

# **Texas Water Development Board**

## **Report 327**

### **Evaluation of Ground Water Resources in the Vicinity of the Cities of Henderson, Jacksonville, Kilgore, Lufkin, Nacogdoches, Rusk, and Tyler in East Texas**

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**February 1991**

# **Texas Water Development Board**

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**ABSTRACT**

This evaluation of water resources in parts of Angelina, Cherokee, Gregg, Nacogdoches, Rusk, and Smith Counties was in response to the 69th Texas Legislature passing a bill calling for the identification of areas within the State either with critical ground-water problems, or the potential for such problems within the next 20 years.

The study area is located in east Texas and is characterized by a warm sub-humid climate, receiving from 43 to 47 inches of rainfall yearly. The area has a diverse economy with agriculture, lumber and lumber products, petroleum and petroleum products, and other light and heavy manufacturing contributing.

The area uses water from both ground-water and surface-water sources. The major source of ground water in the area is the Carrizo-Wilcox aquifer, but significant amounts are produced from the Queen City and Sparta aquifers. Surface water is obtained from several reservoirs.

Historically, large withdrawals of ground water have caused water-level declines in the study area, especially within relatively small areas with large numbers of high-capacity municipal and industrial supply wells. The two most significant areas with very large drawdowns and deep pumping levels are the central part of Smith County around Tyler, and the area between Lufkin and Nacogdoches in Angelina and Nacogdoches Counties. Water levels in both of these areas have declined as much as 500 feet since before World War II. Recent measurements indicate that the declines have slowed and are perhaps stabilizing due to some reduction in ground-water pumpage by Tyler, Nacogdoches, and industrial users within the area and the increased use of surface water.

The chemical quality of ground water is generally good throughout the area. The major quality problem is the erratic occurrence of relatively high concentrations of iron. There is some evidence of past contamination of ground water by oil-field brine, but reported sites are few and of limited extent.

Population growth is continuing within the study area, especially in and around the larger cities, including Tyler, Lufkin, Nacogdoches, Jacksonville, Henderson, and Kilgore. From 1980 to 1985, population increased about 10 percent, and is projected to total 486,388 by 2010. This is an increase of about 45 percent over the 1985 total.

In response to population growth, water use within the area increased from 96,072 acre-feet in 1980 to 101,712 acre-feet in 1985. About one-half of the total 1985 use was for municipal supply, and an additional 39 percent was for industrial supply. About 63 percent of the total water use in 1985 was from ground-water sources, while ground water provided 66 percent of the 1980 total. In response to expected population growth, total water demand is projected to increase to 135,425 acre-feet in 2010. Most of the increase will be for municipal and industrial uses.

The Texas Water Development Board has estimated the annual effective recharge of the State's aquifers and apportioned a total for each aquifer within each county. Within Angelina, Cherokee, Gregg, Nacogdoches, Rusk, and Smith Counties, the estimated totals amount to 105,000 acre-feet for the Carrizo-Wilcox aquifer, 208,000 acre-feet for the Queen City

aquifer, and 31,000 acre-feet for the Sparta aquifer. Relatively low well yields and high concentrations of iron make much of the water from the Queen City and Sparta uneconomical for municipal and industrial development. Large amounts of additional pumpage could be derived from the Carrizo-Wilcox over much of the study area, but steps should be taken to insure that new wells are located an adequate distance from existing centers of heavy pumpage and constructed in such a manner to insure the most efficient production operation possible. The artesian nature of the aquifer over most of the study area coupled with the large distance from areas of recharge has resulted in increased pumping heads. These factors, along with the inefficient spacing and construction of many existing wells, may reduce the total amount of water available from the Carrizo-Wilcox aquifer on a long-term basis.

Large amounts of surface water is available from several reservoirs both within and just outside of the study area. The cities of Tyler, Nacogdoches, Jacksonville, Kilgore, and Liberty City and industries in the vicinity of Lufkin-Nacogdoches are currently using surface water in conjunction with ground water from the Carrizo-Wilcox aquifer. The total surface-water supply capacity from Lakes Tyler, Jacksonville, Kurth, Striker Creek, and Nacogdoches is over 160,000 acre-feet per year. In addition, Kilgore receives water from Lake Cherokee. Tyler has rights to about 67,000 acre-feet of water per year from Lake Palestine. Also, the City of Lufkin has rights to over 25,000 acre-feet per year of water from Lake Sam Rayburn, and another 14,000 acre-feet per year is reportedly available for purchase from this reservoir. Considering these totals and the present surface-water use, it is evident that there is adequate surface water available if used in conjunction with available ground-water supplies to provide for growth in the study area well beyond 2010.

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## INTRODUCTION

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### Purpose

In 1985, the 69th Texas Legislature enacted House Bill 2 which instructed the Texas Department of Water Resources, now the Texas Water Development Board (TWDB) and Texas Water Commission (TWC), to identify and evaluate present and potential (over the next 20 years) ground-water problem areas in the State. The legislation also provided a method for the TWC to initiate action toward forming underground water conservation districts within these areas, but left the final decision with the local voters through a confirming election. The TWDB and TWC identified several areas for study including this area consisting of parts of six counties in east Texas. The area has experienced significant historical water-level declines due to heavy ground-water pumpage for municipal and industrial uses, especially in the immediate vicinity of the Cities of Tyler, Nacogdoches, and Lufkin.

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### Location and Extent

The study area includes all or parts of Angelina, Cherokee, Gregg, Nacogdoches, Rusk, and Smith Counties, and is located within the Sabine, Neches, and Angelina River basins. Figure 1 shows the extent of the study area within the individual counties which includes a total of about 3,600 square miles.

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### Geographic Setting

The study area is located on the western edge of the Mississippi embayment, a northern extension of the Gulf Coastal Plain. The northern part of the area is affected by the Tyler basin and the Sabine uplift. Topographically, the area is characterized by north-south trending relatively flat valleys formed by the major streams with rolling to hilly terrane between these valleys. There is a general slope of the land surface from north to south and the elevations range from about 600 feet above sea level in the north to about 200 feet in the south. Local relief may be as much as 150 to 200 feet.

The area is drained by the Sabine, Neches, and Angelina Rivers and their tributaries. Major creeks which drain to the Sabine include Saline, Harris, Prairie, Rabbit, Mill, Martin, and Murvaul Creeks. Those which drain to the Angelina are Mud and Bowles Creeks, Attoyac Bayou, Bayou Loco, and Bayou Carrizo. Creeks draining to the Neches are Crawford, Bowden, Larrison, Box, Tails, Flat, and Saline. Several man-made reservoirs are located within or just outside of the study area. These include Lake Palestine on the Neches River between Smith, Henderson, Anderson, and Cherokee Counties; Tyler East and West Lakes on two branches of Mud Creek in southeast Smith County; Lake Jacksonville on Gum Creek in northwest Cherokee County; and Lake Nacogdoches on Bayou Loco in western Nacogdoches County. Sam Rayburn Reservoir is located just to the southeast of the study area on the Angelina River in southern Angelina and Nacogdoches Counties and extending into San Augustine and Jasper Counties. Lake Cherokee is located along the Gregg-Rusk County line, a few miles east of Kilgore and southeast of Longview.

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## **Climate**

The area is characterized by a warm sub-humid climate, with long hot summers and short mild winters. The average annual precipitation ranges from about 43 inches per year at Lufkin to over 47 inches per year east of Kilgore. Much of the rainfall occurs in May-June and September-October. The annual average lake-surface evaporation is about 60 inches. The July mean temperature is between 94 and 96 degrees Fahrenheit and the January mean ranges from 37 to 39 degrees F. The growing season ranges from 243 to 259 days, with the last frost in early to mid March 20 and the first occurring about November 13 to 21.

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## **Economy**

The economic base of the study area is highly diversified. Petroleum production and refining, forest and wood products, agriculture, and many types of light to heavy manufacturing are the most important segments of the area's economy. Manufacturing added about \$4,845,400,000 to the economy of the six counties in 1985, while agriculture added about \$288,500,000. Receipts of service industries totaled \$759,712,000, and 57,357,918 barrels of oil, worth \$1,014,617,257, were produced. In 1984, timber with a total value of \$77,209,000 was harvested within the six counties.

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## **Previous and Current Investigations**

The occurrence and quality of ground water within the study area has been studied by many people since the 1800's. In addition, the search for minerals such as oil, gas, lignite, and salt have resulted in many studies covering the geology of the area. The United States Geological Survey and the Texas Water Development Board and its predecessor agencies have completed ground-water studies on all of the counties covered by this study. These have been published by the State as bulletins and reports series of the TWDB and are included in the Selected References Section of this report. This area is also included within a detailed study of the Carrizo-Wilcox aquifer which is being conducted by the TWDB in northeast Texas. The field data collection phase of the study is currently underway. A part of this study will include a computer model of the aquifer.

The Bureau of Economic Geology of the University of Texas at Austin has completed two series of studies which deal with all or portions of the study area and involve the geology and hydrology of the aquifers, at least indirectly. One series describes the occurrence and availability of lignite resources and includes a study of the Wilcox Group in East Texas. The other is concerned with aspects of the buried salt structures found in the Tyler basin and the eastern Texas Gulf Coast area. Various reports which cover the results of these studies are also included in the Selected References section of this report.

Water level and chemical quality data are collected periodically from wells throughout the State by TWDB and monitoring programs which have been maintained within the study area for many years. Many of the interpretations in this report are based on data from these monitoring programs.

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## **Acknowledgements**

The cooperation of numerous individuals in this study and the preparation of this report is greatly appreciated, especially the city and water supply district officials and property owners who furnished information on their water wells and allowed access to the wells to measure water levels and collect water samples for chemical analysis.



