538 acft/yr in 2000, declining to 7,404 acft/yr in 2050.

5.3.18.5.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
  - Cost Source: Section 5.1.8, Table 5-60
  - Date to be Implemented: 2000
  - Total Project Cost: $5,854,410
  - Annual Cost: $301,619; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-150).

Table 5-150.
Recommended Plan Costs by Decade for Irrigation—Parmer County

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Irr. Water Conservation						
Projected Shortage (acft/yr)	-34,176	-42,245	-48,530	-54,632	-59,986	-64,700
Quantity Available (acft/yr)	12,538	11,284	10,156	9,140	8,226	7,404
Annual Cost ($/yr)	$301,619	$301,619	$301,619	$301,619	$301,619	$301,619
Unit Cost ($/acft)	$24.06	$26.73	$29.70	$33.00	$36.67	$40.74

5.3.19 Swisher County Water Supply Plan

Table 5-151 lists each water user group in Swisher County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-151.
Swisher County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Kress	-65	-59	Projected shortage – see plan below
City of Tulia[2]	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected surplus/shortage
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-44,468	-43,862	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected surplus/shortage
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-19, Section 4.1 – Water Needs Projections by Water User Group.

[2] The City of Tulia is projected to obtain 417 acft/yr from MMWA with the remainder of the City's demand being met from its own groundwater supplies.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.19.1 The City of Kress

5.3.19.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2005, at which time additional supplies will be needed.

5.3.19.1.2 Options Considered

Table 5-152 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Kress.

Table 5-152.
Water Management Strategies Considered for the City of Kress

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	261	$20,286[4]	$78[4]
Hartley County Regional Pipeline (Sec. 5.1.2)	95	$64,695	$681[5]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-16 and 5-153 for annual and unit costs for each decade.
[5] Source of Cost Estimate: Section 5.1.2.

5.3.19.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Kress through 2050:

- Local groundwater development beginning in 2001 needed to supply an additional 261 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately six miles from the City of Kress into which the city could locate new municipal water supply wells.

5.3.19.1.4 Costs

Costs of the recommended plan for the City of Kress to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-16
   - Date to be Implemented: 2001
   - Total Project Cost: $904,112
   - Annual Cost: See Table 5-153 for a cost summary of this option.

Table 5-153.
Recommended Plan Costs by Decade for the City of Kress

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	-84	-72	-65	-61	-59
Quantity Available (acft/yr)	0	396	357	322	290	261
Annual Cost ($/yr)	-	$85,969	$85,969	$85,969	$20,286	$20,286
Unit Cost ($/acft)	-	$217	$240	$267	$70	$78

5.3.19.2 Irrigation

5.3.19.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** 102,705 acft/yr in 2000, decreasing to 100,012 acft/yr in 2050.

5.3.19.2.2 Options Considered

Table 5-154 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-154.
Water Management Strategies Considered for Irrigation—Swisher County

Option	*Yield (acft/yr)*[1]	*Approximate Cost*[2]	
		Annual Cost[3]	*Unit ($/acft in 2000)*
Irrigation Water Conservation (Sec. 5.1.8)	39,709	$1,726,060	$43.47[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.19.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages through 2050 for irrigation in Swisher County. However, the Llano Estacado Regional Water

Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of Swisher County nor the region at this time (Section 5.1.8.5).

- Irrigation water conservation by individual farmers to supply an additional 39,709 acft/yr in 2000, declining to 23,448 acft/yr in 2050.

5.3.19.2.4 Costs

Costs of the recommended plan for irrigation to meet 2050 shortages are:

a. Irrigation water conservation:
   - Cost Source: Section 5.1.8, Table 5-60
   - Date to be Implemented: 2000
   - Total Project Cost: $33,502,716
   - Annual Cost: $1,726,060; including debt service, and averaged over the 25 year useful life of LEPA Systems (Table 5-155).

Table 5-155.
Recommended Plan Costs by Decade for Irrigation--Swisher County

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Irr. Water Conservation						
Projected Shortage (acft/yr)	-45,350	-45,061	-42,472	-44,468	-44,167	-43,862
Quantity Available (acft/yr)	39,709	35,738	32,164	28,948	26,053	23,448
Annual Cost ($/yr)	$1,726,060	$1,726,060	$1,726,060	$1,726,060	$1,726,060	$1,726,060
Unit Cost ($/acft)	$43.47	$48.30	$53.66	$59.63	$66.25	$73.61

5.3.20 Terry County Water Supply Plan

Table 5-156 lists each water user group in Terry County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-156. Terry County Surplus/Shortage

Water User Group	Surplus/Shortage[1] 2030 (acft/yr)	Surplus/Shortage[1] 2050 (acft/yr)	Comment
City of Brownfield	744	614	Projected surplus
City of Meadow	0	0	No projected surplus/shortage
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected demand
Mining	0	0	No projected surplus/shortage
Irrigation	-1,615	-1,406	Projected shortage – see plan below
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-20, Section 4.1 – Water Needs Projections by Water User Group.

* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.20.1 Irrigation

5.3.20.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** 105,005 acft/yr in 2000, decreasing to 80,729 acft/yr in 2050.

5.3.20.1.2 Options Considered

Table 5-157 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for irrigation.

Table 5-157.
Water Management Strategies Considered for Irrigation—Terry County

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Irrigation Water Conservation (Sec. 5.1.8)	0	-	-[4]

[1] The project's estimated yield in 2000.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for water conserved by use of LEPA systems.
[3] Includes debt service at 6% annual interest, with loans repaid in 8 years, and total repayment averaged over 25 years.
[4] Source of Cost Estimate: Section 5.1.8.

5.3.20.1.3 Water Supply Plan

Considering the option analysis for irrigation water conservation, there does not appear to be any additional water available for irrigation from this source. However, the Llano Estacado Regional Water Planning Group concluded that it is not economically feasible to meet all of the projected irrigation water needs of Terry County nor the region at this time (Section 5.1.8.5).

5.3.21 Yoakum County Water Supply Plan

Table 5-158 lists each water user group in Yoakum County and its corresponding surplus or shortage in years 2030 and 2050. For each water user group with a projected shortage, a water supply plan has been developed and is presented in the following subsections.

Table 5-158.
Yoakum County Surplus/Shortage

Water User Group	*Surplus/Shortage*[1]		*Comment*
	2030 (acft/yr)	*2050 (acft/yr)*	
City of Denver City	-1,458	-1,657	Projected shortage – see plan below
City of Plains	-477	-501	Projected shortage – see plan below
County Other	0	0	No projected surplus/shortage
Industrial	0	0	No projected demand
Steam Electric	0	0	No projected surplus/shortage
Mining	0	0	No projected surplus/shortage
Irrigation	0	0	No projected surplus/shortage
Beef Feedlot Livestock	0	0	No projected demand
Range & All Other Livestock	0	0	No projected surplus/shortage

[1] From Table 4-21, Section 4.1 – Water Needs Projections by Water User Group.
* Computations are at the county level of detail, and although the county data show a surplus or shortage, there no doubt are individual water users of each county who have a shortage when the county shows an overall surplus; e.g., the projected surplus water is not located such that those who have shortages can obtain it.

5.3.21.1 The City of Denver City

5.3.21.1.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2022, at which time additional supplies will be needed.

5.3.21.1.2 Options Considered

Table 5-159 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Denver City.

Table 5-159.
Water Management Strategies Considered for the City of Denver City

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	1,949	$153,369[4]	$79[4]

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-7 and 5-160 for annual and unit costs for each decade.

5.3.21.1.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Denver City through 2050:

- Local groundwater development beginning in 2000 needed to supply an additional 1,949 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately 14 miles from the City of Denver City into which the city could locate new municipal water supply wells.

5.3.21.1.4 Costs

Costs of the recommended plan for the City of Denver City to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-7
   - Date to be Implemented: 2000
   - Total Project Cost: $4,939,748
   - Annual Cost: See Table 5-160 for a cost summary of this option.

Table 5-160.
Recommended Plan Costs by Decade for the City of Denver City

Plan Element	2000	2010	2020	2030	2040	2050
Local Groundwater Development						
Projected Shortage (acft/yr)[1]	-144	-156	-163	-1,633	-1,729	-1,856
Quantity Available (acft/yr)	213	192	1,934	2,154	1,940	1,949
Annual Cost ($/yr)	$284,763	$284,763	$428,847	$190,248	$190,248	$153,369
Unit Cost ($/acft)	$1,337	$1,483	$222	$88	$98	$79

[1] Includes additional municipal need for adjoining subdivision served by the City of Denver City.

5.3.21.2 City of Plains

5.3.21.2.1 Description of Supply

- **Source:** Ogallala Aquifer
- **Current Supply:** Adequate to meet demands until approximately 2019, at which time additional supplies will be needed.

5.3.21.2.2 Options Considered

Table 5-161 lists the water management strategies, references to the report section detailing the strategy, the project's annual cost, and unit costs that were considered for the City of Plains.

Table 5-161.
Water Management Strategies Considered for the City of Plains

Option	Yield (acft/yr)[1]	Approximate Cost[2]	
		Annual Cost[3]	Unit ($/acft)
Local Groundwater (Sec. 5.1.1)	606	$41,721[4]	$69[4]
Municipal Water Conservation (Sec. 5.1.7)	101		$9

[1] The project's estimated average yield in 2050, however, the project is sized to meet peak day demands.
[2] Costs are Annual Cost and Unit Cost ($/acft per year) for that particular water user group. Unit cost is for full utilization of project capacity.
[3] Includes debt service at 6% annual interest for 30 years.
[4] Cost is for 2050. See Tables 5-21 and 5-162 for annual and unit costs for each decade.

5.3.21.2.3 Water Supply Plan

Working within the planning criteria established by the Llano Estacado RWPG and TWDB, the following water supply plan is recommended to meet the projected shortages of the City of Plains through 2050:

- Local groundwater development beginning in 2012 needed to supply an additional 606 acft/yr in 2050. There appears to be adequate saturated thickness of the Ogallala Aquifer approximately three miles from the City of Plains into which the city could locate new municipal water supply wells.

5.3.21.2.4 Costs

Costs of the recommended plan for the City of Plains to meet 2050 shortages are:

a. Local groundwater development (See Section 5.1.1 for scheduling and a cost summary of this option):
   - Cost Source: Section 5.1.1, Table 5-21
   - Date to be Implemented: 2012
   - Total Project Cost: $982,916
   - Annual Cost: See Table 5-162 for a cost summary of this option.

Table 5-162.
Recommended Plan Costs by Decade for the City of Plains

Plan Element	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*
Local Groundwater Development						
Projected Shortage (acft/yr)	0	0	-457	-477	-486	-501
Quantity Available (acft/yr)	0	0	830	748	674	606
Annual Cost ($/yr)	-	-	$113,129	$113,129	$113,129	$41,721
Unit Cost ($/acft)	-	-	$136	$151	$168	$69

5.3.22 Water Supply Plans for Major Water Providers

Table 5-163 lists each Major Water Provider identified by the Llano Estacado RWPG and their corresponding surplus or shortage in years 2030 and 2050. There are no projected shortages for any of the Major Water Providers within the Llano Estacado Region, and consequently, no recommended water management plans are needed for the Major Water Providers within the Llano Estacado Region.

Table 5-163.
Major Water Provider Surplus/Shortage

Water User Group	Surplus/Shortage[1]		Comment
	2030 (acft/yr)	2050 (acft/yr)	
Canadian River Municipal Water Authority (CRMWA)	13,723	14,386	Projected surplus
White River Municipal Water District (WRMWD)	2,341	2,448	Projected surplus
Mackenzie Municipal Water Authority (MMWA)	2,962	3,000	Projected surplus

[1] From Table 4-23, Section 4.2 – Water Needs Projections by Major Water Provider.

5.3.23 Region-Wide Water Management Strategies Included in the Llano Estacado Water Plan

5.3.23.1 Interconnect Cities and Feedlots (Water from Region A) (See Section 5.1.2 for a description of this option)

Near the end of this planning effort, an alternative conceptual region-wide type of water supply alternative was identified, in which groundwater would be obtained from counties of Region A to the north, and piped to cities and feedlots in a large area of the Llano Estacado Region. This option includes the construction of a regional pipeline that could potentially serve many cities in the western part of the Llano Estacado Region that are currently projected to have needs during the 50-year planning period. Interconnecting cities and feedlots with water supplied from Region A is included in the Llano Estacado Regional Water Plan. Feedlots can be customers of publicly operated water systems. The quantity of water of this option is 59,200 acft/yr at an average cost of $681 per acft or $2.09 per 1,000 gallons.

5.3.23.2 Precipitation Enhancement (See Section 5.1.3 for a description of this option)

Weather modification is included in the Llano Estacado Regional Water Plan. Weather modification, or precipitation enhancement, has the potential to increase the quantity of water that would be available to all water user groups in the Llano Estacado Region, as well as reduce pumpage requirements from the Ogallala Aquifer. Several cloud seeding operations are already underway in Texas, including the High Plains Underground Water Conservation District's (HPUWCD) operation in the Llano Estacado Region.

Annual precipitation in the area seeded by the High Plains UWCD's project was estimated to have been 1.47 to 1.97 inches more in 1997 and 1999, respectively, than the 1945 through 1997 long-term average of 18.29 inches. Although available data and cloud seeding experience are not adequate to give reliable estimates of long-term increases in precipitation, the present information indicates that precipitation can be increased by cloud seeding. For the 20,294 square mile (12,988,160-acre) Llano Estacado Planning Region, an increase in precipitation of one and one-half inches would result in an increase of about 1,623,520 acft of water per year to the land surface. At a cost of 7.2 cents per acre, the cost per acft of water is $0.57.

Additional precipitation during the growing season, which is the period during which present cloud seeding projects are operated, would directly and immediately benefit dryland and irrigated agriculture. Crop and grazing yields will be increased, irrigation water pumped from the Ogallala Aquifer can be reduced, and lawn irrigation can be reduced. The latter effect will contribute to meeting projected municipal water needs by reducing the quantities used per year from present supplies. Additionally, increased runoff could increase the water supply in public water supply reservoirs. An increase of water supply in playa lakes would increase natural recharge and provide water for wildlife.

5.3.23.3 Brush Control (See Section 5.1.4 for a description of this option)

Brush control is included in the Llano Estacado Regional Water Plan. Brush control could increase water supply in the Llano Estacado Region by increasing the runoff into lakes and reservoirs. The areas of the region where significant concentrations of brush occur are in the east "caprock counties" and in the western counties. In addition, there are approximately one million acres in the U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) located within the region. As the current contracts with USDA expire on these CRP areas and as the USDA programs change, some of the land may be returned to cultivated row crops; however, some of the land is expected to remain in grass. If these grassland acres are not managed to prevent brush infestation, these areas could become brush covered and thereby further contribute to the brush problem of the region.

Of the 21 counties in the region, 13 counties meet the condition of having 50,000 or more acres of mesquite and shinnery oak combined. The counties located in the southwest corner of the region and along the caprock have the highest acreages of mesquite and shinnery oak and would primarily be the locations where brush control can be applied to increase water supplies. As has been demonstrated in Crosby County on the White River Reservoir watershed, brush control can contribute to increased inflows to a reservoir. The existing Alan Henry Reservoir and the proposed Post Reservoir are located in Garza County, which has over 185,000 acres of mesquite and shinnery oak. Brush control projects on the watersheds of these two reservoirs could result in increased firm yields and thereby contribute to the region's water supply.

The capital outlay to implement brush control upon 50 percent of the mesquite and shinnery oak infested acres in counties having more than 50,000 acres of these two species of brush is estimated at $39.2 million, with an annual cost of $2.55 million (see Section 5.1.4 for a detailed discussion on costing assumptions and procedures). For example, if brush control were to be implemented on the Alan Henry Reservoir contributing watershed, the annual cost would be approximately $300,625. If the yield of the reservoir were increased by 10 percent, or 2,900 acft/yr, the cost per acft of raw water yield at the reservoir would be $104, or $0.31 per thousand gallons. The owners of the Alan Henry Reservoir and the proposed Post Reservoir should cooperate with the landowners of the watersheds and the Texas State Soil and Water Conservation Board to implement brush control on these watersheds.

5.3.23.4 Desalt Brackish Groundwater (See Section 5.1.5 for a description of this option)

Desalting brackish groundwater is included in the Llano Estacado Regional Water Plan. The potential source of water for this option is the Santa Rosa Aquifer of the Dockum Formation, which underlies the entire area of the Llano Estacado Water Planning Region. Data currently available indicate that the quality of water in the Santa Rosa in the majority of the planning region is unsuitable for most uses without treatment, including most municipal and irrigation uses. Water treatment costs are estimated at $281 to $342 per acft, depending upon brine concentration of the feedwater. Individual cities that need water could consider this source.

5.3.23.5 Use of Reclaimed Water (See Section 5.1.6 for a description of this option)

Use of reclaimed water is included in the Llano Estacado Regional Water Plan. Reclaimed water is treated municipal and feedlot wastewater. This reclaimed water can be used for non-potable purposes as a replacement for potable water supply. Examples of the reuse of reclaimed municipal wastewater includes the irrigation of golf courses and other public lands, and irrigation of agricultural land near to or adjacent to the town or city from which the effluent is obtained. In the Llano Estacado Region, the primary use of reclaimed municipal wastewater is to irrigate farmland. Reclaimed feedlot wastewater is also used in this way. The irrigating entity or entities using the reclaimed water are, in effect, adding a new source of water supply to their existing supplies. In the Llano Estacado Region approximately 95 percent of all the water obtained from the Ogallala Aquifer is used for irrigation purposes. By substituting water pumped from the Ogallala Aquifer with reclaimed water, the amount of groundwater withdrawal can be decreased.

5.3.23.6 Municipal Water Conservation (See Section 5.1.7 for a description of this option)

Municipal water conservation is included in the Llano Estacado Regional Water Plan. Municipal water is freshwater that meets drinking water standards. Such water is supplied by both public and private utilities. The objective of the municipal water conservation option is to reduce per capita water use without adversely affecting the quality of life of the people involved. The potentials for additional municipal water conservation in the Llano Estacado Region are about 2,000 acft/yr or 2.2 percent of the projected 2050 municipal demand. Although the potential is modest, it is very important that municipal water conservation continue to be emphasized through active public information and education programs in the public schools, through the media, and at the individual water utility levels. With respect to the latter, it is suggested that each water utility of the region measure its water distribution system leaks and unaccounted for water and set goals to bring this parameter into the 12 to 15 percent range. **In addition, during droughts municipalities are expected to follow their respective Demand Management and Drought Contingency Plans and to practice additional water conservation, if needed.**

5.3.23.7 Irrigation Water Conservation (See Section 5.1.8 for a description of this option)

Irrigation water conservation is included in the Llano Estacado Regional Water Plan (see the individual county sections). The goal of this option is to bring the number of acres irrigated by Low Energy Precision Application (LEPA) and Low Pressure Sprinkler (LESA) systems to 95 percent of the total irrigated acres for each county within the Llano Estacado Region. In 1998, six counties (Cochran, Dawson, Gaines, Motley, Terry, and Yoakum) had irrigation with center pivot systems of 95 percent or greater. If each county in the Llano Estacado Region increased its use of center pivot (LEPA or LESA) systems to 95 percent of the total irrigated acreage, an additional 716,925 acres would be irrigated with these systems instead of other irrigation methods, resulting in approximately 355,451 acft/yr of irrigation water savings due to lower irrigation water application rates.

5.3.23.8 Agricultural Water Conservation Practices on Farms (See Section 5.1.9 for a description of this option)

Agricultural water conservation practices on farms are included in the Llano Estacado Regional Water Plan in order to sustain the present water supplies, enhance agricultural profitability, and enhance playa basins for wildlife habitat and aquifer recharge. In the Llano Estacado Region, both irrigation and non-irrigated, or dryland farming is projected. For the most part, the irrigated acreages are those acres lying above saturated sections of the Ogallala Formation that have sufficient quantities of water to justify drilling, equipping, and pumping irrigation wells. Such wells supply water that is used to supplement precipitation for crop production.

Irrigated and dryland farming attempt to maximize the efficiency of use of irrigation water and precipitation in the area. This is done through the use of Low Energy Precision Application (LEPA) and Low Pressure Sprinkler (LESA) irrigation systems, furrow diking, plant residue management, bench leveling, and terracing.

5.3.23.9 Recovery of Capillary Water (See Section 5.1.10 for a description of this option)

Recovery of capillary water is included in the Llano Estacado Regional Water Plan. Capillary water is the water that is retained in the formation by capillary forces following gravity drainage. Capillary forces are the result of the molecular attraction between formation particles and water. The method of recovery is air injection into the dewatered layers of the aquifer through specially designed wells. The injected air causes capillary water to move to the water table and become available to wells.

5.3.23.10 Cistern Well Construction (See Section 5.1.11 for a description of this option)

Cistern well construction is included in the Llano Estacado Regional Water Plan. A cistern well is a well that can produce a small quantity of water for domestic and/or range livestock use in areas where the saturated thickness of the Ogallala Formation or alluvium are thin, or the formation will not yield large enough quantities of water to support a pump and/or a windmill. Water from the saturated layers of the formation drain into a cistern constructed in the bottom of the well and can be pumped out as needed.

5.3.23.11 Post Reservoir (See Section 5.1.12 for a description of this option)

Post Reservoir is included in the Llano Estacado Regional Water Plan. The proposed Post Reservoir Project is located on the North Fork of the Double Mountain Fork of the Brazos River northeast of Post, Texas in Garza County. Post Reservoir could serve as a future water supply source for cities and industries in the eastern part of the planning area. The firm yield of Post Reservoir is 9,500 acft/yr. The cost of raw water at the reservoir is $214 per acft.

5.3.23.12 Research and Development of Drought Tolerant Crops and New Technology (See Section 5.1.13 for a description of this option)

Both public and private agricultural research organizations are presently engaged in plant crop breeding, plant nutrition, and cultural practices to improve the productivity, quality, and other characteristics of crops that can be produced in the Llano Estacado and other regions of Texas, the United States, and other countries of the world. The Llano Estacado Regional Water Planning Group recommends that funding be continued at adequate levels for research and development of new and improved technology in the fields of drought tolerant strains of crops, new or alternative crops for arid and semiarid regions, plant nutrition, irrigation application methods, brush control, weather modification, aquifer recharge, and development of better information about the aquifers and other water resources of the region.

5.3.23.13 Interconnect Cities, Industries, and Feedlots (Alan Henry and Post) (See Section 5.2.1 for a description of this option)

Interconnecting cities, industries, and feedlots from water supplies at Lake Alan Henry and Post Reservoir is included in the Llano Estacado Regional Water Supply Plan. This option would include the construction of a pipeline from Lake Alan Henry, which has a firm yield of 29,900 acft/yr, to the City of Lubbock. A second pipeline would also be constructed from the proposed Post Reservoir, which would have a firm yield of approximately 9,500 acft/yr, and tie into the pipeline from Lake Alan Henry to Lubbock. The treated water could be utilized by the City of Lubbock as an additional source, or the city could sell this water to its existing customers or new customers within the Lubbock general area. This pipeline could be interconnected with the Mackenzie Municipal Water Authority distribution line and/or the White River Municipal Water District distribution line. The cost per acft of this option including cost for the water is $594 per acft, or $1.82 per 1,000 gallons.

5.3.23.14 Reuse of Municipal Effluent for Potable Water Supply (See Section 5.2.3 for a description of this option)

Of the total quantities of water used for municipal purposes, approximately 45 percent to 65 percent is returned to the respective municipal wastewater treatment plants for treatment and disposal. In the Llano Estacado Water Planning Region a large percentage of this treated effluent or reclaimed water is used for irrigation of open spaces, golf courses, and neighboring farmland. The quantity is between 45 percent and 65 percent of the quantity of municipal use and can be a significant source of municipal water in the future, if treatment levels can be increased to the extent that the use of such water does not pose a health risk. The Llano Estacado Regional Water Planning Group recommends that funding be made available to universities, water districts, and the cities to further study the quantity of water available from this option and to study treatment technologies to make this option feasible.

5.3.23.15 Stormwater Capture, Treatment, and Use (See Section 5.2.4 for a description of this option)

In some cities of the Llano Estacado Water Planning Region disposal of stormwater has become a serious problem. Lubbock is one of the cities having this problem. Therefore, in this water-short region, it has become desirable to evaluate the possibility to capture, treat, and use this water as a source of supply for non-potable as well as potable uses. The Llano Estacado

Regional Water Planning Group recommends that funding be made available to the cities and water districts to further study the quantity of water available from this option and to study ways to successfully integrate flood protection, store this stormwater, and treat this water for useful purposes.

5.3.24 Public Education

Underground water conservation districts, cities, universities, the Texas Agricultural Extension Service and other water agencies will continue existing education and information dissemination programs. In addition, Llano Estacado Region water suppliers and agencies will build a strong cooperative relationship with formal and informal educators including the region's Educational Service Centers and Independent School Districts.

5.4 Drought and Drought Response

Water supplies are included in Section 3 of the Llano Estacado Regional Water Plan as firm yields during drought of record for surface water sources, and dependable supplies during drought of record for groundwater sources, i.e., drought of record conditions underlie the calculations of water supply available from each source, included in Section 3 for each water user group. Therefore, each source of supply is for drought conditions. In addition, in accordance with requirements of SB 1, TNRCC has required retail water suppliers to prepare drought contingency plans. However, Texas Water Code Section 16.053(e)(3)(A) and 31 TAC 357.5(e)(7) require that for each source of water supply in the regional water planning area designated in accordance with 31 TAC 357.7(a)(1), the regional water plan shall identify: (A) factors specific to each source of water supply to be considered in determining whether to initiate a drought response, and (B) actions to be taken as part of the response.

Given that the major source of water for all uses in the Llano Estacado Region is the Ogallala Aquifer, with surface water from the Canadian River Municipal Water Authority, White River Municipal Water District, and Mackenzie Municipal Water Authority, for some municipal and industrial uses, the effects of drought are through increased demands upon the water supply facilities to provide larger quantities of water from each water supply source. For example, in the region, demands increase during droughts, placing ever-greater demands upon wells, pumps, motors, storage facilities, and the aquifer and surface water reservoirs. Therefore, the primary factor specific to each water supply is atmosphere conditions affecting precipitation, evaporation, and evapotranspiration. Thus, when atmospheric conditions result in: (1) reduced precipitation and (2) increased evaporation and evapotranspiration, the Llano Estacado Regional Water Plan recommendation is that drought response be initiated as described below.

Drought Trigger Conditions will be based on local atmospheric conditions using the currently available PET stations. For the purposes of this planning cycle, it is recommended that local precipitation be factored into the consideration of implementing a drought trigger. Recommended drought triggers are presented as follows.

5.4.1 Drought Triggers

Alert Stage of Drought: Precipitation at less than 50 percent of the 30 year average for the month and 55 percent of the 30 year average of the preceding twelve months.

Warning Stage of Drought: Precipitation at less than 25 percent of the 30 year average for the month and 45 percent of the 30 year average of the preceding twelve months.

The Llano Estacado Water Planning Area will be divided into geographical areas based on location of existing PET stations for drought trigger and response purposes. The current locations of a PET stations within Region O are Dimmitt, Earth, Farwell, Halfway, Lamesa, Lubbock, and Seminole.

The drought trigger and response zones in the Llano Estacado Water Planning Area are as follows:

Table 5-164
Drought Trigger and Response Zones
in the Llano Estacado Water Planning Area

PET Stations	*Counties*
Dimmitt	Castro, Deaf Smith, and Swisher
Earth	Cochran and Lamb
Farwell	Bailey and Parmer
Halfway	Briscoe, Floyd, Hale, and Motley
Lamesa	Dawson, Garza, and Lynn
Lubbock	Crosby, Dickens, Hockley, and Lubbock
Seminole	Gaines, Terry, and Yoakum

5.4.2 Drought Response

As the LERWPG is a planning body only, with no implementation authority, it is emphasized that these drought triggers and responses are recommendations only. Since local public water suppliers and water districts are all required to have adopted a Drought Contingency Plan that contains drought responses unique to each specific entity, these entities are the only ones who have the authority to manage their particular water supply or area of authority. Therefore, the LERWPG recommends that these entities carry out their respective plans based upon the triggers listed above.

For example:

When the Alert Stage Drought Conditions have been triggered as described above, the (RELEVANT BODY, COMMITTEE, ETC.) will notify all affected entities in the relevant geographical area. Those entities exercise their authority to implement their own Drought Contingency Plans, as they deem necessary.

When the Warning Stage Drought Conditions have been triggered as described above, the (RELEVANT BODY, COMMITTEE, ETC.) will notify all affected entities in the relevant geographical area. These entities exercise their authority to implement their own Drought Contingency Plans, as they deem necessary.

Section 6
Recommendations

6.1 Legislative Recommendations

1. The Llano Estacado Regional Water Planning Group urges the Legislature to continue the regional water planning effort with adequate funding to:

   a. Pay the administrative costs associated with the regional water planning effort;

   b. Pay for the collection, assimilation, and analysis of basic data needed to assess the ground and surface water resources of each planning region of the state to a 90 percent accuracy level;

   c. Pay for the development and maintenance of a basic data network adequate to maintain a current inventory of the ground and surface water resources of the state;

   d. Pay for development and maintenance of computer models which will utilize the data described in "b" and "c" above to quantify the groundwater resources in each aquifer in the state and project future availability based on historical net changes in storage (i.e., the average annual net change in storage that occurred during the past 10 years, plus any known increases in water use or decrease in water use that may be achieved through conservation efforts). This should provide a reasonably accurate glimpse of future water availability when used in the model projections. Using net depletion eliminates the need to use estimates of pumpage and natural recharge, neither of which are well documented and can easily be over or under estimated; and

   e. Pay for costs associated with on-going efforts to educate the public about the regional water planning process, water management strategies, and conservation needed within the 16 respective water planning regions.

2. The Planning Group concurs with the Legislature that underground water conservation districts should be the preferred method of managing groundwater in the State of Texas.

3. The Planning Group supports the creation and operation of underground water conservation districts that are organized and function under Chapter 36 of the Texas Water Code.

4. The Planning Group supports the Rule of Capture as modified by the Rules and Regulations of existent underground water conservation districts, provided in those areas of the state where underground water conservation districts have not been created and/or are not functional, the Planning Group supports a modification to the Rule of Capture, which can be achieved by requiring spacing of wells from property lines based on limiting production to a level that the cone of depression will not extend beneath a neighbor's property line after 90 days of continuous pumping.

5. The Planning Group recommends that the Legislature remove all Chapter 36 mandated exceptions related to permitting and production limitations of water wells within underground water conservation districts.

6. The Planning Group does not support a transport fee for surface or groundwater transported within the State of Texas.

7. The Planning Group recommends a modification of the SB1 restrictions on TWDB financing and TNRCC permitting to include "alternative water management strategies," provided that the alternatives are developed under the same evaluation criteria as selected strategies and the alternatives are included in the RWPG's adopted regional water plan.

8. The Planning Group recommends that the Legislature make it very clear to all Texans that the boundaries of the regional water planning regions were drawn only to define water planning regions and that the boundaries are not intended to be barriers to prevent water transport from one region to another – not to pit one region against another for any reason.

9. The Planning Group supports the creation of underground water conservation districts or surface water conservation districts in all areas of the State of Texas currently designated priority groundwater/surface water areas.

10. The Planning Group recommends that the Legislature provide adequate funding for the implementation of water management strategies in the plan, including loans for public water supplies, precipitation enhancement, brush management, water conservation, and research and development of drought tolerant species and more efficient irrigation technology.

6.2 Identification of Unique Ecological Stream Segments and Reservoir Sites

The Texas Parks and Wildlife Department identified three stream segments in the Llano Estacado Region that it has classified as ecologically significant. Two pass through Caprock Canyons State Park in Briscoe County. They are: (1) North Prong Little Red River, and (2) South Prong Little Red River. The third is Prairie Dog Town Fork Red River from SH 70 crossing at the Briscoe/Hall County line upstream to the Briscoe/Armstrong County line.

The Llano Estacado Regional Water Planning Group did not identify any unique ecological stream segments or reservoir sites in the region.

Section 7
Regional Plan Adoption

7.1 Public Involvement Program

Public involvement was started at the beginning of the Llano Estacado regional water planning process in order to provide ample opportunity for public input into the process of developing the water plan, as well as opportunity to review and comment upon the Initially Prepared Regional Water Plan. For the past 2 years, the High Plains Underground Water Conservation District has provided information to the public about the proposed Llano Estacado Regional Water Management Plan. The public information activities are described and listed below.

The Llano Estacado Regional Water Management Plan web site (www.llanoplan.org) is the primary source of information. This site contains a brief explanation of the Senate Bill 1 water planning process; regional water plan meeting agendas; minutes from all regular and committee meetings (1998-2000); articles about the water plan as published in the Water District's monthly newsletter, *The Cross Section*; a map of the regional water planning area; the complete draft Llano Estacado Regional Water plan in PDF format for viewing by the public; and a listing of all water planning group members and committees. The site has received more than 650 hits since May 1, 2000.

In addition, High Plains Underground Water District staff members have written and distributed news released to media within the region about the water plan and information contained within it. For example, news releases were written about the number of center pivots in operation within the water planning region, the small town and city water assessment studies, and the water planning group meetings. Also, a series of news releases were written which discussed the amount of water needed to produce one unit of the various agricultural commodities produced in the region and the consumer products derived from that product.

High Plains Water District staff members have also given numerous presentations about the draft plan's content to civic clubs and professional groups. District staff have also spent many hours answering public inquiries about the plan during the past 2 years.

The public involvement program included duly noticed public meetings, news releases, articles in the Cross Section, and presentations at public meetings. A listing of the public participation and public information activities is given below.

A public hearing on the scope of work was held at Lubbock, Texas on June 18, 1998. There were no public comments.

The following news releases about the Llano Estacado Regional Water Management Plan were distributed to media organizations within the 21-county region:

December 17, 1997	11 named to initial Region O Water Planning Group.
April 28, 1998	Passage of SB1 affects water management in planning area.
June 1998	Public invited to comment on draft regional water management plan (scope of work).
January 6, 1999	Advance on quarterly LERWPG meeting.
April 22, 1999	Agricultural water use benefits consumers (beef) Agricultural water use benefits consumers (corn) Agricultural water use benefits consumers (cotton) Agricultural water use benefits consumers (peanuts) Agricultural water use benefits consumers (sorghum) Agricultural water use benefits consumers (soybeans) Agricultural water use benefits consumers (wheat)
May 5, 1999	14,620 center pivots in operation within LERWPG.
February 29, 2000	Small town water assessment study completed.
May 8, 2000	LERWPG web site now available for public access.
July 12, 2000	Advance on monthly LERWPG meeting.
August 9, 2000	Advance on monthly LERWPG meeting.
August 22, 2000	Public hearing scheduled for initially-prepared Llano Estacado water plan
August 22, 2000	Draft water plan available on LERWPG web site.
October 3, 2000	Llano Estacado Regional Water Plan presented during public hearing.
November 6, 2000	Planning group considers draft tasks for second water planning cycle.

The following articles about the Llano Estacado Regional Water Management Plan were published in the *Cross Section:* a monthly publication of the High Plains Underground Water Conservation District No. 1:

January 1998	Nominations accepted for initial water planning group members.
March 1998	Region O begins initial water planning effort
May 1998	Senate Bill 1 impacts statewide water resource development/management
June 1998	Public invited to comment on proposed water management plan
September 1998	Group faces challenge in developing regional water plan
January 1999	Advance notice of January 21 LERWPG meeting
May 1999	Small town water assessment studies completed
July 1999	Group evaluates ground water reserves

	Precipitation largest reoccurring/renewable water supply
August 1999	16,420 center pivot sprinklers in operation within LERWPG area
September 1999	Group reviews TWDB water use projection data
October 1999	Total water demand projections compared to available supply
December 1999	Significant natural recharge can occur in LERWPG in wet years
	Wildlife industries important to area economy (Jim Steiert article)
January 2000	Organic matter important to soils of LERWPG
June 2000	Cistern well construction discussed
July 2000	Groundwater purchase/transfer via pipeline included as LERWPG strategy
September 2000	September 26 hearing to discuss draft water plan
October 2000	Llano Estacado Regional Water Plan overview presented at hearing
November 2000	Secondary recovery of capillary water considered as water plan strategy

The following interviews and presentations about the Llano Estacado Regional Water Management Plan were given by members of the staff of The High Plains Underground Water Conservation District No.1 during 2000:

January 17, 2000	Interview on AG ED (Carmon McCain, host and Ken Carver, guest)
February 7, 2000	Interview on AG ED (Carmon McCain, host)
February 9, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain)
March 8, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain)
March 13, 2000	Interview with Tony St. James of KFLP Radio in Floydada (Carmon McCain)
May 3, 2000	Interview on AG ED (Carmon McCain, host and Wayne Wyatt, guest)
May 8, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain)
June 20, 2000	Plainview Optimist Club meeting (Carmon McCain)
July 11, 2000	Water Issues workshop for teachers at Texas Tech University (Carmon McCain)
July 12, 2000	Interview with Tony St. James of KFLP Radio in Floydada (Carmon McCain)
August 7, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain and Comer Tuck)
August 14, 2000	Interview on AG ED (Wayne Wyatt)
September 7, 2000	Interview with Latha Garcia of KLLL Radio (Wayne Wyatt)
September 8, 2000	Interview on AG ED (Wayne Wyatt and Carmon McCain)
September 11, 2000	Meeting with Lubbock Avalanche Journal editorial board (Wayne Wyatt, Carmon McCain, Bo Brown)

September 13, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain)
September 13, 2000	Presentation at "Evenings with ED-ucation" workshop (Carmon McCain)
September 21, 2000	Interview on AG ED (Wayne Wyatt, Herb Grubb, Stefan Schuster, and Carmon McCain)
October 30, 2000	Interview on AG ED (Wayne Wyatt)
November 3, 2000	Muleshoe Lions Club meeting (Carmon McCain)
November 4, 2000	Radio interview with Tony St. James (Carmon McCain)
November 8, 2000	Update at Lubbock Chamber of Commerce, Agricultural Committee Meeting (Carmon McCain)
November 11, 2000	Presentation at Texas Farmer-Stockman Show (Comer Tuck)
November 20, 2000	Levelland Evening Lions Club meeting (Carmon McCain)

Presentations were made at the following Meetings to Explain the SB-1 regional water planning concept, process, and progress:

Date	Location	Association	Attendance
01/27/1998	Dimmitt	Texas Corn Growers Annual Meeting	100
02/17/1998	Lubbock	With Sonny Kretzschmar - "Big Ed" Radio Show	
02/23/1998	Lubbock	American Society of Agronomy	150
02/27/1998	Lubbock	Water Resources Center/Advisory Board of Directors Meeting	25
03/08/1998	Amarillo	USDA-SCS Meeting	30
03/12/1998	Lubbock	Ogallala Symposium	150
03/19/1998	Dimmitt	Castro County Farm Bureau	80
03/24/1998	Lubbock	Coordinating Board Meeting	25
03/26/1998	Lubbock	"Big Ed" Radio Show	
04/16/1998	Lubbock	SB-1 Planning Meeting	25
04/20/1998	Lubbock	Grad School - Texas Tech	15
05/13/1998	Lubbock	South Plains Electric Co-op Board Meeting	35
05/26/1998	Lubbock	Llano Estacado Regional Water Plan Group	60

06/10/1998	Dickens	Dickens/Motley Counties S&WCD Boards	12
06/17/1998	Lubbock	"Big Ed" Radio Show	

Grant Approved/Regional Planning Members Appointed/Regular Meetings Begun

06/18/1998	Lubbock	Ag Committee discussion	8
06/18/1998	Lubbock	Llano Estacado Regional Planning Group Meeting	60
06/18/1998	Lubbock	Public Hearing	55
06/18/1998	Lubbock	Ag Committee discussion	8
07/15/1998	Lubbock	Scope of Work Committee	12
07/16/1998	Lubbock	Scope of Work Committee Meeting	12
07/16/1998	Lubbock	Llano Estacado Regional Planning Group	60
07/22/1998	Lubbock	Scope of Work, Technical Committee Meeting	12
07/24/1998	Lubbock	Scope of Work Committee	12
07/27/1998	Lubbock	Scope of Work Committee	12
07/28/1998	Lubbock	Llano Estacado Regional Planning Group	12
07/31/1998	Lubbock	Finance Committee	10
08/13/1998	Lubbock	Ag Committee	8
08/13/1998	Lubbock	Regional Water Planning Group Meeting	60
08/13/1998	Lubbock	Finance Committee	6
08/25/1998	Lubbock	Finance Committee, Regional Water Plan	6
08/28/1998	Lubbock	Revised Scope of Work Committee	15
08/28/1998	Lubbock	Regional Water Planning Group Meeting	31
09/23/1998	Lubbock	Scope of Work Committee (no quorum)	6
10/09/1998	Lubbock	Scope of Work/Executive Committees	10

10/15/1998	Austin	Regional Chairs Meeting	50
10/19/1998	Lubbock	“Big Ed” Radio Program	
10/22/1998	Lubbock	Scope of Work/Executive Committees	8
10/22/1998	Lubbock	Regional Water Planning Group Meeting	60
12/15/1998	Tahoka	Lynn/Garza SWCD Meeting	40
12/22/1998	Lubbock	“Big Ed” Radio Program	
01/13/1999	Lubbock	“Big Ed” Radio Program	
01/14/1999	Lubbock	Region O Executive Committee Meeting	10
01/21/1999	Lubbock	Region O Planning Group, Plus Public	60
01/28/1999	Lubbock	Lubbock Area Realtors and Appraisers Meeting	60
02/17/1999	Lubbock	Regional Soil and Water Conservation District Meeting	120
02/18/1999	Lubbock	Llano Estacado Agri. Committee Meeting	16
03/12/1999	Lubbock	Market Lubbock/Economic Development Committee Meeting	25
03/29/1999	Lubbock	Agri. Meeting - Agricultural Experiment Station	30
03/31/1999	Lubbock	Partners With Producers Meeting	25
04/01/1999	Lubbock	Lubbock Chamber of Commerce, Agri. Committee	50
04/20/1999	Lubbock	TAEX Center, County Extension Agents	35
04/22/1999	Lubbock	Llano Estacado Environmental Committee	6
04/22/1999	Lubbock	Llano Estacado Regional Water Planning Meeting	50-60
04/29/1999	Lubbock	TAEX Meeting	10
05/27/1999	Lubbock	Plains Cotton Oil - first public required meeting on Plan	40-60
06/03/1999	Lubbock	Region O Technical Committee Meeting	15

06/09/1999	Lubbock	Texas Tech Ag Economics Seminar	30
06/10/1999	Lubbock	Texas Public Works Association	250
06/17/1999	Lubbock	Region O Technical Committee Meeting	15
07/20/1999	Lubbock	Region O Technical Committee Meeting	15
07/22/1999	Lubbock	Region O Planning Group Meeting	60
07/24/1999	Lubbock	Agri. Committee discussion	8
07/28/1999	Lubbock	Region O Technical Committee	10
08/11/1999	Lubbock	Region O Technical Committee	12
08/12/1999	Lubbock	TALL (Texas A&M-Texas Adult Lifetime Leaders)	25
08/13/1999	Lubbock	Agri. Committee, Lubbock Chamber of Commerce	30-50
08/19/1999	Dimmitt	Dimmitt Presentation	30
09/03/1999	Lubbock	Clements Corporation Stockholders	50
09/10/1999	Lubbock	Lubbock Chamber of Commerce Ag Committee	50
09/21/1999	Lubbock	Grain Sorghum Producers Board Meeting	30
09/30/1999	Lubbock	Brandon & Clark Electric Employees Association	50
10/11/1999	Lubbock	Unity in Agriculture Conference	50
10/21/1999	Lubbock	Llano Estacado Regional Planning Meeting	60
10/27/1999	Lubbock	Ag/Environmental/Small Business Committees	25
11/01/1999	Brownfield	Water Districts Committee	6
11/11/1999	Lubbock	Deaf Smith County Extension Serv. Exe. Board	30
11/17/1999	Lubbock	Lubbock Rotary Club, Downtown Chapter	100+
11/17/1999	Lubbock	Lubbock County Soil and Water Conservation District Board	7
12/10/1999	Lubbock	Lubbock Rotary Club, Hub City Chapter	30

12/17/1999	Lubbock	Ag Committee Meeting (Planning Group)	15
12/17/1999	Lubbock	Llano Estacado Regional Planning Group Meeting	60
01/05/2000	Lubbock	KLBK Interview	

Presentations Regarding Region O Water Planning in 2000

01/19/2000	Lubbock	Llano Estacado Regional Water Planning Group Technical Committee	11
01/20/2000	Lubbock	Llano Estacado Regional Water Planning Group	36
01/25/2000	Dimmitt/Castro/Bailey/Parmer Counties	Elected Officials/Water District County Committees and Spouses/County Secretaries	24
02/01/2000	Canyon/Randall/Counties Armstrong/Potter/Deaf Smith Counties	Elected Officials and Spouses/Water District County Committees	36
02/04/2000	Lubbock	Llano Estacado Regional Water Planning Group Agri/Environmental/Small Business Committees	17
02/17/2000	Lubbock	Llano Estacado Regional Water Planning Group	33
02/18/2000	Lubbock	Interview News Media (Channel 13 TV)	
03/16/2000	Lubbock	Llano Estacado Regional Water Planning Group Environmental Committee	8
03/16/2000	Lubbock	Llano Estacado Regional Water Planning Group	31
03/21/2000	Lubbock	Llano Estacado Regional Water Planning Group Executive Committee Meeting	8
04/20/2000	Lubbock	Llano Estacado Regional Water Planning Group	34
05/05/2000	Amarillo	Panhandle Grain and Feed Association Meeting	60
05/11/2000	Lubbock	American State Bank Directors	40
05/18/2000	Lubbock	Llano Estacado Regional Water Planning Group	33

06/01/2000	Hereford	Radio Live Broadcast	
06/15/2000	Lubbock	Llano Estacado Regional Water Planning Group	44
07/10/2000	Hale Center	Hale Center City Council	30
07/14/2000	Lubbock	Llano Estacado Regional water Planning Group Technical Committee	10
07/20/2000	Lubbock	Llano Estacado Regional Water Planning Group	37
07/21/2000	Amarillo	American Quarter Horse Association	40
08/03/2000	Lubbock	Texas Vo Ag Teachers Association Annual Meeting	850
08/11/2000	Lubbock	Llano Estacado Regional Water Planning Group Executive Committee	7
08/14/2000	Lubbock	"Ag Ed" Radio Program	
08/15/2000	Canyon	Panhandle Livestock Feeders	35
08/17/2000	Lubbock	Llano Estacado Regional Water Planning Group Ag Committee	19
08/17/2000	Lubbock	Llano Estacado Regional Water Planning Group	35
09/01/2000	Lubbock	Clements Corporation Stockholders	50
09/08/2000	Lubbock	"Ag Ed" Radio Program	
09/11/2000	Lubbock	A-J Editorial Board	5
09/14/2000	Lubbock	A-J Interview	
09/19/2000	Amarillo	Panhandle Water Planning Group, Region A	
09/21/2000	Lubbock	County Judges/Commissioners	35
09/26/2000	Lubbock	Llano Estacado Regional Water Planning Group	24
09/26/2000	Lubbock	Llano Estacado Regional Water Planning Group Public Hearing on Water Plan	150
10/01/2000	Lubbock	Texas Farmer-Stockman Show	11

10/09/2000	Lubbock	Second Baptist Church Natural Resources Forum	60
10/27/2000	Lubbock	Public Officials Forum	40
10/30/2000	Lubbock	“Ag Ed” Radio Program	
11/13/2000	Lubbock	Work Tasks & Response to Comments Committees	12
11/15/2000	Lubbock	Llano Estacado Regional Water Planning Group	32
11/16/2000	Plainview	Caprock Water Distributors Association	50
11/29/2000	Dimmitt	Livestock Feeders	50+
12/07/2000	Lubbock	Mayors/City Managers/Public Utility Directors	65+

A total of 126 informational and public meetings were held where presentations were made or meetings were hosted and conducted by the regional chair person.

Notices of all public meetings were duly posted.

7.2 Data Gathering and Coordination with Water Supply Entities

An informational mailing was made to all identified public water systems within the region. The mailout introduced the Senate Bill 1 water planning process to these systems and provided information on the planning process, the Llano Estacado Regional Water Planning Group, the means for obtaining public input, and a schedule of the major work tasks to be accomplished.

A survey was mailed to designated community water systems in the region (approximately 78) to verify and augment existing data contained in the TWDB and TNRCC databases regarding population, water source, and interconnection with other systems. The survey included information regarding current water supply, water supply planning, growth projections and service area.

7.3 Informational Mailouts to Water Supply Entities

Mailings were made to 36 cities. The water supply analyses of estimated quantities of water remaining in each city’s well fields, projected demands, estimated dates at which additional supplies will be needed, and saturated thickness maps of the Ogallala Aquifer in the vicinity of each city were sent to each city for the city's information and review. In addition, each city was sent a copy of the water plan for the city, in which a schedule of new wells and costs to obtain the water that is estimated to be needed were presented.

7.4 Llano Estacado Regional Water Planning Group Meetings

The Llano Estacado Regional Water Planning Group met quarterly during the first year of the project, and approximately once every month during the second year in order to facilitate and direct the water planning project for the region. Notices of all public meetings were duly posted.

7.5 Coordination with Other Regions and Counties of Region O

Notices of all public meetings were sent to representatives of all adjacent regional planning groups and to all who requested them. The LERWPG Chairman attended several meetings with the Region A RWPG and exchanged information on surface water supply and water management strategies. The Region O Consultant coordinated with the Region A Consultant in the preparation of Special Water Resource tables for reservoirs that supply water into Region O.

The Region O Consultant presented a detailed briefing to a special meeting of County officials of Region O to ensure maximum communication of planning results to counties of the region.

7.6 Texas Water Development Board Comments and LERWPG Responses

TWDB Preliminary Staff Comments
Region O Llano Estacado Regional Water Planning Group
Initially Prepared Plan (IPP)
October 13, 2000

SECTION 1: Comments that have to be satisfactorily addressed in order to meet statute, Texas Water Development Board Rules and the Regional Water Planning Contract.

1. According to TWDB contract Exhibit B, Part 1, Section 1.2 Initially Prepared and Adopted Regional Water Plan Outline, a task chapter entitled Plan Adoption (31 TAC 357.11-12) needs to be included. This chapter outlines the description of the public participation, facilitation, and plan implementation issues. Please note that this chapter must be included in the adopted plan.

   Section 7.0 Regional Water Plan Adoption is included in the Final Plan.

2. As stated in 31 TAC 357.7(a)(4), social and economic impacts of not meeting needs must be included in the adopted plan. Exhibit B Tables 9, Social and Economic Impacts of not Meeting Needs by Region, and Table 10, Social and Economic Impacts of not Meeting Needs by Basin, are not included in the IPP. Tables 9 and 10 need to be included in the adopted plan.

   The information of Exhibit B Tables 9 and 10 is included in the IPP and Final Plans, as follows:

Population	**Table 4-24**	**Pages 4-90 and 4-91**
School Enrollment	**Table 4-25**	**Pages 4-98 and 4-99**
Gross Business	**Table 4-26**	**Pages 4-104 and 4-105**
Employment	**Table 4-27**	**Pages 4-110 and 4-111**
Personal Income	**Table 4-28**	**Pages 4-116 and 4-117**

3. Texas Water Code Section 16.053(e)(3)(A) and 31 TAC 357.5(e)(7) require that for each source of water supply in the regional water planning area designated in accordance with 31 TAC 357.7(a)(1), the regional water plan shall identify: (A) factors specific to each source of water supply to be considered in determining whether to initiate a drought response, and (B) actions to be taken as part of the response. This information is not included in the IPP. Please consider this requirement to add clarity to your plan and to explicitly address the referenced Statute and rule.

   Subsection 5.4 Drought and Drought Response has been added.

4. 31 TAC §357.5 (d) requires that in developing regional water plans, regional water planning groups shall use state population and water demand projections contained in the state water

plan or those modified by the LERWPG and adopted by the TWDB. The water demand projections presented in Exhibit B Table 2 do not match the numbers adopted by the TWDB for the LERWPG on September 15, 1999. Please correct these discrepancies in order to meet the referenced rule.

In the LE Regional Plan, water demand for a new steam-electric power plant in Yoakum County in the amount of 2,200 acft/yr has been included, and in Swisher County 3 acft/yr was shifted from Tulia's municipal demand to industrial demand. A letter has been sent to the TWDB requesting approval of these water demand changes.

5. According to TWDB contract Exhibit B, Part 1, Section 1.7 Evaluation of Water Management Strategies, Table 13 entitled Recommended Management Strategies by Major Provider of Municipal and Manufacturing Water needs to be included. This table highlights the strategies implemented by MWP during drought of record conditions. Please note that this table must be included to meet the terms of the TWDB contract. If, however, there are no needs for the MWP, please provide a narrative explaining that there are no needs in the adopted plan.

   There are needs for one of the MWPs (Mackenzie Municipal Water Authority). Water supply strategies (use of water from the individual members own groundwater sources) have been used to meet the needs of each member, respectively) and Exhibit B Table 13 has been included. The water supplies available from Lake Mackenzie have been reduced from the "Officially Permitted" quantity of 5,200 acft/yr to 864 acft/yr, the latter being based upon the quantities that have been supplied since 1994. Changes have been made in the text of the Plan to explain these adjustments (See Page ES-12, Table 2-22 (Page 2-55), Page 4-84, Table 5-71 (Page 5-157), and Table 5-93 (Page 5-174).

6. 31 TAC §357.7(a)(7)(C) requires that in evaluating water management strategies, regional water planning groups shall evaluate a strategy for impacts on other water resources of the state including other water management strategies and groundwater surface water interrelationships. The evaluations provided in the IPP do not include the evaluation for impacts on other water resources of the state. Please include this information prior to submittal of the adopted plan.

   Evaluations were in the IPP and have been included in the Final Plan as follows;

Page	**Table**
5-33	**5-29**
5-39	**5-31**
5-42	**5-32**
5-50	**5-34**
5-64	**5-42**
5-76	**5-47**
5-83	**5-50**
5-103	**5-56**
5-116	**5-61**
5-124	**5-64**

7. 31 TAC §357.7(a)(7)(D) requires that in evaluating water management strategies, regional water planning groups shall evaluate a strategy for impacts on threats to agricultural and natural resources of the planning area. The evaluations provided in the IPP do not include the evaluation for impacts on agricultural and natural resources. Please include this information prior to submittal of the adopted plan.

   See response to number 6 above.

8. 31 TAC §357.7(a)(7)(F) requires that water management strategies must be evaluated based on an equitable comparison and consistent application of all water management strategies determined to be potentially feasible. Please indicate in the plan how this requirement was met.

   The following statement was added at the beginning of Section 5 on Page 5-1.

   > ***"The LERWPG believes that these procedures will, to the extent possible, meet water needs of water user groups of the region in an equitable and consistent manner."***

SECTION II: Comments/Suggestions for Improvements to the Regional Water Plan

1. 31 TAC §357.7(a)(1) requires that in developing regional water plans, regional water planning groups shall provide a description of the area to include a description of major water providers. The description of the area provided in the IPP does not include the information on major water providers. The information on MWP is only included in the Executive Summary and should also be included in Chapter 1. Please include this description prior to submittal of the adopted plan.

   Subsection 1.12 Major Providers of Municipal and Manufacturing Water was added to the text of the Regional Water Plan.

TWDB Partial Staff Comments
Region O – Llano Estacado Regional Water Planning Group
Initially Prepared Plan (IPP)
December 5, 2000

Section 1. Comments that have to be satisfactorily addressed in order to meet statute, Texas Water Development Board Rules and the Regional Water Planning Contract.

1. TWDB rules [31 TAC §357.5(d)] require regional water planning groups to use population and water demand projections contained in the state water plan or to use revisions approved by TWDB. The IPP submitted contains inconsistencies

with the adopted water demand use projections. Please correct the following inconsistencies. An electronic file named, Table_2_corrections, contains all necessary revisions to these discrepancies and has been forwarded to the political subdivision and consultant.

The changes were made.

2. TWDB rules [31 TAC §357.5(k)(1)(F)] require consideration of water availability requirements promulgated by a county commissioner's court. This item could not be found in the draft IPP. Please address this requirement by providing the referenced information or stating that such conditions do not exist.

   Section 1.10.4 entitled, "Water Availability Requirements Promulgated by County Commissioners Courts," was added.

3. TWDB rules [31 TAC §357.7(a)(1)] require a description of the identified threats to the agricultural and natural resources due to water quantity and quality problems. Discussions on page 1-61 in the submitted IPP do not address how regional water quantity problems may be caused by or are impacted by water quality issues. Please provide this information.

   Language addressing this comment was added.

4. TWDB rules [31 TAC §357.5(e)(4)] require the RWPG to provide specific recommendations of water management strategies based upon identification, analysis, and comparison of all strategies the group determines to be potentially feasible so that the **cost effective water management strategies which are environmentally sensitive are considered and pursued**, where appropriate. The current discussions of selected water management strategies in the submitted IPP do not address this comparison. Please provide this information.

   An explanation was added at the beginning of Section 5. In addition, in Section 5.3 where plans are shown to meet needs of individual water users, the options considered for each, are shown and comparisons of the costs of each are displayed.

5. TWDB rules [31 TAC §357.7(a)(7)(A)] require the evaluation of the quantity, reliability, and cost of water delivered and treated for the end user's requirements. On page 5-36, in Section 5.1.2.2, Available Supply, staff determined that the evaluation of the Hartley County Interconnect strategy does not adequately address the quantity and reliability of the strategy. Please complete the analysis to address these issues.

   Section 5.1.2.2 was expanded to address the comment.

6. TWDB rules [31 TAC §357.5(h)] requires that in developing the regional water plan, the RWPG shall protect the water rights, water supply contracts, and water supply option agreements to a Special Water Resource so that supplies obligated to meet demands outside the regional water planning area shall not be impacted. Any plans that could impact the water rights, water supply contracts, or water supply option agreements associated with this SWR shall be based only on potential adjustments to the water

rights, water supply contracts or option agreements by those entities holding interests in such water rights, water supply contract, or water supply option agreements. Any amendments would require eventual consent of the owner. In Section 5.1.2, Interconnect Cities and Feedlots, on page 5-34, there is inadequate information for staff to determine how the existing water rights, water supply contracts, or option agreements will be protected in the evaluation of the strategy. Please provide this information.

Language was added in Section 5.1.2 to address this comment.

7. Table 4-22, on page 4-83, lists Projected Demands, Supplies, and Needs for the LERWPA. Table 4-22 is inconsistent with Table 4-24, on page 4-91, which shows different values for needs for Municipalities for the planning period. Please correct this inconsistency.

   Table 4-22 shows the algebraic sum of demands, supplies and needs (shortages) for the region. Table 4-24 shows only the sum of the needs (shortages) of the individual water user groups that have needs (shortages). The two are distinctly different. However, a section was added to Table 4-22 to show the needs (shortages) by water user group for the region.

8. Item 3F, on page 5, of the scope of work delineates the contractor to discuss 'the laws of physics which control water well yields from the saturated sections of the Ogallala, Cretaceous, and Dockum formations and clearly illustrate to the ground water users why and how much water well yields are likely to change as the water table declines'. This information could not be located in the draft IPP. Please provide the missing information.

   A new Section 1.11 "Laws of Physics which Affect Water Well Yields--Described and Illustrated for the Ogallala, Dokum, and Cretaceous Formation in the Llano Estacado Regional Water Planning Area" was added.

EXECUTIVE SUMMARY

9. On page ES-11, in the 1st paragraph, the report states: "Overall, water use in this sector is expected to decline by 20.4% by 2050.." The calculation is incorrect and should be a decline of 61% (11,824/30,383 acre-feet = 0.39). Please correct this statement in the Executive Summary.

   The correction was made.

10. On page ES-11, in the 3rd paragraph, the report states that total Livestock water use in 1990 was 34,492 acre-feet. The correct value for 1990 should be 36,492 acre-feet. Please correct this statement in the Executive Summary.

    The correction was made.

CHAPTER 1

11. On page 1-51, Section 1.6.3.1, the firm yield of Lake Meredith is listed as 74,350 acre-feet/year. On page 3-2, in Section 3.2.1, the projected firm yield of Lake Meredith in the year 2000 is listed as 76,000 acre-feet/year. Please provide a correct and consistent value of the firm yield for Lake Meredith.

The correction was made.

CHAPTER 2

12. On page 2-14, in the 3rd paragraph, the report states: "Overall, water use in this sector is expected to decline by 20.4% by 2050.." The calculation is incorrect and should be a decline of 61% (11,824/30,383 acre-feet = 0.39). Please correct this statement.

The correction was made.

Section 2. Comments/Suggestions for improvement to the Regional Water Plan.

CHAPTER 5

13. Beginning on page 5-73 with Table 5-158 and continuing through page 5-152 with Table 5-221, there are 13 municipalities that have "Water Management Strategies Considered" to meet their needs that include the Hartley County Regional Pipeline. Although all needs for these municipalities are expected to be met through local groundwater supplies, the presentation of the pipeline as a strategy is misleading to the reader. Please consider removing the pipeline from these tables in order to provide a clear distinction of the strategies available to these municipalities at this time.

The RWPG does not feel that this would be appropriate, and consequently the suggested change was not made. For example, the tables in which the pipeline is included show the strategies that were considered to meet each need (shortage), respectively. The plans to meet the needs (shortages) are shown in the following table for the water user, and in no case is the pipeline chosen because it is a higher cost option.

14. On page 5-71, in the 1st paragraph, it states: '….pumping 600 gpm from the Santa Rosa Aquifer, with a transmissivity of 22,000 gpd/sf…….' The unit for the transmissivity should be gallons for day per foot (gpd/f). Please consider making this correction.

Typo was corrected.

7.7 Public Comments and LERWPG Responses

Issue 1 : Public/Private Partnership Regional Plan Supplied with Water from Hartley and/or Roberts Counties.

Comments:

CRMWA:

- References to CRMWA system and resources is being made in advance of coordination with CRMWA and its members.

City of Lubbock: Conceptual project presents infrastructure problems for Lubbock:

- Existing CRMWA and Bailey County pipelines are at full capacity during peak demands. Need additional pipeline capacity.
- Lubbock is willing to explore development of regional supply system. With condition that plan would not increase costs to Lubbock ratepayers.

League of Women Voters of Lubbock:

- This is mining Region A groundwater to meet shortages within the next 50 years, without consideration for use beyond 2050.
- Include a water balance assessment for Region A.
- Option should be balanced by recharge.
- Concerned that if supplier is private entity, there will be less concern for water prices and pumping rates, particularly during drought.

Responses:

- Informal, preliminary communication has been done with Amarillo, Lubbock, CRMWA, cities, and feedlots showing water needs (shortages). Discussions are continuing in order to determine interest of those who would be customers. Implementation would be pursued only if sufficient interest is shown and tentative commitments are obtained. Overall objective is to develop mutually beneficial plan to all participants without increasing costs to present CRMWA members . Water from Roberts County, representing the Mesa Option is a part of the Public/Private Partnership concept.
- Public/Private Partnership Regional Plan (Section 5.1.2) does not include a description of all of the assumptions underlying the proposed option. The assumptions are as follows, and will be included in the final plan:
- The source of water will be from beneath rangeland or other lands that are not capable of being irrigated.
- Withdrawal rates would be within Region A’s water supply management strategy of not using more than 50 percent of current saturated thickness during the 2000—2050 period.
- All well permits would be subject to local district rules.

Issue __2__: Inclusion of Nursery and Landscape Growers in Definition of Agriculture

Comments:

Texas Nursery and Landscape Association:

- Requests that definition of agriculture include floriculture and horticulture products.

Responses:

- Irrigation water demands include these uses to the extent that water use data were reported to the TWDB. In the case of nursery types of establishments that obtain water as commercial customers of municipal systems, municipal water demands include water for these purposes.
- By virtue of this comment, the LERWPG assumes that TWDB is notified of the request.

Issue __3__: Control of Drilling Wells and Building Dams on Private Property.

Comments:

James A Davidson:

- Opposes control by water districts of drilling wells and building dams on one's own land.
- Do not disturb the Rule of Capture in Texas.

Texas Farm Bureau:

- Opposed to removing exemptions for groundwater wells under Section 36.117 of the Texas Water Code.

Responses:

- The Plan supports certain modifications of underground water district law to extend permitting of wells to those now exempt in order to be able to protect those and neighboring wells from contamination and from competition with each other for water.

Issue __4__: Transport Fees for Surface and Groundwater

Comments:

Texas Farm Bureau:

- Supports transport fees to mitigate harm to local areas from which water would be obtained.

City of Lubbock:

- Supports Plan's position on transport fees (Opposes transport fees).
- Groundwater districts should be supported by taxes to insure local fiscal accountability.
- Export and surcharge fees are punitive to water rights holders.
- Opposes legislation to assess monthly tap fees to be collected by municipalities to fund state water programs.

Responses:

- In the case of surface water, under Texas water planning directives, only surface (state) water that is surplus to the needs of the basin of origin can be considered for transfer to areas of need, thus, the need to mitigate is obviated.
- In the case of groundwater, which is private property, subject to the Rule of Capture, as modified through the creation of underground water conservation districts, the LERWPG believes that each landowner of a district is subject to district rules, and that transport fees discriminate against those landowners who choose to sell their water directly instead of through sale of a commodity produced with the water.
- The LERWP has not addressed monthly tap fees to fund state water programs.
- No changes were made in the recommendations.

Issue 5 : Aquifer Contamination

Comments:

City of Levelland:

- Northwest of the City, the Ogallala is contaminated with petroleum refinery products. The plume is moving toward the City's wells.
- Area has been added to EPA Superfund list.
- Without cleanup, Levelland may need replacement supplies, which can be obtained by bringing pipeline from Lubbock's Bailey County pipeline, or expanding capacity of Lubbock to Levelland CRMWA pipeline.

League of Women Voters of Lubbock:

- Historically, West Texas has witnessed localized groundwater quality deterioration near military facilities, underground storage tanks, oilfield facilities, and confined animal feeding operations.

Responses:

- Levelland's comment is well taken, and noted in the plan in a footnote on page 5-2, and in Table 5-113 on page 5-190.

- Levelland's needs could be met from the regional Public/Private Partnership strategy described on page 5-34, or by addition of capacity of existing pipelines, as mentioned in Levelland's comment.
- There have been incidents as mentioned by the League of Women Voters, with the exception of confined animal feeding operations. Although there could be potential for contamination of the aquifer, to date there is no evidence that contamination has occurred from properly designed, constructed, and maintained feedlots. Results from a recent study conducted by Texas A&M University, Texas Tech University, and the High Plains Underground Water Conservation District involving beef and dairy operations support earlier views that the Randall Clay playas and other properly constructed retention ponds can be used for feedlot waste runoff/storage without posing a significant contamination threat to the underlying groundwater. However, caution needs to be observed around the coarser-textured playa rim, because this area is a more permeable zone, where deeper leaching of soluble nutrients may occur. At the conclusion of the study, it was determined that most accumulations occurred in the top foot of the playa soil surface. Nitrate was the nutrient that leached most. Its maximum concentrations in the top 5 feet of soil were, on average, about 65 parts per million (ppm) reported as N. At no location was there evidence that appreciable nitrate had penetrated the playa bottom proper below 10 feet, indicating no aquifer contamination associated with any of the feedlots (See Plan page 1-60).
- The LERWPG supports the TNRCC's waste discharge permitting, monitoring, and enforcement of waste discharge permits, which appears to be protecting the quality of water resources of the Llano Estacado planning region.

Issue 6 : Water supply available from Mackenzie Municipal Water Authority (MMWA)

Comments:

Mackenzie Municipal Water Authority:

- Requests a change in statement on page ES-12 regarding a surplus of water available from Lake Mackenzie for 4 member cities of MMWA. Reports that that Lake is 80 percent below capacity, and that water allocations have been reduced by 60 percent since 1994.
- Lockney, Tulia, and Silverton should be shown as inadequate water supply; Floydada has adequate supply without water from the Lake.
- Suggests the following be added to the plan;
- Install a raw water line from existing Lake Meredith pipeline to the water treatment plant at Lake Mackenzie.
- Install a treated water line from Tulia to Happy and Kress, allowing MMWA to supply its 4 members and these 2 adjoining communities in Swisher County.

City of Tulia:

- Explains that statement on page ES-12 regarding a surplus of water from Lake Mackenzie is inaccurate, that MMWA has reduced by 60 percent the quantity of water it can supply its member cities since 1994, that Tulia uses water from MMWA only 2 or 3 days per week, and relies on own wells remainder of the time.
- Tulia has 4 wells in Ogallala contaminated with atrazine, 2 of which have been removed from service and TNRCC recommending other 2 be removed.
- City is planning to drill an additional well into the Santa Rosa to replace capacity losses of Ogallala Wells.

Responses:

- Corrections have been made to the tabular analyses of the MMWA and its member cities, as follows; The water supplies available from Lake Mackenzie have been reduced from the "Officially Permitted" quantity of 5,200 acft/yr to 864 acft/yr, the latter being based upon the quantities that have been supplied since 1994. Changes have been made in the text of the Plan to explain these changes (See Page ES-12, Table 2-22 (Page 2-55), Page 4-84, Table 5-71 (Page 5-157), and Table 5-93 (Page 5-174).
- Water needs of each MMWA city are projected to be met from supplies available from Lake Mackenzie at levels of recent years, as follows: Tulia---417 acft/yr, Floydada---212 acft/yr, Lockney---150 acft/yr, and Silverton--- 85 acft/yr, with the remainder being met from each city's present groundwater sources, with the exception of Lockney, which will need to obtain additional groundwater. In the case of Lockney, cost estimates have been made for the additional supplies needed (See Tables 5-17 and 5-94).
- The Public/Private Partnership Regional Plan supplied with water from Hartley and/or Roberts Counties, if implemented, would afford the opportunity to extend raw water lines from the existing pipeline from Lake Meredith to the Lake Mackenzie water treatment plant, with distribution of treated water to MMWA members and others, as needed.

Issue 7 : Roberts and Hartley County Water to Other Areas

Comments:

Dan W. Slaughter:

- Don't let Roberts and Hartley County water be sent to San Antonio.

Bill Rich:

- References news articles of Mesa Water, Inc.'s interest in selling water to other areas. Ogallala is in recession and the water is needed for agriculture in the area.

Responses:

- LEWRPG has no authority to deal with this issue. However, the Llano Estacado Plan includes a Public/Private Partnership option to obtain Hartley or Roberts County water for the Llano Estacado Region (See Page 5-34).

Issue __8__: Public Education and Information

Comments:

Richard Leonard:

- Llano Estacado Plan does not, but should include an education component.

City of Lubbock:

- Supports the role of education to achieve water conservation goals.

Judy A. Reeves, Ph.D.

- Supports water education programs in elementary and secondary science programs.

League of Women Voters of Lubbock

- Supports stronger emphasis and commitment to public education programs on water conservation and protection of our limited water resources.

Responses:

- The Plan has been modified to include Subsection 5.3.23.16 Public Education (Page 5-236).

Issue __9__: Laws of Physics which Affect Water Well Yields

Comments:

James P. Mitchell:

- Scope of work includes Task 3 F, Laws of Physics which control water well yields is not included in the Plan.

Responses:

- Subsection 1.11, page 1-93, which addresses this Task is now included in the plan.

Issue __10__: Water for Agriculture

Comments:

Susan Combs, Commissioner of Agriculture:

- Pleased to be ex-officio member of RWPG.
- Since agriculture is so important to the region, pleased to see Plan includes agriculture water as top priority.
- Pleased to see strategies to meet agricultural shortages.
  - Conservation and increased efficiency.
  - Precipitation enhancement.
  - Brush management.
  - Research and development of drought tolerant crops and new technology.
- Recommends including requests for funding of strategies in legislative recommendations.

Responses:

- LERWPG is pleased to have TDA as ex-officio member of RWPG.
- A funding recommendation has been added (See page 6-2).

Issue __11__: Motley County

Comments:

Lavernia M. Price, County Judge:

- Motley County is not considered in the Plan.
- Local supply is very limited.
- Please include Motley County in the Plan.

Responses:

- Although data for Motley and other eastern counties of the region are not as complete as for counties of the groundwater conservation districts, these counties were considered and, to the extent data are available, were treated in the same manner as all other counties of the region.
- As required by TWDB Rules, data supplied by the TWDB for Motley County are included in the tables of population, water demands, and water supplies.
- A comparison of projected future water demands and available data about water supplies do not show that the county, as a whole, has shortages. However, individual water users located within the county no doubt do, or will have shortages (See Table 5-141, page 5-212).

Issue __12__:Water Demand for Livestock

Comments:

League of Women Voters of Lubbock:

- Are current livestock water use data based upon actual consumption, or maximum number of head currently permitted?
- Does projected increase reflect additional permitted facilities?

Responses:

- Current figures are actual consumption.
- The increase is for increases in numbers that can be accommodated by expansion of existing facilities plus projected new facilities.

Issue __13__: Reuse of Municipal Effluent for Potable Supply

Comments:

League of Women Voters of Lubbock:

- Supports the reuse of municipal effluent for potable supply.
- Supports funding for water treatment research to implement this strategy.

Responses:

- The LERWPG appreciates the support.

Issue __14__: Playa Recharge and Subsurface Hydrogeology of Southern High Plains

Comments:

League of Women Voters of Lubbock:

- Supports research funding to better understand Playa Recharge and Subsurface Hydrogeology of Southern High Plains.
- Thorough understanding of aquifer replenishment is critical to water planning.

Responses:

- The TWDB GAMS program is expected to address these issues to the extent that data are available. Additional funding can be considered as that program progresses and the needs are better defined.

Issue __15__: Development and Maintenance of Computer Models

Comments:

League of Women Voters of Lubbock:

- Planning Group recommends adequate funding to develop groundwater models.
- Plan contains a section entitled, "Groundwater Modeling for the Southern High Plains," and thereby indicates that a MODFLO Computer model was developed.
- League of Women Voters of Lubbock finds it disconcerting that RWPG is requesting additional funds for models.
- Available computer model should be incorporated into the Plan.

Judy A. Reeves, Ph.D:

- Supports use of the Texas Tech groundwater model to project water supply and demands for the region.

Responses:

- One of the reasons the results of the Texas Tech Ogallala model are not used as the water supply data for the planning process is a matter of timing. The groundwater availability data was needed fairly early in the planning process, as this data was needed to compare with the projected demand data to identify water supply needs by the various water user groups. After the needs were identified, water management strategies had to be identified and then fully evaluated. All of this had to be drafted, reviewed, and approved in time to have a draft plan for public review by early August 2000. In fact, the draft model report was not available until mid-August, barely in time for it to be included as an attachment to the Plan. Because of the timing, the LERWPG approved groundwater availability based on a continued specific decline in saturated thickness for those counties with declines in the base period and a constant level of saturated thickness for those counties with constant levels or increases in saturated thickness during the base period. This method was approved by the Planning Group.
- The results of the Texas Tech model analyses for 4 levels of withdrawals were summarized and included in the water supply analyses section of the plan.
- The Texas Water Development Board has already begun a process to fund development of a new Groundwater Availability Model (GAM) for the Southern Ogallala Aquifer, which will be available to the LERWPG. Several of the proposals for this study indicated that the new Tech Model would be evaluated, expanded, and improved for use in the new GAM. Therefore, the current effort and expenditures may be utilized. The results of the new GAM for the Southern Ogallala Aquifer can be utilized in the planned 2005 update of the LERWPG Regional Water Plan. In the meantime, the data in the current Plan and the Tech Ogallala Model are both available to those who may wish to study the data and make any additional specific water supply studies.

Issue 16 : Federal Agency Comments

Comments:

U. S. Fish and Wildlife Service:

1. Plan contains comprehensive outline of future water demands.
2. Plan does not contain sufficient information for USFWS to consider site specific impacts on fish and wildlife resources.
3. Plan is too extensive for USFWS to provide detailed comments on all sections.
4. USFWS focused on parts of the Plan with highest likelihood of positive or negative effects on fish and wildlife resources.
5. USFWS offers assistance in early planning stages of projects in determining potential effects of individual projects.
6. USFWS reviews projects requiring Section 404 permits.
7. USFWS applauds Texas for SB1.
8. The Public/Private Partnership project to interconnect cities and feedlots has potential to reduce flows to the Canadian River and could result in violation of Section 9 of the ESA (Endangered Species Act) for the Arkansas River shiner and interior least tern.
9. Two candidate species (lesser prairie chicken, and black tailed prairie dog) could be affected by the water supply projects of the Plan.
10. The Plan should recognize the need for appropriate instream flows for fish and wildlife as beneficial uses.
11. The Plan should identify conservation measures to ensure protection of quantity and quality of aquatic habitats of the region.
12. USFWS commends water conservation of the Plan, and urges it to be included in local plans.
13. Drought management plans should include measures for environmental purposes.
14. USFWS has reservations about brush control. Has potential negative effects for aquatic and terrestrial habitats. Requests opportunity to review specific brush control projects.
15. Any specific water project will require environmental review, and may require consultation with USFWS.
16. Repeats---Get USFWS involved early in planning each project.

Responses:

- With respect to comments 1 through 6, it is expected that when individual entities are ready to implement individual projects, each will be planned, and permit applications will be prepared at that time.
- The LERWPG acknowledges USFWS's comment No. 7.
- Regarding comments Nos. 8 and 9, these issues will be addressed at the permit application stages of implementation. That level of detail is not possible in this planning effort.
- Regarding comments Nos. 10 and 11, the only water management strategy that directly involves instream and aquatic habitats is the Post Reservoir and associated interconnect system. The instream flow and aquatic habitat issues will be addressed at the time of permitting.

- Local water suppliers do include water conservation, which the Regional Planning Group encourages and fully supports(comment 12).
- With respect to including measures for environmental purposes in drought management plans, the LERWPG notes this recommendation, and in the case of playas and other surface water sources, recognizes the need, and has included an atmospheric factor in its Drought and Drought Response part (Subsection 5.4) of the plan (comment 13).
- With respect to comment 14 regarding brush management, the Plan includes provisions to design brush management projects in accordance with principles and procedures to protect and enhance wildlife habitat. Coordination and review of proposed projects is to be done by The Texas State Soil and Water Conservation Board, Texas Parks and Wildlife Department, and federal agencies, as appropriate.
- Regarding comments 15 and 16, in the implementation sections of the water management strategies, a statement is included regarding the need for the implementing agency or entity to obtain state and federal permits. At this stage of Plan implementation the necessary permit applications, and associated conferences are expected to be held.
- The LERWPG disagrees with the USFWS' position that the pipeline project will violate Section 9 of the ESA for the Arkansan River shiner and interior least tern or affect the lesser prairie chicken and black tailed prairie dog. The LERWPG also disagrees that properly implemented brush control has potential negative effects for aquatic and terrestial habitats. However, LERWPG is committed to working with USFWS to resolve these concerns.

Issue __17__: National Wildlife Federation (NWF)

Comments:

1. The National Wildlife Federation (NWF) states that it reviewed and commented according to its "Principles for an Environmentally Sound Regional Water Plan" that NWF forwarded to each member of the Region O Planning Group via letter dated August 7, 2000.
2. NWF is concerned that regional water plans are approaching environmental water needs as an afterthought, as opposed to a true need for water, and that the Region O Plan does not contain any substantive discussion of the amount of flow needed to meet environmental water needs in rivers and streams.
3. NWF understands that Region O has never had an abundance of surface flows, but that there have been a number of spring-fed streams in the area in the past, as documented in *"Springs of Texas."*
4. Past mining of groundwater has dried up many of the springs, leaving the remainder even more important. Information is needed about trends in spring flows and expected trends for the levels of the aquifers that feed the springs.
5. NWF believes that water conservation must be a keystone of water planning, and commends the Plan's attention to water conservation to meet irrigation needs, but urges the strategy be applied to all user groups.
6. NWF commends the inclusion of suggestions for protecting playas, but finds the Plan deficient in its treatment of springs and species that depend upon flowing water.