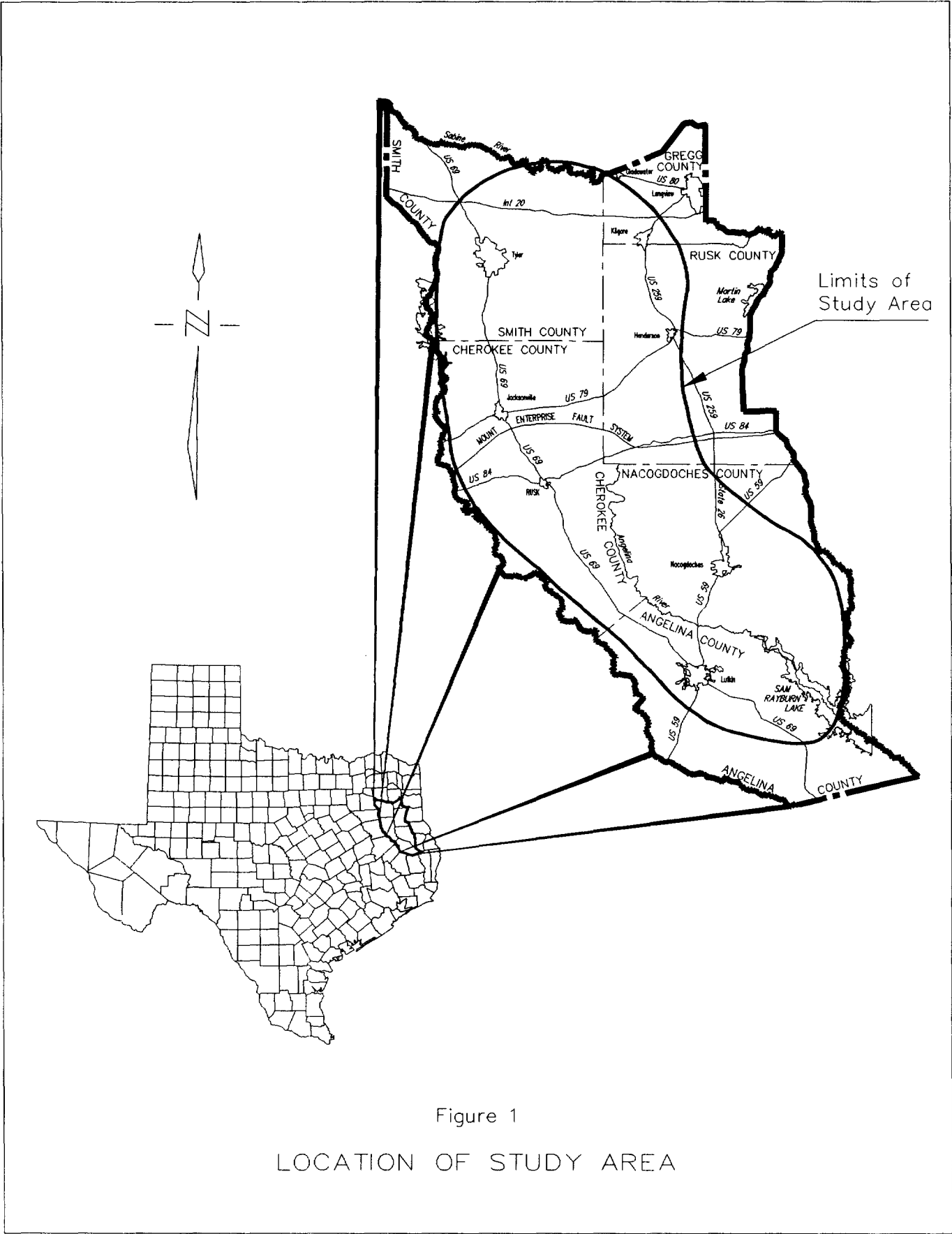


Figure 1

LOCATION OF STUDY AREA

Special thanks are extended to the members of the Citizen's Advisory Committee which served for this study. This group of concerned and knowledgeable citizens provided valuable information and insight on the ground-water and surface-water conditions within the study area and the varied problems of the many water users within the area.

## GEOHYDROLOGY

The following is a summary of the stratigraphy, structure, and general geohydrology of the geologic formations which provide ground water to the people of the study area. More detailed discussions are available in many of the reports listed in the Selected References section, especially in some of the bulletins and reports of the TWDB and its predecessor agencies and reports by the Bureau of Economic Geology. Several of these were used liberally in the preparation this discussion, especially the following:

Baker, Dillard, Souders, and Peckham, 1963a  
Baker, Dillard, Souders, and Peckham, 1963b  
Broom, 1969  
Dillard, 1963  
Fogg, Kaiser, Ambrose, and MacPherson, 1983  
Fogg and Kreitler, 1982  
Guyton and Associates, 1970  
Guyton and Associates, 1972  
Kaiser and others, 1986  
Kreitler and others, 1980  
Peckham, Souders, Dillard, and Baker, 1963  
Sandeen, 1987

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### Geology as Related to Ground Water

In the study area, as well as most of east Texas, the geologic formations generally dip gently south and southeast toward the Gulf of Mexico at less than 100 feet per mile. The rate of dip is greater than that of the land surface and as a result the older formations crop out to the north and west of younger formations at progressively higher elevations. These outcrops occur as relatively narrow bands as illustrated on Figure 2, a generalized surface geologic map of the study area. The major structural features which modify this regional dip and affect ground-water flow within the aquifers of the study area include the East Texas basin, the Sabine uplift, and the Mount Enterprise fault zone (see Figure 3). Western Smith County and northwestern Cherokee County are located within the East Texas salt diapir province which contains numerous buried salt structures. Figure 4 shows the location of several relatively shallow salt domes which have affected Carrizo-Wilcox deposition, and in some cases, that of the overlying formations.

The formations dip eastward on the west flank and westward on the east flank of the Tyler basin, the axis of which runs generally northward through eastern Anderson and western Smith Counties. On the eastern flank of the basin, the beds dip westward into the basin off of the Sabine uplift, a structural high located on the Texas-Louisiana border and centered in Panola County. The Mount Enterprise fault system strikes generally west to east, and is located across southern Rusk and northern Cherokee Counties. The full effect of the faults on ground-water flow and conditions within the area is not known, but there is some reduction in flow in parts of this area.

The stratigraphy of the geologic units which affect the ground-water supply of the study area is summarized on Table 1 and in Figures 5, 6, and 7. The geologic units which supply significant amounts of ground water within the study area are, from oldest to youngest, The Wilcox Group and

the Carrizo, Queen City, and Sparta sands of the Claiborne Group. Lying below the Wilcox are rocks of the Midway Group and a thick sequence of rocks of Cretaceous age. Parts of these older Cretaceous rocks are aquifers to the west, but contain only some hydrocarbons and very saline waters within the study area. Between the Carrizo and the Queen City and the Queen City and the Sparta are the rocks of the Reklaw and Weches formations. In isolated areas on their outcrops the Reklaw and Weches units may provide small amounts of water for rural domestic and livestock uses, but in general serve as aquitards, at least restricting the flow of water between the aquifers. In the far southern part of the study area, the Sparta is overlain by younger rocks of Tertiary age which may provide small amounts of water on their outcrops. To the south of the study area, some of the rocks of the Yegua and Jackson Groups provide small to moderate amounts of water for municipal and industrial uses.

All of these units were deposited in various near shore environments, as a result of a shoreline which has repetitively moved back and forth across east and southeast Texas since Cretaceous time.

The Wilcox Group consists of interbedded gravel, sand, clay, and shale, with lignite deposits in some areas. These rocks were deposited in river, delta, and shallow marine environments, with the more massive sands occurring in the river alluvium and delta parts of the system. In east Texas, the total thickness of the Wilcox varies from 0 to about 1,100 feet near the outcrop, but may thicken to well over 2,000 feet in the downdip part of the study area north of Lufkin. About 40 to 60 percent of the total thickness is sand. Because of the deposition of the sand portion of the rocks of the Wilcox Group in river and delta environments, individual sand units are linear in nature, following stream courses. Therefore, individual sand beds are generally connected up and down dip but are often isolated from nearby sand beds along strike, with shales, muds, and muddy sands in between. Because the heavier sands tend to sink into the finer deposits, there is a definite tendency for sand bodies to stack above each other in subsequent depositional sequences. Therefore the Wilcox is characterized by linear, northwest-southeast trending areas with not only higher percentages of sand, but with more thicker individual sand bodies. The interlying areas have more muds and shales and thinner sand bodies. The better, higher-producing water wells are, of course, found in the areas with more, thicker sands.

The Carrizo Formation was mostly deposited in an alluvial environment, and over most of the study area is composed of about 90 percent sand interbedded with silt and clay. The thickness of the Carrizo ranges from less than 50 to over 200 feet, but in general averages about 100 feet. In a few areas, the Carrizo thins and in addition may contain more silt, severely reducing its effectiveness as an aquifer.

Sands of the Carrizo are often separated from sands within the Wilcox by significant intervals of shale and clay, but in some instances may be in contact with each other. Therefore, at least locally, there is significant movement of water between the Carrizo and the Wilcox, and they are generally considered to be one aquifer system. Figure 8 shows the total thickness of the Carrizo-Wilcox aquifer in and around the study area.

The Queen City Formation is separated from the underlying Carrizo by the Reklaw Formation which consists of up to 300 feet of shale with a few thin sand layers. The Queen City is made up of sand interbedded with shale and sandy

shale. The sands are generally fine grained and often micaceous. Minor amounts of lignite occur locally. The total thickness of the Queen City ranges from 0 to about 600 feet within the study area. The thickness is greatest in the center of the Tyler basin and thins generally to the east and south. Net sand thickness varies from 25 to 85 percent. Out of the Tyler basin, the dip is south and southeast toward the Gulf of Mexico at 60 to 70 feet per mile.

Above the Queen City is the Weches Formation which acts as an aquitard between it and the Sparta sand. The Weches consists of glauconitic sandstone and shale and ranges up to 250 feet in thickness.

The Sparta formation consists of massive, poorly cemented sand in the lower portion, with thinner sands interbedded with clays and shales in the upper part. The sands are fine to medium grained. The beds of the Sparta dip to the south and southeast toward the Gulf at 60 to 100 feet per mile. Within much of the study area, especially along the axis of the Tyler basin in Smith and Cherokee Counties, extensive outliers of Sparta occur at the surface. The largest of these occurs around Tyler and has a surface area of about 240 square miles. The thickness of the Sparta ranges from 0 to about 260 feet in the outcrop, but may increase to nearly 350 feet in some downdip areas.

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## Source and Occurrence of Ground Water

The ultimate source of the ground water within the aquifers of the study area is rainfall on the outcrop, with a significant portion coming from the areas where the runoff from this rainfall is concentrated, such as rivers and lakes. In addition, water may move between aquifers due to relatively different hydraulic forces within them.

As in all sand and gravel aquifers, the ground water in the study area aquifers occurs within the inter-granular space of the grains which make up the beds of the geologic formations.