7. Environmental flows in streams and rivers are an issue of particular importance in the region since surface flows are so rare. However, NWF was unable to locate any substantive discussion of those needs or of the impacts on environmental flows of the strategies considered
8. Information provided about Post Reservoir is inadequate to allow informed decision about this strategy, as follows;
   - Impacts of the Post Reservoir on environmental flows of streams, and aquatic resources.
   - No information on existing habitat of Post Reservoir site.
   - This option nor the associated proposed interconnect are not named to meet a specific water need.
9. The absence of recommendations regarding streams of unique ecological value is disappointing, since The Texas Parks and Wildlife Department has identified a limited number of segments in the Region that would potentially qualify for such designation.
10. The draft plan presents a very mixed message with respect to municipal water conservation.
    - The importance of municipal water conservation is discussed.
    - Additional municipal water conservation is not included as a water management strategy.
11. In order to plan for protecting the natural resources of the area the Plan must assess the effect of current water development projects and existing permits on relevant environmental flows (See NWF Principles).The Plan makes no attempt to assess the degree to which flows needed for fish and wildlife resources in rivers and streams have been impaired by existing water development projects.
12. Discussion of the Public/Private Partnership Regional Plan with water supplied from Hartley and/or Roberts Counties is incomplete with respect to :
    - Trends in aquifer levels from where water is to be obtained.
    - Long term effects of pumping on water availability.
    - Long term implications for agriculture and natural resources.
    - Information of effects upon springs.
    - Implications upon the counties of origin.
    - No information on willingness and abilities of feedlots to pay the unit costs of the strategy.
13. Inadequate discussion of environmental implications of water importation from White River in Arkansas. Protection of White River is major NWF priority.
14. NWF appreciates the recognition of municipal water conservation, notes the wide variation in per capita water use rates among cities, and essentially urges that the Planning Group to specify conservation measures and drought management triggers to be applied throughout the Region.
15. NWF cites the cities of Dimmitt, Morton, Whiteface, Hereford, Seagraves, Earth, Olton, Sudan, Farwell, Friona, and Plains, listed in Table 5-54 of the Plan as having per capita water use rates that are too high, and should be reduced through water conservation.
16. The brush control option should be limited to specific locations where significant benefits to water supply are likely, and should be done with the environmental constraints discussed in Section 5.1.4.

17. The environmental implications of desalt brackish water not adequately considered:

- Disposal of brine concentrate, in user's wastewater.
- Identification of cities to consider desalt.
- TDS of wastewater and fate of wastewater.

18. A complete evaluation of environmental water needs should be done in order for the Planning Group to complete a comprehensive review of the water situation.

- More information is needed about impacts on spring flows and surface flows.
- A clearer picture of the predicted effect of plan implementation on water levels of the aquifers would be helpful.
- More information is needed to assess what the recommendations in the Plan portend for future generations.

<u>Responses:</u>
Responses are numbered and presented in the numbered order of the comments summarized above.

1. The LERWPG had no knowledge of NWF's water planning principles, and has no record of having received the document mentioned. However, in any event the LERWPG was bound to follow SB1, TWDB Rules, and Texas Law in preparation of the Regional Plan.
2. The basic principle underlying the SB1 water planning process is to address instream needs when considering surface water options before any water management strategy considers the use of those stream flows for other purposes. Since the only surface water strategy in the Plan is Post Reservoir and the associated interconnect system, that was the only opportunity to address instream needs. Since this is a long term strategy for consideration after 2030, instream needs and other environmental issues will be considered in future plans and at the time permits are being sought.

3 At the present time, there is practically no evidence of springs except in very wet weather cycles. Thus, there are no data with which to address this comment, except to say that the regional description notes known springs, and gives their locations.

4. The water supply analysis of Section 3 provides estimates of net water depletion in each county, and voluminous files of water level contour maps are available in the offices of the underground water conservation districts.
5. Water conservation is included in the plan for all user groups.
6. See responses numbers 4 and 5.
7. Inasmuch as there are practically no surface water flows in the Region, there is no opportunity to discuss them.
8. See response number 2.
9. Texas Parks and Wildlife Department did not provide a list of streams in Region O.
10. Both municipal and agricultural water conservation are included in the Regional Plan (See Sections 5.3.23.6 and 5.3.23.7).
11. See response Numbers 3 and 4 above. TWDB Rules nor scopes of work authorized the analyses mentioned in comment Number 11.
12. Informal, preliminary communication has been done with Amarillo, Lubbock, CRMWA, cities, and feedlots showing water needs. Discussions are continuing in order to determine interest of those who would be customers. Implementation would be pursued

only if sufficient interest is shown and tentative commitments are obtained. The overall objective is to develop a mutually beneficial plan to all participants without increasing costs to present CRMWA members. The assumptions used in the present description of this strategy are as follows, and will be included in the final plan:

- The source of water will be from beneath rangeland or other lands that are not capable of being irrigated.
- Withdrawal rates would be within Region A's water supply management strategy of not using more than 50 percent of current saturated thickness during the 2000—2050 period. These rates have been established so as to mitigate effects upon springs of the counties from which water would be obtained.
- All well permits would be subject to local district rules.

13. Importation of water from the White River in Arkansas is not included as a selected strategy in the Plan. However, the extensive environmental assessment of the management option is referenced in the option analysis in Section 5.2.2.3.
14. Per capita water use rates of cities of the Region vary widely, and are recognized as being unique to each city by both the TWDB and the LERWPG. In fact, per capita water use rates are determined by the characteristics of each water system with respect to age of the system, building codes of each city, and tastes and preferences of the people who live within each city. Thus the recommendation that the LERWPG establish conservation measures to be applied throughout the region is akin to making "one size fit all." The LERWPG has included a description of water conservation measures available to each city and water supply entity (See Section 5.1.7). In addition, Drought Triggers have been included in new Subsection 5.4.
15. The cities listed as having per capita water use rates that are "Too High," with the exception of Hereford, are those that have been identified in Table 5-54 of the plan as having conservation potentials, with the potentials calculated and tabulated in Table 5-54. NWF has not fully understood the table and the text which accompanies it. Hereford was not included in the list because its per capita data were only slightly higher than the level at which additional conservation appears to be feasible and significant.
16. The LERWPG agrees with this comment, and refers to Sections 5.3.23.3 and 5.1.4 where the principles expressed in the comment are presented.
17. Desalt of brackish groundwater is included in the Plan as a potential source of supply for those cities having little if any other source of supply. The comment is well taken. Each case will have to be evaluated on its own merits if and when there is interest in implementation. The present planning effort was hampered by lack of data about available supplies of brackish groundwater.
18. The LERWPG believes that it has complied with requirements of SB1 and TWDB Rules with regard to this comment (See responses Numbers 1, 2, 3, 4,and 5).

Issue __18___: Texas Parks and Wildlife Department

<u>Comments:</u>

1. In the Region O Plan, emphasis has been placed upon water management strategies that increase efficiency of water use, and augment supplies through precipitation

enhancement and brush management in order to sustain the Region's groundwater supplies as far into the future as possible. There strategies could have fairly small environmental effects. However, the Post Reservoir could affect downstream surface water, including instream uses, aquatic and riparian habitat, and water quality.

2. While not a recommended option, water importation from Texas, Oklahoma, and Arkansas could have considerable environmental implications.
3. The effects of previous decline of groundwater levels on springs, surface water, and associated habitats is missing.
4. Water demand projections in the plan do not match TWDB projections ans for several municipalities seem high. Realistic per capita use is needed, and it is not unrealistic to assume that water use technology will change in the future.
5. The Plan includes a good discussion on brush control, but brush control should only be used where the water benefit is high, and related soil and habitat losses are small.
6. The Plan fails to mention ecologically important stream segments. TPWD identified 3 stream segments in the region that are ecologically significant. Two pass through Caprock Canyons State Park in Briscoe County. They are: (1) North Prong Little Red River and (2) South Prong Little Red River. The third is Prairie Dog Town Fork Red River from SH 70 crossing at the Briscoe/Hall County line upstream to the Briscoe/Armstrong County line.

Responses:

Responses are presented below in the order of the comments; e.g.; the number of the response is to the comment with the same number, as listed above.

1. The LERWPG acknowledges that TPWD has understood a principle objective of the Plan. The only water management strategy that directly involves instream and aquatic habitats is the Post Reservoir and associated interconnect system. The instream flow and aquatic habitat issues will be addressed at the time of permitting. It was not possible to The effects of decline of groundwater levels on springs, surface water, and associated habitats perform a permitting level of analysis for the plan.
2. Importation of water from Texas, Oklahoma, and Arkansas is not included as a selected strategy in the Plan. However, the extensive environmental assessment of the management option is referenced in the option analysis in Section 5.2.2.3.
3. The effects of previous decline of groundwater levels on springs, surface water, and associated habitats are not included in the scope of work for water plan development.
4. The water demand projections used in the plan are those provided by the TWDB. The point about levels of per capita water use is well taken, and the plan identifies municipalities that are encouraged to implement water conservation programs to reduce them.
5. The LERWPG concurs with this comment, and agrees fully.
6. The LERWPG has been laboring under the impression that no such listing had been made for Region O. This is the first time that this information has been presented to the LERWPG. Thus, it is too late to give attention to this comment.

7.8 Final Plan Adoption

The LERWGP held a public hearing in Lubbock, Texas on September 26, 2000 and gathered written comments submitted by various individuals and organizations as well as public agencies, including the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department. The TWDB reviewed the IPP and sent two letters of comments and questions. The TWDB comments, together with LERWPG responses are included in Section 7.5. A summary of public comments and RWPG responses are presented in Section 7.6. In response to the comments, revisions were made to the Initially Prepared Plan (IPP). The Llano Estacado Regional Water Planning Group formally approved the revised Llano Estacado Regional Water Plan on January 3, 2001.

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Appendix A

Threatened, Endangered, and Rare Species of the Llano Estacado Region

TABLE 1
THREATENED, ENDANGERED, AND RARE SPECIES OF THE LLANO ESTACADO REGION

Common Name	Scientific Name	Habitat Preference
Baird's Sparrow	*Ammodramus bairdii*	Shortgrass prairie with scattered low bushes and matted vegetation
Bald Eagle	*Haliaeetus leucocephalus*	Found primarily near seacoasts, rivers, and large lakes; nests in tall tree or on cliffs near water; communally roosts, especially in winter; hunts live prey, scavenges, and pirates food from other birds
Ferruginous Hawk	*Buteo regalis*	Open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers
Interior Least Tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars within braided streams and rivers; known to nest on man-made structures as well
Lesser Prairie Chicken	*Tympanuchus pallidicinctus*	Arid grasslands, generally interspersed with shrubs and dwarf trees; nests in a scrape lined with grasses
Mountain Plover	*Charadrius montanus*	Breeding: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous
Snowy Plover	*Charadrius alexandrinus*	Formerly an uncommon breeder in the Panhandle; potential migrant
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows
Whooping Crane	*Grus americana*	Potential migrant
Black-footed Ferret	*Mustela nigripes*	Considered extirpated in Texas; potential inhabitant of any prairie dog towns in the general area
Cave Myotis Bat	*Myotis velifer*	Colonial and cave-dwelling; also roosts in rock crevices, old buildings, carports, under bridges, and even in abandoned Cliff Swallow (*Hirundo pyrrhonota*) nests; roosts in clusters of up to thousands of individuals; hibernates in limestone caves of Edwards Plateau and gypsum cave of Panhandle during winter; opportunistic insectivore
Jones' Pocket Gopher	*Geomys knoxjonesi*	Southwestern plains of Texas; deep sandy soils of aeolian origin; small isolated population vulnerable to land use changes
Palo Duro Mouse	*Peromyscus truei comanche*	Rocky, juniper-mesquite-covered slopes of steep-walled canyons of the eastern edge of the Llano Estacado; juniper woodlands in canyon country of the panhandle; primarily nocturnal
Plains Spotted Skunk	*Spilogale putorius interrupta*	Open fields, prairies, croplands, fence rows, farmyards, forest edges, and woodlands; prefers wooded, brushy areas and tallgrass prairie
Swift Fox	*Vulpes velox*	Restricted to current and historical shortgrass prairie; western and northern portions of Panhandle
Texas Garter Snake	*Thamnophis sirtalis annectens*	Wet or moist microhabitats are conducive to the species occurrence, but is not necessarily restricted to them; hibernates underground or in or under surface cover; breeds March-August

TABLE 1 (CONTINUED)
THREATENED, ENDANGERED, AND RARE SPECIES OF THE LLANO ESTACADO REGION

Common Name	Scientific Name	Habitat Preference
Texas Horned Lizard	*Phrynosoma cornutum*	Open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sand to rocky; burrows in soil, enters rodent burrows, or hides under rocks when inactive; breeds March-September
Texas Kangaroo Rat	*Dipodomys elator*	Mesquite not required, but mostly in association with scattered mesquite shrubs and sparse short grasses in areas underlain by firm clay soils; along fencerows adjacent to cultivated fields/roads; burrowing into soil with openings usually at base of mesquite or shrub; dirt pushed into openings to give burrow a closed appearance; active throughout year; nocturna feeds on grass, seeds, insects, and annual and perennial forbs; metabolizes water from foo but will drink water when available; young born in underground nest chamber
Cylinder spikesedge	*Eleocharis cylindrica*	Shallow water and calcareous mud, at desert springs and in streams; flowering June-July
Mexican mud-plantain	*Heteramthera mexicana*	Aquatic; ditches and ponds; flowering June-August

LE, LT - Federally Listed Endangered/Threatened
E/SA, T/SA - Federally Endangered/Threatened by Similarity of Appearance
C1 - Federal Candidate, Category 1; information supports proposing to list as endangered/threatened
E, T - State Endangered/Threatened
"blank" - Rare, but with no regulatory listing status

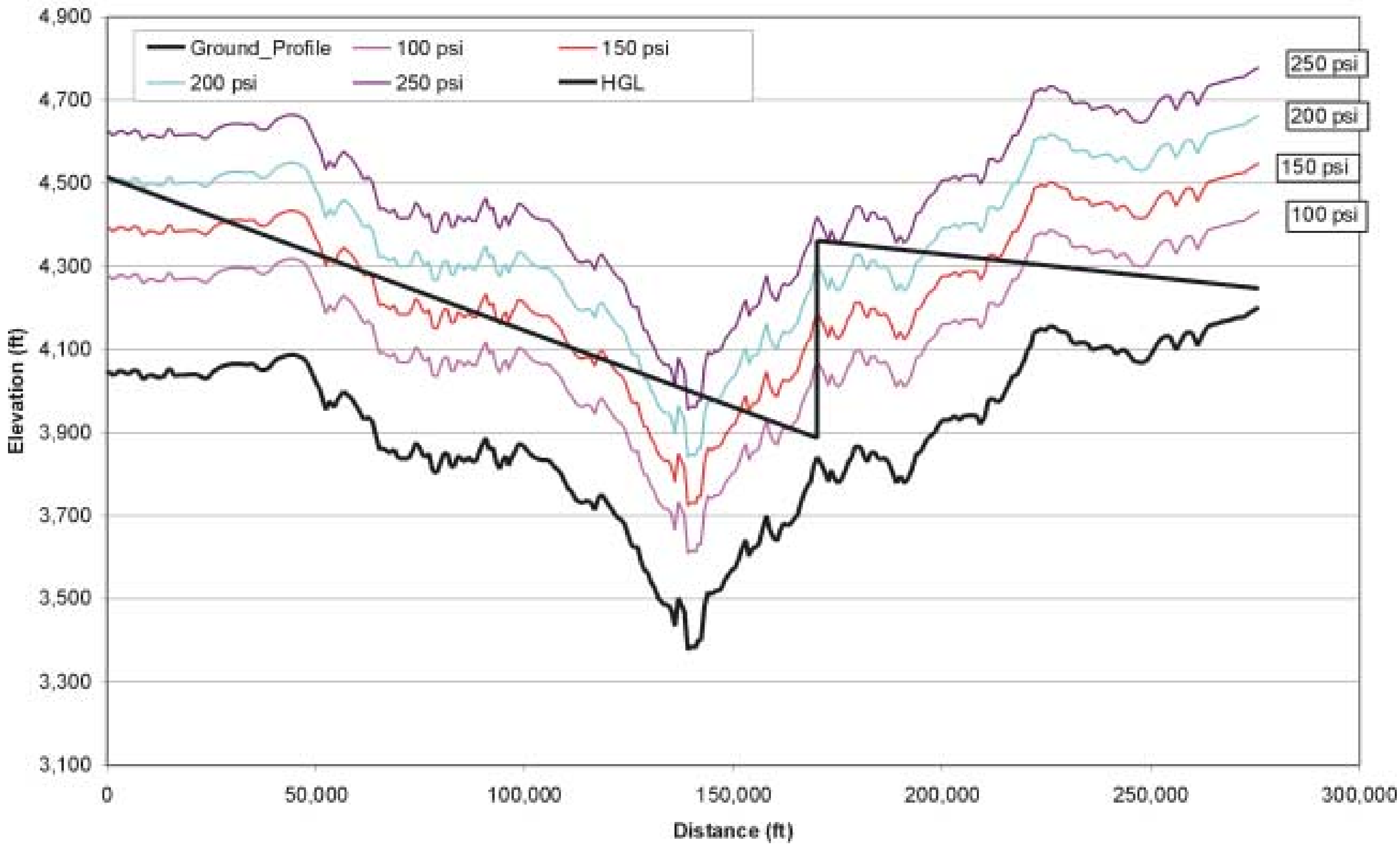
Species appearing on these lists do not all share the same probability of occurrence. Some species are migrants or wintering residents only, or may be historic or considere

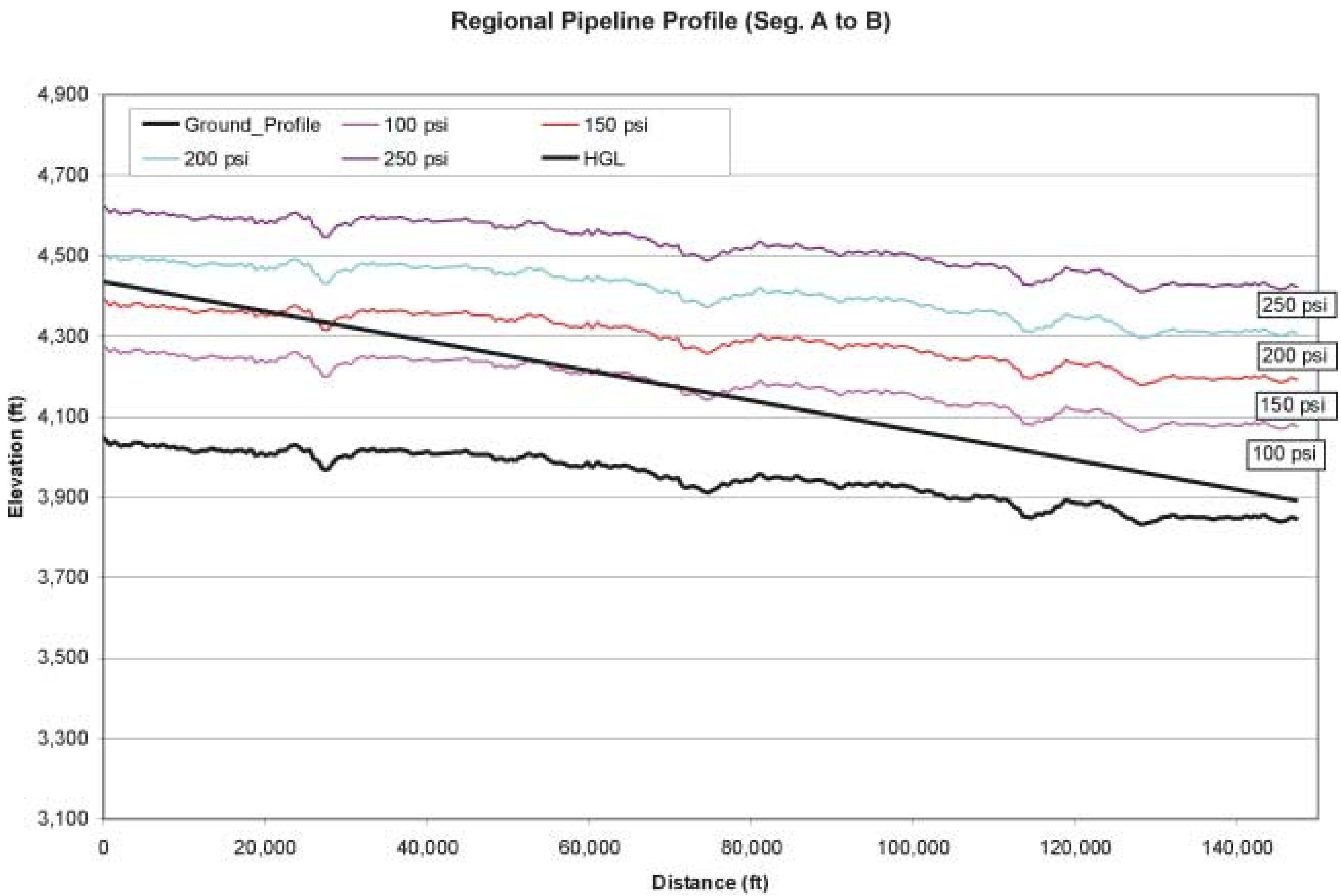
Source: Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. County lists of Texas' Special Species.

Appendix B

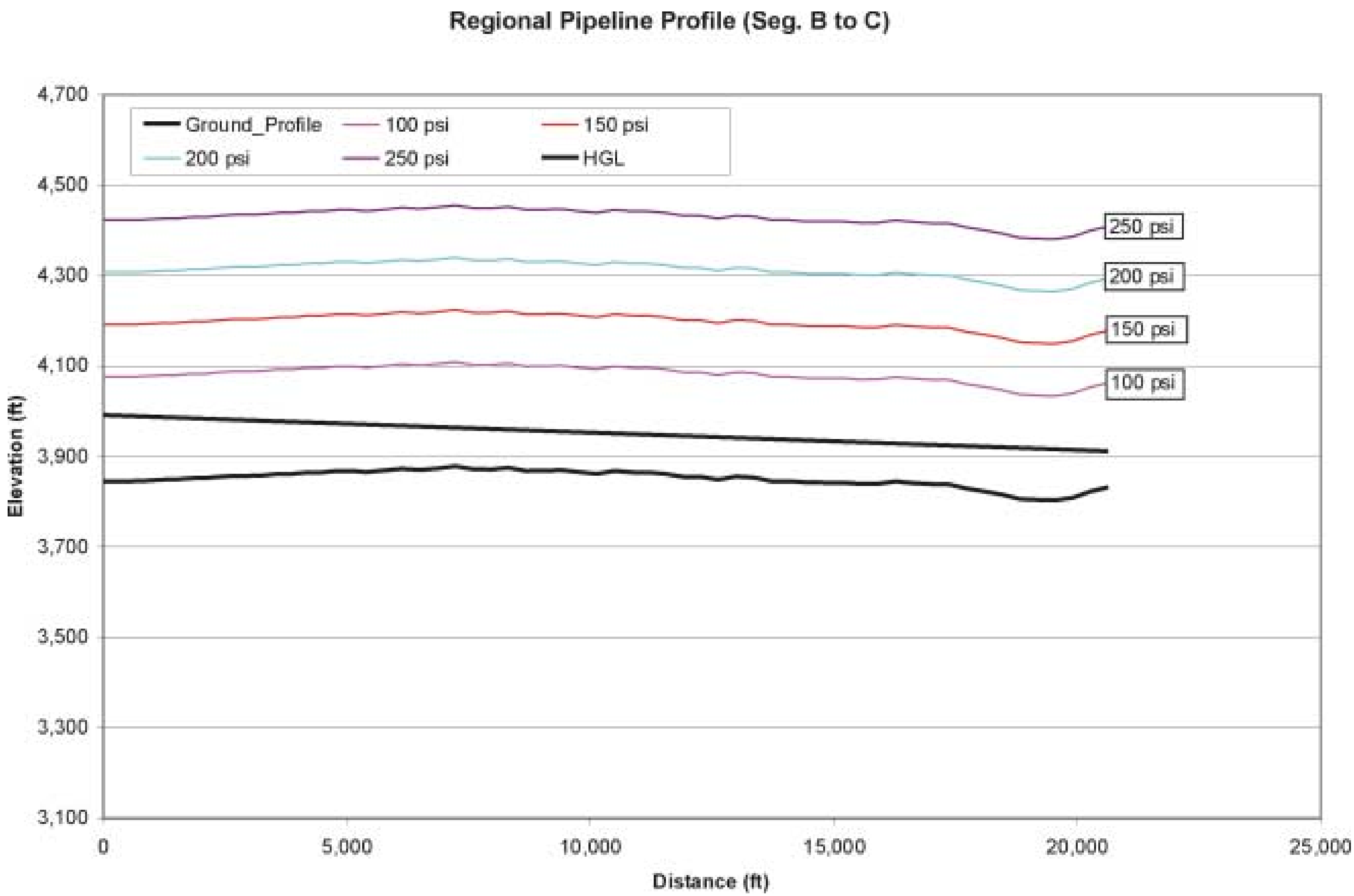
Pipeline Profiles

Regional Pipeline Profile (Seg. X to A)





Regional Pipeline Profile (Seg. A to B)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
4,900
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Elevation (ft)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Distance (ft)
250 psi
200 psi
150 psi
100 psi



Regional Pipeline Profile (Seg. B to C)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Elevation (ft)
0
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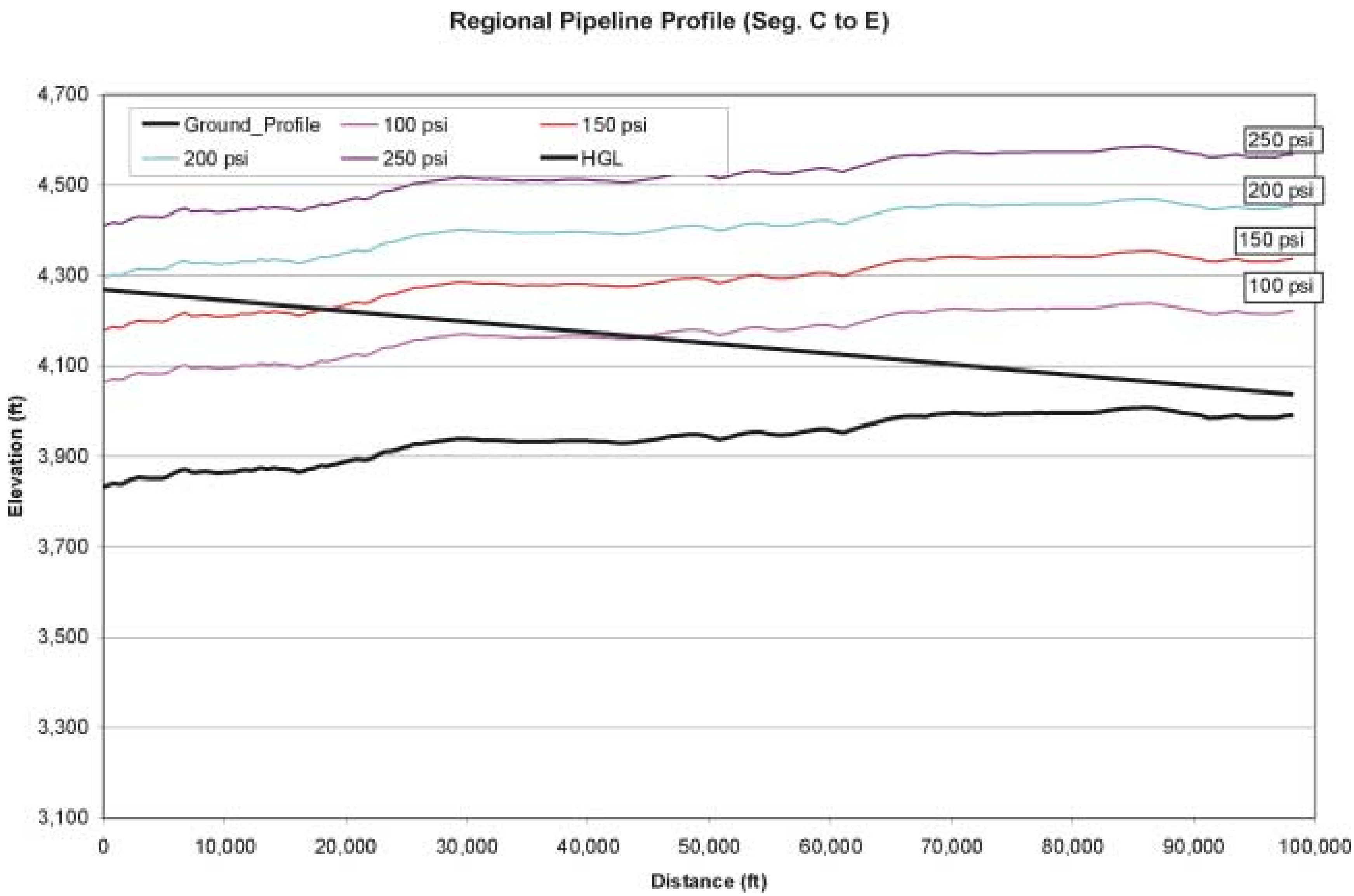
10,000
15,000
20,000
25,000
Distance (ft)
250 psi
200 psi
150 psi
100 psi


Regional Pipeline Profile (Seg. C to E)
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150 psi
200 psi
250 psi
HGL
250 psi
200 psi
150 psi
100 psi
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Elevation (ft)
0
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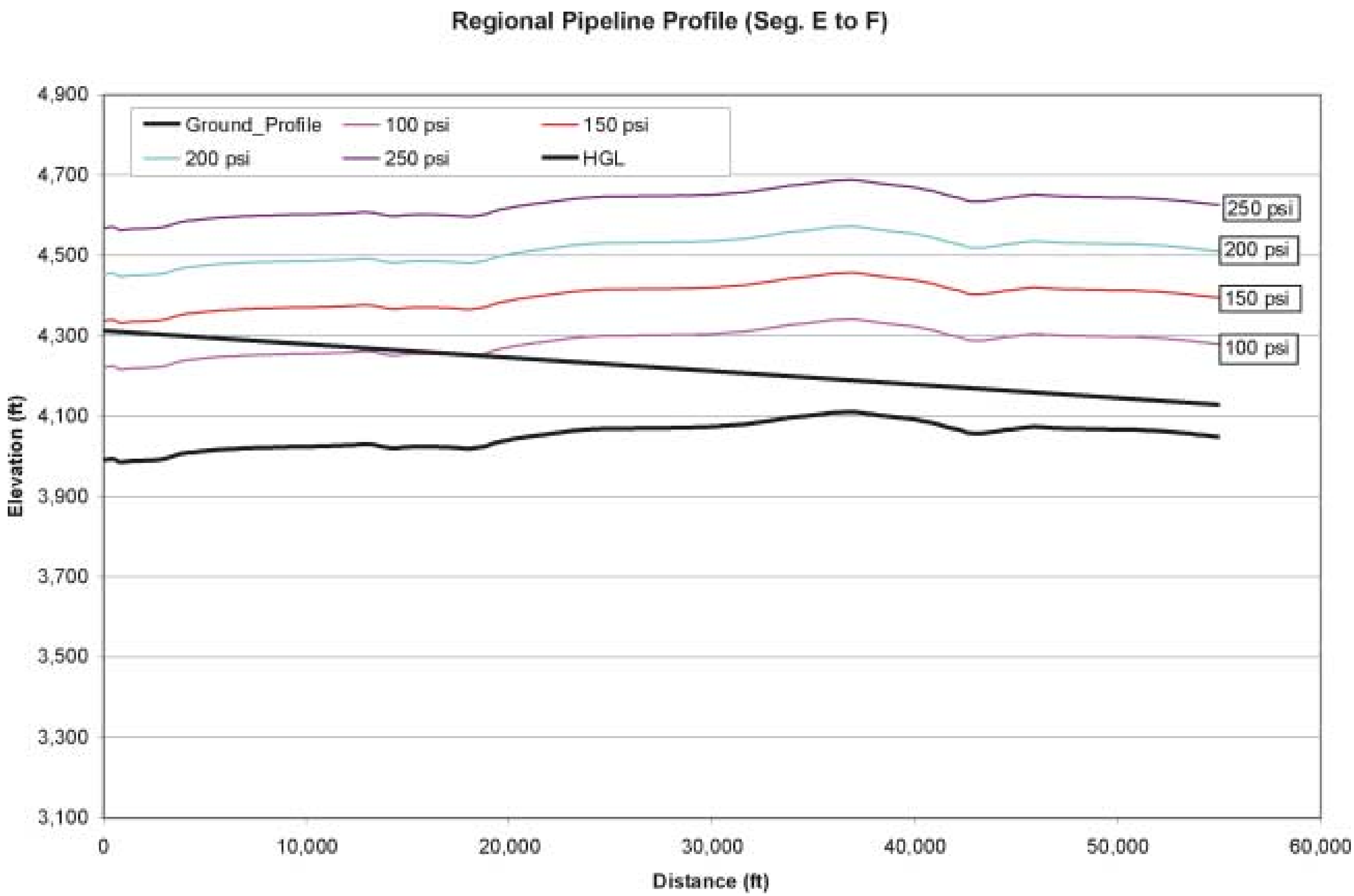
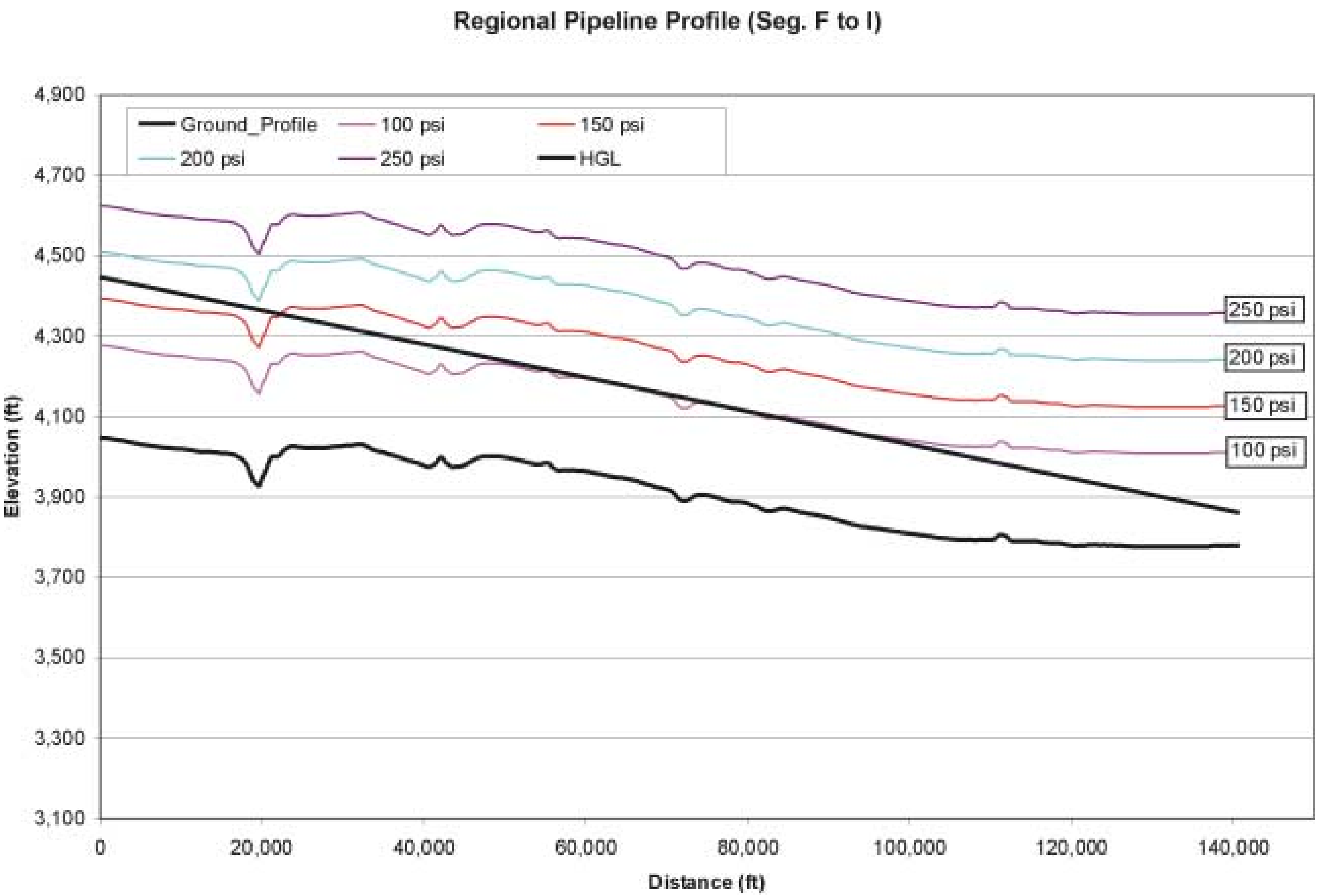
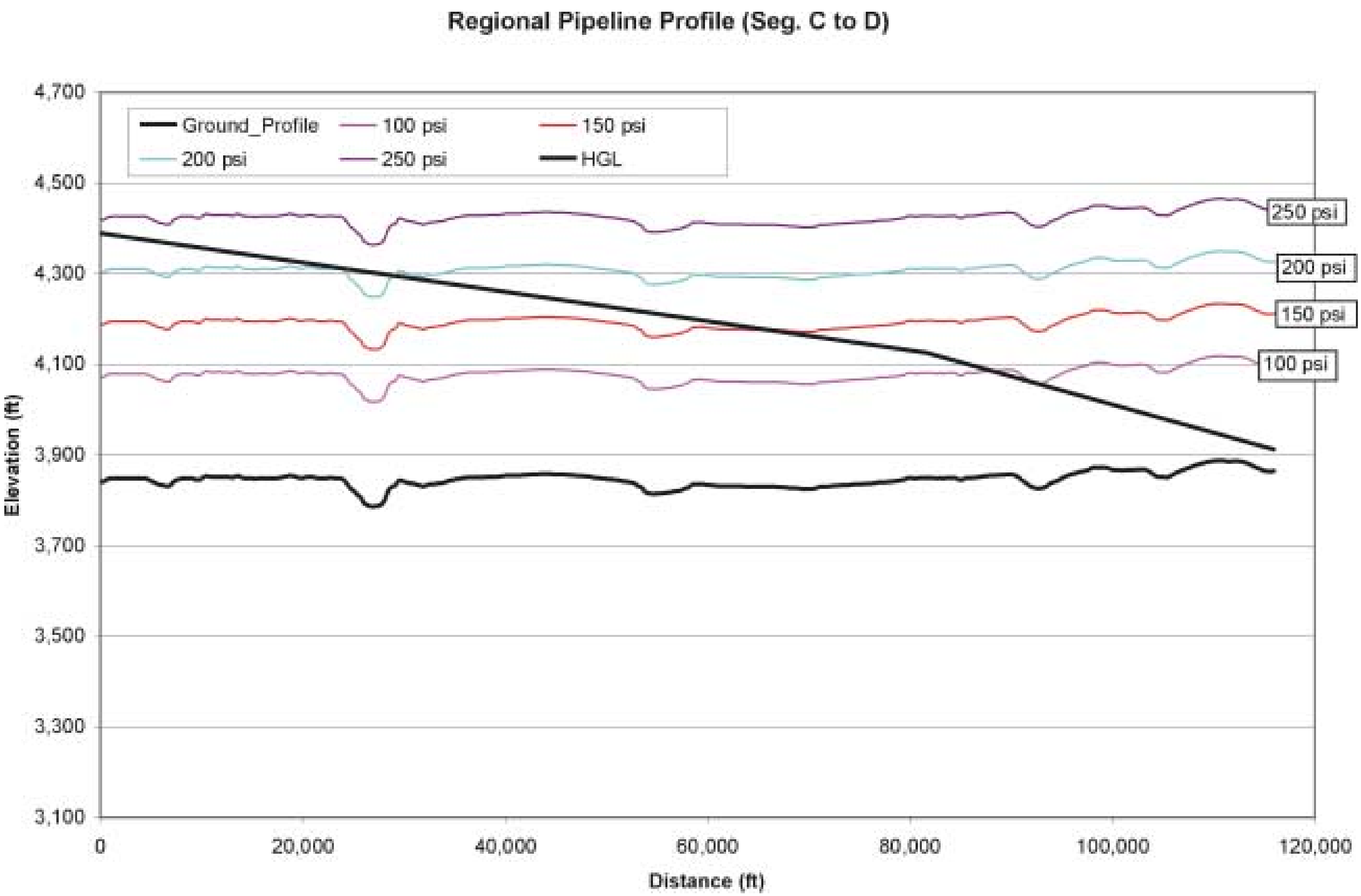
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
Distance (ft)