As mentioned above, individual beds of sand within the Wilcox are not continuous. This is because of interfingering with and lateral gradations into shale and clay beds. As a result, in local areas, these individual sand beds or small groups of beds may behave as separate aquifers of limited areal extent.

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## Recharge, Movement, and Drainage

As in most sand aquifers, recharge to the Carrizo-Wilcox and other aquifers of the study area occurs mostly on the outcrop, especially the outcrop of the sandy portions of the formations which make up the aquifers. Because of the structural control of the Tyler basin and Sabine uplift, recharge enters the artesian part of the Carrizo-Wilcox aquifer from both the east and west. On the west, most of this recharge occurs in outcrop areas in Van Zandt, Henderson, and Anderson Counties, out of the study area. On the east, the outcrop areas in Panola, Shelby, Nacogdoches, and Rusk Counties provide much of the recharge. Additional water is entering the Carrizo-Wilcox aquifer through vertical movement from overlying aquifers (Fogg and Kreitler, 1982). This vertical flow is relatively slow, but when the entire area is considered, the total amount of water is significant.

In general, ground water moves under the influence of gravity from areas of recharge to areas of discharge. In the study area before heavy pumpage began, movement was down dip in the interstream areas, with some local discharge to springs and seeps. In the down dip portion of the aquifer, there was movement toward areas of upward vertical discharge along the major streams. Except where modified by pumpage, these movement patterns continue today. Current movement of water within the aquifer has been severely modified by man's pumpage, especially within and around the large areas of heavy municipal and industrial use and resulting water-level drawdowns in the Tyler and Lufkin-Nacogdoches areas.

While some natural discharge continues through seeps and springs, especially on the outcrop, pumpage is by far the largest contributor to drainage of the aquifer.

Recharge to the Sparta and Queen City aquifers occurs on the outcrop over their entire areal extent. Because of their large amount of outcrop and the gently rolling to flat topography over most of it, and the relatively large amounts of rainfall which occur within the area, these two aquifers probably receive a maximum amount of recharge. In fact, during rainy periods, a considerable amount of potential recharge is rejected. In addition, relatively large amounts are lost within the outcrop areas through seeps, springs, and evapotranspiration. This is especially true around the outer perimeters of the numerous outliers of Sparta Sand in Smith and Cherokee Counties. Ground-water flow is generally down dip and over much of the study area, and studies by the Bureau of Economic Geology indicate a high potential for downward movement into the underlying formations. In local areas, flow is toward centers of pumpage. While pumpage is significant in some parts of the study area, natural discharge through seeps and springs and downward into underlying aquifers is probably more important outlet of water from these aquifers.

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## Hydraulic Characteristics

The hydraulic characteristics of an aquifer are generally expressed in terms of its coefficients of transmissivity, permeability, and storage. These are functions of the porosity and hydraulic conductivity of the sediments within the aquifer, and control its capacity to yield water to wells. Many of the reports listed in the Selected References include references to testing for hydraulic characteristics of the Carrizo-Wilcox, Queen City, and Sparta aquifers within the counties which make up the study area. In general, the aquifer characteristics derived from various pumping tests of wells within the study area show a wide range in values as might be expected from the interbedded nature and mode of deposition of the sediments and the large size of the area.

Transmissivities for the Carrizo range from less than 3,000 to over 30,000 square feet per day and average about 12,000 square feet per day. Those for the Wilcox range from less than 1,000 to over 30,000 feet per day and average about 15,000 square feet per day. Those for the Queen City are generally 2,000 to 4,000 square feet per day but occasionally higher in areas of high net sand thickness. Those for the Sparta are from 1,000 to about 5,000 square feet per day. These figures are based on calculations of data from many pumping tests of wells, and therefore, especially in the case of the Wilcox Group, represent the transmissive ability of only the sands of the intervals screened in the individual wells tested. This is commonly a small portion of the total saturated sand thickness. This is also true, though in a lesser degree, for the calculations

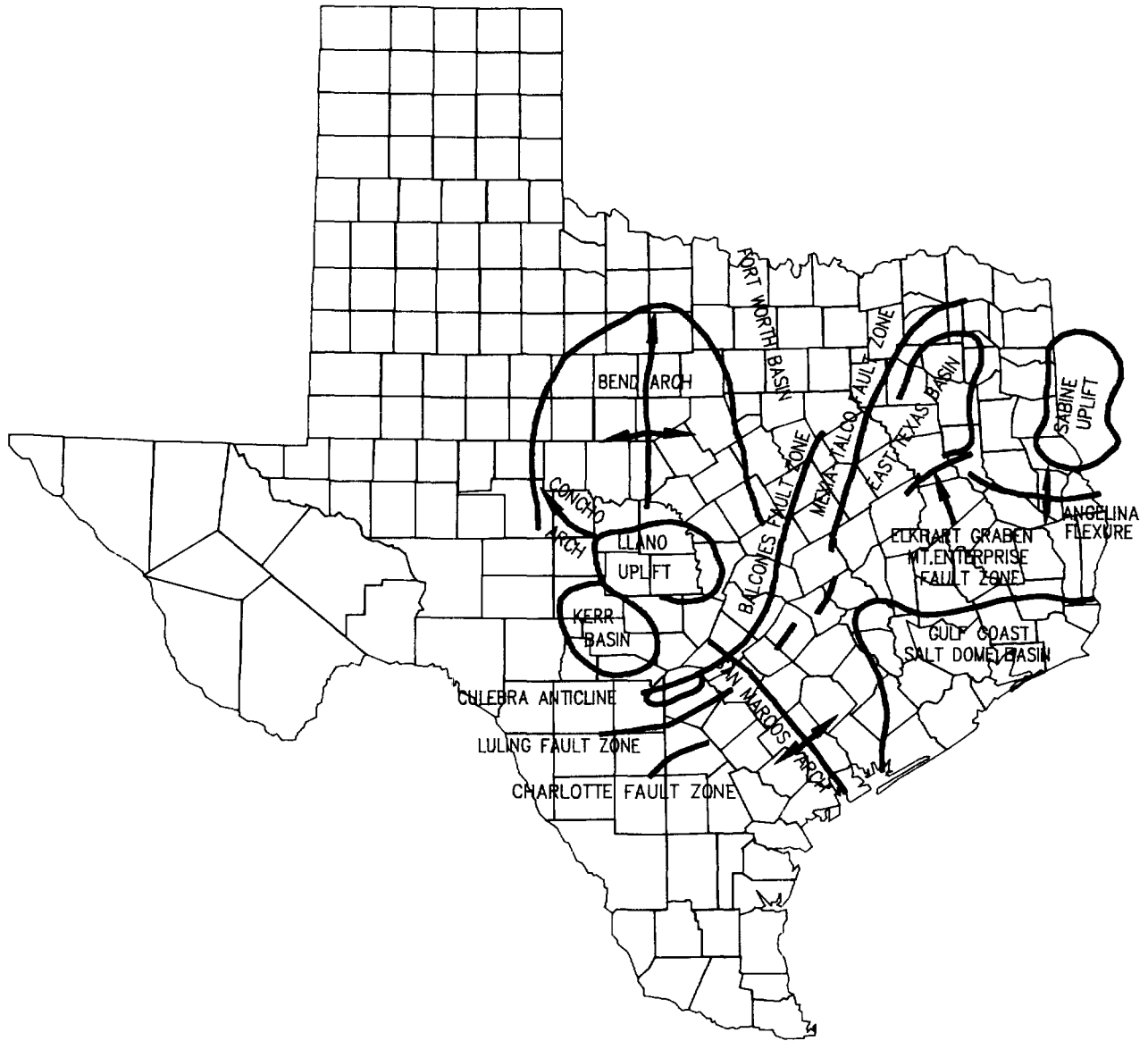


Figure 3

MAJOR STRUCTURAL FEATURES  
IN EAST AND CENTRAL TEXAS

**Table 1  
Geologic Units and Their Water Bearing Characteristics**

System	Series	Group	Stratigraphic Unit		Hydrologic Name	Water-bearing Properties	
		Jackson				May yield small to moderate amounts of useable – quality water in isolated areas on or near the outcrop.	
			Cook Mountain and Yegua Formations				
Tertiary	Eocene	Claiborne	Sparta Formation		Sparta Aquifer (minor)	Yields small to moderate amounts of useable – quality water over much of the study area.	
			Mount Selman	Weches Formation			May yield small amounts of useable – quality water over much of the study area.
				Queen City Formation		Queen City Aquifer (minor)	Yields moderate amounts of useable – quality water over much of the study area.
				Reklaw Formation			May yield small amounts of useable – quality water in isolated areas on the outcrop.
				Carrizo Formation		Carrizo-Wilcox Aquifer (major)	Yields large amounts of useable – quality water throughout the study area.
		Wilcox					
		Midway				Not known to yield useable – quality water within the study area.	
		Cretaceous					

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of tests in wells completed in the Queen City and Sparta aquifers. The figures for the Carrizo aquifer may better represent the aquifer, since many Carrizo wells are completed opposite a higher percentage of the available sand thickness.

Field coefficients of permeabilities for the Carrizo average about 200 and range from less than 50 to over 500 gallons per day per square foot. Those for the Wilcox average about 150 and range from less than 50 to over 300. Those for the Queen City average about 100. Those for the Sparta average about 125.

Calculated artesian storage coefficients for the Carrizo range from 0.00007 to 0.0002. Those for the Wilcox are in a similar range, as are those of the Queen City. Artesian storage coefficients for the Sparta ranged up to 0.00048. The water table storage coefficients of the three aquifers also vary considerably within the study area, ranging from less than 0.10 to over 0.20.