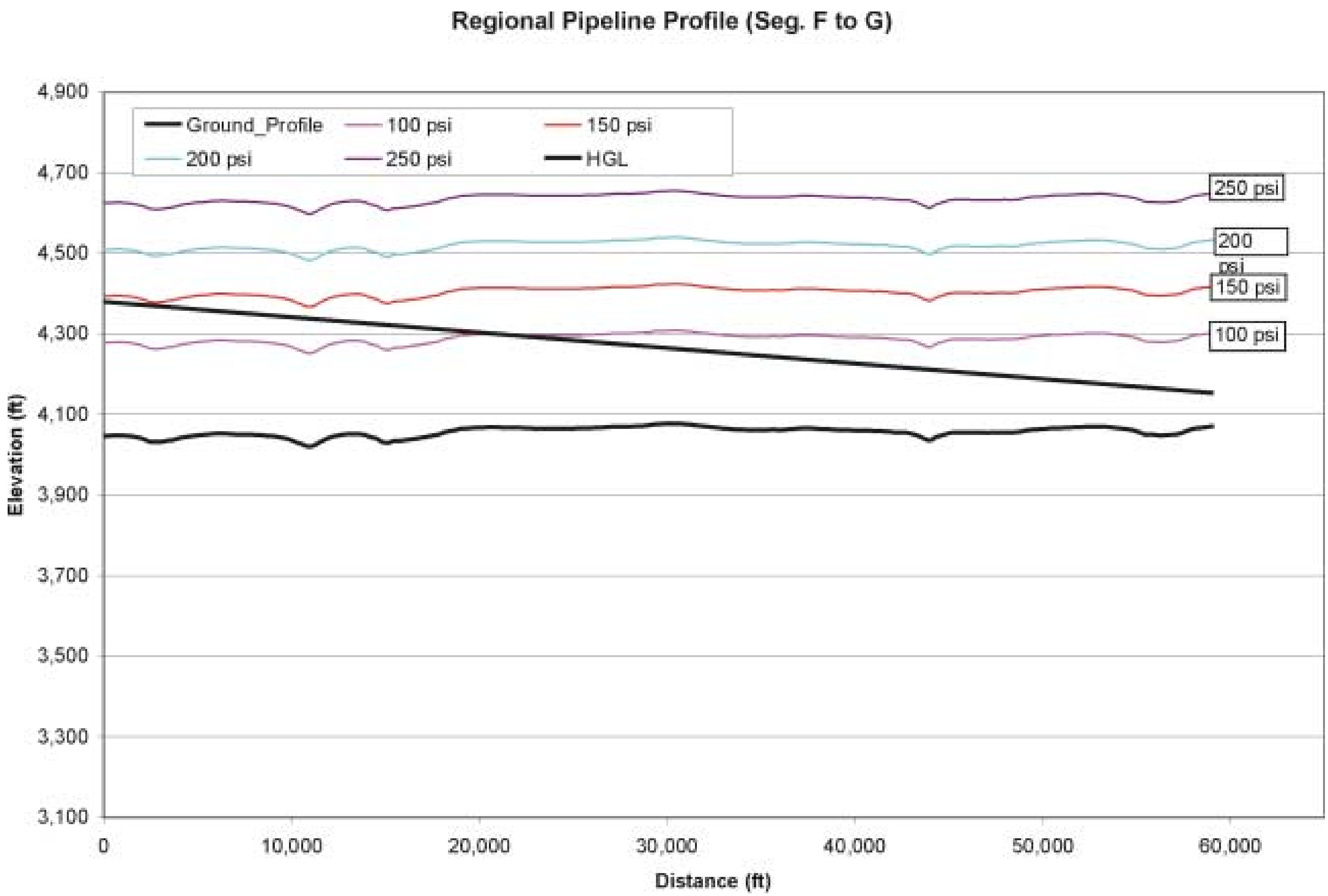
Regional Pipeline Profile (Seg. E to F)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
250 psi
200 psi
150 psi
100 psi
4,900
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Elevation (ft)
0
10,000
20,000
30,000
40,000
50,000
60,000
Distance (ft)

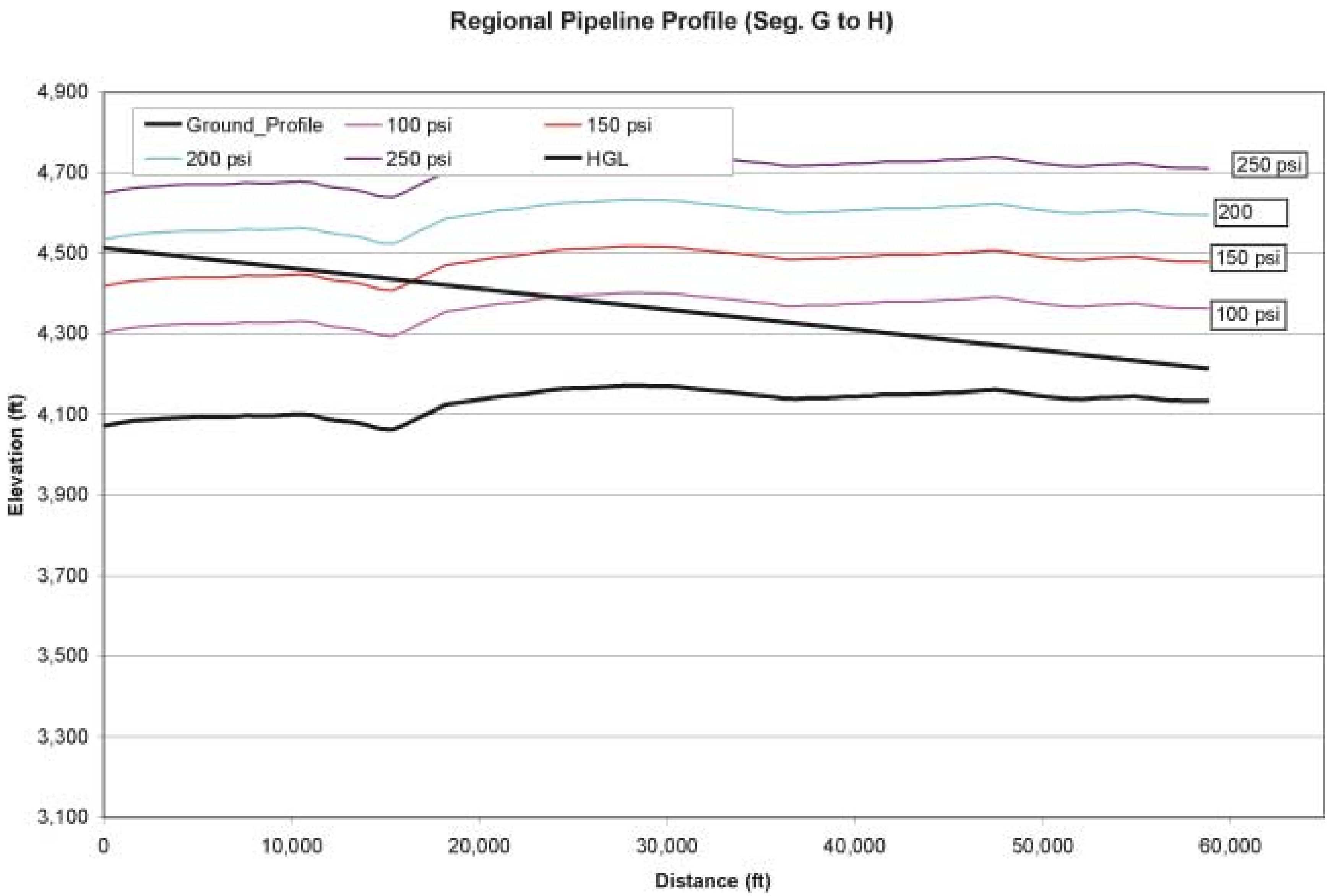


Regional Pipeline Profile (Seg. F to I)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
250 psi
200 psi
150 psi
100 psi
Elevation (ft)
4,900
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Distance (ft)



Regional Pipeline Profile (Seg. C to D)
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Elevation (ft)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
250 psi
200 psi
150 psi
100 psi
0
20,000
40,000
60,000
80,000
100,000
120,000
Distance (ft)


Regional Pipeline Profile (Seg. F to G)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
250 psi
200 psi
150 psi
100 psi
Elevation (ft)
4,900
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
Distance (ft)
0
10,000
20,000
30,000
40,000
50,000
60,000



Regional Pipeline Profile (Seg. G to H)
Ground_Profile
100 psi
150 psi
200 psi
250 psi
HGL
250 psi
200
150 psi
100 psi
Elevation (ft)
4,900
4,700
4,500
4,300
4,100
3,900
3,700
3,500
3,300
3,100
0
10,000
20,000
30,000
40,000
50,000
60,000
Distance (ft)

Appendix C

A Brief Description of Water Management Practices Irrigation Systems

Appendix C
Llano Estacado Regional Water Planning Group
Agriculture Committee
A Brief Description of Water Management Practices
Irrigation Systems

1. **SDI – Subsurface Drip Irrigation**
   A. 90% to 98% Application Efficiency
   B. SDI has the potential for the highest application efficiency of all irrigation systems when properly designed. SDI can also effectively utilize the lowest flowrate per acre of all irrigation systems.
   C. SDI is the most flexible irrigation system available when considering soils, field shape, field slope, and irrigation water availability. SDI is suitable for all irrigated areas on the High Plains, but has limited acceptance because of the relatively high cost of the system.
   D. SDI conversation cost an average $700 to $1400 per acre.
2. **LEPA – Low Energy Precision Application (Pivot)**
   A. 90% to 95% Application Efficiency
   B. LEPA irrigation has the potential for the highest application efficiency of any type of sprinkler system. When combined with management practices such as land slope <1%, farming in a circle, furrow diking, soil moisture monitoring, and irrigation scheduling, 95% of the water pumped can be made available to the crop. LEPA systems have the lowest evaporation losses of any above-surface irrigation system.
   C. LEPA systems are suitable for cropland fields with slopes less than 1% and have been widely accepted on the High Plains.
   D. LEPA system conversions can be classed in two ways:
      1) Conversion to a new LEPA system. On the High Plains this is changing from a surface irrigation system or an old high pressure sprinkler system to a new pivot.
         a) Cost is $250 to $300 per acre.
      2) Conversion of an existing pivot to a LEPA system. This is the conversion of a wide spaced, mid pressure spray pivot to a low pressure, alternate row system with LEPA nozzles.
         a) Conversion cost is $25 to $50 per acre.
3. **LESA / LPIC – Low Elevation Spray Applicator / Low Pressure In Canopy**
   A. 80% to 90% Application Efficiency
   B. LESA and LPIC systems are generally identified as alternate row sprays with low drift nozzles placed one to four feet above the ground. This system may be used with circular rows, contour rows, or straight rows, and on land that is too steep for LEPA systems (>1% slope) where contour rows or terraces are needed to control rainfall runoff. Sprays placed closest to the ground surface have the highest

application efficiency, and those at higher levels have lower application efficiency. Once the crop canopy is established, evaporation losses due to wind drift and heat are minimized.

C. LESA/LPIC systems are suitable for fields with greater than 1% slopes and undulating terrain where circular rows are not practical. Many systems sold as "LEPA Pivots" are really LESA/LPIC systems.

D. LESA/LPIC conversions can be classified in two ways:

1) Conversion to a new LESA/LPIC system. On the High Plains this is a conversion from the surface irrigation system or an old high pressure sprinkler system to a new pivot.

a) Conversion cost is $150 to $300 per acre.

2) Conversion of an existing pivot to a LESA/LPIC system. This is the conversion of a wide spaced, mid pressure spray pivot to a low pressure, alternate row system with low drift nozzles placed closer to the ground surface.

a) Conversion cost is $20 to $40 per acre.

4. Surge Valves

A. Surge Valves can increase the application efficiency of a furrow irrigation system by 10% to 40%.

B. Surge Valves reduce infiltration rates, decrease advance time, reduce tailwater at the lower end of the field, and reduce deep percolation at the upper and lower ends of the field. Surge Valves help the irrigator make lighter applications of irrigation water and can be used with an irrigation scheduling program.

C. Furrow irrigation with a Surge Valve is suitable for areas that cannot be irrigated with a pivot. Light furrow irrigation applications are difficult to achieve even with a Surge Valve, which reduces the ability of the irrigator to practice short interval irrigation scheduling.

D. Surge Valves cost $1,000 to $1,500 per valve (a Surge Valve can be used on more than one field).

5. Pipelines

A. Plastic pipelines replacing open ditches or leaking pipelines can increase system efficiency by 5% to 15%.

B. Plastic pipelines have been used to replace open ditches and older concrete pipe and for irrigation system reorganization for more than twenty years. Many of these pipelines have exceeded their life expectancy and may soon need to be replaced. Most irrigation system reorganizations require the installation of additional plastic pipeline (new pivot installations, for example).

C. Plastic pipeline is suitable for nearly all areas on the High Plains.

D. The total installation cost of plastic pipeline is $1.00 to $5.00 per foot.

6. Lay Flat Tubing

A. Lay flat tubing can increase system efficiency by 5% to 20%.

B. Lay flat tubing is a thin wall polyethylene tube used to transport irrigation water for furrow irrigation systems. It is also used as gated pipe.

C. Lay flat tubing is a good temporary substitute for earthen ditches and aluminum surface and gated pipe. It has a very low pressure rating and is not suitable for pressured irrigation systems. It is a disposable product, usually used only one or two years and is not included as a cost-shared practice on the High Plains.

7. **Furrow Diking**
   A. Furring Diking does not directly conserve irrigation water, however, this practice can conserve (capture) as much as 100% of rainfall runoff.
   B. Furrow Diking is used to prevent irrigation runoff under LEPA systems. This maintains high irrigation uniformity. Furrow Diking also captures excess rainfall which can replace required irrigation water. Furrow Diking on dryland cropland can maximize normal rainfall utilization by the crop and may contribute recharge to the Ogallala Aquifer during periods of rainfall which are in excess of the soil's water holding capacity.
   C. Furrow Diking requires additional tillage equipment.
   D. Furrow Diking cost is $3.00 to $5.00 per acre.

8. **Soil Moisture Monitoring**
   A. Soil Moisture Monitoring helps the irrigators to utilize their irrigation water efficiently by preventing over or under irrigation.
   B. Soil Moisture Monitoring techniques can be as simple and inexpensive as using the "feel method" or as sophisticated as using electronic sensors throughout the field tied into a pivot irrigation scheduling program.
   C. The value of Soil Moisture Monitoring is directly related to the ability of the irrigators to control their irrigation applications. Soil Moisture Monitoring for SDI, LEPA, and LESA/LPIC has a high value and cost effectiveness, but it is less effective with furrow irrigation. Soil Moisture Monitoring is most effective when used with an irrigation scheduling program.
   D. The cost of Soil Moisture Monitoring is initially high because of the cost of the instruments, but annual costs are then usually low.

9. **Irrigation Scheduling**
   A. Irrigation Scheduling is the most effective method of efficiently utilizing irrigation water.
   B. Irrigation Scheduling is the practice of applying irrigation water to the crop in amounts that the crop can efficiently utilize, when the crop needs it, and in amounts that are not in excess of the soil water holding capacity. Proper Irrigation Scheduling also maintains a storage deficit in the soil profile to make room available for rainfall when it occurs, thus maximizing the utilization of natural rainfall as well as irrigation water.
   C. Irrigation Scheduling requires a high level of management from the irrigator.
   D. Costs associated with Irrigation Scheduling are generally labor costs related to the time spent scheduling, subscriber costs to a PET network, or consultant fees.

Appendix D

OVERVIEW OF THE METHODOLOGY USED BY THE TEXAS WATER DEVELOPMENT BOARD TO ESTIMATE SOCIAL AND ECONOMIC IMPACTS OF NOT MEETING PROJECTED WATER NEEDS
Copied directly from Texas Water Development Board Preliminary Report to Region O RWPG on August 8, 2000

APPENDIX D

OVERVIEW OF THE METHODOLOGY USED BY THE TEXAS WATER DEVELOPMENT BOARD TO ESTIMATE SOCIAL AND ECONOMIC IMPACTS OF NOT MEETING PROJECTED WATER NEEDS

Copied directly from Texas Water Development Board Preliminary Report to Region O RWPG on August 8, 2000

Estimation of the socioeconomic impact of unmet water needs begins with estimation of the direct impact of the absence of water on the individual or business making productive use of the water. The direct economic impact of unmet water needs is 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. This direct impact per acre-foot was estimated by region for each type of water user – residential, commercial, manufacturing, irrigation, livestock, mining, and steam-electric.

The term *Water Use Coefficients* is used in this study to refer to the direct impact on the different water user groups of the loss of one acre-foot of water. Estimates were based on the average value of output added per acre-foot of water used by those firms/individuals that are reliant on water (i.e., where lack of water would result in inability to operate or at least cause significant curtailment of operations).

The total regional impact of water shortage does not end with the direct impact. Indirect impacts (often referred to as third-party impacts) refer to the reduction of output by firms/individuals which result from change in operations by those who are directly impacted by lack of water. Those who are directly impacted, producing less due to lack of water, will make fewer purchases of inputs, thus resulting in losses to the firms/individuals who produce and sell those products. These firms, facing less demand for their products, then reduce their purchases from their own suppliers. Indirect impacts can thus be said to continue to ripple throughout the economy.

The most common method of estimating the extent of indirect impact is the *Input-Output Model*. This type of model uses actual data from local economies to show the buying and selling linkages among the different economic sectors. For this study, input-output models were assembled for each of the 16 regions from county-level input-output models developed by the Minnesota Implan Group. Data from these models are available in the coefficients section below.

The total extent of economic loss, direct plus indirect impact relative to the estimated direct impact, is derived from the input-output model in the form of a *multiplier*. Multipliers have been derived to estimate the total impact on three important economic variables – Total business output, personal income, and employment.

In addition to the economic impacts related to water shortages, demographic changes would also be expected to take place. While availability of jobs is not the sole reason for living in a given place, the absence of jobs created would be expected to cause many current residents to leave a region in search of other opportunities or cause reduction of anticipated migration into the region by current nonresidents. Thus, the estimated employment impact was used to estimate change in two important social variables – regional population and school enrollment.

The relationship between employment change and change in population and school enrollment was estimated using the model developed for the Texas Population Estimates and Projections Program, specifically modified for the purposes of this study by the Department of Rural Sociology at Texas A&M University.

WATER USE COEFFICIENTS (REGION O)

Water Use Coefficients, as used in this study, represent the average dollar value of output sold to final demand per acre-foot of water used in the production of this output.

For 4 of the 6 types of Water User Group, a single Water Use Coefficient has been estimated for all users in the region:

Water User Group	Water Use Coefficient ($ per acre-foot)
Steam Electric	11,744
Mining	18,792
Irrigation	169
Livestock	31,986

The Municipal water user group provides water for both commercial and residential users, each of which were estimated to have a different water use coefficient. The distribution of water use between the two types of users was assumed to vary depending on whether the water user group had a city or a "county other" classification. For cities, the assumed distribution is dependent on population.

User Type	Water Use Coefficient ($ per acre-foot)
Residential	34,771
Commercial	208,509

Population	% Sales to Residential	% Sales to Commercial
< 5000	87.44%	12.56%
5,000-10,000	78.16%	21.84%
10,000-25,000	80.60%	19.40%
25,000-50,000	79.38%	20.62%
50,000-250,000	68.57%	31.43%
> 250,000	61.49%	38.51%
"County Other"	88.81%	11.19%

Water use coefficients for manufacturing were estimated separately for individual counties, based on the distribution of water use among different manufacturing industries in the county and the average productivity of water in different types of manufacturing industries.

County	Water Use Coefficient ($ per acre-foot)
BAILEY	138,963
CASTRO	131,577
CROSBY	138,963
DAWSON	48,260
DEAF SMITH	138,963
FLOYD	423,858
GAINES	48,260
GARZA	138,963
HALE	132,935
HOCKLEY	138,963
LAMB	138,963
LUBBOCK	287,224
PARMER	138,963
TERRY	48,260

REGIONAL ECONOMIC MODEL DATA, MULTIPLIERS AND BASE YEAR VARIABLES (REGION O)

The impact analysis was conducted using a regional interindustry (input/output) model for the region. These models were developed by TWDB using IMPLAN Professional™ Version 2.0 software, a proprietary product of MIG, Inc. of Stillwater, MN. The county economic data was provided in a dataset containing details for 586 economic sectors in Texas for 1995. TWDB collapsed these sectors into models of seven sectors, representing the major water use categories used in water development planning. The data are unique to the region.

For this region, the summary data in IMPLAN for the 1995 base year for major economic variables were as follows:

POPULATION	449,429
EMPLOYMENT	249,113
HOUSEHOLDS	176,927
TOTAL PERSONAL INCOME	$8.568 Billion In 1999 dollars– $9.365 Billion

The tables on the following pages include 1) the base year Final Demands for the seven water use sectors and 2) the multipliers used to estimate the indirect impacts from economic changes due to water shortages by sector.

The Final Demand data were used to calculate the Water Use Coefficients by matching each sector's dollar totals to volumes of water use in the corresponding category for the calendar year–base year 1995. The result is an average of production associated with an acre-foot of water use. This measure produces an average value of water in terms that can be used to apply the IMPLAN multipliers. Regional indirect economic changes can then be estimated.

The multipliers are ratios that, when applied to the direct changes (estimated by the Water Use Coefficients listed above), result in a total impact on the entire region. The impact totals represent the sum of successive changes among all economic sectors caused by the initial change in the affected sector. Multipliers are listed for Employment, Output (Gross Sales or Receipts), and Income (earned income from business and labor activity, not including transfer payments).

IMPLAN REPORT
OF INDUSTRY FINAL DEMAND
AGGREGATED TO 7 SECTORS

	Millions of Dollars							
Industry	**Households**	**Federal Gov't**	**State & Local Gov't**	**Capital**	**Inventory**	**Domestic Exports**	**Foreign Exports**	**Final Demand (Sum)**
Livestock	17.926	0.251	2.63	0.851	0.262	1,828.93	12.723	1863.575
Irrigation	9.087	0.116	1.005	0.127	7.448	549.619	428.749	996.151
Mining	14.419	0.012	2.273	2.299	1.754	930.554	16.511	967.822
Manufacturing	695.372	0.602	97.923	104.467	30.43	535.468	476.413	1940.675
Steam Electric	115.682	4.409	31.322	0.018	0.006	0.021	0.406	151.864
Municipal Commercial	2,137.17	82.57	530.902	87.224	29.971	106.662	98.339	3072.833
Municipal Household	157.3	1,507.3	0.0	0.0	293.6	0.0	308.4	2266.6

NOTE: The sum of these final demands are not total final demand for the region. These numbers include only selected sectors from a larger (528 sector) regional model that reported significant water use in the base year. Total final demand for the region would include all remaining, lower water use sectors.

IMPLAN REPORT
OF MULTIPLIERS

Llano Estacado Water Planning Region (Region O)

Employment

	Jobs Per Million Dollars of Output					
Industry	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total**	**Type I Multiplier**	**Type II Multiplier**
Livestock	3.1	8.4	3.8	15.3	3.721	4.949
Irrigation	8.9	10.7	4.5	24.1	2.209	2.720
Municipal Commercial	21.9	3.5	9.4	34.8	1.161	1.588
Mining	5.3	2.4	4.4	12.1	1.449	2.284
Manufacturing	4.5	6.5	4.9	15.8	2.451	3.544
Steam Electric	2.7	1.9	4.4	9.0	1.707	3.334
Municipal Household	9.8	1.8	2.9	14.5	1.184	1.480

Output

(Gross Business Receipts/Sales)

Industry	Direct Effects	Indirect Effects	Induced Effects	Total	Type I Multiplier	Type II Multiplier
Livestock	1	0.735	0.249	1.984	1.735	1.984
Irrigation	1	0.702	0.297	1.999	1.702	1.999
Municipal Commercial	1	0.265	0.615	1.880	1.265	1.880
Mining	1	0.266	0.290	1.556	1.266	1.556
Manufacturing	1	0.665	0.320	1.986	1.665	1.986
Steam Electric	1	0.171	0.287	1.458	1.171	1.458
Municipal Household	1	0.130	0.178	1.309	1.130	1.309

Labor Income

Industry	Direct Effects*	Indirect Effects*	Induced Effects*	Total*	Type I Multiplier	Type II Multiplier
Livestock	0.064	0.188	0.087	0.339	3.952	5.323
Irrigation	0.072	0.228	0.104	0.404	4.191	5.645
Municipal Commercial	0.530	0.092	0.216	0.837	1.174	1.581
Mining	0.223	0.071	0.102	0.395	1.318	1.775
Manufacturing	0.147	0.177	0.112	0.437	2.209	2.976
Steam Electric	0.234	0.057	0.101	0.391	1.242	1.673
Municipal Household	0.206	0.043	0.062	0.311	1.211	1.514

*** Income Portion of Gross Outputs**

COMMENTS ABOUT THE ESTIMATES

Users are cautioned not to assume that the entire list of needs with impacts is a prediction of future water disasters. These data simply give regional planners one source of information by which to develop efficient and effective means to meet the needs and avoid calamities.

Some clarification is needed to understand the impact numbers. The following points must be kept in mind when using the data:

a) The impacts are expressed in terms of <u>regional impact</u>. Thus, individual water user group shortages are shown as they influence the entire region's economy and not just the limits of the direct impact. The total impact of municipal shortage for a particular city, for example, includes the direct impact within the city limits and the impact indirectly through the region. The indirect linkages were derived from regional economic models. There are no models for individual water user groups.

b) While the entirety of an estimated impact applies to the region as a whole, a significant portion will generally be felt in the local area where the shortage occurs. An impact that is of a small magnitude relative to impacts of other shortages on other areas may be extremely severe if its magnitude is large relative to the size of the local economy. Thus, while the absolute magnitude of agricultural shortages may appear to be small, the true severity of the impact may be much more significant to the surrounding rural area.

c) Water supplies are calculated on drought-of-record levels. Shortages that show up for the 2000 decade and beyond are considered to be mostly the result of severe dry conditions; this contributes to the apparent abnormally large size of some impacts. This approach to supply analysis results in a worst-case scenario. Historically, most water user groups have at least partially met their needs through management of the remaining supplies, either by conservation, limitations on lower-valued uses such as lawn watering, or finding alternative sources of water. The results in this report <u>assume no applied management strategies</u>. The entirety of the needs is not met in any fashion.

d) The analysis begins by calculating water use coefficients–defined as production (dollars of sales to final customers, or final demand) resulting from use of an acre-foot of water. This measure is considered an <u>average, not marginal measure</u> of water use. Thus, the analysis does not attempt to measure the market forces that would tend to drive the price of water higher or reserve limited water for the highest-valued uses, as it becomes scarce. The average value approach was used because the analysis is intended to show the present value in today's regional economies of differing amounts of water use. With this information analysts can answer the question, "How much water does it take to support the current level and structure of economic activity and population?" The baseline projections for the future of regional economies assume a continuation of this known relationship of volumes of water use to economic output, under current structures of use. The models do not attempt to estimate the market allocation of the resource among competing activities because this change in structure is considered a possible management strategy–relying on market forces to work in a water-marketing system. Marginal cost analysis would be necessary for evaluating such an approach.

e) The Municipal water use category includes commercial establishments. The impacts from even small shortages in many such establishments are considerably higher on a per-acre-foot basis than in any other category. Thus, relatively small Municipal shortages can have a very large amount of economic impact, since the analysis assumes a direct relationship between curtailed water use and lost economic production. Since this analysis is intended to provide impacts without assuming any strategies, the normal response of conservation programs is not assumed. The impact data appear to overstate the Municipal category, but the results are consistently measured, since no response to the shortage is assumed that would mitigate loss of critical water used in commercial and residential settings.

f) The sizes of the projected impacts do not represent reductions from the current levels of economic activity or population. That is, the data are a comparison between a baseline forecast, assuming no water shortages, and a restricted forecast, based on the assumption of future water shortages. In some cases, with severe water shortages the regional economy could actually decline, dropping employment below current levels. For most regions, however, the measurement of impact represents an opportunity cost, or lost potential development that would be foregone in the absence of water management strategies.

APPENDIX E
Abridged Results from Groundwater Modeling for the Southern High Plains

Submitted by

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High Plains Underground Water Conservation District No. 1
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The groundwater model has been developed using the best available data and guidelines issued by the LERWPG. However, the LERWPG urges the reader to use caution when interpreting the model results. The computer model simply predicts possible future conditions given historical trends and known geological features. It is entirely possible that future conditions will be different than those projected. The reader is encouraged to read the entire report by the Texas Tech University Water Resources Center team.

December, 2000

Abridged Results from
Groundwater Modeling for the Southern High Plains

1 Model Calibration

The parameters identified for calibration were recharge, distribution of pumpage, hydraulic conductivity, and specific yield. The primary calibration area was limited to the area of the HPUWCD#1 by the LERWPG because the data available for that district was assumed to be most reliable. The water level records for 1985 and 1995 served as the starting and ending points, respectively, for the calibration. The telescopic mesh refinement (TMR) ability of the Ground Water Vistas™ was used to break up the HPUWCD#1 into nine subregional areas for more precise calibration. After completion of the primary calibration efforts using thousands of calibration targets, the mean error was 0.38 ft, with the absolute mean error at 4.74 ft with a standard deviation of 6.44 ft. The percentages of the targets that were within 5, 10, and 25 ft of the observed 1995 values were 62.7, 89.7, and 99.8, respectively. Next, the area outside the HPUWCD#1 was calibrated to a lesser degree using the more limited data available from the TWDB groundwater database. The mean error of calibration for the entire area of the Ogallala aquifer in the Southern High Plains was 0.62 ft, and the absolute mean error was 8.57 ft. Of the over two thousand calibration targets used for regional calibration, 43.7 percent were within 5 ft of the observed values, and 68.5 percent were within 10 ft of the observed values.

It should be noted that the computer model had difficulty representing the behavior of the aquifer in Briscoe, Dickens, Garza, and Motley counties because of their positions along the boundary of the aquifer and the lack of adequate hydrologic and geologic information available from local or state agencies. Each of these counties has only a small area underlain by the Ogallala Aquifer as limited by the Caprock escarpment, and production levels are small compared to the central and western counties of Region O. Earlier modeling efforts by the TWDB and others used larger cell sizes, 2.9 miles by 2.9 miles as opposed to the 1 mile by 1 mile cells in the current model, and assigned most of the Ogallala area in the counties as constant head boundary cells. Thus, no previous effort was spent on gathering more detailed information in these counties. It is anticipated that the Groundwater Availability Modeling study planned in the near future by the TWDB will provide the time and effort to deal with these counties more precisely.

Table 1 lists the combined total of primary and secondary recharge estimated for each county in the region. The table also reports the total recharge in each river basin in each county. Results are reported by river basin to meet requirements set by the TWDB for regional water planning. Figure 1 shows the total recharge estimated for all of Region O. The average total recharge for Region O was 2.75 in/yr. The relative distribution of recharge is shown in Figure 2.

Figure 3 is a map showing the calibrated distribution of pumpage in each county. This pumpage distribution was used in all predictive simulations to assign withdrawal rates to the cells. Each color on the map represents the ratio of the groundwater pumped in each cell to the county's total groundwater use, expressed as a percentage. Thus, an area of a county colored in yellow means that each square mile of the yellow area accounts for 0.02% to 0.1% of the total county pumpage. However, areas having the same color in different counties do not account for the same pumping rate.

Table 1. Region O Calibrated Estimates of Total Recharge.

County	Basin	Area	Recharge (1000 ac-ft)						
		sq miles	1995	2000	2010	2020	2030	2040	2050
Bailey	Total	843	111	111	109	108	108	108	107
	Brazos	843	111	111	109	108	108	108	107
Briscoe	Total	911	89	89	89	89	89	89	89
	Red	911	89	89	89	89	89	89	89
Castro	Total	911	144	144	138	137	135	134	133
	Brazos	492	85	85	82	81	81	80	79
	Red	419	58	58	56	55	55	54	54
Cochran	Total	776	123	123	121	120	119	118	118
	Brazos	224	24	24	23	23	23	23	23
	Colorado	552	100	100	97	97	96	96	95
Crosby	Total	904	167	167	163	162	161	160	160
	Brazos	893	165	165	162	161	160	159	159
	Red	11	1	1	1	1	1	1	1
Dawson	Total	900	151	151	150	150	150	149	149
	Brazos	23	15	15	15	15	15	15	15
	Colorado	877	136	136	135	135	135	135	134
Deaf Smith	Total	1,485	140	140	140	140	140	140	140
	Canadian	89	8	8	8	8	8	8	8
	Red	1,396	132	132	132	132	132	132	132
Dickens	Total	912	39	39	37	37	37	36	36
	Brazos	127	31	31	30	29	29	29	29
	Red	785	48	48	48	48	48	48	48
Floyd	Total	1,015	102	102	102	102	102	102	102
	Brazos	442	41	41	41	41	41	41	41
	Red	573	61	61	61	61	61	61	61
Gaines	Total	1,507	271	271	268	268	267	267	266
	Colorado	1,507	271	271	268	268	267	267	266
Garza	Total	904	177	177	171	169	167	166	165
	Brazos	904	177	177	171	169	167	166	165
Hale	Total	1,033	133	133	132	131	131	131	130
	Brazos	1,030	132	132	130	130	130	129	129
	Red	3	1	1	1	1	1	1	1
Hockley	Total	914	121	121	120	120	120	119	119
	Brazos	775	101	101	100	100	100	99	99
	Colorado	139	20	20	20	20	20	20	20
Lamb	Total	1,013	134	134	132	132	131	131	130
	Brazos	1,013	134	134	132	132	131	131	130
Lubbock	Total	908	160	160	158	158	157	157	156
	Brazos	908	160	160	158	158	157	157	156
Lynn	Total	893	261	261	258	258	257	256	256
	Brazos	829	239	239	236	235	234	234	233
	Colorado	64	23	23	23	23	23	23	22
Motley	Total	994	31	31	31	31	31	31	31
	Red	994	31	31	31	31	31	31	31
Parmer	Total	854	115	115	113	112	112	111	111
	Brazos	535	75	75	74	73	73	73	72
	Red	319	39	39	39	39	39	39	39
Swisher	Total	915	173	173	166	164	162	161	159
	Brazos	116	16	16	15	15	15	14	14
	Red	799	158	158	151	149	148	146	145
Terry	Total	904	191	191	190	190	189	189	189
	Brazos	60	16	16	16	16	16	16	16
	Colorado	844	175	175	174	174	174	173	173
Yoakum	Total	798	145	145	143	143	142	142	142
	Colorado	798	145	145	143	143	142	142	142
Region O Totals	Total	20,294	2,978	2,978	2,931	2,921	2,907	2,897	2,888
	Brazos	8,732	1,522	1,522	1,494	1,486	1,480	1,474	1,467
	Canadian	94	8	8	8	8	8	8	8
	Colorado	4,787	870	870	860	860	857	856	852
	Red	6,681	618	618	609	606	605	602	601

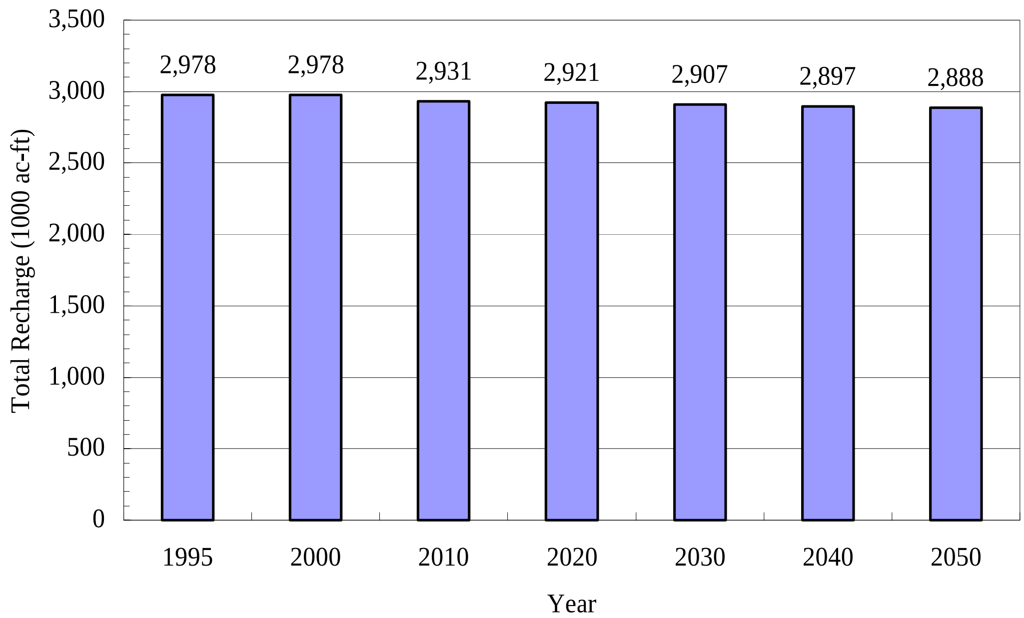

Figure 1. Region O Calibrated Estimates of Total Recharge.

Figure 4 shows the calibrated zones of hydraulic conductivity ranging from 4.7 ft/day to 116.6 ft/day. The model results showed relatively little sensitivity to specific yield, so the distribution of values from the previous modeling studies by the TWDB and USGS were retained.