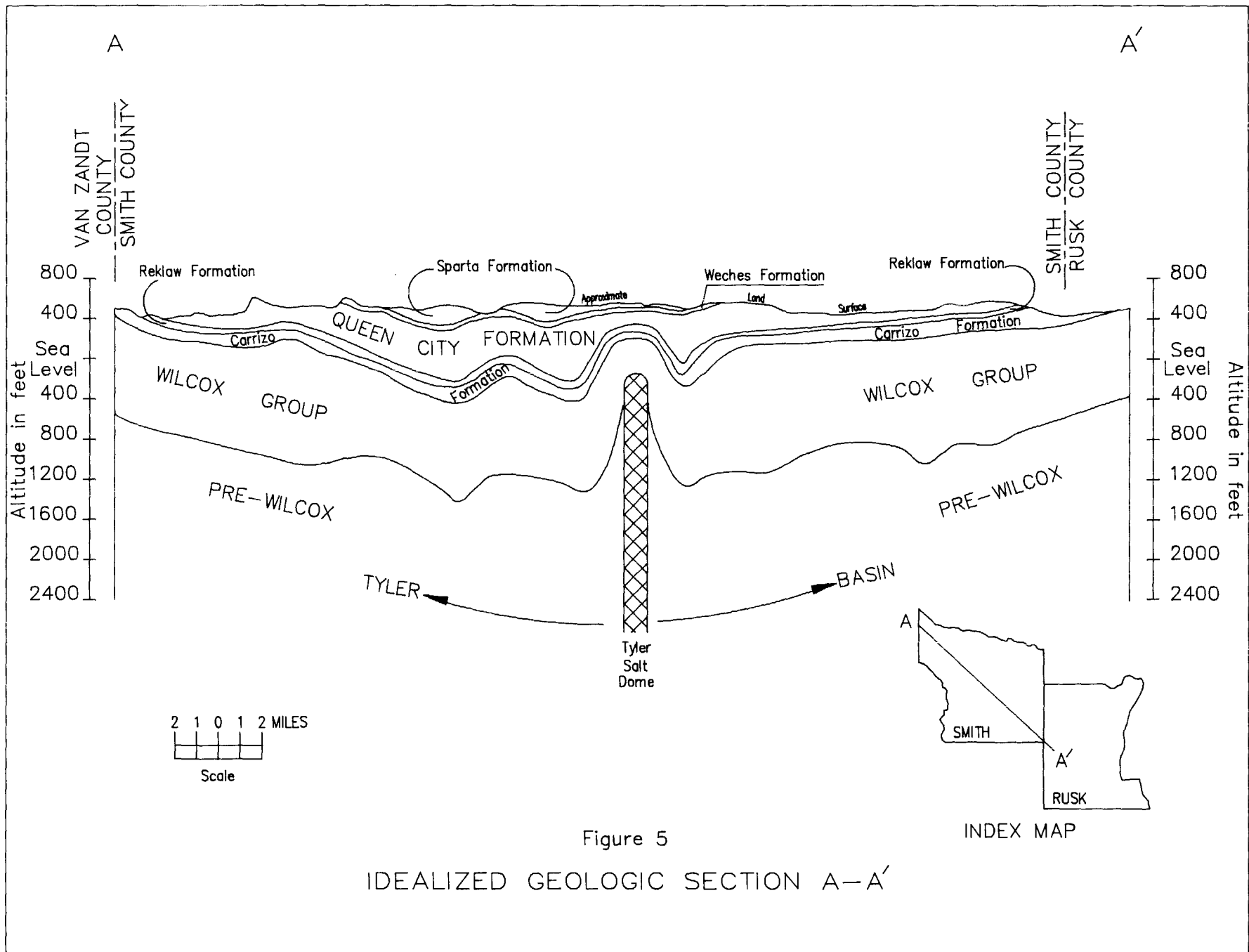


Figure 5  
IDEALIZED GEOLOGIC SECTION A-A'

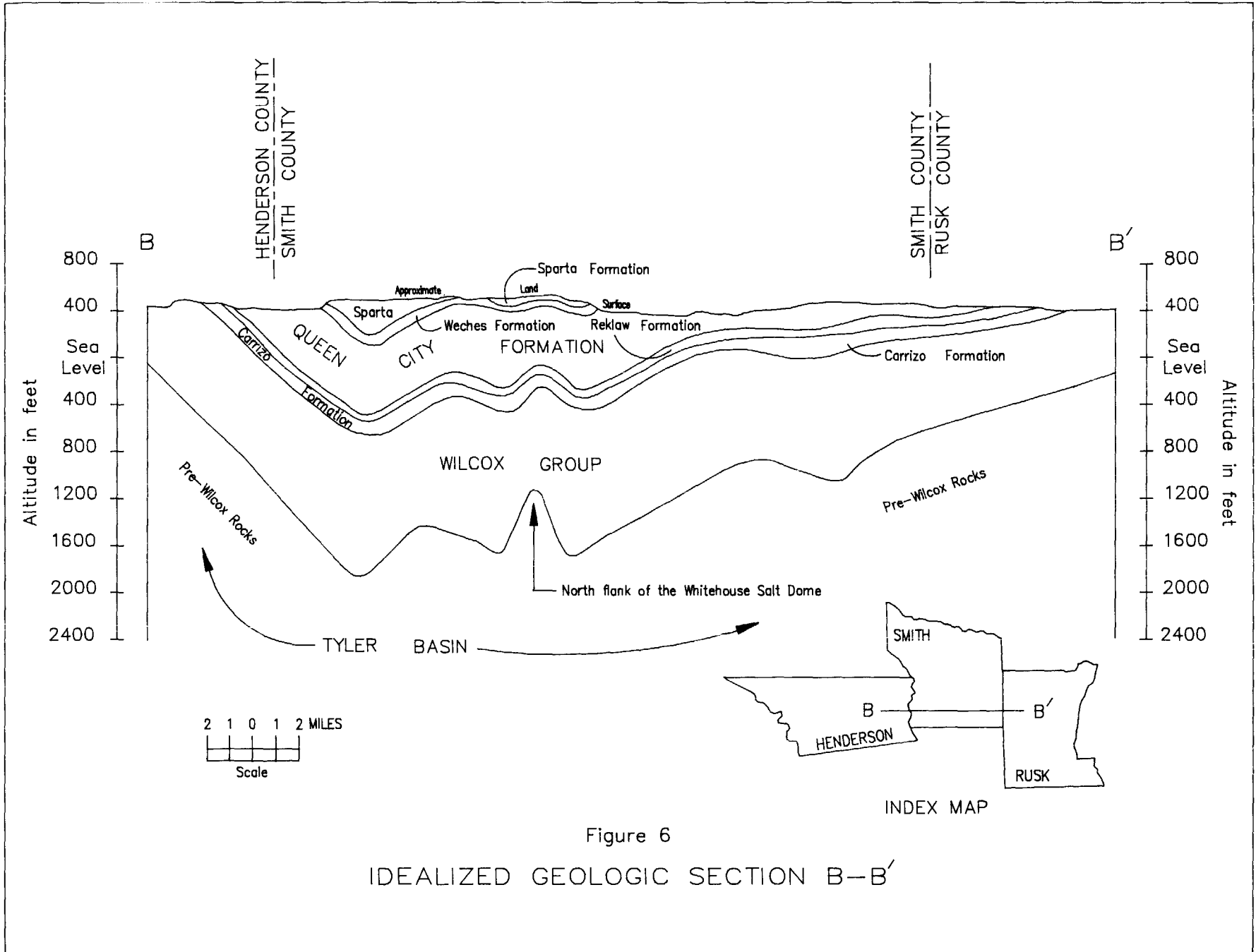


Figure 6  
IDEALIZED GEOLOGIC SECTION B-B'

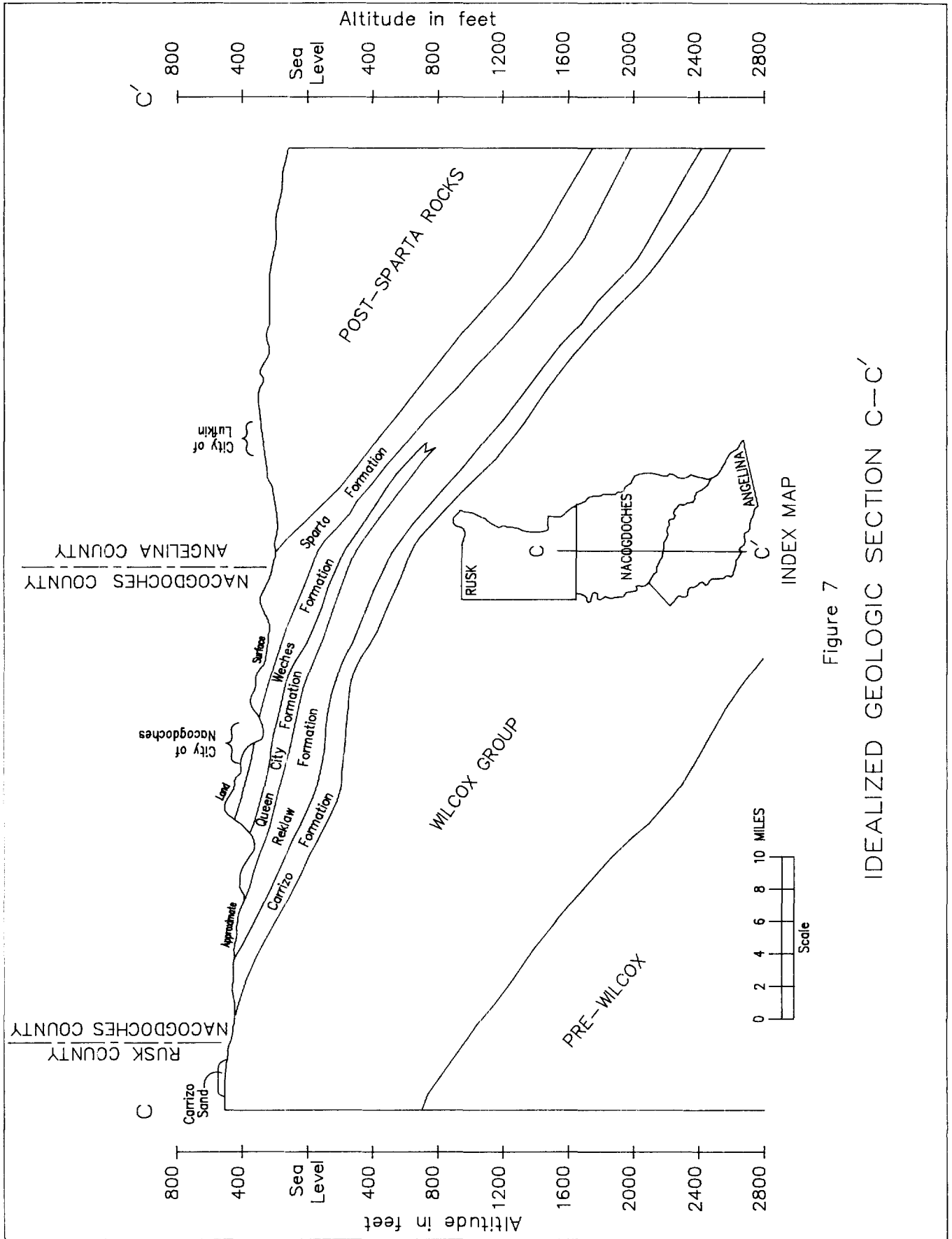


Figure 7  
IDEALIZED GEOLOGIC SECTION C-C'

## GROUND-WATER PROBLEMS

### Water-Level Decline

In general, some water-level declines have occurred in most wells completed in the Carrizo-Wilcox aquifer over much of the study area, but the largest and most significant declines have been around Tyler and in the Lufkin-Nacogdoches area. Within these areas, water-level declines in many wells have exceeded 300-400 feet, and in a few wells 500 feet, since before World War II. These two areas are characterized by long-term heavy pumpage from many high capacity wells located within relatively small areas. Much of this pumpage has been for municipal supply, but industrial pumpage is also significant, especially that for the paper mills northeast of Lufkin. Other areas have experienced significant water-level declines, but most seem to be relatively small areas around heavily pumped high-capacity municipal wells or well fields. Hydrographs of selected wells in each county of the study area are included in Figure 9.