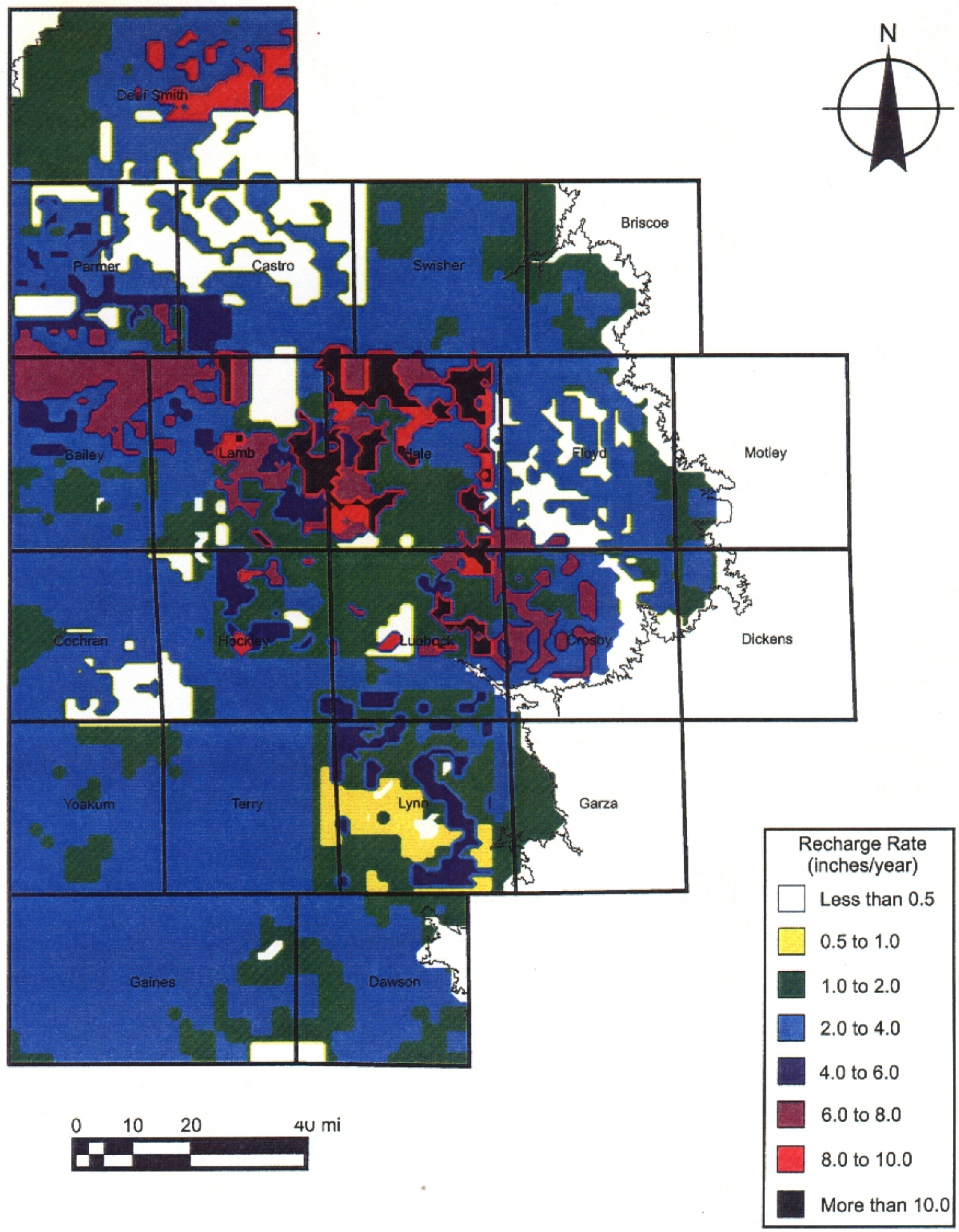

Figure 2. Calibrated Distribution of Primary Recharge.

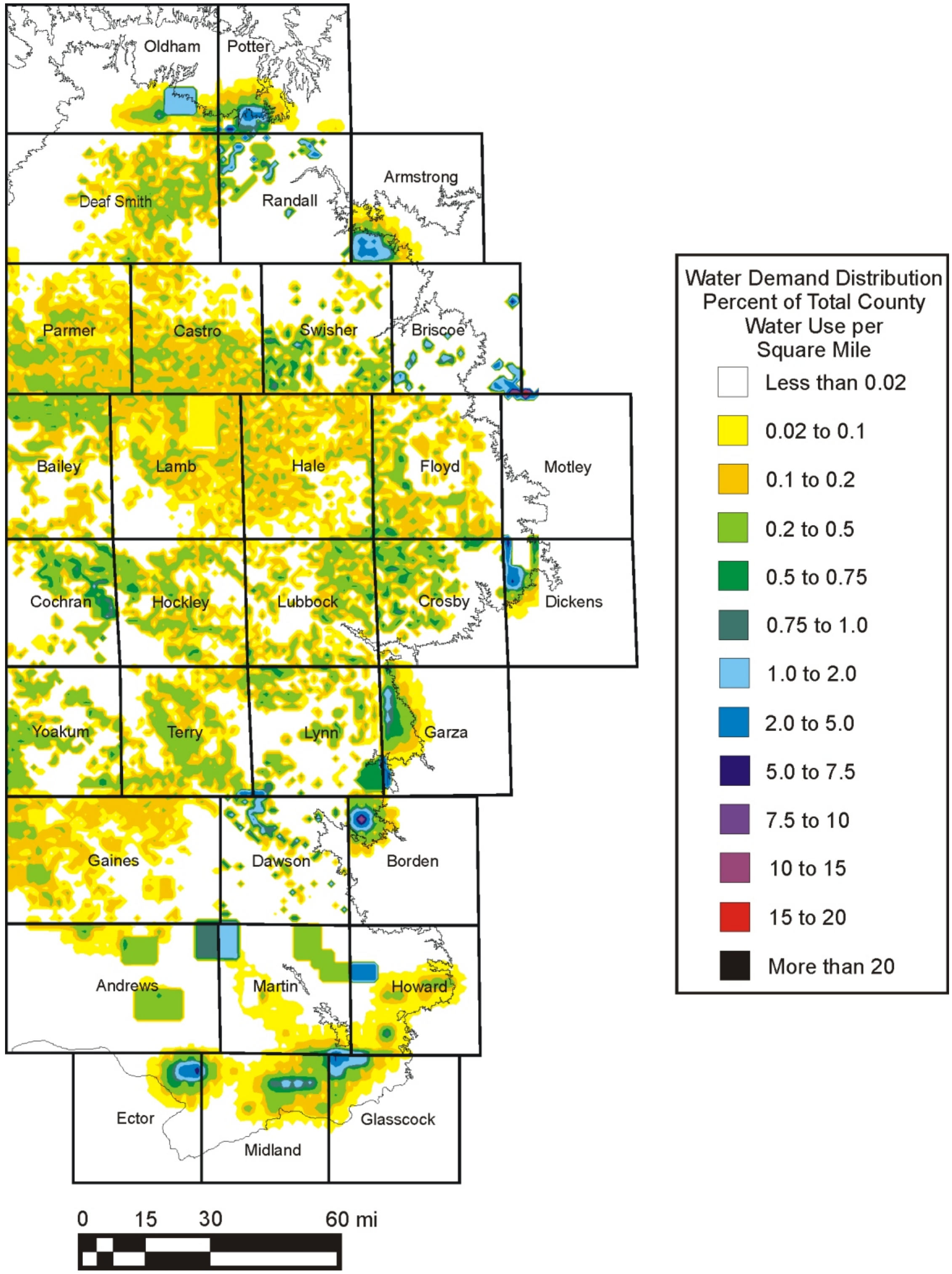

Figure 3. Calibrated Water Demand Distribution.

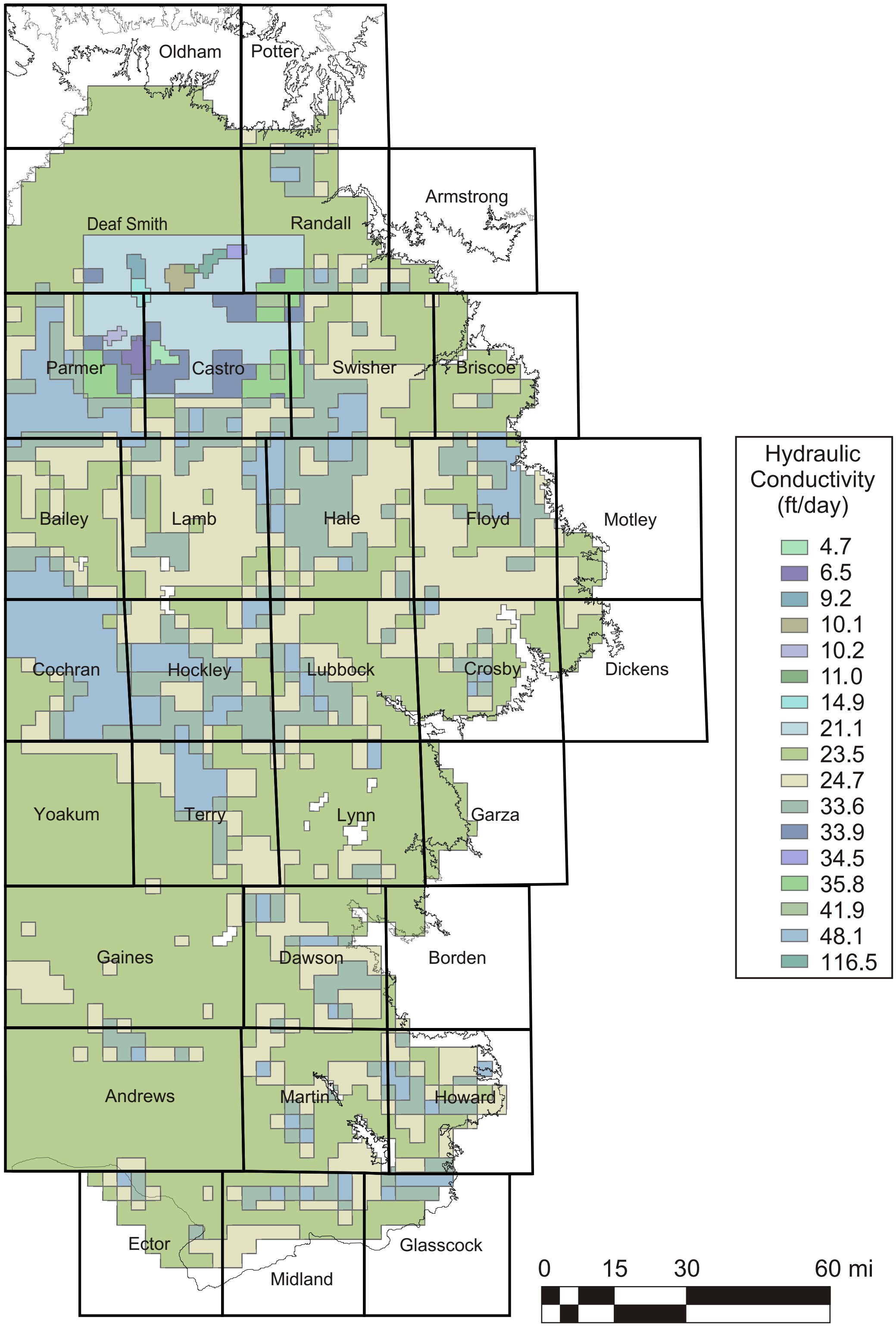

Figure 4. Calibrated Zones of Hydraulic Conductivity.

2 Simulation of Projected Groundwater Use

2.1 Volume in Storage

Historical water table measurements published by TWDB and HPUWCD#1 showed that the Ogallala aquifer underlying Region O held approximately 132,360,000 acre-feet of water, calculated using a range of values for specific yield of the aquifer as determined by aquifer tests (Knowles et al., 1984). Using the projections developed by the LERWPG, the model indicates that approximately 104,000,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050. This number represents 79 percent of the volume of water in storage measured in 1995. Figure 5 shows the volume in storage in Region O in 1995 and at the end of each decade of the planning period. Figure 6 shows the volume in storage in the three main river basins in 1995 and at the end of each decade of the planning period. Of the 21 counties in the region, 12 counties have at least 80 percent of the 1995 volume in storage remaining in 2050. The remaining nine counties have from 21 to 78 percent of the 1995 volume in storage remaining. Castro, Garza, Lamb, and Parmer counties have less than 50 percent of the 1995 volume in storage remaining. Table 2 shows the volume of water in storage by decade by county, river basin in each county, total in Region O, total by river basin in Region O, and percent of 1995 volume in storage remaining. The table also reports the total area of each county and the area of each county in each river basin.

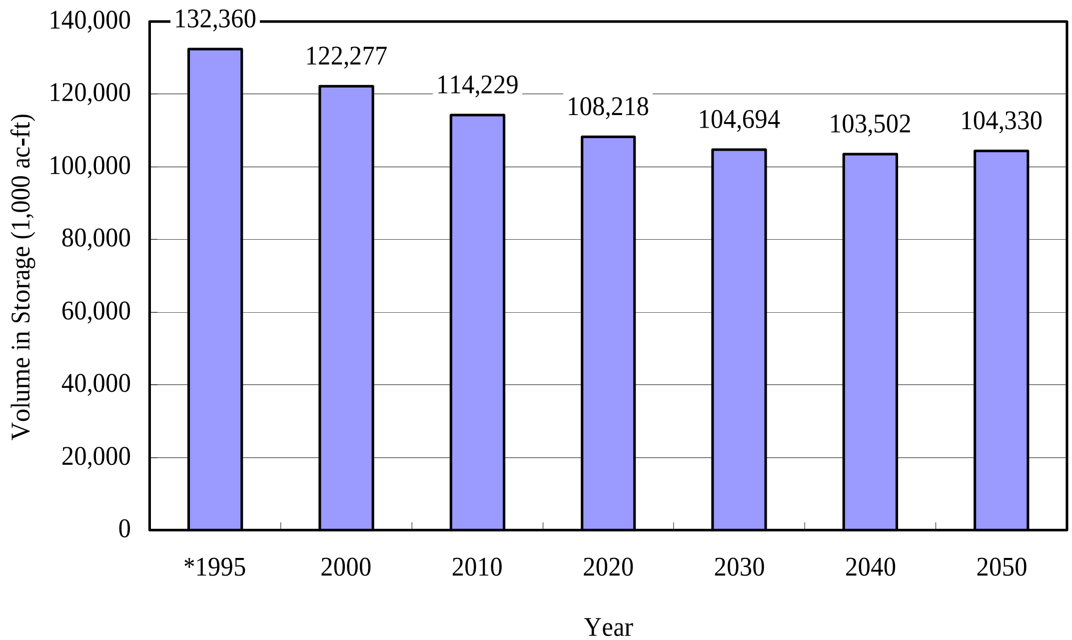

Figure 5. Region O Simulated Volume
in Storage, Baseline Simulation.

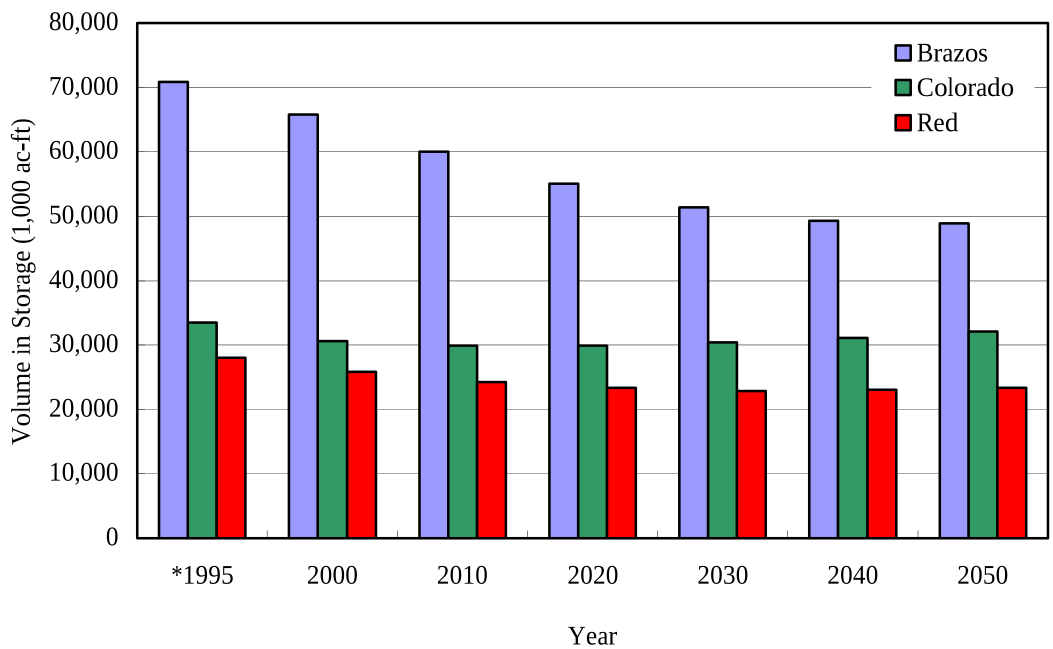

Figure 6. Region O Basins Simulated Volume
in Storage, Baseline Simulation.

Table 2. Region O Simulated Volume in Storage, Baseline Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Bailey	Total	843	6,220	5,397	87	5,212	84	5,014	81	4,884	79	4,740	76	4,709	76
	Brazos	843	6,220	5,397	87	5,212	84	5,014	81	4,884	79	4,740	76	4,709	76
Briscoe	Total	911	1,601	1,524	95	1,792	112	2,031	127	2,227	139	2,398	150	2,544	159
	Red	911	1,601	1,524	95	1,792	112	2,031	127	2,227	139	2,398	150	2,544	159
Castro	Total	911	12,204	11,037	90	8,754	72	6,452	53	4,643	38	3,325	27	2,580	21
	Brazos	492	8,290	7,385	89	5,640	68	3,876	47	2,412	29	1,301	16	759	9
	Red	419	3,914	3,651	93	3,114	80	2,576	66	2,230	57	2,024	52	1,821	47
Cochran	Total	776	3,829	4,046	106	4,548	119	5,053	132	5,597	146	6,144	160	6,693	175
	Brazos	224	1,294	1,311	101	1,369	106	1,449	112	1,550	120	1,666	129	1,794	139
	Colorado	552	2,535	2,735	108	3,179	125	3,605	142	4,047	160	4,479	177	4,899	193
Crosby	Total	904	6,223	6,632	107	7,228	116	7,682	123	8,081	130	8,422	135	8,732	140
	Brazos	893	6,113	6,521	107	7,109	116	7,551	124	7,938	130	8,270	135	8,573	140
	Red	11	110	111	101	118	107	130	118	142	129	152	138	160	145
Dawson	Total	900	7,101	5,836	82	6,320	89	6,599	93	6,763	95	6,854	97	6,914	97
	Brazos	23	103	55	53	66	64	69	67	70	68	70	68	70	68
	Colorado	877	6,997	5,781	83	6,254	89	6,531	93	6,694	96	6,784	97	6,843	98
Deaf Smith	Total	1,485	9,649	9,050	94	8,219	85	7,589	79	7,089	73	6,917	72	6,837	71
	Canadian	89	4	4	100	4	100	4	100	4	100	4	100	4	100
	Red	1,396	9,645	9,045	94	8,215	85	7,585	79	7,085	73	6,912	72	6,833	71
Dickens	Total	912	1,141	991	87	1,177	103	1,246	109	1,276	112	1,291	113	1,299	114
	Brazos	127	210	282	134	332	158	347	165	353	168	356	170	358	170
	Red	785	930	709	76	845	91	899	97	923	99	934	100	941	101
Floyd	Total	1,015	9,654	9,274	96	8,708	90	8,335	86	8,087	84	7,923	82	7,828	81
	Brazos	442	6,003	5,672	94	5,117	85	4,687	78	4,341	72	4,028	67	3,773	63
	Red	573	3,652	3,602	99	3,591	98	3,647	100	3,746	103	3,895	107	4,055	111
Gaines	Total	1,507	13,188	11,646	88	10,176	77	9,374	71	9,029	68	8,882	67	8,894	67
	Colorado	1,507	13,188	11,646	88	10,176	77	9,374	71	9,029	68	8,882	67	8,894	67
Garza	Total	904	484	163	34	177	37	189	39	202	42	215	44	228	47
	Brazos	904	484	163	34	177	37	189	39	202	42	215	44	228	47
Hale	Total	1,033	10,880	10,558	97	9,915	91	9,346	86	8,919	82	8,598	79	8,450	78
	Brazos	1,030	10,786	10,467	97	9,835	91	9,271	86	8,843	82	8,519	79	8,368	78
	Red	3	94	91	97	80	85	75	80	77	82	79	84	83	88

Table 2. Region O Simulated Volume in Storage, Baseline Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Hockley	Total	914	4,753	4,811	101	4,893	103	5,108	107	5,347	112	5,645	119	5,975	126
	Brazos	775	4,155	4,184	101	4,208	101	4,368	105	4,554	110	4,798	115	5,074	122
	Colorado	139	598	627	105	685	115	740	124	793	133	847	142	902	151
Lamb	Total	1,013	9,269	8,500	92	7,099	77	5,870	63	4,933	53	4,359	47	4,152	45
	Brazos	1,013	9,269	8,500	92	7,099	77	5,870	63	4,933	53	4,359	47	4,152	45
Lubbock	Total	908	5,603	5,574	99	5,463	98	5,482	98	5,593	100	5,765	103	5,995	107
	Brazos	908	5,603	5,574	99	5,463	98	5,482	98	5,593	100	5,765	103	5,995	107
Lynn	Total	893	3,818	2,587	68	2,854	75	3,100	81	3,322	87	3,518	92	3,692	97
	Brazos	829	3,495	2,471	71	2,748	79	2,997	86	3,218	92	3,412	98	3,585	103
	Colorado	64	323	116	36	106	33	102	32	104	32	106	33	107	33
Motley	Total	994	1,125	656	58	729	65	768	68	793	70	808	72	819	73
	Red	994	1,125	656	58	729	65	768	68	793	70	808	72	819	73
Parmer	Total	854	10,635	9,553	90	7,272	68	5,299	50	3,828	36	2,971	28	2,518	24
	Brazos	535	7,648	6,751	88	4,797	63	3,155	41	1,875	25	1,148	15	757	10
	Red	319	2,987	2,802	94	2,474	83	2,144	72	1,953	65	1,823	61	1,762	59
Swisher	Total	915	4,673	4,281	92	3,685	79	3,685	79	3,895	83	4,185	90	4,469	96
	Brazos	116	714	596	83	377	53	226	32	173	24	160	22	141	20
	Red	799	3,959	3,684	93	3,308	84	3,458	87	3,721	94	4,025	102	4,327	109
Terry	Total	904	4,977	4,801	96	4,674	94	4,639	93	4,713	95	4,852	97	5,033	101
	Brazos	60	504	463	92	464	92	473	94	487	97	504	100	522	104
	Colorado	844	4,472	4,338	97	4,210	94	4,165	93	4,226	94	4,348	97	4,511	101
Yoakum	Total	798	5,333	5,360	101	5,334	100	5,357	100	5,473	103	5,690	107	5,969	112
	Colorado	798	5,333	5,360	101	5,334	100	5,357	100	5,473	103	5,690	107	5,969	112
Region O Totals	Total	20,294	132,360	122,277	92	114,229	86	108,218	82	104,694	79	103,502	78	104,330	79
	Brazos	8,732	70,891	65,792	93	60,013	85	55,024	78	51,426	73	49,311	70	48,858	69
	Canadian	94	4	4	100	4	100	4	100	4	100	4	100	4	100
	Colorado	4,787	33,446	30,603	91	29,944	90	29,874	89	30,366	91	31,136	93	32,125	96
	Red	6,681	28,017	25,875	92	24,266	87	23,313	83	22,897	82	23,050	82	23,345	83

* 1995 values represent historical measurements as reported by TWDB and HPUWCD#1.

2.2 Saturated Thickness

Figure 7 is a set of maps depicting the simulated saturated thickness of the Southern Ogallala Aquifer for the years 1995, 2000, 2030, and 2050. According to the maps, the areas having the greatest depletion of the aquifer included parts of Castro, Deaf Smith, Floyd, Gaines, Garza, Lamb, and Parmer counties. The areas of saturated thickness exceeding 200 ft in 1995 declined significantly in Castro, Deaf Smith, Floyd, and Parmer counties.

These maps depicted a significant increase of saturated thickness in parts of Crosby, Dawson, and Dickens counties. During the calibration period from 1985 to 1995, the water table elevation in these counties rose considerably in some areas. Therefore, the recharge values assigned to these counties as a result of calibration were large enough to produce a continuing trend of increasing saturated thickness during the predictive simulation. Thus, the increase of saturated thickness predicted by the model reflects the conditions observed during the calibration period, but may not be physically reasonable.

2.3 Satisfied Demand Percentage

Irrigation demand accounted for over 96 percent of total groundwater use in Region O in 1996 and was projected to account for a similar percentage throughout the planning period. Under the baseline simulation, the model indicated that approximately 65 percent of the total groundwater demand for Region O can be met in 2050. Figures 8 and 9 show the satisfied demand percentage for every five years of the planning period for Region O and the three main river basins in Region O, respectively. Seven counties in Region O are capable of supplying at least 80 percent of the projected demand, while 4 counties supply less than 50 percent of the demand. Table 3 reports the satisfied demand percentage by county, river

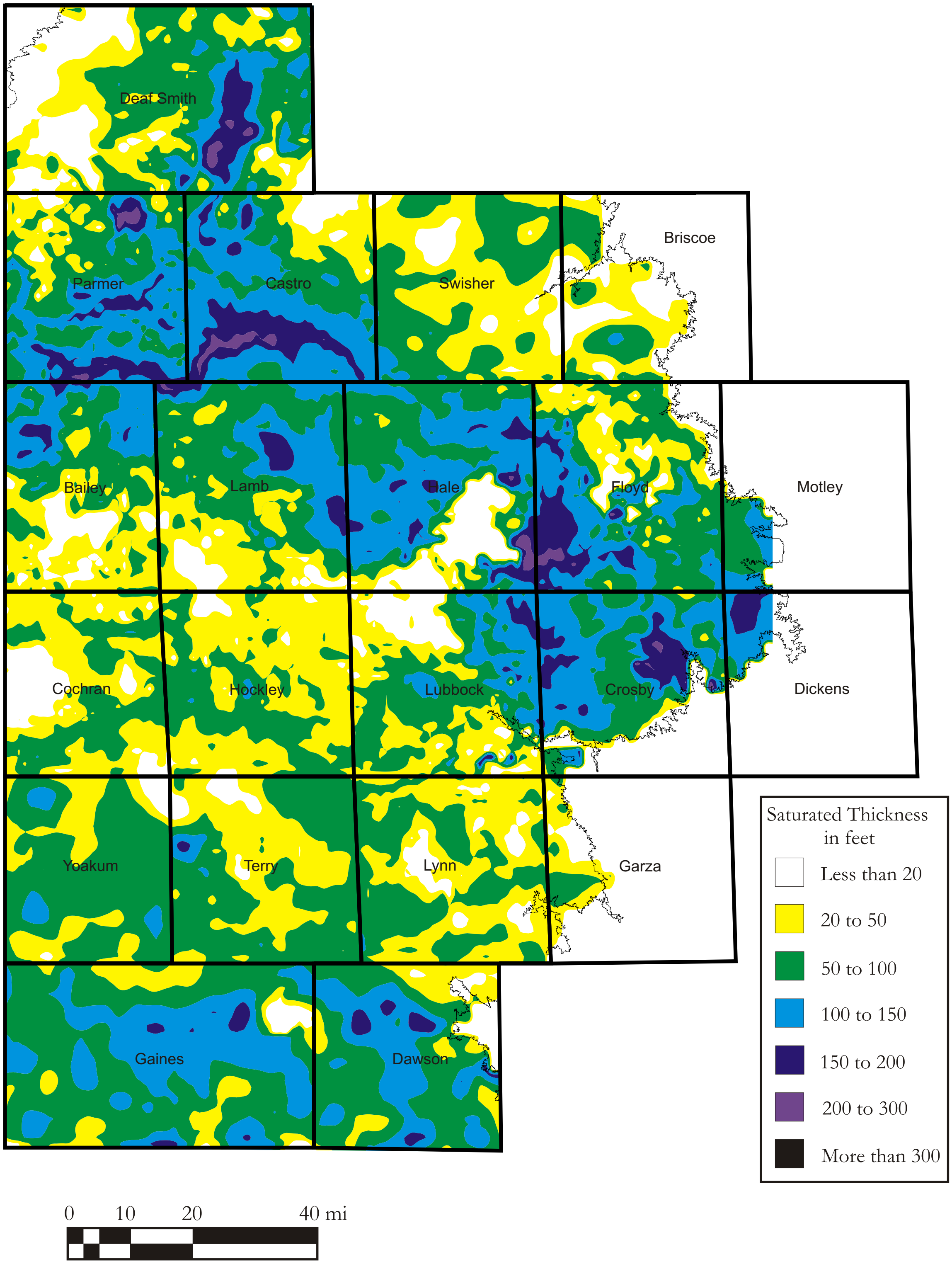

Figure 7(a). 1995 Region O Saturated Thickness.

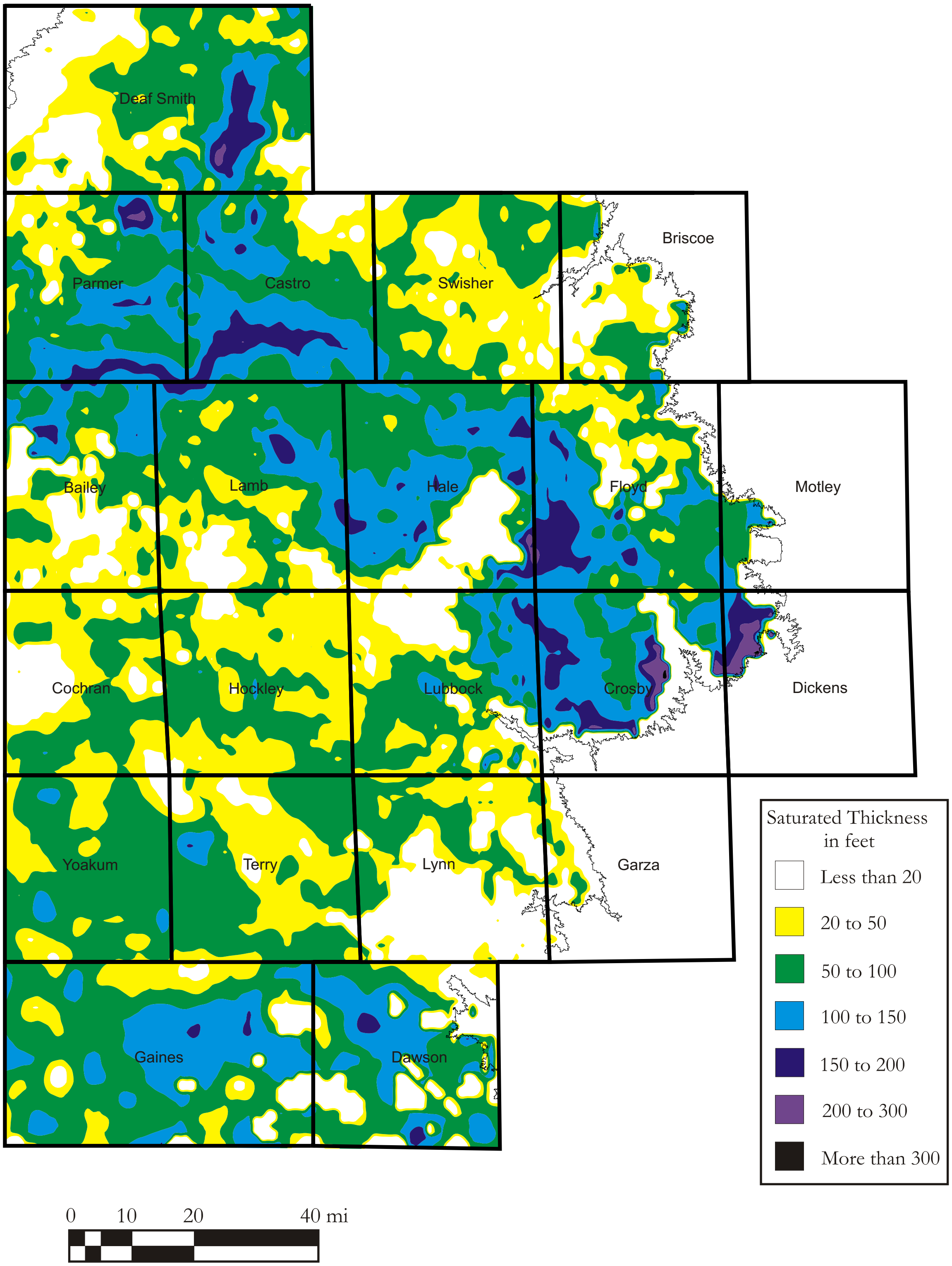

Figure 7(b). 2000 Region O Simulated Saturated Thickness, Baseline Simulation.

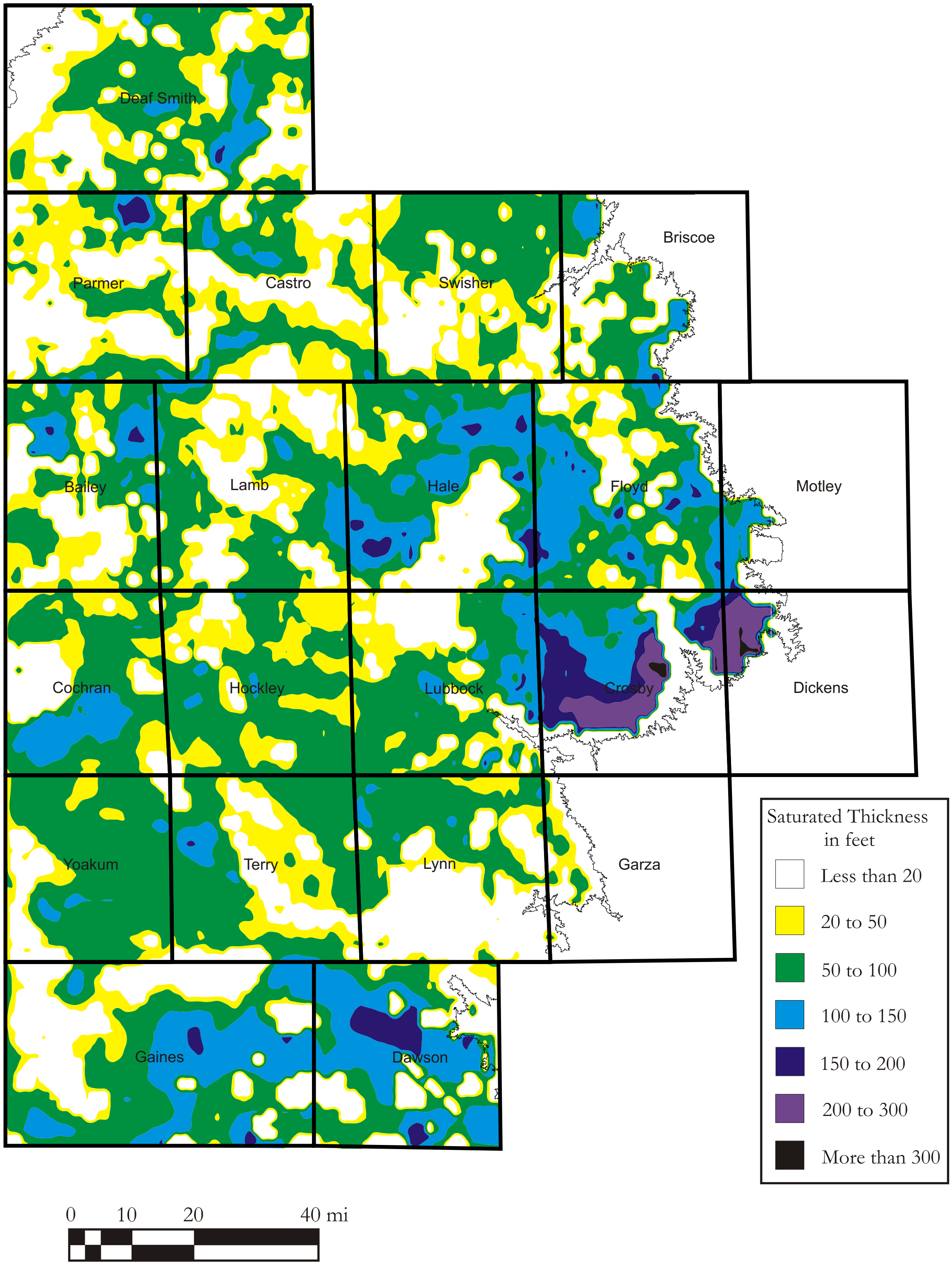

Figure 7(c). 2030 Region O Simulated Saturated Thickness, Baseline Simulation.

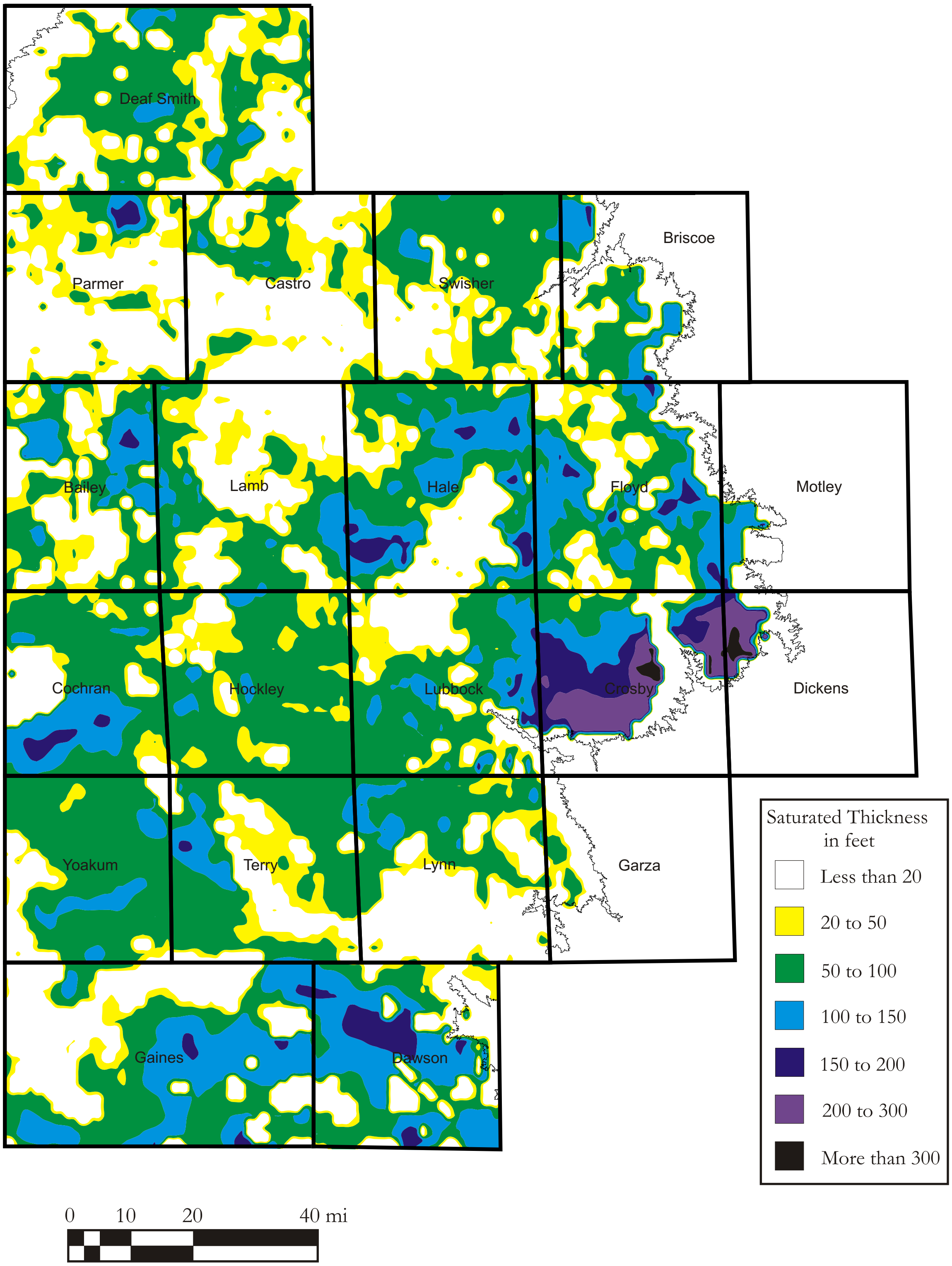

Figure 7(d). 2050 Region O Simulated Saturated Thickness, Baseline Simulation.