In some of the most significant areas of water-level decline, recent leveling off and/or reductions of ground-water pumpage has resulted in reductions of annual water-level decline rates and in some cases even water-level rises. Such reductions have occurred in the Lufkin-Nacogdoches area since Nacogdoches initiated use of surface water from Lake Nacogdoches as a major part of its supply in 1979, and because of the increased use of surface water and a reduction of ground-water pumpage by the paper industry northeast of Lufkin in the late 1970's and again in 1988.

The City of Tyler has been practicing conjunctive use of ground and surface water for many years, and has reduced ground-water use to less than 20 percent of its total pumpage. In this immediate area, water levels measured over the past few years in Tyler's City wells completed in the Carrizo-Wilcox aquifer have shown erratic rises and falls, perhaps due more to changes in recharge rates than to pumpage.

In the study area, the major areas of water-level decline are all within the downdip artesian portion of the Carrizo-Wilcox aquifer, and are a function of the aquifer's need to establish a steeper hydraulic gradient in order to move adequate water from its source on the outcrop or other areas of recharge to areas of heavy pumpage. When this gradient is sufficient to move enough water, as is apparently now the case, the water levels may stabilize or even rise. Based on Texas Water Development Board records and water levels measured by municipal and industrial well owners in both of the major decline areas, the current rate or even a slightly accelerated rate of pumpage can probably be continued indefinitely.

While there is some general water-level decline in the Carrizo-Wilcox aquifer throughout much of the study area, declines are significant only in the immediate vicinity of some other isolated municipal wells or small well fields. Much of this water-level decline is due to the fact that many of the relatively high capacity city or water supply corporation wells have been located too close to each other. Therefore, since the drawdown caused by each well adds to that caused by all of the others, significant increase in pumping head may occur, with corresponding declines in static water

levels. This, in turn, causes an increase in the cost of pumping and reduction of the production rate. An extreme case of this has occurred in many small cities, where two or even three wells have been located on the same city block, obviously much too close.

Pumping rates of large-capacity wells within the study area vary greatly due to a combination of factors. First, the net sand thickness varies considerably from place to place, as does the hydraulic conductivity of the sands themselves. Therefore, two wells of identical construction may have different pumping rates. To a large extent, the potential yields of wells can be maximized by drilling small diameter test holes to locate the area of maximum sand occurrence before constructing a new pumping well. The second problem, quite common in the study area, has to do with the construction of the well itself. Many wells drilled to supply water for municipal purposes, especially some of those drilled by some water supply corporations, were constructed on a very tight budget. They are drilled and completed in a manner similar to that of the left well in Figure 10. Such wells usually have very small diameter screens, often only hacksaw or torch slotted, and the amount or length of the screened interval is minimal as well. When a well is completed in the Carrizo-Wilcox in this manner and it is pumped at the maximum rate, water enters the screen at a very high speed because of the small open area. Water flowing from a fine sand aquifer at such speeds as is common in this type of well completion will move a lot of sand into the well. This sand is destructive to the screen and to the pump. In addition, the sand may fill surface storage facilities and cause damage to pumps, meters, valves, etc. associated with surface storage and distribution of the water. If wells are located and constructed properly, with adequate size of casing and screen, with a maximum screened interval, and with adequate underreaming and properly sized gravel pack, then the maximum amount of water can be produced efficiently, and in the long run economically. The well on the right in Figure 10 illustrates many of the construction methods needed for such an efficient well.

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## Water Quality

In general, the Carrizo-Wilcox, Queen City, and Sparta aquifers contain relatively good quality water throughout most of the study area. In erratically occurring isolated areas, water within some sand intervals in the three aquifers may contain concentrations of dissolved iron in excess of the recommended limit (0.3 milligrams per liter). But within most of the area, the quality of ground water is well within the recommended limits for concentrations of both secondary and primary constituents in drinking water. Within each of the three aquifers, water quality deteriorates with depth. This is a natural occurrence. In the Queen City and Sparta, this is quite rapid and may occur just downdip of the outcrop in some cases. These two aquifers rarely contain fresh water (less than 1,000 milligrams per liter dissolved solids) below depths of 600 to 700 feet. Fresh water may occur in the Carrizo-Wilcox down to depths in excess of 2,500 to 3,000 feet in some areas. North of the bad water line near Lufkin (Figure 8), fresh water occurs in the upper sands of the Wilcox at depths of 1,500 to 1,600 feet.

A few isolated instances of shallow poor quality ground water have been reported within the study area. Relatively high concentrations of dissolved solids, sulfate, and chloride have been reported, with some documentation. Some of these sites are in or near areas where lignite is known to occur and may be due mineralization by waters passing through the lignite, especially in the case of high sulfate. Others are most likely due to past oil-field practices, especially the practice of disposing of and/or storing oil-field brines in unlined

surface storage pits. Figure 11 shows the approximate location and extent of oil and gas fields in and around the study area, indicating the most likely areas where some type of pollution from oil-field sources might be found.

In general, ground-water quality is not a significant problem within the study area, but the potential for pollution, especially of shallow sands, remains very high.

## PROJECTED WATER DEMAND

### Population

Within the study area as a whole, population continued recent trends, growing steadily from 1980 through 1985. During this period, population rose from 303,649 to 334,983, an increase of over 10 percent. A summary of the 1980 and 1985 population estimates and projections for 1990, 2000, and 2010 is included in Table 2. In 1980, about 59 percent of the people in the study area lived in cities with over 1,000 population, by 1985, only 57 per cent. This decrease is projected to continue with only 54 per cent of the total population of the study area living within these cities by 2010. From 1980 to 1985, estimated rural population within the study area increased about 15.1 percent from 124,406 to 143,131, while major city population rose from 179,243 to 191,852, an increase of 7.0 percent. Most of the growth in both categories is occurring in and around the cities of Henderson, Jacksonville, Kilgore, Lufkin, Nacogdoches, and Tyler (see Table 3). Total population within the study area is projected to increase to 486,388 by 2010, with 260,842 in the cities which had a 1980 population over 1,000 and 225,546 in rural areas. Population projections for the study area were calculated using the revised Texas Water Development Board High Series population projection methodology (September, 1988 preliminary draft).

### Water Use

Within the study area, water used for all purposes comes from both surface-water and ground-water sources, with most of the ground-water pumpage coming from the Carrizo-Wilcox aquifer. Table 4 shows total reported water use for 1980 and 1985 and projected water demands for 1990, 2000, and 2010. Table 5 shows Texas Water Development Board estimates of the amounts of ground water pumped from the various aquifers within Angelina, Cherokee, Gregg, Nacogdoches, Rusk, and Smith Counties during 1980, 1984, and 1985. This includes some portion of these counties outside the study area (See Figure 1). While almost all of the ground water produced in the study area for industrial and municipal purposes comes from the Carrizo-Wilcox aquifer, a significant amount is produced from the Queen City and Sparta aquifers mostly for rural domestic and livestock uses.

Surface water used within the study area comes from various sources, including the Tyler city lakes, Lake Cherokee, etc. (see section that follows on surface-water availability). The City of Tyler not only provides water from its lakes for itself, but also sells water to several water supply corporations in the area.

Kilgore purchases some surface water from Longview which comes from Lake Cherokee. The City of Jacksonville produces surface water from Lake Jacksonville and the City of Nacogdoches from Lake Nacogdoches. Champion Paper Company uses surface water from Lake Kurth and Striker Creek Reservoir for industrial purposes.

In 1980, a total of 96,072 acre-feet of water was used for all purposes within the study area. This included 63,596 acre-feet of ground water and 32,476 acre-feet of surface water. Over half of the total, 51,906 acre-feet, was used for municipal purposes, and over 40 percent or 39,545 acre-feet was used for industrial purposes. Ground-water pumpage was 35,472 acre-feet for municipal use and 26,069 acre-feet for industrial use. In 1985, total pumpage increased nearly six percent to 101,712 acre-feet. Most of the increase in total pumpage,



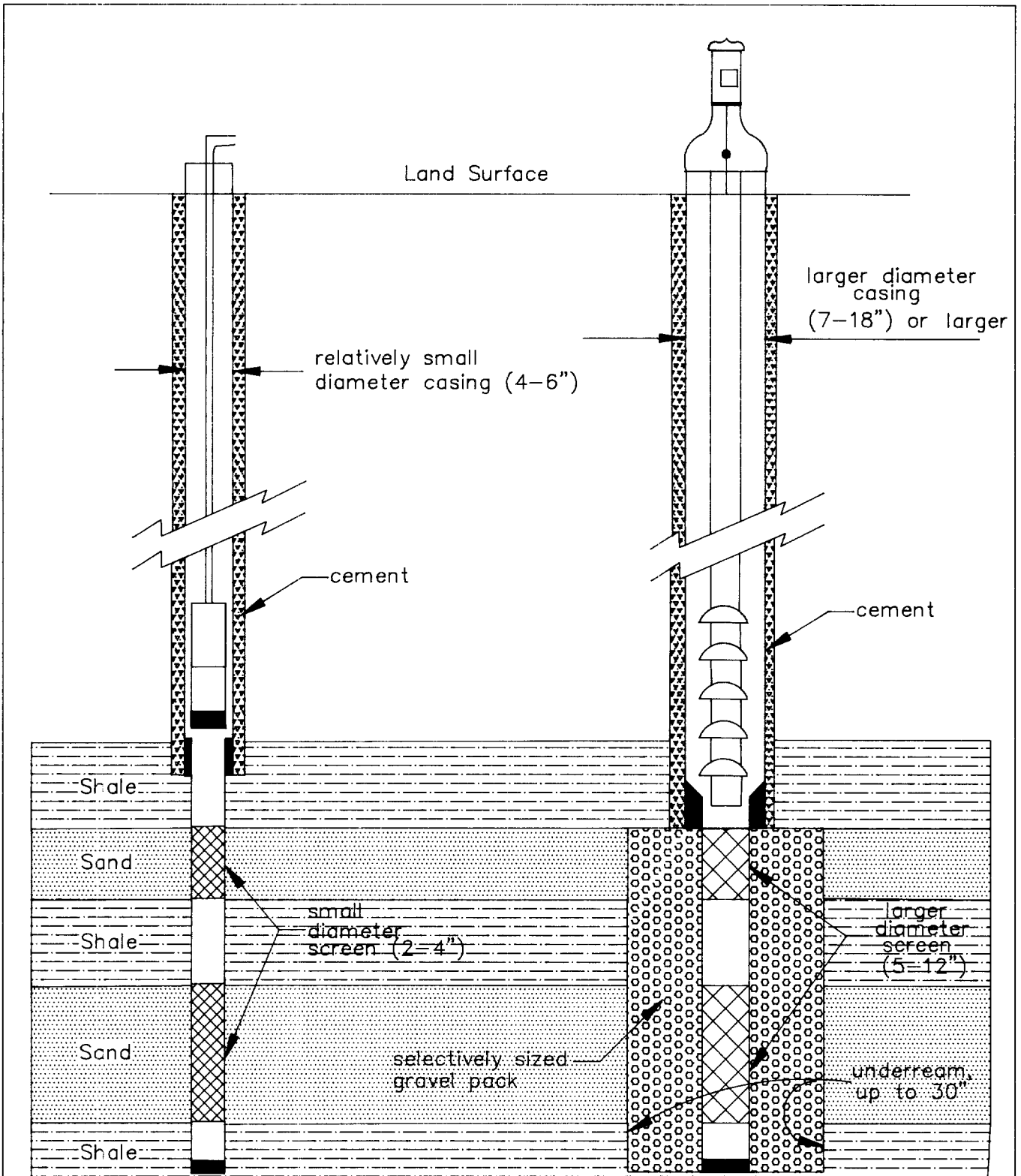


Figure 10

PUBLIC-SUPPLY WELL CONSTRUCTION METHODS

(Not to scale)

in fact about 85 percent, was surface water, but ground-water pumpage for municipal use increased nearly seven percent to 38,088 acre-feet. During this period, surface water pumpage increased for both municipal and industrial uses, to 18,593 and 15,242 acre-feet respectively, but ground-water pumpage for industrial use fell to 24,534 acre-feet, about a six percent decrease. Table 4 includes 1980 and 1985 pumpage by use and source and projected water demands for 1990, 2000, and 2010 for that part of each of the six counties that is within the study area. In Table 4, the total under the heading "industrial" includes the total amount of water used for manufacturing, steam-electric generation, and mining. The heading "other" includes water for irrigation and livestock use.

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**Projected  
Water  
Demand –  
1990-2010**

The projections of future municipal and rural water requirements shown in Table 4 are based on 1988 Texas Water Development Board Revised Data Series population projections and projected high series per capita use. Figure 12 shows the approximate areas currently served by public water-supply systems in the general study area. The future projections of irrigation, industrial, and livestock demand are based on high series projected demands apportioned by county based on the part of the county within the study area. These high series projections take into account the demands that are likely to occur under drought conditions. The use of significant amounts of both ground and surface water is expected to continue within the study area, but a large proportion of the increases in pumpage, especially for municipal and industrial use will probably come from surface-water sources.

Total water demand is estimated to be 135,425 acre-feet by 2010, an increase of 39,353 acre-feet or over 40 percent from 1985 total use. Almost all of this increase in demand is for municipal supply, up about 50 percent or 25,947 acre-feet to 77,853 acre-feet; and for industrial supply up 11,032 acre-feet to a total of 50,577 acre-feet, an increase of about 28 percent.

## AVAILABILITY OF WATER

### Current Ground-Water Availability

Relatively large amounts of ground water are recoverable from the aquifers underlying the study area. Much of this water is not very economical for recovery in the large amounts needed for municipal supply, however, especially much of that from the Queen City and Sparta aquifers. This is because so many relatively small capacity wells would be needed. There are still large amounts of water available from the Carrizo-Wilcox aquifer throughout most of the area, in fact enough to supply most of the water for all projected uses. The larger cities, however, will need to continue to supplement their ground water with surface water. This is mainly because of the economics and hydraulic problems inherent in developing such large amounts of ground water from within relatively small areas, and/or the cost of transporting relatively small amounts of ground water from many widely-spaced individual wells and/or well fields.

The total and yearly availability of ground water in the three aquifers which underlie the study area have been estimated by the Texas Water Development Board and other agencies and are summarized in Board reports *Water For Texas* (Texas Water Development Board, 1984) and *Ground-Water Availability in Texas* (Muller and Price, 1979). To most hydrologists, the annual effective recharge is considered to be a good estimate of long-term availability for an aquifer. The annual effective recharge for the Carrizo-Wilcox, Queen City, and Sparta aquifers in central and east Texas as estimated above has been divided among the individual counties based on the ratio of the area of occurrence of each aquifer within the county to the total area of the aquifer. Using this method, the estimated total annual effective recharge for the three aquifers within Angelina, Cherokee, Gregg, Nacogdoches, Rusk, and Smith Counties totals over 340,000 acre-feet. This estimate is based on the infiltration of various percentages of rainfall on the outcrops, and the calculated ability of the sediments to transmit the water down-dip into the artesian portion of the aquifers. This total includes over 105,000 acre-feet for the Carrizo-Wilcox, over 208,000 acre-feet for the Queen City, and about 31,000 acre-feet for the Sparta.

For the Sparta and Queen City aquifers, the actual outcrop is within the counties and therefore much of the recharge in question occurs within the study area. Only a relatively small portion of the recharge area of the Carrizo-Wilcox aquifer is within the study area, however, and that part of the effective recharge assigned to these counties occurs in other counties. To reach some of the major areas of pumpage within the study area water must pass from the outcrop areas in the surrounding counties where it is under water-table conditions and travel relatively great distances. While in transit, the water may be captured by wells and/or well fields along the way. The amount of water that can be transmitted by the aquifer is dependent on several factors, including the hydraulic characteristics of the aquifer, the aquifer's thickness, and the gradient between the areas of recharge and the area of pumping or other discharge. The pumping water level of a well or well field lowers until the slope of the hydraulic gradient provides enough water flow for the pumpage. When this happens, the

Table 2.  
Current and Projected Population of the Study Area <sup>1</sup>

County <sup>2</sup>	Year	Cities <sup>3</sup>	Rural <sup>4</sup>	Total
Angelina	1980	33,363	20,530	53,893
	1985	36,704	21,779	58,483
	1990	41,001	22,692	63,693
	2000	45,819	27,553	73,372
	2010	53,309	31,309	84,618
Cherokee	1980	18,148	19,068	37,216
	1985	18,573	20,281	38,854
	1990	19,775	21,719	41,494
	2000	22,368	24,871	47,239
	2010	24,608	27,144	51,752
Gregg	1980	1,121	5,350	6,471
	1985	1,215	5,096	6,311
	1990	1,335	5,038	6,373
	2000	1,471	5,752	7,223
	2010	1,595	6,092	7,687
Nacogdoches	1980	27,149	15,910	43,059
	1985	28,416	17,399	45,815
	1990	29,501	20,515	50,016
	2000	34,247	21,375	55,622
	2010	39,452	24,573	64,025
Rusk	1980	13,903	15,619	29,522
	1985	14,238	16,502	30,740
	1990	14,823	17,707	32,530
	2000	16,026	19,416	35,442
	2010	17,536	20,793	38,329
Smith <sup>5</sup>	1980	85,559	47,929	133,488
	1985	92,706	62,074	154,780
	1990	101,909	68,886	170,795
	2000	113,006	101,029	214,035
	2010	124,342	115,635	239,977
Area Totals	1980	179,243	124,406	303,649
	1985	191,852	143,131	334,983
	1990	208,344	156,557	364,901
	2000	232,937	199,996	432,933
	2010	260,842	225,546	486,388

<sup>1</sup> 1980 and 1985 population is based on Bureau of Census statistics. 1990, 2000, and 2010 population is based on 1988 Texas Water Development Board Revised High Series population projections.

<sup>2</sup> Population estimates are for the area of each county that falls within the study area as delineated on Figure 1.

<sup>3</sup> The term "cities" includes Huntington, Lufkin, Fuller Springs, Hudson, Alto, Jacksonville, Rusk, Liberty City, Kilgore, Nacogdoches, Henderson, Overton, Troup, Tyler, and Whitehouse.

<sup>4</sup> The term "rural" includes cities and unincorporated areas with a 1980 population of less than 1,000 and all rural population.

<sup>5</sup> The city of Kilgore is located within the study area in Gregg and Rusk counties, but the city's water wells are located in Smith County. Therefore, information for Kilgore is included with Smith County statistics.

Table 3.  
Population Projections, Larger Area Cities

City	1980	1985	1990	2000	2010
Henderson	11,473	11,852	12,445	13,433	14,684
Jacksonville	12,264	12,863	14,012	16,106	17,720
Kilgore	10,968	12,177	12,773	13,067	14,201
Lufkin	28,562	31,347	35,136	39,256	45,932
Nacogdoches	27,149	28,416	29,501	34,247	39,452
Tyler	70,508	74,603	81,658	91,044	100,340

pumping level will stabilize. Because of all these limiting factors, the estimated long-term availability, particularly that of the Carrizo-Wilcox aquifer, may represent an idealized amount that is impossible to be realized, especially from an economical standpoint. To even approach this maximum yield would take a large number of wells, each located at exactly the proper spacing and pumping at the most optimum rate determined. In addition, the water would have to be gathered, stored, and distributed through a very expensive system of water works, with many parts of the existing systems abandoned. Such a scenario would be much too expensive to ever happen.