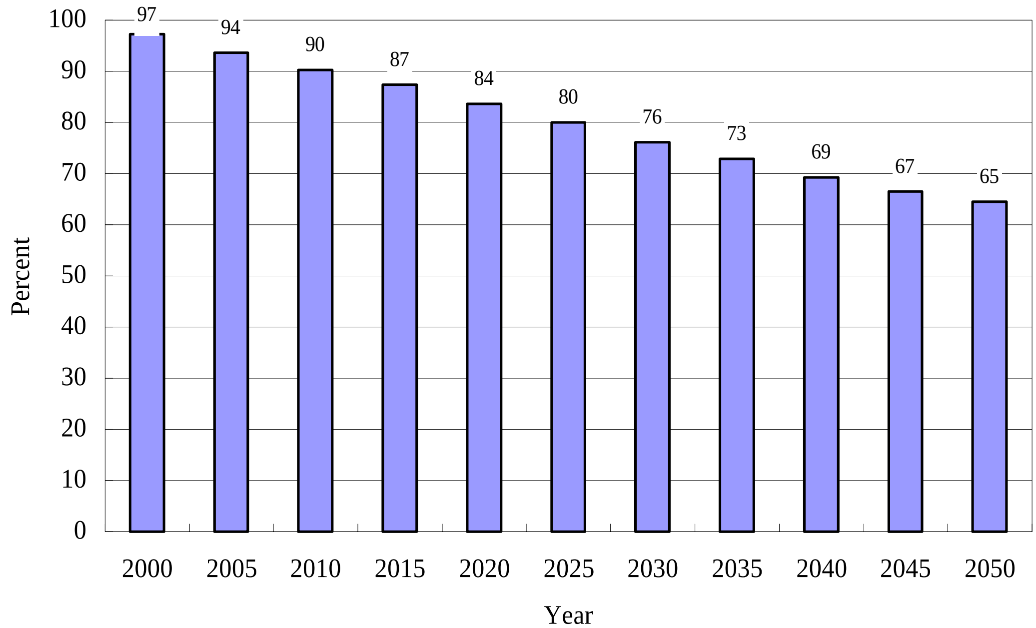

Figure 8. Region O Satisfied Demand
Percentage, Baseline Simulation.

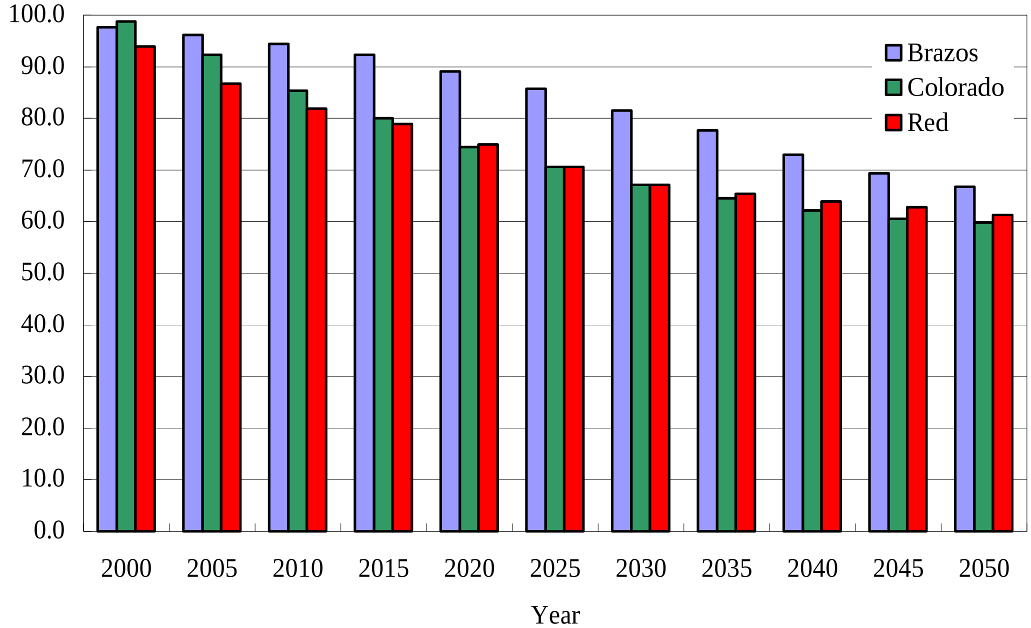

Figure 9. Region O Basins Satisfied Demand
Percentage, Baseline Simulation.

Table 3. Region O Satisfied Demand Percentage, Baseline Simulation.

County	Basin	Area (mi^2)	Satisfied Demand Percentage										
			2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bailey	County	843	93.5	92.9	91.5	90.9	89.2	88.7	88.3	86.5	83.7	82.4	79.9
	Brazos	843	93.5	92.9	91.5	90.9	89.2	88.7	88.3	86.5	83.7	82.4	79.9
Briscoe*	County	911											
Castro	County	911	99.5	98.9	98.3	96.4	90.8	83.9	74.4	68.2	59.1	51.7	45.4
	Brazos	492	100.0	100.0	100.0	99.0	93.6	86.4	75.6	68.2	56.5	47.0	39.9
	Red	419	97.9	95.4	93.1	88.7	82.4	76.4	70.6	68.2	67.2	66.2	62.2
Cochran	County	776	98.3	97.7	97.7	96.9	96.0	96.0	96.0	96.0	96.0	96.0	96.0
	Brazos	224	100.0	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8
	Colorado	552	96.4	96.4	96.4	94.8	92.9	92.9	92.9	92.9	92.9	92.9	92.9
Crosby	County	904	100.0	100.0	98.5	97.8	96.8	96.0	95.8	95.8	95.2	95.2	94.4
	Brazos	893	100.0	100.0	98.5	97.8	96.8	96.0	95.7	95.7	95.1	95.1	94.4
	Red	11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dawson	County	900	96.1	83.4	83.4	82.0	79.3	77.5	77.5	77.5	77.5	77.5	77.5
	Brazos	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	877	96.1	83.4	83.4	82.0	79.3	77.5	77.5	77.5	77.5	77.5	77.5
Deaf Smith	County	1,485	99.1	97.5	95.3	92.9	90.7	84.5	80.8	78.5	76.7	75.0	72.9
	Canadian	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Red	1,396	99.1	97.5	95.3	92.9	90.7	84.5	80.8	78.5	76.7	75.0	72.9
Dickens*	County	912											
Floyd	County	1,015	98.3	95.8	94.0	93.1	92.2	91.3	91.1	90.8	88.6	87.1	85.8
	Brazos	442	100.0	98.4	97.7	97.0	97.0	97.0	97.0	96.6	93.9	91.7	89.6
	Red	573	95.0	90.9	87.1	85.7	82.9	80.3	79.8	79.8	78.5	78.5	78.5
Gaines	County	1,507	99.2	89.8	78.8	71.6	64.5	59.4	55.1	51.2	48.3	46.2	45.0
	Colorado	1,507	99.2	89.8	78.8	71.6	64.5	59.4	55.1	51.2	48.3	46.2	45.0
Garza*	County	904											
Hale	County	1,033	95.2	94.8	94.2	93.8	92.6	91.6	90.7	89.7	88.6	87.4	86.7
	Brazos	1,030	95.2	94.7	94.4	94.0	93.1	92.1	91.3	90.3	89.1	87.9	87.2
	Red	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hockley	County	914	99.6	98.6	96.7	95.7	95.7	95.4	94.5	94.5	94.3	93.9	93.9
	Brazos	775	99.6	98.5	96.5	95.5	95.5	95.2	94.2	94.2	94.0	93.6	93.6
	Colorado	139	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lamb	County	1,013	98.5	96.8	94.6	92.3	86.8	83.5	77.9	73.5	66.6	60.8	59.0
	Brazos	1,013	98.5	96.8	94.6	92.3	86.8	83.5	77.9	73.5	66.6	60.8	59.0
Lubbock	County	908	93.2	89.2	88.2	86.8	86.0	84.9	84.8	84.8	83.9	83.5	83.5
	Brazos	908	93.2	89.2	88.2	86.8	86.0	84.9	84.8	84.8	83.9	83.5	83.5
Lynn	County	893	88.7	88.7	87.1	84.6	82.4	82.4	81.7	81.7	81.7	81.2	81.2
	Brazos	829	90.6	90.6	88.9	87.3	85.0	85.0	84.2	84.2	84.2	84.2	84.2
	Colorado	64	65.2	65.2	65.2	51.3	51.3	51.3	51.3	51.3	51.3	44.3	44.3
Motley*	County	994											
Parmer	County	854	99.4	98.4	94.6	89.2	82.1	72.9	62.8	53.1	45.5	40.0	36.0
	Brazos	535	99.8	98.8	94.1	88.0	80.7	70.3	59.8	48.1	39.5	33.1	28.5
	Red	319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swisher	County	915	93.0	69.6	55.9	47.1	39.6	35.7	32.8	31.3	30.5	30.1	29.0
	Brazos	116	100.0	80.3	69.9	54.1	43.8	36.9	29.2	26.7	24.7	24.7	20.6
	Red	799	90.3	65.6	50.8	44.4	38.0	35.3	34.2	33.0	32.7	32.1	32.1
Terry	County	904	99.0	96.9	94.4	91.2	88.0	87.4	84.9	83.8	81.6	80.5	79.1
	Brazos	60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Colorado	844	98.9	96.7	94.0	90.7	87.3	86.6	84.0	82.8	80.5	79.3	77.9
Yoakum	County	798	100.0	100.0	98.1	95.2	90.7	85.1	81.4	79.4	77.7	76.9	76.9
	Colorado	798	100.0	100.0	98.1	95.2	90.7	85.1	81.4	79.4	77.7	76.9	76.9
Region O Totals	Region O	20,294	97.2	93.6	90.3	87.4	83.6	80.0	76.1	72.9	69.3	66.5	64.5
	Brazos	8,732	97.7	96.1	94.4	92.3	89.1	85.7	81.5	77.7	73.0	69.3	66.8
	Canadian	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	4,787	98.8	92.3	85.3	80.0	74.5	70.6	67.1	64.5	62.2	60.6	59.8
	Red	6,681	93.9	86.7	81.9	78.9	75.0	70.6	67.1	65.4	63.9	62.8	61.3

* Due to boundary effects of the groundwater model, the data for this county has been omitted.

basin in each county, total for Region O, and total by river basin. Due to boundary effects of the groundwater model and the limited data available for these counties, demand percentages were not calculated for Briscoe, Dickens, Garza, and Motley counties.

3 Simulation of the Drought of Record

3.1 Volume in Storage

The drought of record was simulated as a four-year drought cycle starting first in 2015 and again in 2035 based on the observed historical droughts that have occurred in the 1930s, 1950s, 1970s, and 1990s. The model indicated that approximately 96,600,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050 under the assumed drought conditions. This number represents 73 percent of the volume of water in storage measured in 1995. The results of the drought simulation indicated the removal of an additional 7.4 million acre-feet of water, about 5.6 percent of the 1995 volume in storage, from the aquifer compared to the baseline simulation. Figure 10 shows the volume in storage in Region O in 1995 and in each decade of the planning period. Figure 11 shows the volume in storage in the three main river basins in 1995 and in each decade of the planning period for the drought simulation. Table 4 reports the volume in storage for each area in the planning region under the drought simulation.

3.2 Saturated Thickness

Figure 12 is a set of maps depicting the simulated saturated thickness of the Southern Ogallala Aquifer for the years 2020, 2030, and 2050. These maps resemble the maps of saturated thickness for the baseline simulation, but the drought declines were more

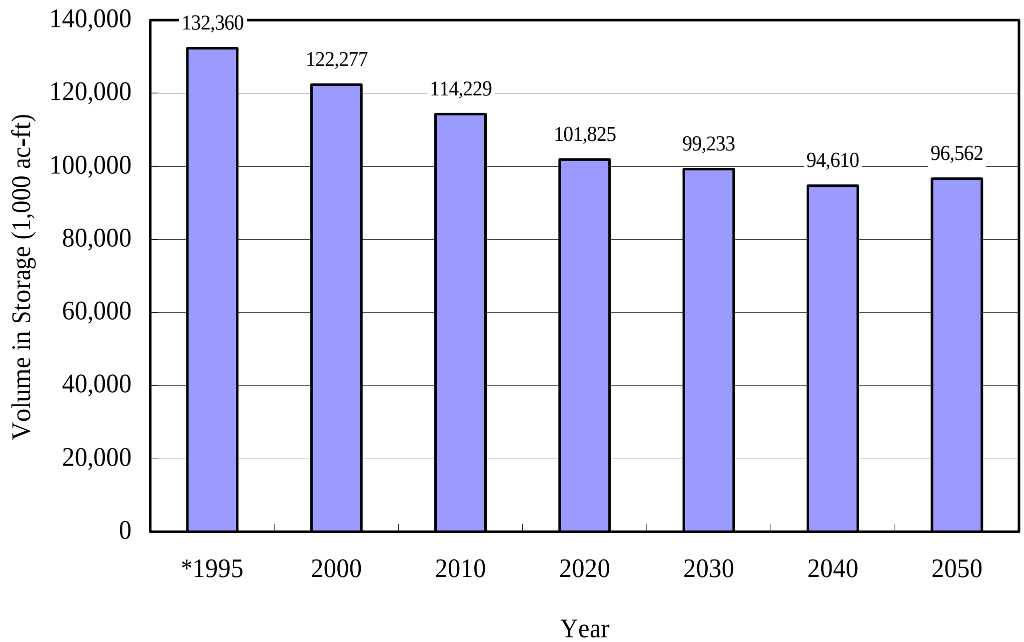

Figure 10. Region O Simulated Volume in Storage, Drought Simulation.

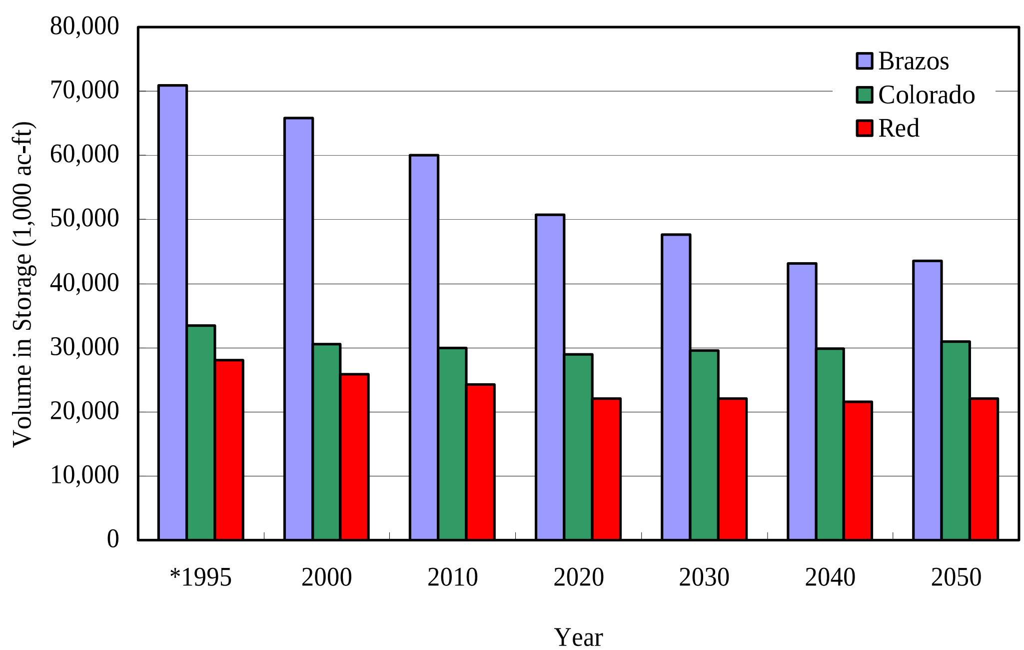

Figure 11. Region O Basins Simulated Volume in Storage, Drought Simulation.

Table 4. Region O Simulated Volume in Storage, Drought Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Bailey	Total	843	6,220	5,397	87	5,212	84	4,736	76	4,545	73	4,245	68	4,301	69
	Brazos	843	6,220	5,397	87	5,212	84	4,736	76	4,545	73	4,245	68	4,301	69
Briscoe	Total	911	1,601	1,524	95	1,792	112	2,022	126	2,211	138	2,379	149	2,527	158
	Red	911	1,601	1,524	95	1,792	112	2,022	126	2,211	138	2,379	149	2,527	158
Castro	Total	911	12,204	11,037	90	8,754	72	5,802	48	4,166	34	2,638	22	2,174	18
	Brazos	492	8,290	7,385	89	5,640	68	3,397	41	2,049	25	825	10	495	6
	Red	419	3,914	3,651	93	3,114	80	2,405	61	2,117	54	1,813	46	1,678	43
Cochran	Total	776	3,829	4,046	106	4,548	119	4,927	129	5,476	143	5,921	155	6,478	169
	Brazos	224	1,294	1,311	101	1,369	106	1,380	107	1,484	115	1,537	119	1,672	129
	Colorado	552	2,535	2,735	108	3,179	125	3,546	140	3,992	157	4,384	173	4,806	190
Crosby	Total	904	6,223	6,632	107	7,228	116	7,380	119	7,795	125	7,886	127	8,251	133
	Brazos	893	6,113	6,521	107	7,109	116	7,251	119	7,654	125	7,736	127	8,092	132
	Red	11	110	111	101	118	107	129	117	141	128	150	136	159	145
Dawson	Total	900	7,101	5,836	82	6,320	89	6,547	92	6,730	95	6,793	96	6,867	97
	Brazos	23	103	55	53	66	64	69	67	70	68	70	68	70	68
	Colorado	877	6,997	5,781	83	6,254	89	6,478	93	6,661	95	6,723	96	6,797	97
Deaf Smith	Total	1,485	9,649	9,050	94	8,219	85	6,980	72	6,661	69	6,270	65	6,222	64
	Canadian	89	4	4	100	4	100	4	100	4	100	4	100	4	100
	Red	1,396	9,645	9,045	94	8,215	85	6,976	72	6,657	69	6,266	65	6,218	64
Dickens	Total	912	1,141	991	87	1,177	103	1,245	109	1,275	112	1,290	113	1,298	114
	Brazos	127	210	282	134	332	158	346	165	353	168	356	170	358	170
	Red	785	930	709	76	845	91	898	97	922	99	934	100	941	101
Floyd	Total	1,015	9,654	9,274	96	8,708	90	7,882	82	7,654	79	7,095	73	7,039	73
	Brazos	442	6,003	5,672	94	5,117	85	4,391	73	4,025	67	3,421	57	3,199	53
	Red	573	3,652	3,602	99	3,591	98	3,490	96	3,629	99	3,674	101	3,839	105
Gaines	Total	1,507	13,188	11,646	88	10,176	77	9,039	69	8,761	66	8,492	64	8,580	65
	Colorado	1,507	13,188	11,646	88	10,176	77	9,039	69	8,761	66	8,492	64	8,580	65
Garza	Total	904	484	163	34	177	37	189	39	202	42	215	44	228	47
	Brazos	904	484	163	34	177	37	189	39	202	42	215	44	228	47
Hale	Total	1,033	10,880	10,558	97	9,915	91	8,451	78	8,130	75	7,141	66	7,072	65
	Brazos	1,030	10,786	10,467	97	9,835	91	8,383	78	8,061	75	7,074	66	7,002	65
	Red	3	94	91	97	80	85	68	72	69	73	67	71	70	74

Table 4. Region O Simulated Volume in Storage, Drought Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Hockley	Total	914	4,753	4,811	101	4,893	103	4,744	100	4,991	105	4,990	105	5,342	112
	Brazos	775	4,155	4,184	101	4,208	101	4,018	97	4,212	101	4,171	100	4,469	108
	Colorado	139	598	627	105	685	115	726	121	778	130	819	137	872	146
Lamb	Total	1,013	9,269	8,500	92	7,099	77	5,382	58	4,508	49	3,743	40	3,596	39
	Brazos	1,013	9,269	8,500	92	7,099	77	5,382	58	4,508	49	3,743	40	3,596	39
Lubbock	Total	908	5,603	5,574	99	5,463	98	5,099	91	5,217	93	5,106	91	5,395	96
	Brazos	908	5,603	5,574	99	5,463	98	5,099	91	5,217	93	5,106	91	5,395	96
Lynn	Total	893	3,818	2,587	68	2,854	75	3,017	79	3,251	85	3,395	89	3,583	94
	Brazos	829	3,495	2,471	71	2,748	79	2,917	83	3,147	90	3,291	94	3,477	99
	Colorado	64	323	116	36	106	33	101	31	103	32	104	32	106	33
Motley	Total	994	1,125	656	58	729	65	768	68	792	70	806	72	817	73
	Red	994	1,125	656	58	729	65	768	68	792	70	806	72	817	73
Parmer	Total	854	10,635	9,553	90	7,272	68	4,589	43	3,373	32	2,425	23	2,170	20
	Brazos	535	7,648	6,751	88	4,797	63	2,581	34	1,523	20	768	10	560	7
	Red	319	2,987	2,802	94	2,474	83	2,008	67	1,850	62	1,657	55	1,610	54
Swisher	Total	915	4,673	4,281	92	3,685	79	3,516	75	3,785	81	3,975	85	4,292	92
	Brazos	116	714	596	83	377	53	172	24	143	20	108	15	101	14
	Red	799	3,959	3,684	93	3,308	84	3,344	84	3,642	92	3,867	98	4,191	106
Terry	Total	904	4,977	4,801	96	4,674	94	4,363	88	4,428	89	4,411	89	4,651	93
	Brazos	60	504	463	92	464	92	456	90	471	93	472	94	493	98
	Colorado	844	4,472	4,338	97	4,210	94	3,907	87	3,958	89	3,938	88	4,158	93
Yoakum	Total	798	5,333	5,360	101	5,334	100	5,147	97	5,282	99	5,394	101	5,679	106
	Colorado	798	5,333	5,360	101	5,334	100	5,147	97	5,282	99	5,394	101	5,679	106
Region O Totals	Total	20,294	132,360	122,277	92	114,229	86	101,825	77	99,233	75	94,610	71	96,562	73
	Brazos	8,732	70,891	65,792	93	60,013	85	50,767	72	47,664	67	43,138	61	43,508	61
	Canadian	94	4	4	100	4	100	4	100	4	100	4	100	4	100
	Colorado	4,787	33,446	30,603	91	29,944	90	28,944	87	29,535	88	29,854	89	30,998	93
	Red	6,681	28,017	25,875	92	24,266	87	22,108	79	22,030	79	21,613	77	22,050	79

* 1995 values represent historical measurements as reported by TWDB and HPUWCD#1.

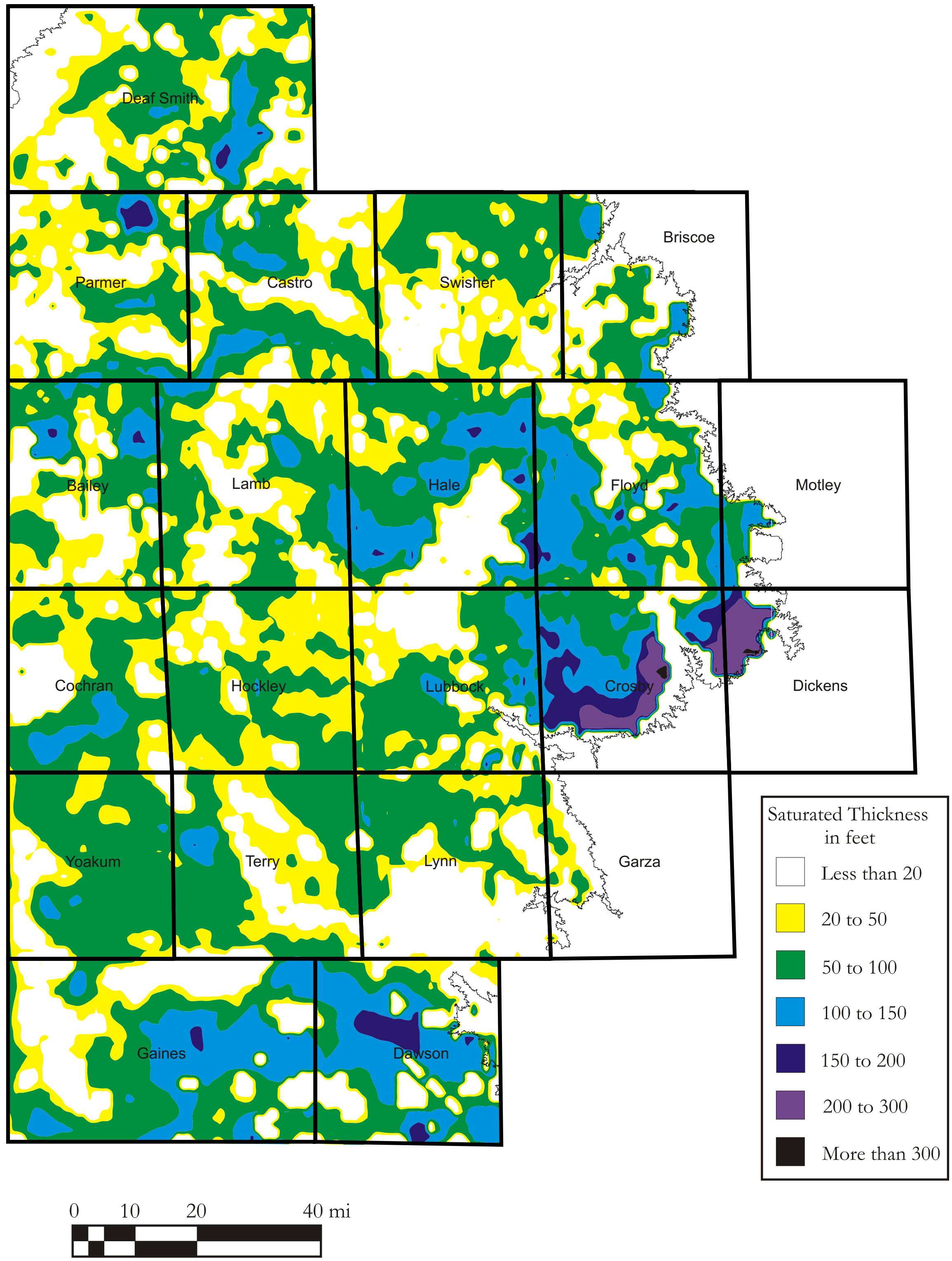

Figure 12(a). 2020 Region O Simulated Saturated Thickness, Drought Simulation.

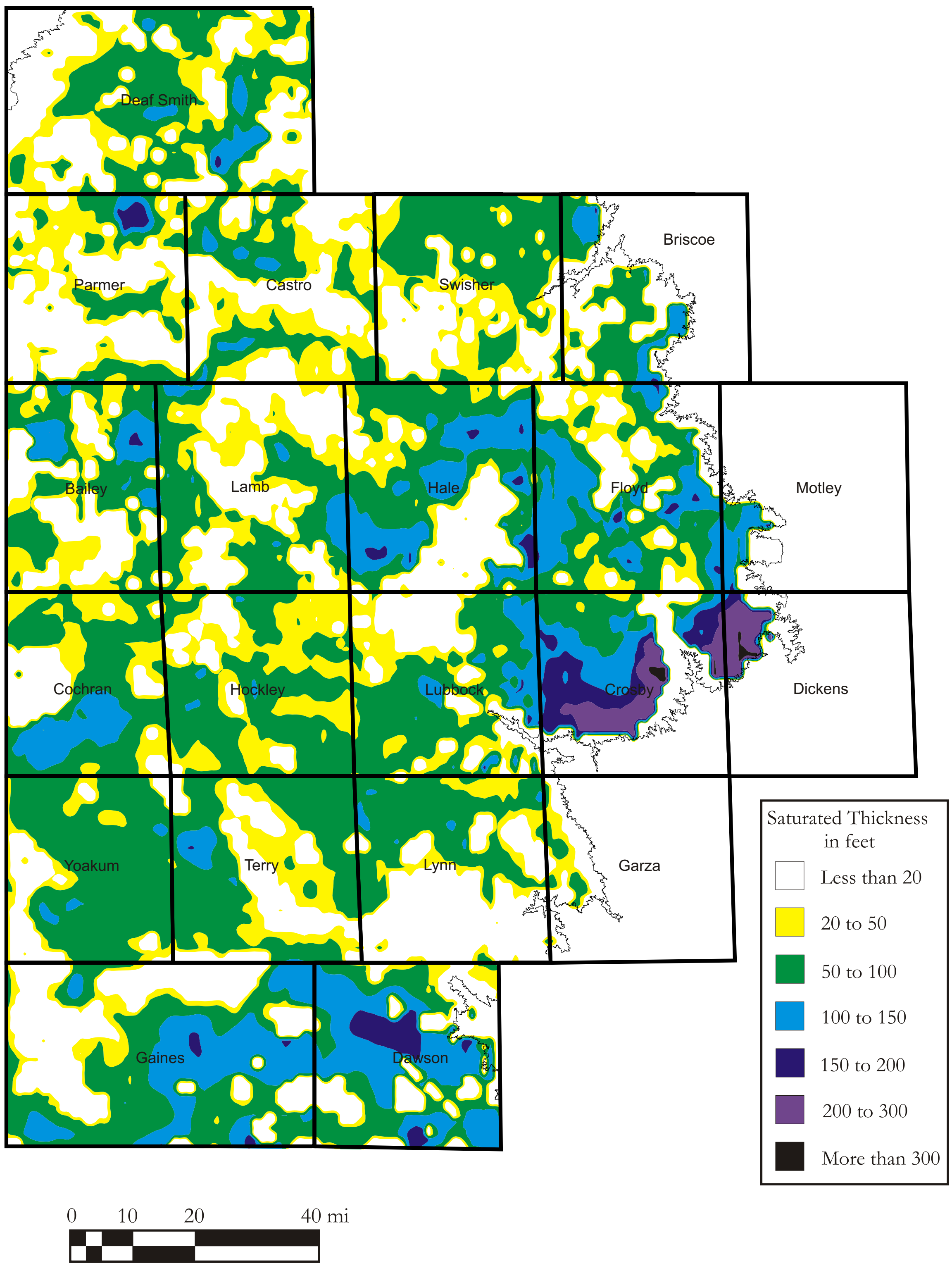

Figure 12(b). 2030 Region O Simulated Saturated Thickness, Drought Simulation.

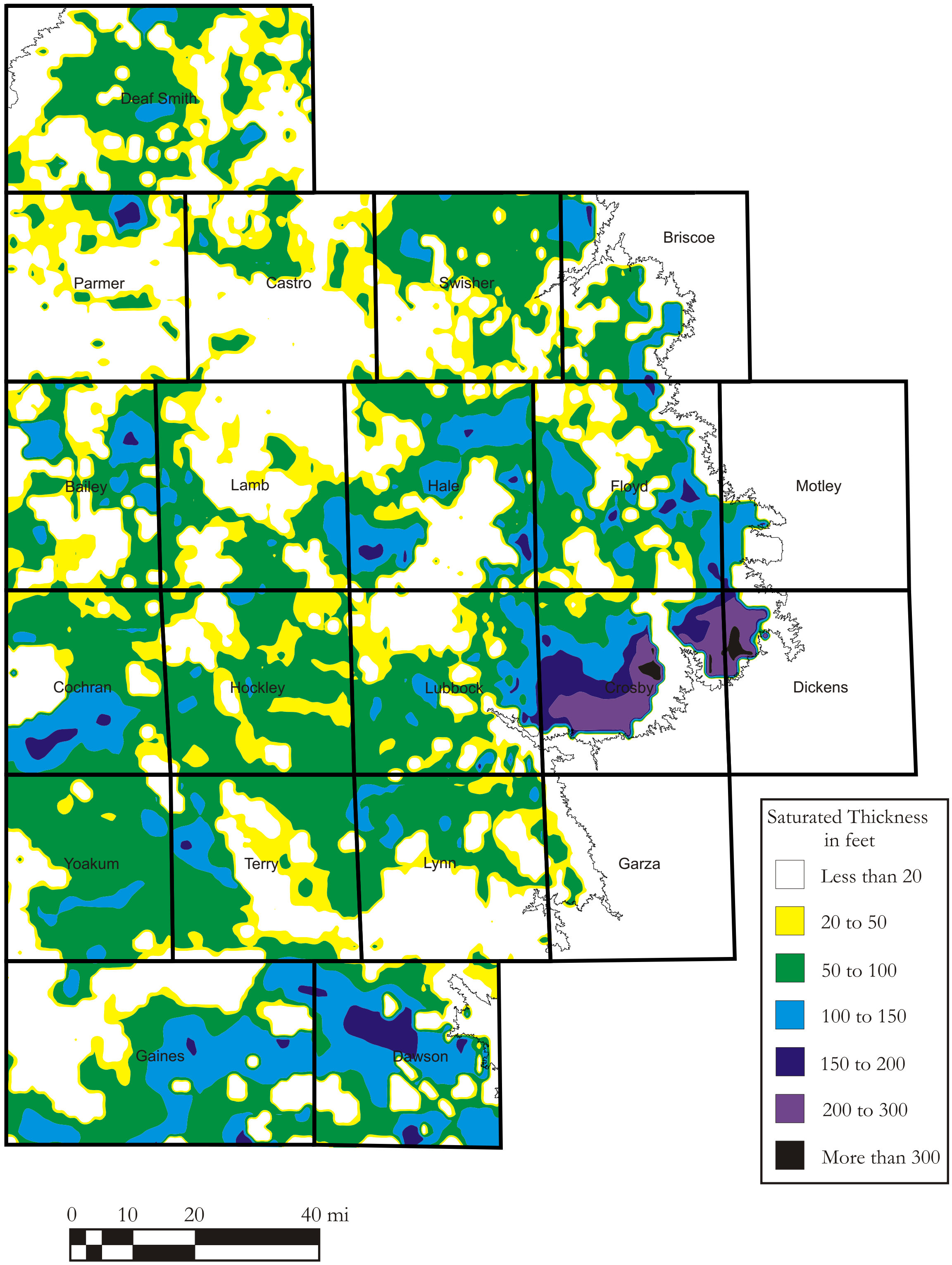

Figure 12(c). 2050 Region O Simulated Saturated Thickness, Drought Simulation.

pronounced and the rises were not as great. Hale and Motley counties could be added to the list of counties experiencing the greatest depletion.

3.3 Satisfied Demand Percentage

Under the drought simulation, the model indicates that approximately 59 percent of the total groundwater demand for Region O can be met in 2050. Figures 13 and 14 show the satisfied demand percentage for every five years of the planning period for Region O and the three main river basins in Region O, respectively. Table 5 reports the satisfied demand percentage by county, river basin in each county, total for Region O, and total by river basin.

4 Simulation of the Precipitation Enhancement Program

4.1 Volume in Storage

The precipitation enhancement program was simulated as a 1-inch reduction of groundwater pumpage and a 0.25-inch increase in recharge across the region. The model indicated that approximately 119,000,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050 under the assumed conditions. This number represents 90 percent of the volume of water in storage measured in 1995. The results of the precipitation enhancement simulation indicated an additional 15 million ac-ft of water, or about 11.3 percent of the 1995 volume in storage remaining in the aquifer compared to the baseline simulation. Figure 15 shows the volume in storage in Region O in 1995 and in each decade of the planning period for the precipitation enhancement simulation. Figure 16 shows the volume in storage in the three main river basins in 1995 and in each decade of the planning period for the precipitation enhancement simulation. Table

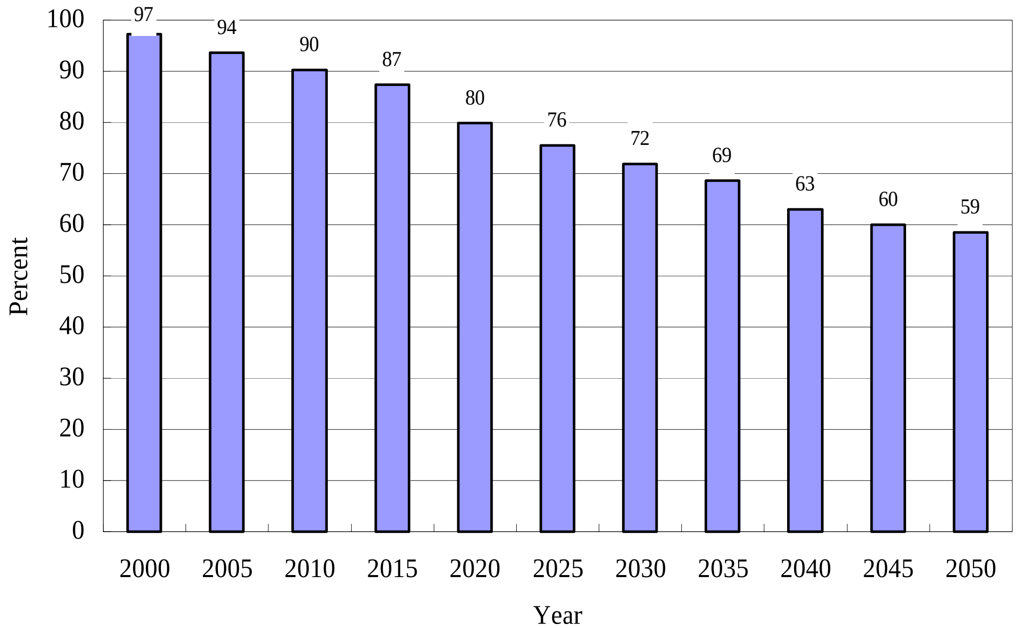

Figure 13. Region O Satisfied Demand Percentage, Drought Simulation.

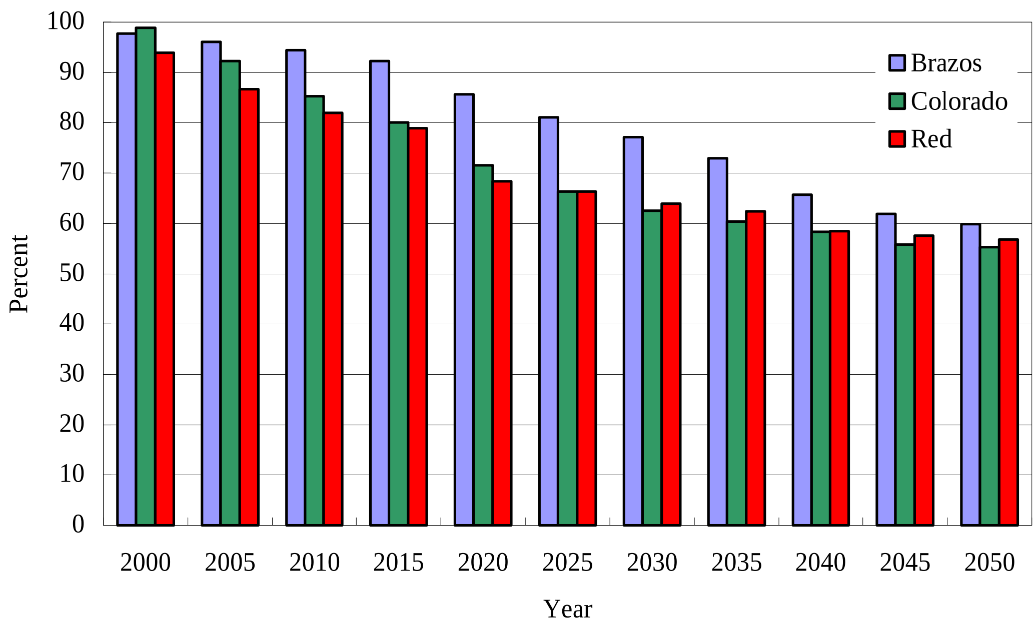

Figure 14. Region O Basins Satisfied Demand Percentage, Drought Simulation.

Table 5. Region O Satisfied Demand Percentage, Drought Simulation.