In addition to that water available from the aquifers of the study area from annual recharge, there are extremely large amounts of water in storage within the aquifers. If the entire thickness of the aquifers is considered, this total represents millions of acre-feet of water. While much of this water occurs at depths uneconomical to produce, and other hydrologic factors reduce the total that is practical to pump even more, this still represents a rich source of additional water in some areas, at least for short term use.

Much of the absolute availability of ground water to the individual entities within the study area is dependant on two factors, the net fresh-water sand thickness within the aquifer, and the design, location, and construction of the individual wells used to produce the water. Therefore much care is needed in the planning, siting, and construction of future wells.

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### Current Surface Water Availability

At the present time, eight reservoirs with storage capacities greater than 5,000 acre-feet supply water to the study area. These include Lake Tyler East, Lake Tyler West, Lake Jacksonville, Lake Nacogdoches, Lake Palestine, Striker Creek Reservoir, and Lake Kurth located within the study area and Lake Cherokee located southeast Longview and east of Kilgore on the Rusk-Gregg County line. Entities within the study area also own water rights in Sam Rayburn Reservoir.

Lakes Tyler East and West supply water to the City of Tyler. The lakes can supply about 37,250 acre-feet of water per year under "drought of record" conditions, but have a total water-supply capacity of 73,700 acre-feet and permits to pump 50,000 acre-feet per year.

Lake Jacksonville supplies water to the City of Jacksonville. The lake is able to supply about 13,000 acre-feet of water per year under drought conditions. The City has a permit to divert only 5,000 acre-feet of water annually, however.

**Table 4.**  
**Historical Water Use and Projected Water Demand, 1980 - 2010<sup>1</sup>**

County	Year	Municipal			Industrial			Other			Totals		
		Ground Water	Surface Water	Totals	Ground Water	Surface Water	Totals	Ground Water	Surface Water	Totals	Ground Water	Surface Water	Totals
Angelina	1980	8,066	0	8,066	22,292	3,360	25,652	60	80	140	30,418	3,440	33,858
	1985	7,890	0	7,890	20,868	6,143	27,011	100	151	251	28,858	6,294	35,152
	1990			10,170			28,997			165	0	0	39,332
	2000			11,098			32,882			191	0	0	44,171
	2010			12,154			32,722			191	0	0	45,067
Cherokee	1980	5,094	1,032	6,126	531	5,491	6,022	634	889	1,523	6,259	7,412	13,671
	1985	4,451	122	5,573	604	6,060	6,664	697	1,266	1,963	5,752	7,448	14,200
	1990			7,087			7,223			2,092	0	0	16,402
	2000			8,420			7,434			2,343	0	0	18,197
	2010			8,723			7,608			2,343	0	0	18,674
Gregg	1980	760	0	760	134	0	134	222	261	483	1,116	261	1,377
	1985	750	93	843	182	71	253	204	306	510	1,136	470	1,606
	1990			955			308			572	0	0	1,835
	2000			1,027			425			661	0	0	2,113
	2010			1,034			557			661	0	0	2,252
Nacogdoches	1980	4,851	2,510	7,361	1,179	1,082	2,261	679	485	1,164	6,709	4,077	10,786
	1985	5,607	2,669	8,275	501	337	838	575	664	1,139	6,683	3,670	10,252
	1990			9,082			1,202			1,543	0	0	11,827
	2000			9,634			1,593			1,757	0	0	12,984
	2010			10,491			2,108			1,757	0	0	14,356
Rusk	1980	4,465	33	4,498	615	16	631	354	491	845	5,434	540	5,974
	1985	4,550	33	4,583	562	77	639	327	496	823	5,439	606	6,045
	1990			5,543			613			1,179	0	0	7,335
	2000			5,722			730			1,329	0	0	7,781
	2010			5,861			831			1,329	0	0	8,021
Smith	1980	12,236	12,859	25,095	1,318	3,527	4,845	106	360	466	13,660	16,746	30,406
	1985	14,740	14,777	29,517	1,817	2,616	4,433	40	529	569	16,597	17,922	34,519
	1990			32,284			4,938			694	0	0	37,916
	2000			38,192			5,909			714	0	0	44,815
	2010			39,580			6,841			714	0	0	47,135
Area Totals	1980	35,472	16,434	51,906	26,069	13,476	39,545	2,310	3,200	4,621	63,851	33,110	96,072
	1985	37,988	17,694	56,681	24,534	15,304	39,838	1,943	3,412	5,255	64,465	36,410	101,774
	1990			65,121			43,281			6,245			114,647
	2000			74,093			48,973			6,995			130,061
	2010			77,843			50,667			6,995			135,505

<sup>1</sup> Both use and demand are estimated for that part of each county that is included within the study area as delineated on Figure 1.

**Table 5**  
**Estimated Ground-Water Pumpage**  
**(acre-feet)**

County	Year	Aquifer <sup>1</sup>	Municipal	Manufacturing	Livestock	Irrigation	Steam-Electric	Mining	Total	
Angelina	1980	CZWX	8,244	21,296	0	0	0	0	29,540	
		Other	2,645	0	70	191	0	0	2,906	
		QC	150	0	23	186	0	0	359	
		SP	150	0	24	186	0	0	360	
	1980	<b>Totals</b>	<b>11,189</b>	<b>21,296</b>	<b>117</b>	<b>563</b>	<b>0</b>	<b>0</b>	<b>33,165</b>	
	1984	CZWX	7,989	19,284	0	0	0	0	27,273	
		Other	2,263	1,002	146	191	0	0	3,602	
		QC	214	0	48	186	0	0	448	
		SP	214	0	49	186	0	0	449	
	1984	<b>Totals</b>	<b>10,680</b>	<b>20,286</b>	<b>243</b>	<b>563</b>	<b>0</b>	<b>0</b>	<b>31,772</b>	
	1985	CZWX	8,222	19,120	0	0	0	0	27,342	
		Other	2,322	892	95	153	0	0	3,462	
		QC	187	0	47	149	0	0	383	
		SP	187	0	47	148	0	0	382	
	1985	<b>Totals</b>	<b>10,918</b>	<b>20,012</b>	<b>189</b>	<b>450</b>	<b>0</b>	<b>0</b>	<b>31,569</b>	
Cherokee	1980	CZWX	4,850	0	0	25	333	0	5,208	
		QC	326	0	380	25	0	53	784	
		SP	108	0	204	0	0	28	340	
	1980	<b>Totals</b>	<b>5,284</b>	<b>0</b>	<b>584</b>	<b>50</b>	<b>333</b>	<b>81</b>	<b>6,332</b>	
	1984	CZWX	4,636	0	252	58	408	117	5,471	
		QC	155	0	252	59	0	0	466	
		SP	52	0	81	0	0	0	133	
	1984	<b>Totals</b>	<b>4,843</b>	<b>0</b>	<b>585</b>	<b>117</b>	<b>408</b>	<b>117</b>	<b>6,070</b>	
	1985	CZWX	4,878	0	269	36	218	120	5,520	
		QC	144	0	269	36	0	0	448	
		SP	53	0	88	0	0	0	141	
	1985	<b>Totals</b>	<b>5,074</b>	<b>0</b>	<b>625</b>	<b>72</b>	<b>218</b>	<b>120</b>	<b>6,109</b>	
	Gregg	1980	CZWX	654	250	47	0	1	152	1,104
			QC	376	28	62	0	0	153	619
		1980	<b>Totals</b>	<b>1,030</b>	<b>278</b>	<b>109</b>	<b>0</b>	<b>1</b>	<b>305</b>	<b>1,723</b>
1984		CZWX	700	196	45	0	1	2,672	3,614	
		QC	258	0	57	0	0	1,312	1,627	
1984		<b>Totals</b>	<b>958</b>	<b>196</b>	<b>102</b>	<b>0</b>	<b>1</b>	<b>3,984</b>	<b>5,241</b>	
1985		CZWX	688	186	36	0	1	128	1,039	
		QC	222	0	46	0	0	1	268	
1985		<b>Totals</b>	<b>910</b>	<b>186</b>	<b>82</b>	<b>0</b>	<b>1</b>	<b>129</b>	<b>1,307</b>	

**Table 5**  
**Estimated Ground-Water Pumpage**  
**(acre-feet)**

County	Year	Aquifer <sup>1</sup>	Municipal	Manufacturing	Livestock	Irrigation	Steam-Electric	Mining	Total
Nacogdoches	1980	CZWX	6,157	21	237	0	0	0	6,415
		Other	0	0	0	0	0	0	0
		QC	372	0	237	0	0	0	609
		SP	267	0	315	0	0	0	582
	<b>1980</b>	<b>Totals</b>	<b>6,796</b>	<b>21</b>	<b>789</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>7,606</b>
	1984	CZWX	6,701	0	391	19	0	0	7,111
		Other	22	0	43	0	0	0	65
		QC	62	0	131	0	0	0	193
		SP	70	0	130	0	0	0	200
	<b>1984</b>	<b>Totals</b>	<b>6,855</b>	<b>0</b>	<b>695</b>	<b>19</b>	<b>0</b>	<b>0</b>	<b>7,569</b>
	1985	CZWX	6,733	0	284	39	0	0	7,056
		Other	1	0	30	0	0	0	31
		QC	0	0	96	0	0	0	96
		SP	6	0	96	0	0	0	102
	<b>1985</b>	<b>Totals</b>	<b>6,740</b>	<b>0</b>	<b>507</b>	<b>39</b>	<b>10</b>	<b>0</b>	<b>7,286</b>
Rusk	1980	CZWX	4,725	0	558	0	0	562	5,845
		QC	680	0	63	0	0	72	815
	<b>1980</b>	<b>Totals</b>	<b>5,405</b>	<b>0</b>	<b>621</b>	<b>0</b>	<b>0</b>	<b>634</b>	<b>6,660</b>
	1984	CZWX	4,341	0	510	33	0	1,521	6,405
		QC	55	0	56	0	0	169	280
	<b>1984</b>	<b>Totals</b>	<b>4,396</b>	<b>0</b>	<b>566</b>	<b>33</b>	<b>0</b>	<b>1,690</b>	<b>6,685</b>
	1985	CZWX	5,427	0	479	38	0	2,279	8,223
		QC	64	0	28	0	0	213	305
	<b>1985</b>	<b>Totals</b>	<b>5,491</b>	<b>0</b>	<b>507</b>	<b>38</b>	<b>0</b>	<b>2,492</b>	<b>8,528</b>
	Smith	1980	CZWX	14,615	10	17	25	0	329
QC			1,863	0	406	25	0	360	2,654
SP			0	0	0	0	0	0	0
<b>1980</b>		<b>Totals</b>	<b>16,478</b>	<b>10</b>	<b>423</b>	<b>50</b>	<b>0</b>	<b>689</b>	<b>17,650</b>
1984		CZWX	17,278	58	108	0	0	358	17,802
		QC	531	32	332	0	0	147	1,042
		SP	0	0	71	0	0	0	71
<b>1984</b>		<b>Totals</b>	<b>17,809</b>	<b>90</b>	<b>511</b>	<b>0</b>	<b>0</b>	<b>505</b>	<b>18,915</b>
1985		CZWX	17,232	1,020	90	0	0	507	18,849
		QC	290	35	278	0	0	309	912
		SP	0	0	61	0	0	0	61
<b>1985</b>		<b>Totals</b>	<b>17,522</b>	<b>1,055</b>	<b>429</b>	<b>0</b>	<b>0</b>	<b>816</b>	<b>19,822</b>