County	Basin	Area (mi^2)	Satisfied Demand Percentage										
			2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bailey	County	843	93.5	92.9	91.5	90.9	88.5	86.4	83.3	82.4	74.7	72.6	71.3
	Brazos	843	93.5	92.9	91.5	90.9	88.5	86.4	83.3	82.4	74.7	72.6	71.3
Briscoe*	County	911											
Castro	County	911	99.5	98.9	98.3	96.4	85.8	76.4	70.8	62.6	47.9	42.1	37.5
	Brazos	492	100.0	100.0	100.0	99.0	88.6	78.3	71.7	61.1	43.0	35.8	30.0
	Red	419	97.9	95.4	93.1	88.7	77.2	70.6	67.8	67.2	62.8	60.9	60.3
Cochran	County	776	98.3	97.7	97.7	96.9	95.0	95.0	95.0	95.0	95.0	95.0	95.0
	Brazos	224	100.0	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8
	Colorado	552	96.4	96.4	96.4	94.8	90.7	90.7	90.7	90.7	90.7	90.7	90.7
Crosby	County	904	100.0	100.0	98.5	97.8	95.6	94.7	94.7	94.7	94.0	94.0	94.0
	Brazos	893	100.0	100.0	98.5	97.8	95.6	94.7	94.7	94.7	93.9	93.9	93.9
	Red	11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dawson	County	900	96.1	83.4	83.4	82.0	77.5	77.5	77.5	77.5	77.5	77.5	77.5
	Brazos	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	877	96.1	83.4	83.4	82.0	77.5	77.5	77.5	77.5	77.5	77.5	77.5
Deaf Smith	County	1,485	99.1	97.5	95.3	92.9	82.7	79.3	76.3	74.8	71.6	69.0	68.2
	Canadian	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Red	1,396	99.1	97.5	95.3	92.9	82.7	79.3	76.3	74.8	71.6	69.0	68.2
Dickens*	County	912											
Floyd	County	1,015	98.3	95.8	94.0	93.1	91.0	90.2	88.3	87.8	84.2	80.0	78.9
	Brazos	442	100.0	98.4	97.7	97.0	97.0	96.6	94.1	93.7	88.9	83.3	81.7
	Red	573	95.0	90.9	87.1	85.7	79.4	77.9	77.2	76.6	75.1	73.6	73.6
Gaines	County	1,507	99.2	89.8	78.8	71.6	60.7	55.6	51.0	48.2	44.1	42.0	41.2
	Colorado	1,507	99.2	89.8	78.8	71.6	60.7	55.6	51.0	48.2	44.1	42.0	41.2
Garza*	County	904											
Hale	County	1,033	95.2	94.8	94.2	93.8	89.9	89.1	88.6	86.5	81.8	80.2	78.8
	Brazos	1,030	95.2	94.7	94.4	94.0	90.5	89.7	89.2	87.1	82.4	80.7	79.3
	Red	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hockley	County	914	99.6	98.6	96.7	95.7	92.9	91.9	91.5	91.3	88.7	87.8	87.4
	Brazos	775	99.6	98.5	96.5	95.5	92.5	91.4	91.1	90.8	88.1	87.2	86.7
	Colorado	139	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lamb	County	1,013	98.5	96.8	94.6	92.3	84.4	77.4	73.6	66.7	57.0	54.1	52.0
	Brazos	1,013	98.5	96.8	94.6	92.3	84.4	77.4	73.6	66.7	57.0	54.1	52.0
Lubbock	County	908	93.2	89.2	88.2	86.8	83.8	81.7	81.3	81.1	79.0	78.9	78.9
	Brazos	908	93.2	89.2	88.2	86.8	83.8	81.7	81.3	81.1	79.0	78.9	78.9
Lynn	County	893	88.7	88.7	87.1	84.6	79.3	79.3	78.9	78.9	78.4	78.4	78.4
	Brazos	829	90.6	90.6	88.9	87.3	81.5	81.5	81.1	81.1	81.1	81.1	81.1
	Colorado	64	65.2	65.2	65.2	51.3	51.3	51.3	51.3	51.3	44.3	44.3	44.3
Motley*	County	994											
Parmer	County	854	99.4	98.4	94.6	89.2	73.9	64.8	53.5	46.9	35.4	31.5	28.9
	Brazos	535	99.8	98.8	94.1	88.0	71.6	61.7	48.9	41.2	28.9	24.7	21.9
	Red	319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swisher	County	915	93.0	69.6	55.9	47.1	33.6	32.0	29.9	27.8	25.9	25.5	25.4
	Brazos	116	100.0	80.3	69.9	54.1	31.7	28.2	22.5	20.4	15.3	14.8	14.8
	Red	799	90.3	65.6	50.8	44.4	34.4	33.4	32.7	30.6	29.9	29.5	29.3
Terry	County	904	99.0	96.9	94.4	91.2	85.2	81.7	77.0	76.0	72.4	72.0	71.7
	Brazos	60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Colorado	844	98.9	96.7	94.0	90.7	84.3	80.6	75.6	74.5	70.7	70.3	70.0
Yoakum	County	798	100.0	100.0	98.1	95.2	84.1	78.2	75.7	73.5	71.9	71.0	70.5
	Colorado	798	100.0	100.0	98.1	95.2	84.1	78.2	75.7	73.5	71.9	71.0	70.5
Region O Totals	Region O	20,294	97.2	93.6	90.3	87.4	79.9	75.5	71.9	68.6	63.0	60.0	58.5
	Brazos	8,732	97.7	96.1	94.4	92.3	85.7	81.1	77.1	72.9	65.7	61.9	59.8
	Canadian	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	4,787	98.8	92.3	85.3	80.0	71.6	66.3	62.5	60.4	58.3	55.8	55.3
	Red	6,681	93.9	86.7	81.9	78.9	68.4	66.3	63.9	62.4	58.4	57.6	56.8

* Due to boundary effects of the groundwater model, the data for this county has been omitted.

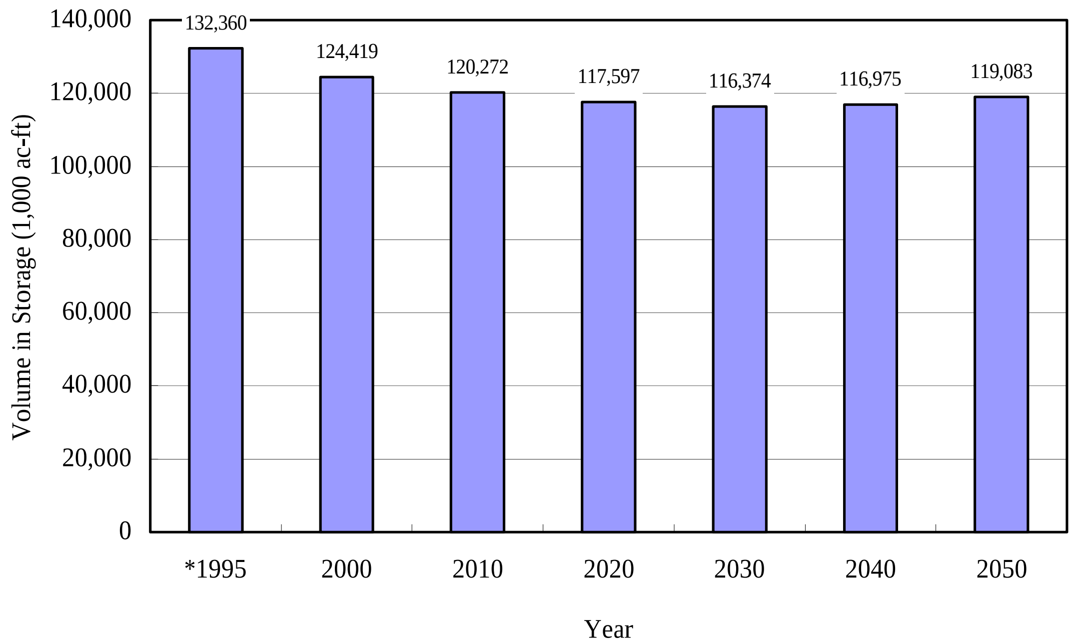

Figure 15. Region O Simulated Volume in Storage,
Precipitation Enhancement Simulation.

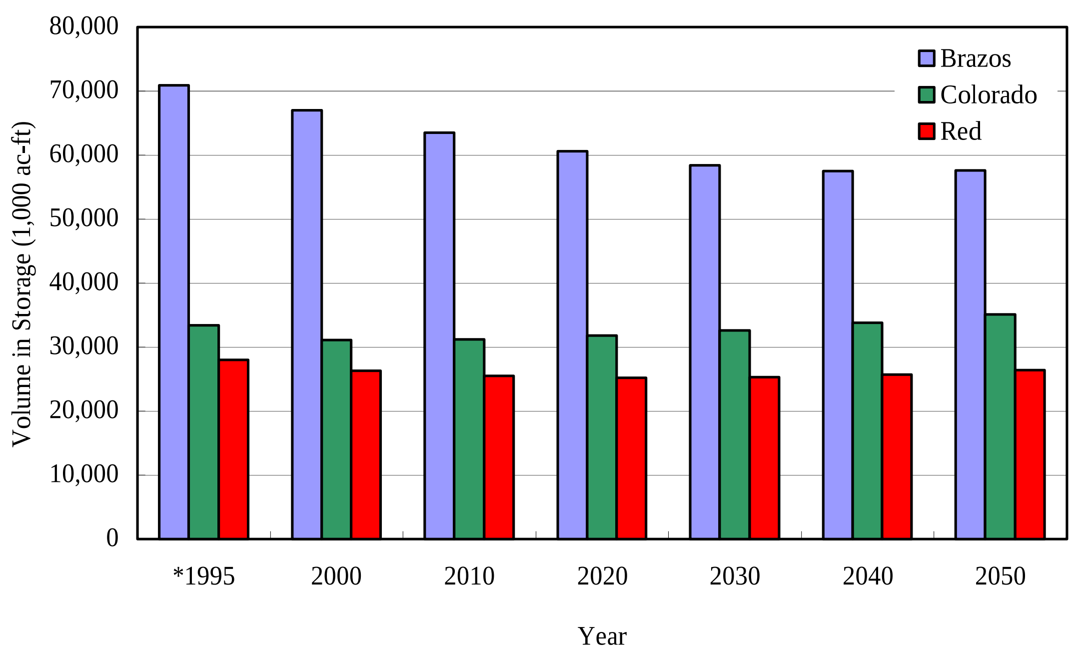

Figure 16. Region O Basins Simulated Volume in Storage,
Precipitation Enhancement Simulation.

6 reports the volume in storage for each area in the planning region under the precipitation enhancement simulation.

4.2 Saturated Thickness

Figure 17 is a set of maps depicting the simulated saturated thickness of the Southern Ogallala Aquifer for the years 2000, 2030, and 2050. Castro, Parmer, and Lamb counties showed signs of significant depletion, while most of the other counties showed increased saturated thicknesses.

4.3. Satisfied Demand Percentage

Under the precipitation enhancement simulation, the model indicates that approximately 72 percent of the total groundwater demand for Region O can be met in 2050. Figures 18 and 19 show the satisfied demand percentage for every five years of the planning period for Region O and the three main river basins in Region O, respectively. Table 7 reports the satisfied demand percentage by county, river basin in each county, total for Region O, and total by river basin.

Table 6. Region O Simulated Volume of Water in Storage,
Precipitation Enhancement Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Bailey	Total	843	6,220	5,492	88	5,489	88	5,494	88	5,504	88	5,528	89	5,505	89
	Brazos	843	6,220	5,492	88	5,489	88	5,494	88	5,504	88	5,528	89	5,505	89
Briscoe	Total	911	1,601	1,545	97	1,837	115	2,095	131	2,314	145	2,501	156	2,663	166
	Red	911	1,601	1,545	97	1,837	115	2,095	131	2,314	145	2,501	156	2,663	166
Castro	Total	911	12,204	11,206	92	9,235	76	7,339	60	5,643	46	4,366	36	3,422	28
	Brazos	492	8,290	7,494	90	5,964	72	4,472	54	3,087	37	2,021	24	1,189	14
	Red	419	3,914	3,712	95	3,271	84	2,868	73	2,556	65	2,345	60	2,233	57
Cochran	Total	776	3,829	4,129	108	4,742	124	5,391	141	6,038	158	6,696	175	7,352	192
	Brazos	224	1,294	1,344	104	1,459	113	1,596	123	1,747	135	1,912	148	2,088	161
	Colorado	552	2,535	2,786	110	3,282	129	3,795	150	4,291	169	4,784	189	5,265	208
Crosby	Total	904	6,223	6,717	108	7,475	120	8,073	130	8,579	138	9,036	145	9,452	152
	Brazos	893	6,113	6,604	108	7,354	120	7,938	130	8,431	138	8,878	145	9,286	152
	Red	11	110	112	102	122	111	135	123	148	135	158	144	166	151
Dawson	Total	900	7,101	5,887	83	6,413	90	6,720	95	6,885	97	6,971	98	7,031	99
	Brazos	23	103	57	55	67	65	69	67	70	68	71	69	71	69
	Colorado	877	6,997	5,831	83	6,346	91	6,651	95	6,815	97	6,900	99	6,961	99
Deaf Smith	Total	1,485	9,649	9,199	95	8,667	90	8,301	86	8,107	84	7,970	83	8,058	84
	Canadian	89	4	4	100	4	100	4	100	4	100	5	125	5	125
	Red	1,396	9,645	9,194	95	8,662	90	8,297	86	8,103	84	7,966	83	8,053	83
Dickens	Total	912	1,141	994	87	1,184	104	1,253	110	1,284	113	1,299	114	1,309	115
	Brazos	127	210	283	135	334	159	348	166	355	169	358	170	360	171
	Red	785	930	712	77	850	91	905	97	929	100	942	101	949	102
Floyd	Total	1,015	9,654	9,405	97	9,127	95	8,995	93	8,941	93	8,999	93	9,119	94
	Brazos	442	6,003	5,749	96	5,361	89	5,071	84	4,860	81	4,718	79	4,628	77
	Red	573	3,652	3,655	100	3,766	103	3,925	107	4,081	112	4,281	117	4,491	123
Gaines	Total	1,507	13,188	11,824	90	10,661	81	10,012	76	9,728	74	9,646	73	9,708	74
	Colorado	1,507	13,188	11,824	90	10,661	81	10,012	76	9,728	74	9,646	73	9,708	74
Garza	Total	904	484	167	35	188	39	206	43	224	46	242	50	258	53
	Brazos	904	484	167	35	188	39	206	43	224	46	242	50	258	53
Hale	Total	1,033	10,880	10,755	99	10,489	96	10,316	95	10,192	94	10,216	94	10,312	95
	Brazos	1,030	10,786	10,661	99	10,397	96	10,229	95	10,101	94	10,119	94	10,208	95
	Red	3	94	94	100	93	99	87	93	91	97	97	103	104	111

Table 6. Region O Simulated Volume of Water in Storage, Precipitation Enhancement Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Hockley	Total	914	4,753	4,923	104	5,270	111	5,675	119	6,141	129	6,637	140	7,159	151
	Brazos	775	4,155	4,286	103	4,556	110	4,886	118	5,278	127	5,700	137	6,147	148
	Colorado	139	598	637	107	714	119	789	132	863	144	937	157	1,012	169
Lamb	Total	1,013	9,269	8,681	94	7,626	82	6,651	72	5,845	63	5,311	57	5,068	55
	Brazos	1,013	9,269	8,681	94	7,626	82	6,651	72	5,845	63	5,311	57	5,068	55
Lubbock	Total	908	5,603	5,700	102	5,773	103	6,023	107	6,311	113	6,651	119	7,026	125
	Brazos	908	5,603	5,700	102	5,773	103	6,023	107	6,311	113	6,651	119	7,026	125
Lynn	Total	893	3,818	2,640	69	2,963	78	3,258	85	3,512	92	3,732	98	3,901	102
	Brazos	829	3,495	2,509	72	2,853	82	3,147	90	3,401	97	3,619	104	3,787	108
	Colorado	64	323	131	41	110	34	111	34	111	34	113	35	114	35
Motley	Total	994	1,125	659	59	736	65	778	69	804	71	822	73	834	74
	Red	994	1,125	659	59	736	65	778	69	804	71	822	73	834	74
Parmer	Total	854	10,635	9,720	91	7,818	74	6,048	57	4,642	44	3,746	35	3,267	31
	Brazos	535	7,648	6,876	90	5,221	68	3,690	48	2,459	32	1,618	21	1,162	15
	Red	319	2,987	2,843	95	2,597	87	2,358	79	2,182	73	2,128	71	2,105	70
Swisher	Total	915	4,673	4,421	95	3,974	85	4,029	86	4,321	92	4,652	100	5,019	107
	Brazos	116	714	616	86	422	59	298	42	240	34	215	30	211	30
	Red	799	3,959	3,805	96	3,553	90	3,731	94	4,081	103	4,437	112	4,808	121
Terry	Total	904	4,977	4,910	99	5,007	101	5,149	103	5,357	108	5,624	113	5,928	119
	Brazos	60	504	469	93	483	96	502	100	525	104	550	109	573	114
	Colorado	844	4,472	4,441	99	4,524	101	4,646	104	4,832	108	5,074	113	5,355	120
Yoakum	Total	798	5,333	5,445	102	5,598	105	5,791	109	6,002	113	6,330	119	6,692	125
	Colorado	798	5,333	5,445	102	5,598	105	5,791	109	6,002	113	6,330	119	6,692	125
Region O Totals	Total	20,294	132,360	124,419	94	120,272	91	117,597	89	116,374	88	116,975	88	119,083	90
	Brazos	8,732	70,891	66,988	94	63,547	90	60,620	86	58,438	82	57,511	81	57,567	81
	Canadian	94	4	4	100	4	100	4	100	4	100	5	125	5	125
	Colorado	4,787	33,446	31,095	93	31,235	93	31,795	95	32,642	98	33,784	101	35,107	105
	Red	6,681	28,017	26,331	94	25,487	91	25,179	90	25,289	90	25,677	92	26,406	94

* 1995 values represent historical measurements as reported by TWDB and HPUWCD#1.

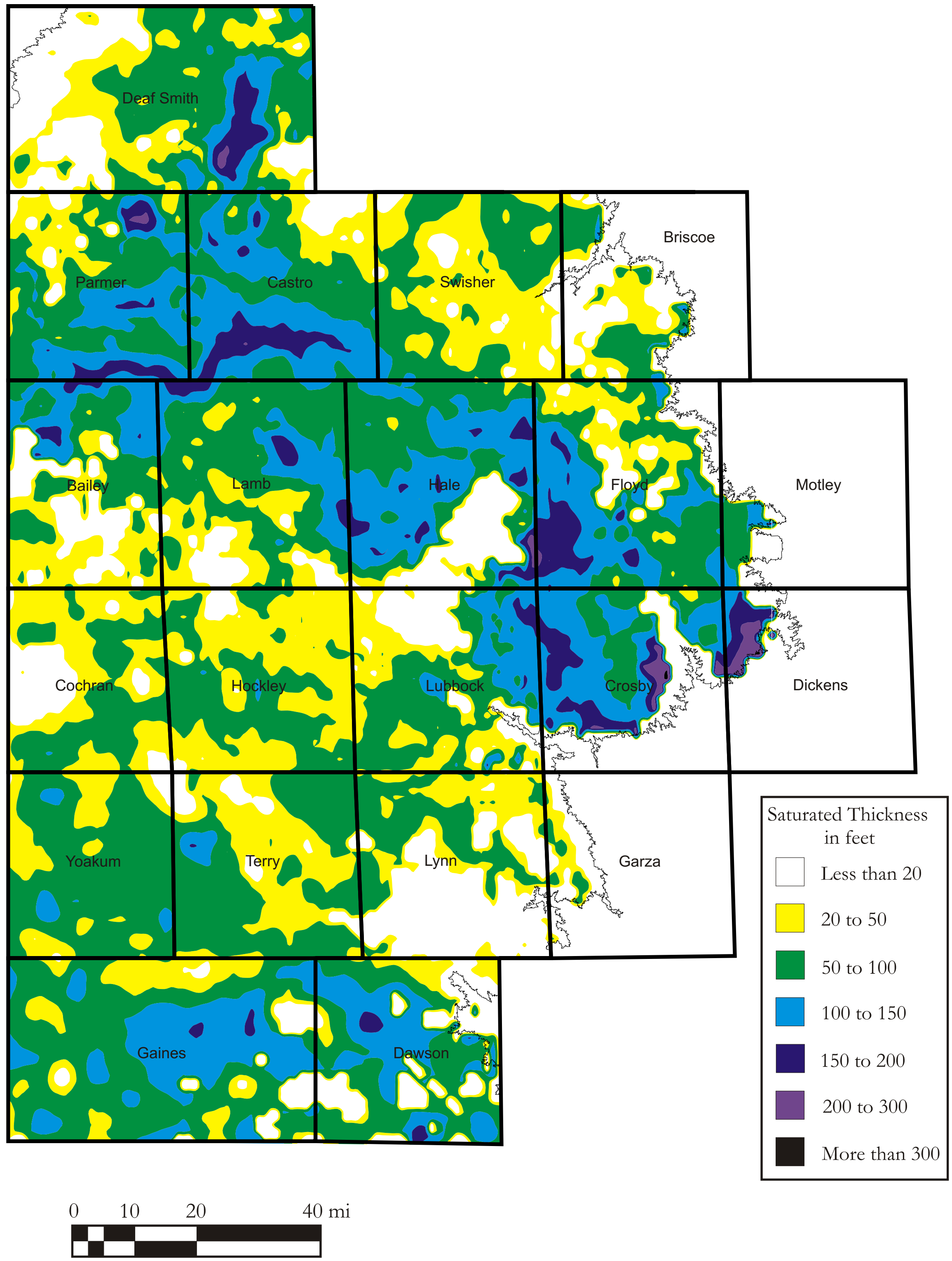

Figure 17(a). 2000 Region O Simulated Saturated Thickness, Precipitation Enhancement Simulation.

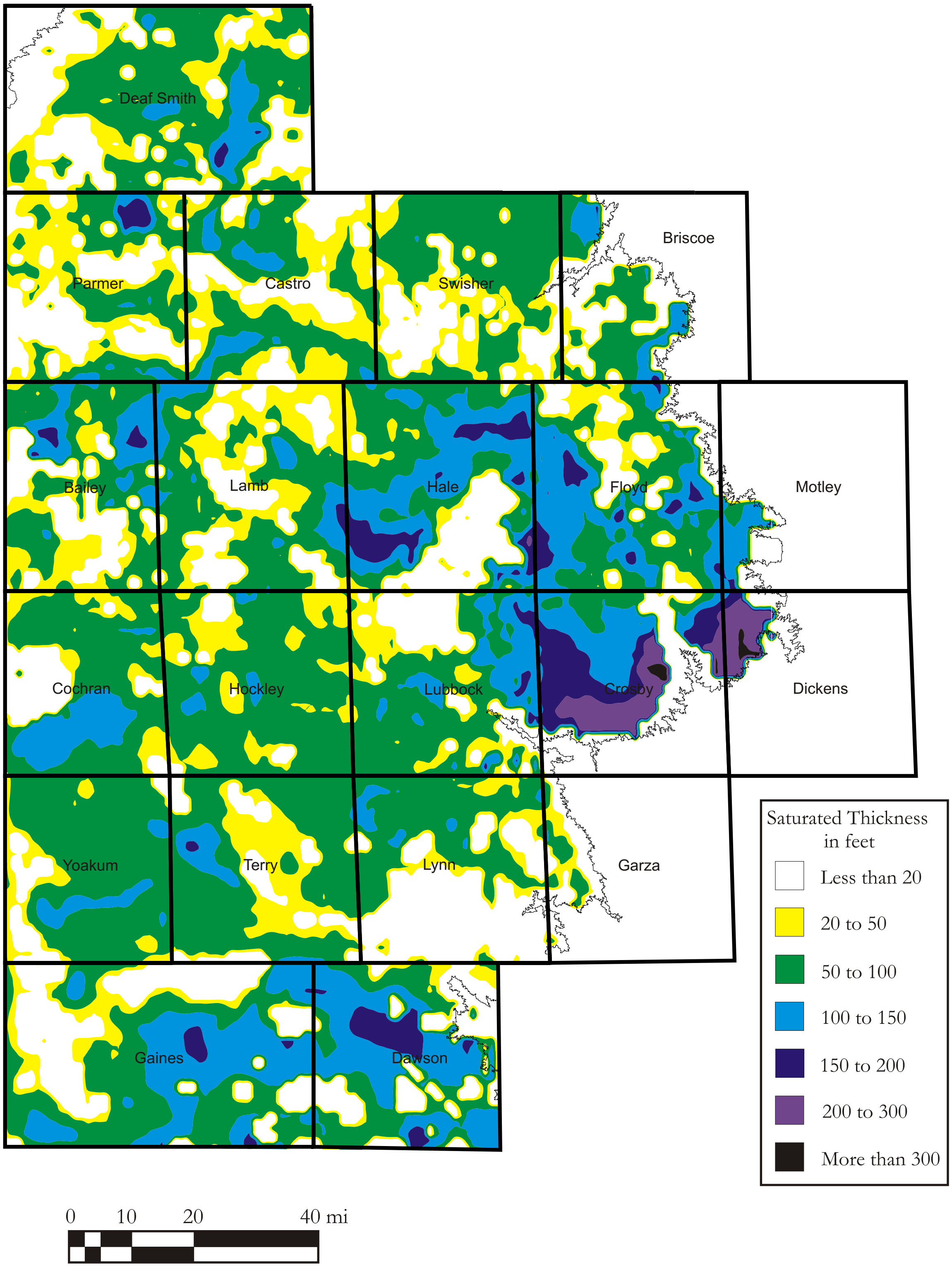

Figure 17(b). 2030 Region O Simulated Saturated Thickness, Precipitation Enhancement Simulation.

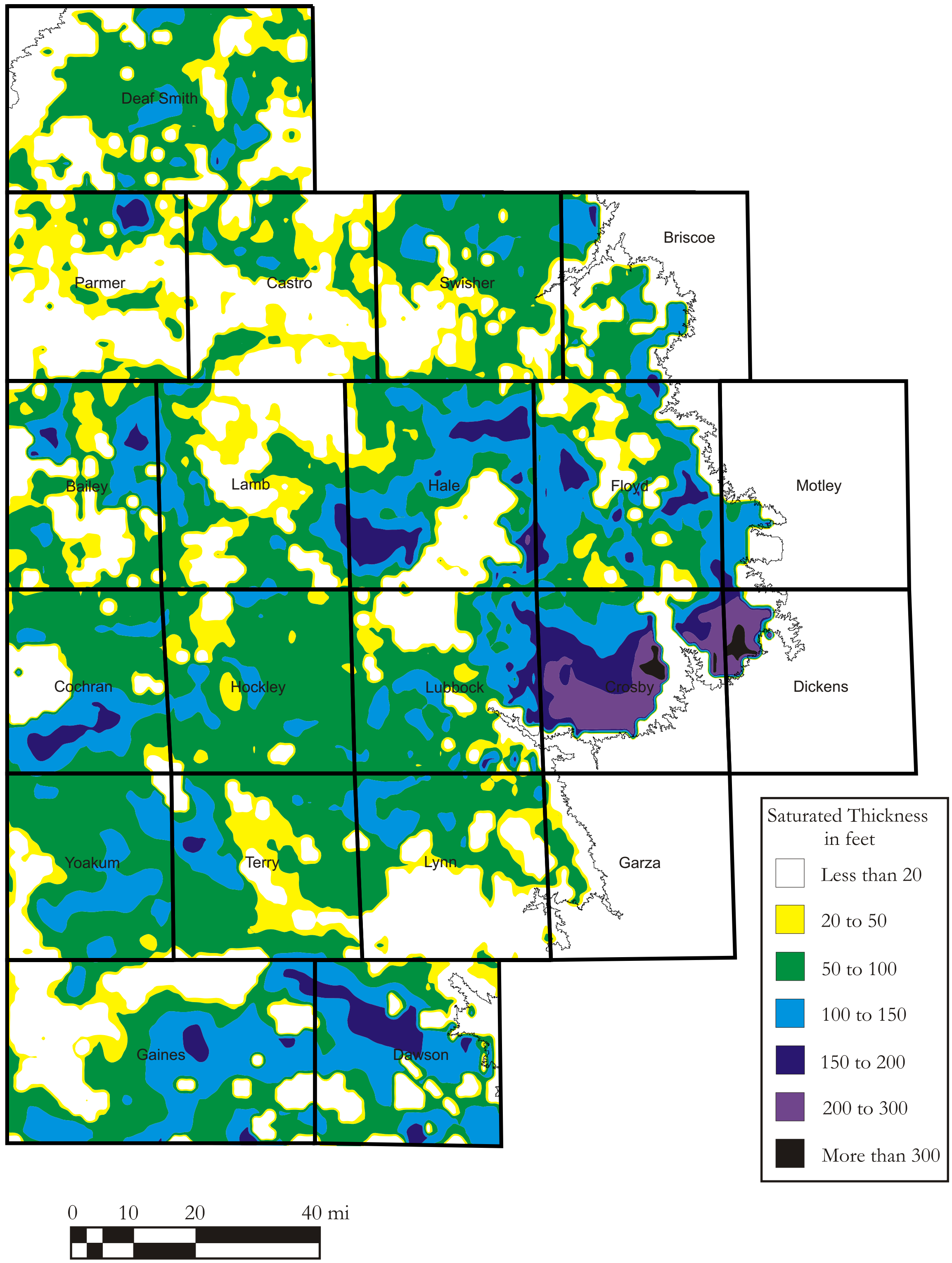

Figure 17(c). 2050 Region O Simulated Saturated Thickness, Precipitation Enhancement Simulation.

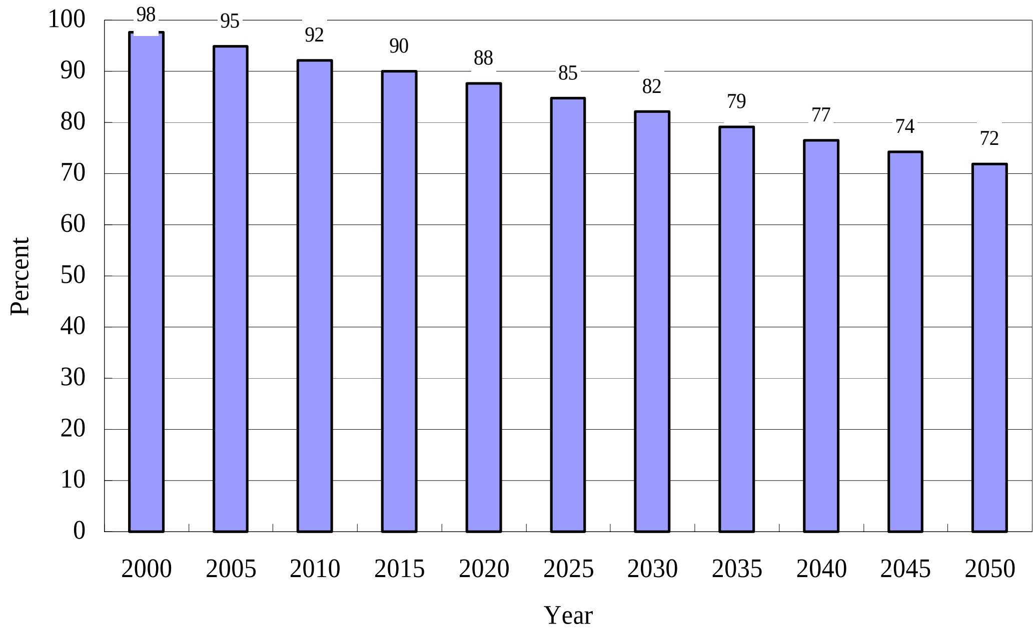

Figure 18. Region O Satisfied Demand Percentage,
Precipitation Enhancement Simulation.

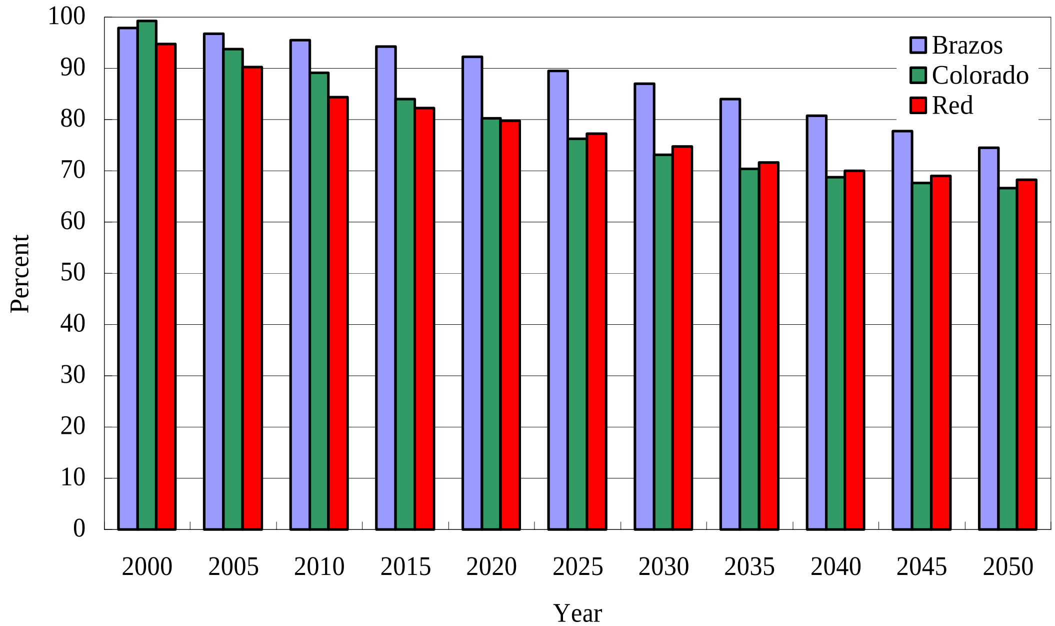

Figure 19. Region O Basins Satisfied Demand Percentage,
Precipitation Enhancement Simulation.

Table 7. Region O Satisfied Demand Percentage,
Precipitation Enhancement Simulation.

County	Basin	Area (mi^2)	Satisfied Demand Percentage										
			2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bailey	County	843	94.0	92.9	92.9	92.4	92.2	92.1	92.1	92.1	92.1	90.2	89.8
	Brazos	843	94.0	92.9	92.9	92.4	92.2	92.1	92.1	92.1	92.1	90.2	89.8
Briscoe*	County	911											
Castro	County	911	99.7	99.2	98.4	97.6	95.2	90.2	84.6	76.4	71.8	64.6	56.5
	Brazos	492	100.0	100.0	100.0	99.6	97.2	92.7	86.8	77.8	72.1	62.8	52.1
	Red	419	98.8	96.6	93.7	91.2	88.9	82.5	77.9	72.2	70.8	70.0	69.7
Cochran	County	776	99.0	98.3	98.3	98.3	98.3	97.5	97.5	97.5	97.5	97.5	97.5
	Brazos	224	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Colorado	552	97.8	96.4	96.4	96.4	96.4	94.8	94.8	94.8	94.8	94.8	94.8
Crosby	County	904	100.0	100.0	99.3	98.5	98.5	96.8	96.8	96.8	96.6	96.6	96.6
	Brazos	893	100.0	100.0	99.3	98.5	98.5	96.8	96.8	96.8	96.5	96.5	96.5
	Red	11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dawson	County	900	100.0	86.0	83.4	83.4	82.0	80.2	80.2	80.2	80.2	80.2	80.2
	Brazos	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	877	100.0	86.0	83.4	83.4	82.0	80.2	80.2	80.2	80.2	80.2	80.2
Deaf Smith	County	1,485	99.1	98.0	96.1	95.1	93.0	92.4	90.0	86.2	83.7	82.4	81.1
	Canadian	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Red	1,396	99.1	98.0	96.1	95.1	93.0	92.4	90.0	86.2	83.7	82.4	81.1
Dickens*	County	912											
Floyd	County	1,015	98.3	96.8	95.4	94.3	93.7	93.4	92.8	92.7	92.6	92.6	92.6
	Brazos	442	100.0	99.5	98.4	97.7	97.0	97.0	97.0	97.0	97.0	97.0	97.0
	Red	573	95.0	91.6	89.9	87.8	87.4	86.6	84.9	84.6	84.1	84.1	84.1
Gaines	County	1,507	99.5	91.7	84.4	76.2	69.8	64.6	60.8	57.0	54.7	52.9	51.2
	Colorado	1,507	99.5	91.7	84.4	76.2	69.8	64.6	60.8	57.0	54.7	52.9	51.2
Garza*	County	904											
Hale	County	1,033	95.4	94.8	94.7	94.7	94.1	93.9	93.3	92.5	92.5	92.3	92.3
	Brazos	1,030	95.3	94.8	94.6	94.6	94.4	94.2	93.5	92.8	92.8	92.6	92.6
	Red	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hockley	County	914	99.6	99.6	98.6	97.4	96.7	96.7	96.7	96.7	96.7	96.7	96.7
	Brazos	775	99.6	99.6	98.5	97.2	96.5	96.5	96.5	96.5	96.5	96.5	96.5
	Colorado	139	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lamb	County	1,013	98.9	97.3	96.1	94.8	91.9	88.5	85.2	82.6	77.4	73.2	67.4
	Brazos	1,013	98.9	97.3	96.1	94.8	91.9	88.5	85.2	82.6	77.4	73.2	67.4
Lubbock	County	908	94.4	90.1	88.4	88.2	88.2	88.2	88.2	88.2	88.1	87.8	87.8
	Brazos	908	94.4	90.1	88.4	88.2	88.2	88.2	88.2	88.2	88.1	87.8	87.8
Lynn	County	893	89.8	89.4	89.4	87.4	86.7	85.7	84.9	84.9	84.2	84.2	84.2
	Brazos	829	91.0	90.6	90.6	88.4	87.7	87.7	86.9	86.9	86.1	86.1	86.1
	Colorado	64	74.5	74.5	74.5	74.5	74.5	60.6	60.6	60.6	60.6	60.6	60.6
Motley*	County	994											
Parmer	County	854	99.4	99.2	96.6	93.2	87.9	79.1	73.0	65.0	56.7	51.0	46.5
	Brazos	535	99.8	99.6	96.6	92.4	86.4	77.0	70.2	62.0	52.0	45.3	40.0
	Red	319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swisher	County	915	96.3	82.0	61.9	54.8	48.0	43.7	41.0	38.7	36.9	35.7	35.1
	Brazos	116	100.0	85.9	73.0	65.6	52.6	47.5	42.8	34.6	30.4	30.4	28.3
	Red	799	94.9	80.6	57.7	50.9	46.3	42.3	40.3	40.3	39.4	37.7	37.7
Terry	County	904	99.0	98.4	96.7	95.3	95.0	94.1	92.6	91.9	91.2	91.2	90.7
	Brazos	60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Colorado	844	98.9	98.3	96.5	95.0	94.7	93.8	92.2	91.4	90.7	90.7	90.2
Yoakum	County	798	100.0	100.0	99.5	98.1	97.7	93.6	88.8	86.0	84.6	83.8	83.2
	Colorado	798	100.0	100.0	99.5	98.1	97.7	93.6	88.8	86.0	84.6	83.8	83.2
Region O Totals	Region O	20,294	97.6	94.9	92.1	90.0	87.6	84.7	82.1	79.1	76.5	74.2	71.9
	Brazos	8,732	97.9	96.7	95.5	94.2	92.2	89.5	87.0	84.0	80.8	77.7	74.5
	Canadian	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	4,787	99.3	93.8	89.1	84.0	80.2	76.2	73.1	70.4	68.8	67.6	66.6
	Red	6,681	94.8	90.3	84.4	82.2	79.7	77.3	74.7	71.6	70.0	69.0	68.2

* Due to boundary effects of the groundwater model, the data for this county has been omitted.

5 Simulation of Reduction of Irrigation Demand

5.1 Volume in Storage

The effects of a combination of improvements in irrigation and application efficiency, plant genetics, cropping patterns, land management, and other agricultural advancements were simulated as a reduction in the projected irrigation demands of 5 percent every five years to a maximum of 25 percent in the year 2020. The model indicated that approximately 109,000,000 acre-feet of water will remain in the Ogallala formation underlying Region O by the year 2050 under the assumed conditions. This number represents 82 percent of the volume of water in storage measured in 1995. The results of the reduction of irrigation demand simulation indicated an additional 5 million acre-feet of water, or about 3.8 percent of the 1995 volume in storage, remaining in the aquifer compared to the baseline simulation. Figure 20 shows the volume in storage in Region O in 1995 and in each decade of the planning period for the pumpage reduction simulation. Figure 21 shows the volume in storage in the three main river basins in 1995 and in each decade of the planning period for the pumpage reduction simulation. Table 8 reports the volume in storage for each area in the planning region under the precipitation enhancement simulation.

5.2 Saturated Thickness

Figure 22 is a set of maps depicting the simulated saturated thickness of the Southern Ogallala Aquifer for the years 2000, 2030, and 2050. While Castro, Parmer, and Lamb counties were significantly depleted, a slight increase of saturated thicknesses was observed in most other counties.

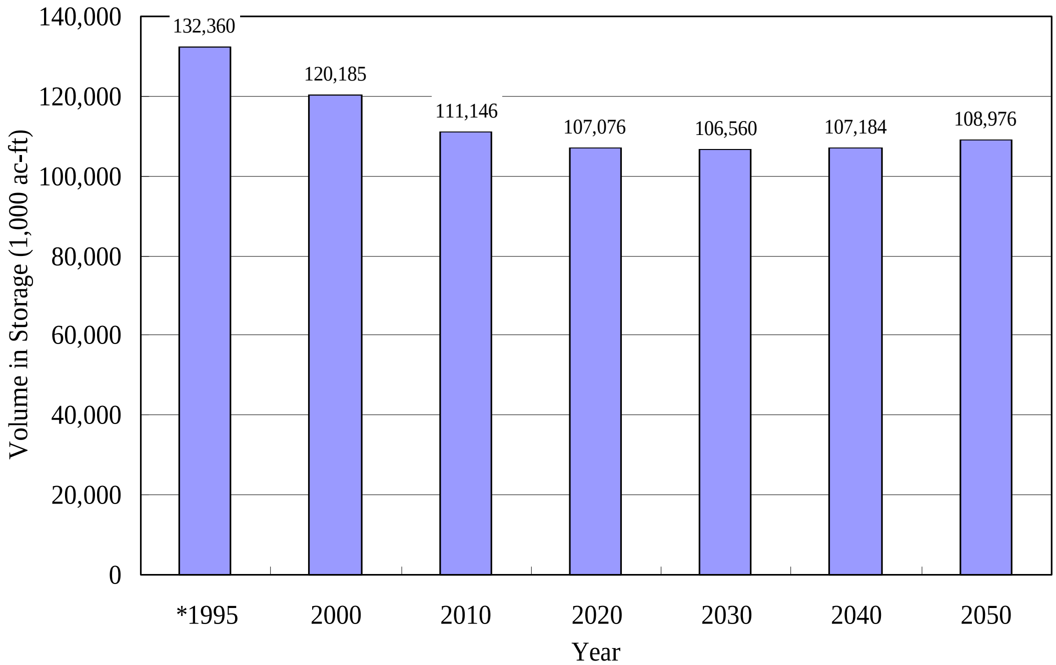

Figure 20. Region O Simulated Volume in Storage,
Pumpage Reduction Simulation.

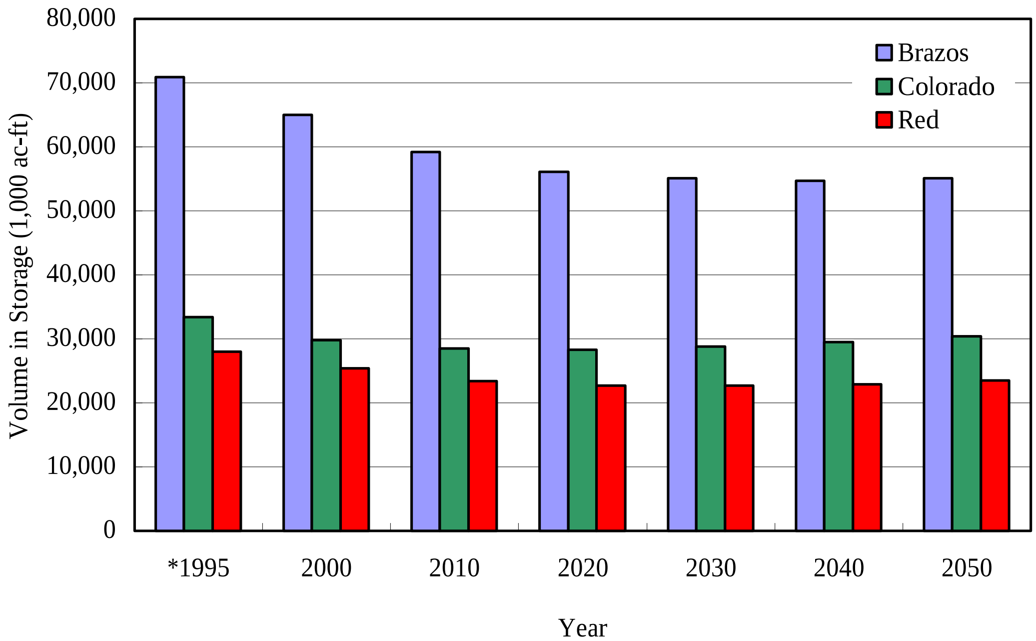

Figure 21. Region O Basins Simulated Volume in Storage,
Pumpage Reduction Simulation.

Table 8. Region O Simulated Volume in Storage,
Pumpage Reduction Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Bailey	Total	843	6,220	5,335	86	5,158	83	5,170	83	5,286	85	5,394	87	5,509	89
	Brazos	843	6,220	5,335	86	5,158	83	5,170	83	5,286	85	5,394	87	5,509	89
Briscoe	Total	911	1,601	1,513	95	1,773	111	1,998	125	2,186	137	2,351	147	2,493	156
	Red	911	1,601	1,513	95	1,773	111	1,998	125	2,186	137	2,351	147	2,493	156
Castro	Total	911	12,204	10,936	90	8,732	72	6,886	56	5,436	45	4,319	35	3,437	28
	Brazos	492	8,290	7,374	89	5,784	70	4,462	54	3,387	41	2,528	30	1,843	22
	Red	419	3,914	3,562	91	2,948	75	2,424	62	2,049	52	1,791	46	1,595	41
Cochran	Total	776	3,829	3,902	102	4,185	109	4,542	119	4,966	130	5,400	141	5,844	153
	Brazos	224	1,294	1,293	100	1,338	103	1,438	111	1,569	121	1,709	132	1,856	143
	Colorado	552	2,535	2,609	103	2,846	112	3,104	122	3,397	134	3,691	146	3,988	157
Crosby	Total	904	6,223	6,491	104	6,923	111	7,322	118	7,744	124	8,132	131	8,498	137
	Brazos	893	6,113	6,384	104	6,817	112	7,211	118	7,627	125	8,007	131	8,368	137
	Red	11	110	108	98	106	96	111	101	117	106	124	113	131	119
Dawson	Total	900	7,101	5,601	79	5,846	82	6,047	85	6,213	87	6,348	89	6,452	91
	Brazos	23	103	54	52	65	63	68	66	69	67	70	68	70	68
	Colorado	877	6,997	5,547	79	5,781	83	5,979	85	6,144	88	6,278	90	6,382	91
Deaf Smith	Total	1,485	9,649	8,939	93	8,108	84	7,707	80	7,690	80	7,665	79	7,805	81
	Canadian	89	4	4	100	4	100	4	100	4	100	4	100	4	100
	Red	1,396	9,645	8,935	93	8,104	84	7,703	80	7,685	80	7,661	79	7,801	81
Dickens	Total	912	1,141	919	81	1,048	92	1,113	98	1,147	101	1,167	102	1,179	103
	Brazos	127	210	278	132	322	153	335	160	340	162	343	163	345	164
	Red	785	930	641	69	727	78	778	84	807	87	824	89	834	90
Floyd	Total	1,015	9,654	8,952	93	7,957	82	7,342	76	6,994	72	6,746	70	6,576	68
	Brazos	442	6,003	5,467	91	4,622	77	4,011	67	3,607	60	3,242	54	2,944	49
	Red	573	3,652	3,484	95	3,335	91	3,330	91	3,388	93	3,504	96	3,632	99
Gaines	Total	1,507	13,188	11,411	87	9,803	74	9,050	69	8,742	66	8,647	66	8,628	65
	Colorado	1,507	13,188	11,411	87	9,803	74	9,050	69	8,742	66	8,647	66	8,628	65
Garza	Total	904	484	163	34	178	37	194	40	212	44	231	48	248	51
	Brazos	904	484	163	34	178	37	194	40	212	44	231	48	248	51
Hale	Total	1,033	10,880	10,441	96	9,872	91	9,765	90	9,980	92	10,253	94	10,625	98
	Brazos	1,030	10,786	10,351	96	9,789	91	9,685	90	9,893	92	10,157	94	10,519	98
	Red	3	94	90	96	84	89	80	85	87	93	96	102	106	113

Table 8. Region O Simulated Volume in Storage,
Pumpage Reduction Simulation.

County	Basin	Area	*1995	2000		2010		2020		2030		2040		2050	
		sq miles	1000 ac-ft	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial	1000 ac-ft	% initial
Hockley	Total	914	4,753	4,759	100	4,832	102	5,127	108	5,537	116	5,972	126	6,429	135
	Brazos	775	4,155	4,136	100	4,158	100	4,401	106	4,758	115	5,141	124	5,545	133
	Colorado	139	598	623	104	675	113	726	121	779	130	831	139	884	148
Lamb	Total	1,013	9,269	8,442	91	7,209	78	6,471	70	6,023	65	5,789	62	5,662	61
	Brazos	1,013	9,269	8,442	91	7,209	78	6,471	70	6,023	65	5,789	62	5,662	61
Lubbock	Total	908	5,603	5,486	98	5,315	95	5,417	97	5,671	101	5,965	106	6,318	113
	Brazos	908	5,603	5,486	98	5,315	95	5,417	97	5,671	101	5,965	106	6,318	113
Lynn	Total	893	3,818	2,560	67	2,807	74	3,062	80	3,310	87	3,531	92	3,728	98
	Brazos	829	3,495	2,444	70	2,701	77	2,956	85	3,201	92	3,421	98	3,616	103
	Colorado	64	323	116	36	106	33	106	33	108	33	110	34	112	35
Motley	Total	994	1,125	627	56	678	60	710	63	733	65	750	67	764	68
	Red	994	1,125	627	56	678	60	710	63	733	65	750	67	764	68
Parmer	Total	854	10,635	9,470	89	7,328	69	5,700	54	4,649	44	3,800	36	3,292	31
	Brazos	535	7,648	6,709	88	4,917	64	3,571	47	2,692	35	1,936	25	1,468	19
	Red	319	2,987	2,762	92	2,411	81	2,129	71	1,956	65	1,864	62	1,825	61
Swisher	Total	915	4,673	4,234	91	3,668	78	3,687	79	3,954	85	4,248	91	4,551	97
	Brazos	116	714	595	83	393	55	290	41	270	38	263	37	259	36
	Red	799	3,959	3,639	92	3,274	83	3,397	86	3,684	93	3,985	101	4,293	108
Terry	Total	904	4,977	4,738	95	4,582	92	4,601	92	4,778	96	4,983	100	5,226	105
	Brazos	60	504	460	91	459	91	469	93	488	97	510	101	532	106
	Colorado	844	4,472	4,277	96	4,124	92	4,132	92	4,290	96	4,473	100	4,694	105
Yoakum	Total	798	5,333	5,266	99	5,144	96	5,165	97	5,309	100	5,493	103	5,712	107
	Colorado	798	5,333	5,266	99	5,144	96	5,165	97	5,309	100	5,493	103	5,712	107
Region O Totals	Total	20,294	132,360	120,185	91	111,146	84	107,076	81	106,560	81	107,184	81	108,976	82
	Brazos	8,732	70,891	64,971	92	59,225	84	56,149	79	55,093	78	54,706	77	55,102	78
	Canadian	94	4	4	100	4	100	4	100	4	100	4	100	4	100
	Colorado	4,787	33,446	29,849	89	28,479	85	28,262	85	28,769	86	29,523	88	30,400	91
	Red	6,681	28,017	25,361	91	23,440	84	22,660	81	22,692	81	22,950	82	23,474	84

* 1995 values represent historical measurements as reported by TWDB and HPUWCD#1.

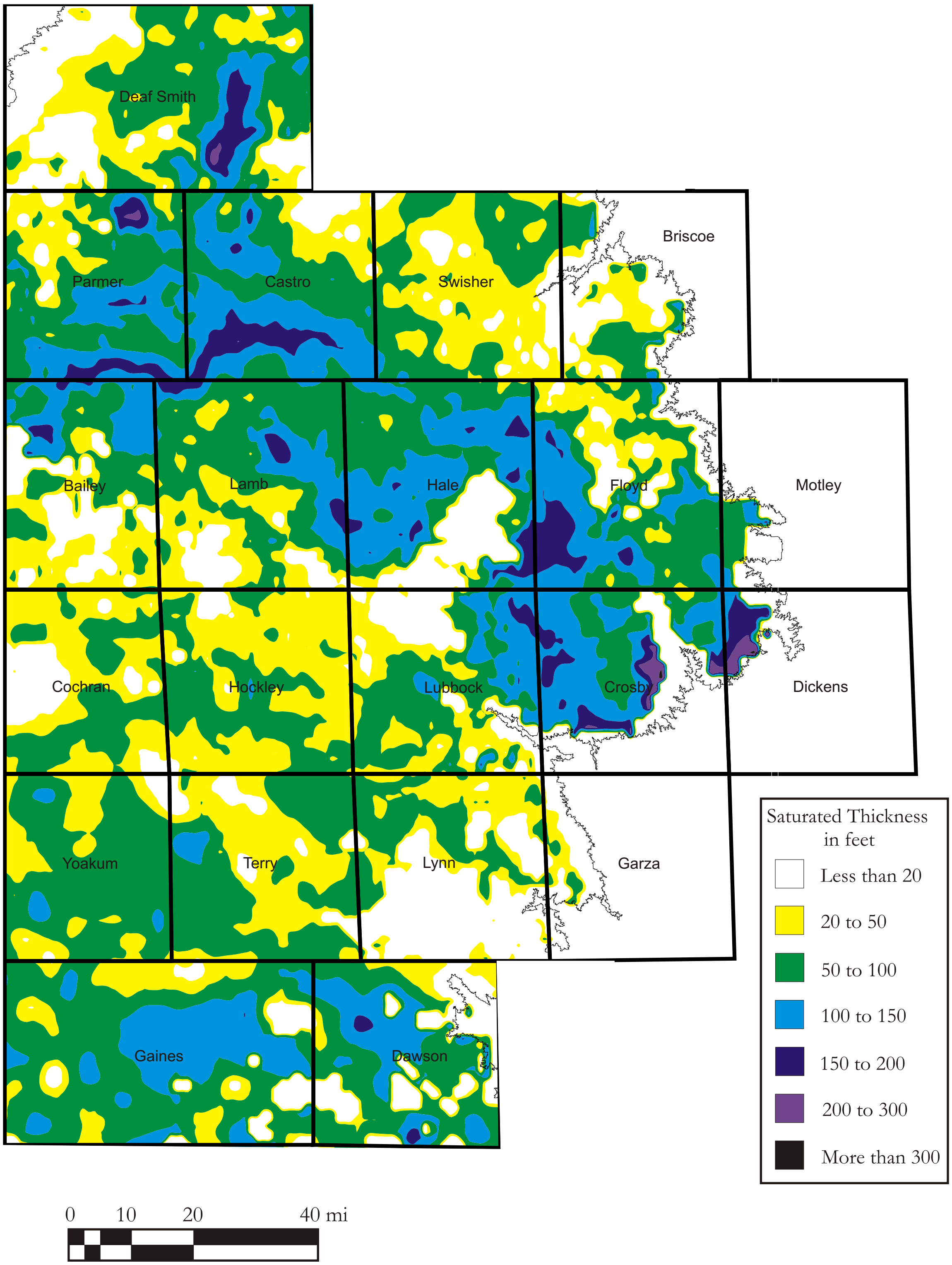

Figure 22(a). 2000 Region O Simulated Saturated Thickness, Pumpage Reduction Simulation.

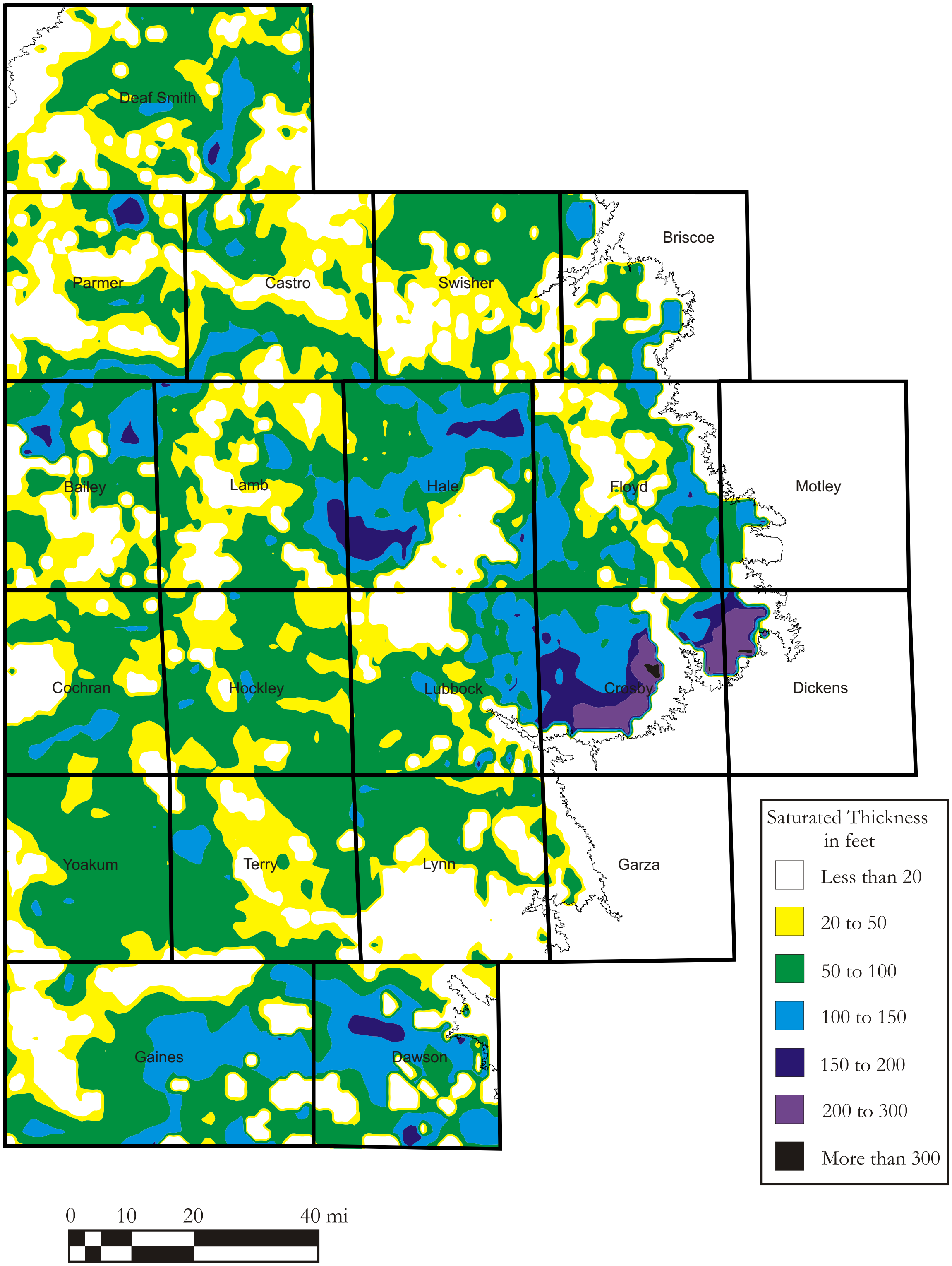

Figure 22(b). 2030 Region O Simulated Saturated Thickness, Pumpage Reduction Simulation.

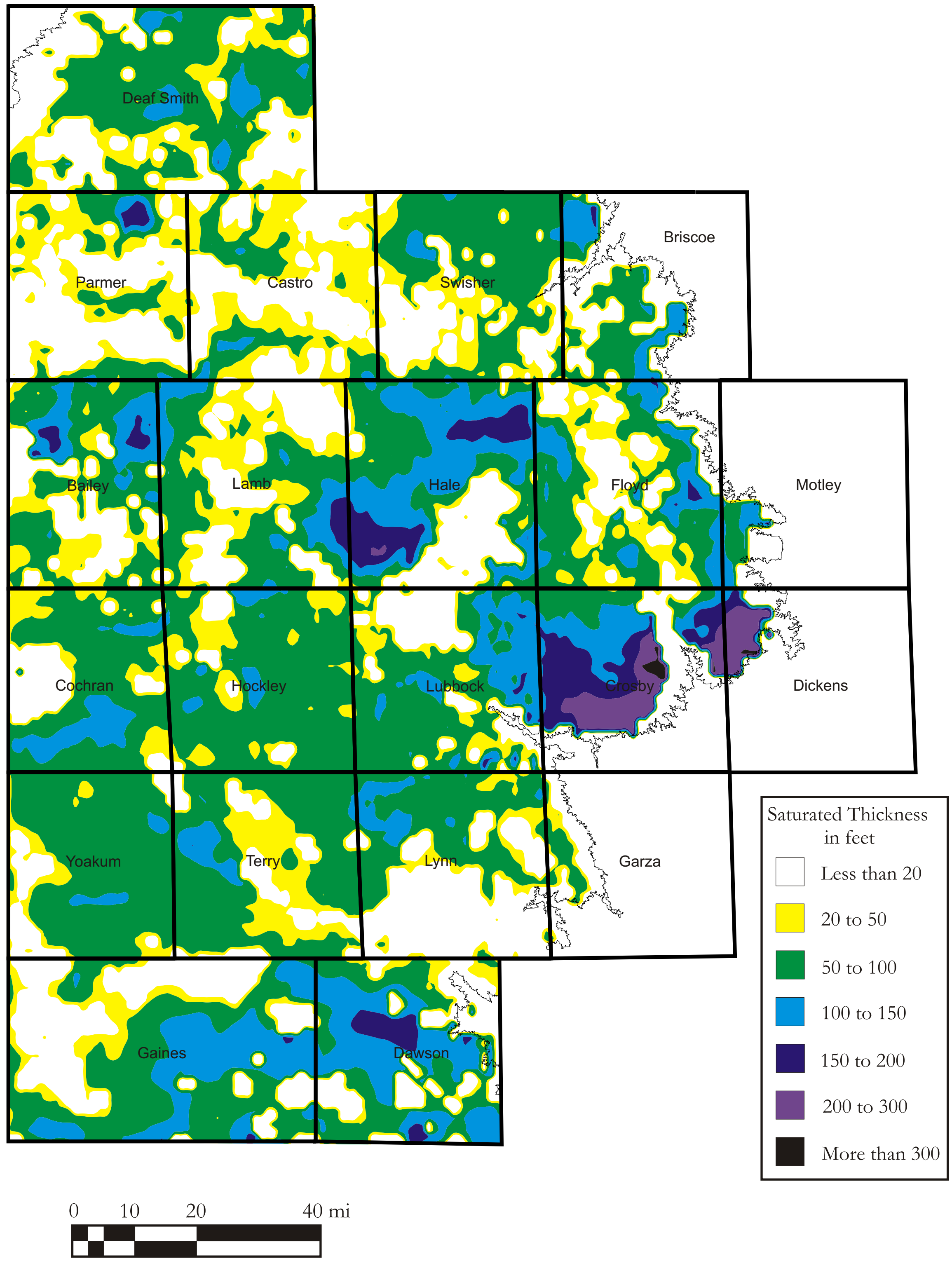

Figure 22(c). 2050 Region O Simulated Saturated Thickness, Pumpage Reduction Simulation.

5.3 Satisfied Demand Percentage

Under the pumpage reduction simulation, the model indicates that approximately 76 percent of the total groundwater demand for Region O can be met in 2050. Figures 23 and 24 show the satisfied demand percentage for every five years of the planning period for Region O and the three main river basins in Region O, respectively. Table 9 reports the satisfied demand percentage by county, river basin in each county, total for Region O, and total by river basin.

6 Simulation of a Uniform Decline in Saturated Thickness

Table 10 shows the volume in storage remaining if a 1 percent annual decline is assumed for the entire simulation. Table 11 shows the water demand required to cause a uniform decline in the water table, and Table 12 shows the volume in storage calculated by the model using these water demands. Comparison of the Region O Total in Tables 10 and 512 reveals that the simulated volume in storage matches the volume in storage calculated for an assumed uniform decline to within 1.5% for all decades.

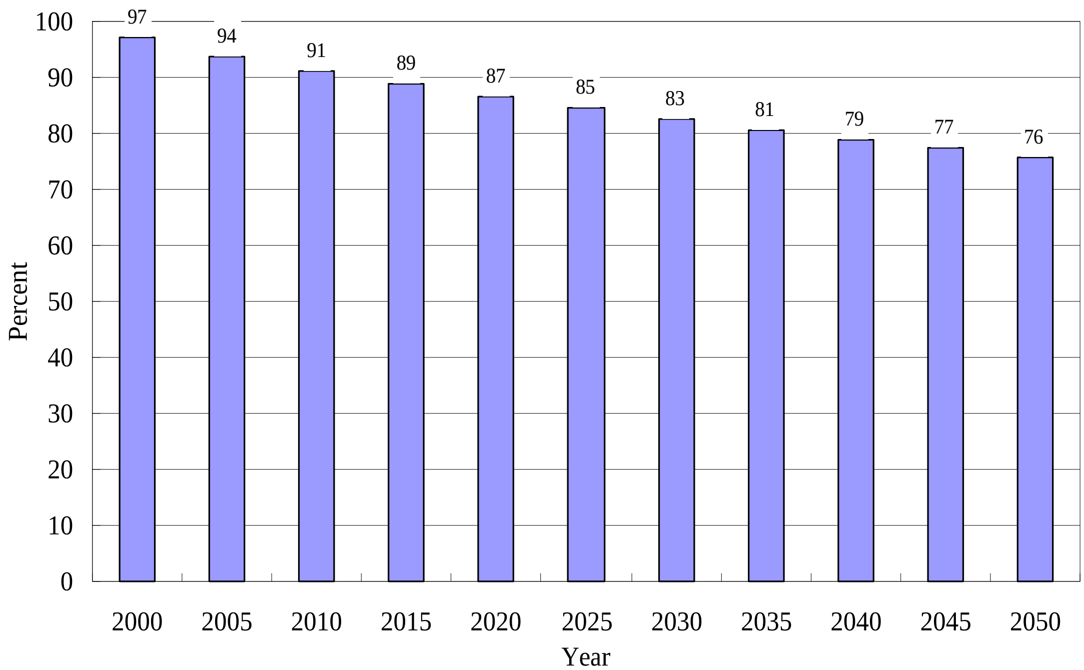

Figure 23. Region O Satisfied Demand Percentage, Pumpage Reduction Simulation.

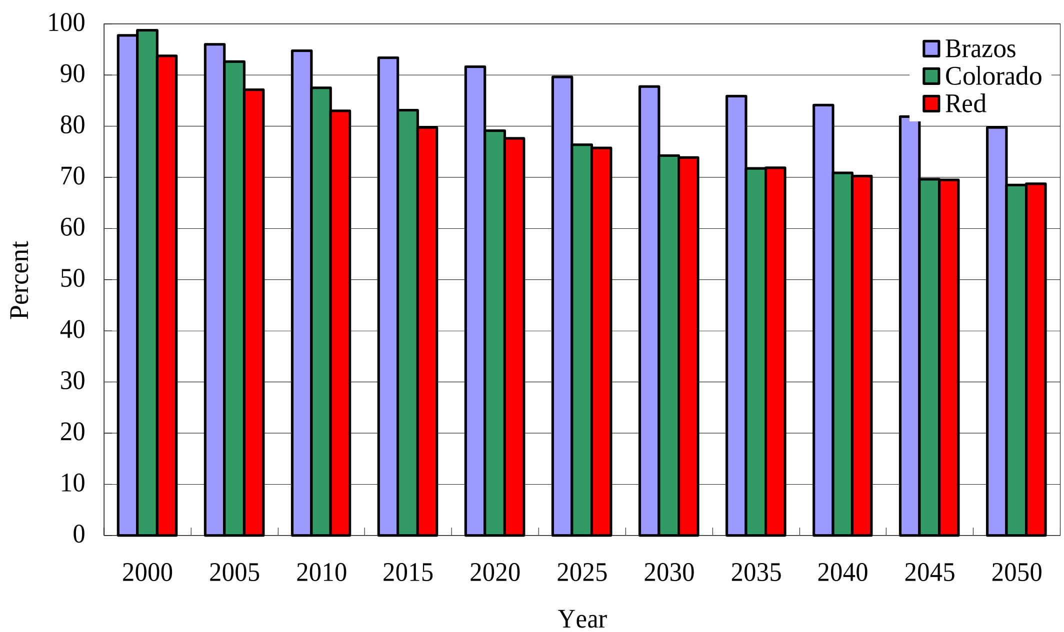

Figure 24. Region O Basins Satisfied Demand Percentage, Pumpage Reduction Simulation.

Table 9. Region O Satisfied Demand Percentage, Pumpage Reduction Simulation.

County	Basin	Area (mi^2)	Satisfied Demand Percentage										
			2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bailey	County	843	93.5	92.9	91.7	91.3	91.2	91.2	91.1	90.9	90.9	90.9	90.8
	Brazos	843	93.5	92.9	91.7	91.3	91.2	91.2	91.1	90.9	90.9	90.9	90.8
Briscoe*	County	911											
Castro	County	911	99.3	98.7	98.4	97.3	94.9	90.9	85.5	82.4	77.3	71.8	68.6
	Brazos	492	100.0	100.0	100.0	99.3	97.3	93.8	88.5	85.3	79.7	73.1	68.9
	Red	419	97.2	94.9	93.4	91.2	87.6	81.9	76.6	73.5	70.1	67.7	67.4
Cochran	County	776	98.3	98.3	97.7	96.9	96.7	96.7	96.7	96.7	96.7	96.7	96.7
	Brazos	224	100.0	100.0	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8
	Colorado	552	96.4	96.4	96.4	94.8	94.2	94.2	94.2	94.2	94.2	94.2	94.2
Crosby	County	904	100.0	100.0	98.5	98.5	96.8	96.8	96.8	96.0	95.8	95.8	95.8
	Brazos	893	100.0	100.0	98.5	98.5	96.8	96.8	96.8	96.0	95.7	95.7	95.7
	Red	11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dawson	County	900	96.1	83.4	83.4	82.0	80.2	80.2	78.5	78.5	78.5	78.5	78.5
	Brazos	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	877	96.1	83.4	83.4	82.0	80.2	80.2	78.5	78.5	78.5	78.5	78.5
Deaf Smith	County	1,485	99.1	97.3	95.5	93.3	91.1	90.9	90.7	89.0	87.3	86.9	85.8
	Canadian	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Red	1,396	99.1	97.3	95.5	93.3	91.1	90.9	90.7	89.0	87.3	86.9	85.8
Dickens*	County	912											
Floyd	County	1,015	98.3	95.7	93.9	92.7	92.1	91.7	90.6	88.8	88.8	88.3	87.0
	Brazos	442	100.0	98.4	97.7	96.8	96.5	96.5	96.5	94.2	94.2	93.3	91.4
	Red	573	95.0	90.6	86.7	84.9	83.7	82.6	79.3	78.7	78.7	78.7	78.7
Gaines	County	1,507	99.2	90.3	82.4	75.6	69.9	66.0	63.0	59.5	58.3	56.6	54.9
	Colorado	1,507	99.2	90.3	82.4	75.6	69.9	66.0	63.0	59.5	58.3	56.6	54.9
Garza*	County	904											
Hale	County	1,033	95.2	94.8	94.5	94.2	93.6	93.4	93.2	92.2	92.0	91.9	91.9
	Brazos	1,030	95.2	94.7	94.4	94.4	93.8	93.7	93.5	92.5	92.3	92.1	92.1
	Red	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hockley	County	914	99.6	98.6	96.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9
	Brazos	775	99.6	98.5	96.8	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7
	Colorado	139	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lamb	County	1,013	98.5	96.7	95.1	94.1	91.9	89.0	87.8	85.9	84.9	83.8	80.7
	Brazos	1,013	98.5	96.7	95.1	94.1	91.9	89.0	87.8	85.9	84.9	83.8	80.7
Lubbock	County	908	93.2	89.2	88.2	88.2	87.5	87.0	87.0	87.0	86.3	86.3	86.3
	Brazos	908	93.2	89.2	88.2	88.2	87.5	87.0	87.0	87.0	86.3	86.3	86.3
Lynn	County	893	88.7	88.7	87.5	86.4	84.6	84.6	83.2	83.2	83.2	82.4	82.4
	Brazos	829	90.6	90.6	89.3	88.1	87.3	87.3	85.7	85.7	85.7	85.0	85.0
	Colorado	64	65.2	65.2	65.2	65.2	51.3	51.3	51.3	51.3	51.3	51.3	51.3
Motley*	County	994											
Parmer	County	854	99.4	97.7	95.4	91.2	86.9	80.5	75.3	71.0	65.3	60.0	55.0
	Brazos	535	99.8	97.9	95.1	90.3	85.4	78.4	72.9	68.4	62.7	56.4	50.5
	Red	319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swisher	County	915	93.0	72.1	58.3	51.0	46.2	42.8	41.3	39.7	39.4	37.3	36.9
	Brazos	116	100.0	80.3	69.9	61.5	52.6	48.5	46.6	45.1	44.1	37.3	37.3
	Red	799	90.3	69.0	54.0	47.1	43.9	40.7	39.4	37.7	37.7	37.3	36.8
Terry	County	904	99.0	97.2	95.3	93.8	92.0	90.8	90.8	89.8	89.5	89.2	89.2
	Brazos	60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Colorado	844	98.9	97.0	95.0	93.5	91.6	90.3	90.3	89.2	88.8	88.6	88.6
Yoakum	County	798	100.0	100.0	98.1	97.2	95.4	93.4	91.1	88.6	87.9	86.0	84.9
	Colorado	798	100.0	100.0	98.1	97.2	95.4	93.4	91.1	88.6	87.9	86.0	84.9
Region O Totals	Region O	20,294	97.2	93.7	91.1	88.9	86.6	84.5	82.6	80.6	79.0	77.3	75.7
	Brazos	8,732	97.7	96.0	94.7	93.4	91.6	89.6	87.8	85.9	84.1	81.9	79.8
	Canadian	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Colorado	4,787	98.8	92.6	87.5	83.1	79.1	76.4	74.2	71.7	70.9	69.6	68.5
	Red	6,681	93.8	87.1	83.0	79.8	77.6	75.8	73.9	71.9	70.2	69.5	68.8

* Due to boundary effects of the groundwater model, the data for this county has been omitted.

Table 10. Volume in Storage Remaining Assuming a 1 Percent Annual Decline in Saturated Thickness of the Ogallala Formation.

County	Volume in Storage Remaining (1000 ac-ft)						
	1995	2000	2010	2020	2030	2040	2050
Bailey	6,220	5,915	5,349	4,839	4,375	3,956	3,577
Briscoe	1,601	1,523	1,377	1,246	1,126	1,018	921
Castro	12,204	11,606	10,495	9,495	8,585	7,762	7,017
Cochran	3,829	3,641	3,293	2,979	2,694	2,435	2,202
Crosby	6,223	5,918	5,352	4,841	4,378	3,958	3,578
Dawson	7,101	6,753	6,107	5,525	4,995	4,516	4,083
Deaf Smith	9,649	9,176	8,298	7,507	6,788	6,137	5,548
Dickens	1,141	1,085	981	888	803	726	656
Floyd	9,654	9,181	8,302	7,511	6,791	6,140	5,551
Gaines	13,188	12,542	11,342	10,260	9,277	8,388	7,583
Garza	484	460	416	377	340	308	278
Hale	10,880	10,347	9,357	8,465	7,654	6,920	6,256
Hockley	4,753	4,520	4,088	3,698	3,343	3,023	2,733
Lamb	9,269	8,815	7,971	7,211	6,520	5,895	5,330
Lubbock	5,603	5,328	4,819	4,359	3,941	3,564	3,222
Lynn	3,818	3,631	3,283	2,970	2,686	2,428	2,195
Motley	1,125	1,070	968	875	791	716	647
Parmer	10,635	10,114	9,146	8,274	7,481	6,764	6,115
Swisher	4,673	4,444	4,019	3,636	3,287	2,972	2,687
Terry	4,977	4,733	4,280	3,872	3,501	3,165	2,862
Yoakum	5,333	5,072	4,586	4,149	3,751	3,392	3,066
Region O Total	132,360	125,874	113,830	102,976	93,108	84,181	76,107

Table 11. Calibrated County-wide Water Demand.

County	Demand (ac-ft/yr)					
	1995	2000	2010	2020	2030	2040
Bailey	219,931	214,156	208,040	202,429	196,587	192,042
Briscoe	80,582	72,211	67,563	84,517	73,283	109,232
Castro	200,033	194,021	184,039	176,563	167,398	160,125
Cochran	115,818	111,339	107,975	105,547	103,645	102,290
Crosby	277,673	254,309	244,448	238,222	237,578	183,143
Dawson	143,116	128,200	120,890	122,765	119,586	115,337
Deaf Smith	262,747	260,298	252,500	248,008	240,411	236,151
Dickens	47,617	50,097	48,875	48,922	45,598	40,426
Floyd	260,575	249,233	239,194	232,172	223,897	218,370
Gaines	288,361	281,464	270,371	262,057	252,289	244,889
Garza	38,510	30,905	30,488	29,245	28,362	28,366
Hale	379,866	372,287	363,345	355,793	346,836	340,920
Hockley	157,341	154,619	150,631	147,766	145,628	142,773
Lamb	297,888	289,364	281,117	274,997	267,293	262,090
Lubbock	198,777	187,647	181,832	176,812	172,057	168,583
Lynn	138,635	134,250	130,529	126,856	123,749	121,706
Motley	40,659	36,499	35,880	35,008	33,887	33,438
Parmer	226,765	218,708	208,893	201,347	192,520	186,038
Swisher	140,766	137,107	132,814	129,507	125,973	123,270
Terry	138,107	135,976	131,470	128,443	125,004	122,125
Yoakum	128,603	125,231	121,565	119,059	115,407	112,850
Region O Total	3,782,370	3,637,918	3,512,459	3,446,033	3,336,988	3,244,164

Table 12. Volume in Storage Remaining Using Calibrated Demand.

County	Volume in Storage (1000 acre-feet)						
	1995	2000	2010	2020	2030	2040	2050
Bailey	6,220	5,888	5,252	4,738	4,303	3,901	3,536
Briscoe	1,601	1,498	1,510	1,345	1,004	1,209	780
Castro	12,204	11,598	10,465	9,462	8,541	7,720	6,977
Cochran	3,829	3,651	3,255	2,949	2,672	2,416	2,186
Crosby	6,223	5,839	5,326	4,858	4,420	3,974	3,686
Dawson	7,101	6,826	6,246	5,729	5,519	5,049	4,645
Deaf Smith	9,649	9,255	8,397	7,603	6,847	6,195	5,595
Dickens	1,141	1,234	1,179	1,137	1,076	1,053	973
Floyd	9,654	9,129	8,524	7,435	6,705	6,055	5,400
Gaines	13,188	12,587	11,410	10,328	9,336	8,449	7,641
Garza	484	495	527	496	470	434	411
Hale	10,880	10,407	9,461	8,571	7,758	7,036	6,364
Hockley	4,753	4,536	4,108	3,697	3,337	3,011	2,709
Lamb	9,269	8,779	7,916	7,158	6,461	5,845	5,282
Lubbock	5,603	5,276	4,764	4,295	3,844	3,449	3,110
Lynn	3,818	3,651	3,342	3,036	2,759	2,503	2,265
Motley	1,125	1,083	1,022	956	891	833	781
Parmer	10,635	10,097	9,040	8,158	7,369	6,661	6,020
Swisher	4,673	4,427	3,984	3,600	3,249	2,934	2,646
Terry	4,977	4,766	4,330	3,922	3,543	3,203	2,898
Yoakum	5,333	5,100	4,565	4,126	3,722	3,367	3,042
Region O Total	132,360	126,122	114,623	103,599	93,826	85,297	76,947