**Table 5**  
**Estimated Ground-Water Pumpage**  
**(acre-feet)**

County	Year	Aquifer <sup>1</sup>	Municipal	Manufacturing	Livestock	Irrigation	Steam- Electric	Mining	Total
<b>Area Totals</b>									
	1980	CZWX	39,345	21,577	859	50	334	1,043	63,108
		Other	2,645	0	70	191	0	0	2,906
		QC	3,767	28	1,171	236	0	638	5,840
		SP	525	0	543	186	0	28	1,282
	<b>TOTALS</b>		<b>46,182</b>	<b>21,605</b>	<b>2,643</b>	<b>663</b>	<b>334</b>	<b>1,709</b>	<b>73,136</b>
	1984	CZWX	41,645	19,538	1,306	110	409	4,668	67,676
		Other	2,285	1,002	189	191	0	0	3,667
		QC	1,275	32	876	245	0	1,628	4,056
		SP	336	0	331	186	0	0	853
	<b>TOTALS</b>		<b>45,541</b>	<b>20,572</b>	<b>2,702</b>	<b>732</b>	<b>409</b>	<b>6,296</b>	<b>76,252</b>
	1985	CZWX	43,180	20,326	1,158	113	219	3,034	68,029
		Other	2,323	892	125	153	0	0	3,493
		QC	907	35	764	185	0	523	2,412
		SP	245	0	291	148	0	0	684
	<b>TOTALS</b>		<b>46,655</b>	<b>21,253</b>	<b>2,338</b>	<b>599</b>	<b>219</b>	<b>3,557</b>	<b>74,618</b>

- <sup>1</sup> CZWX - Carrizo-Wilcox  
 QC - Queen City  
 SP - Sparta

These pumpage totals include pumpage within all of each of the counties, not just that portion within the study area.

Striker Creek Reservoir supplies up to 10,000 acre-feet of water per year to the Champion Paper Company. The lake can supply 20,600 acre-feet of water per year under drought conditions. This lake is used for industrial supply only.

Lake Nacogdoches supplies water to the City of Nacogdoches. This lake can supply about 22,000 acre-feet of water per year.

Lake Kurth supplies water to the Champion Paper Company. The permitted diversion rate is 19,100 acre-feet per year.

Lake Palestine provides water to the City of Palestine and is projected to provide water to Dallas and Tyler. This lake is permitted to provide a total of 212,700 acre-feet per year. The City of Dallas has rights to 114,284 acre-feet per year, and Tyler to about 67,000 acre-feet per year.

Sam Rayburn Reservoir is located on the Angelina River on the southeast boundary of the study area. The City of Lufkin owns rights to 43,000 acre-feet of water annually from this reservoir. Another 14,467 acre-feet per year for municipal supply is reportedly available to be purchased from Sam Rayburn. The total permitted capacity of this reservoir is 820,000 acre-feet per year, but much of this total is committed to irrigation and industrial supply in the lower part of the basin.

Lake Cherokee provides water to Longview, which in turn sells to Kilgore. The total storage of the lake is 46,700 acre-feet. The authorized diversion is 62,400 acre-feet per year for municipal and industrial purposes.

From the above, it appears that there is adequate surface water available from within or near the study area to supplement the available ground-water supplies well beyond 2010.

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**Potential for  
Conjunctive  
Use of Ground  
and Surface  
Water**

Most of the larger cities within the study area are currently using surface water in conjunction with ground water to provide for their citizens' needs. Table 6 shows the combined surface and ground water pumpage for Tyler, Kilgore, Jacksonville, Nacogdoches, and Liberty City in 1980 and 1985. Some of these entities also sell water to some of the water supply corporations and water districts within the study area. In addition to the surface water already available from existing reservoirs (see Surface-Water Availability Section), several cities and rural water corporations are working toward the completion of Lake Eastex to provide even more surface water for use within the study area. These include the cities of Lufkin, Nacogdoches, Jacksonville, Troup, New London, Arp, Rusk, Overton, and Henderson; and the Reklaw WSC, Jackson WSC, New Summerfield WSC, Angelina WSC, Wright City WSC, Star Mountain WSC, Craft-Turney WSC, Woodlawn WSC, Redland WSC, Walnut Grove WSC, and Blackjack WSC; as well as Cherokee County, Temple-Eastex, Inc, and Mr. Leo F. Childs. The estimated total dependable yield for Lake Eastex is 76,336,000 gallons per day or about 85,507 acre-feet per year. Commitments range from less than one-tenth of one percent of the total yield (about 85 acre-feet per year) for Mr. Leo R. Childs to fifteen percent each (over 12,000 acre-feet per year) for the Cities of Jacksonville and Henderson.

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## Potential for Additional Ground-Water Development

In some portions of the study area ground-water supplies have obviously been overdeveloped, as is witnessed by the historical decline of water levels, especially in the vicinity of Tyler, Nacogdoches, and Lufkin. However, there is a significant amount of additional ground water that is available for future development from the Carrizo-Wilcox aquifer within parts of the study area. Throughout most of Cherokee and Rusk Counties and in portions of Angelina, Gregg, Nacogdoches, and even some parts of Smith County, new wells can be drilled to provide additional supplies of water suitable for all uses. Of course, these wells need to be sited in the correct manner, using small-diameter test holes and geophysical logging to find the optimum location. Each new well should be an adequate distance from any existing high-capacity wells to avoid or at least minimize pumping interference between wells and sited where the aquifer has a maximum thickness of sand containing good quality water. Then the most efficient well possible should be constructed (See the well on the right in Figure 10). The test hole at the site selected should be reamed to the largest feasible diameter or a new large-diameter hole drilled nearby. At first, the well should be reamed to a point just above the interval selected for screening. Then the largest possible casing should be set and pressure cemented in place. Then the producing part of the hole should be reamed and formation samples collected within the interval selected for screening. These sediment samples should be tested for grain size and sorting. This information can be used to select the optimum screen opening size as well as the size of gravel-packing material. Then the production interval should be under-reamed to the maximum diameter feasible. Then casing and screen only slightly smaller than the surface casing should be placed in the well and the under-reamed portion filled with gravel of the selected size. Then the well should be cleaned up, developed and tested with a test pump to determine the optimum pumping rate and allow the selection of a well pump of the correct size.

If this type of planning, site selection, and well construction is used in the future, there is adequate water available from the Carrizo-Wilcox aquifer to supply most of the smaller cities, rural water supply corporations, and water districts over much of the study area, especially in Cherokee and Rusk Counties.

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## Potential Methods for Increasing Aquifer Recharge

Aquifer recharge is the sum of those processes by which the aquifer receives water and may occur through both natural and artificial means. As discussed earlier, natural recharge consists of the percolation of water derived from rainfall down into the aquifer, and through the loss of water from other aquifers and aquitards either above or below the aquifer in question. Artificial recharge may result from either direct activities by man or as a outgrowth of activities for other purposes which increase the amount of recharge to an aquifer. Some conservation practices, especially many of those practiced by the agricultural community, may also add to the amount of recharge. If room is available within the aquifer for additional storage of the increased recharge, then artificial recharge may significantly increase the amount of water available from an aquifer.

Most recharge to an aquifer occurs on the outcrop of the geologic formations which make up the aquifer, and therefore, to be efficient, artificial recharge projects must generally be located there. There are several methods of accomplishing artificial recharge. These include recharge through wells, pits, ditches, ponds, and even larger areas of spreading. All of these methods are subject to problems, especially plugging of the aquifer or the beds above the aquifer with silt, clay, and other particles which are suspended in the recharge water. Recharge wells may also be plugged by entrained air, bacterial growth, mineral precipitates caused by interaction of the recharge water with formation water, precipitation of iron due to pH changes, and the mechanical compaction of the aquifer materials due to high injection pressures. The potential for artificial recharge within the study area is small.

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**Projected  
Availability  
Through  
the Year 2010**

Total projected water demand for the study area in 2010 is 135,425 acre-feet. Based on estimates of the availability of surface and ground water within the area, this demand can easily be met from existing sources, but most of the additional water should come from surface water.

In 1985, the total water demand (pumpage) for the study area was 101,712 acre-feet, with 64,465 acre-feet of this reported from ground-water sources. Total 1985 ground-water pumpage for the six counties containing the study area was 74,618 acre-feet. An estimated 91 percent of this total, or 68,029 acre-feet, was pumped from the Carrizo-Wilcox aquifer. Within this six county area, the safe yield (estimated annual effective recharge) for the Carrizo-Wilcox aquifer is 105,000 acre-feet, with restrictions as discussed previously. Over much of the study area, especially in Cherokee and Rusk Counties, some limited amounts of additional ground water can be developed. New wells should be located and constructed using methods described in previous sections of this report. Dense concentrations of wells with pumpage of large amounts of water would result in severe water-level declines, as has occurred in the vicinity of Tyler, Lufkin, and Nacogdoches, however.

Existing surface-water supplies available to entities within the study area total considerably more than 160,000 acre-feet per year. This includes rights to water from Lake Palestine and Sam Rayburn Reservoir belonging to various cities which are not yet in use. In addition, many water-supply entities in the study area are working toward the construction of Lake Eastex and Little Cypress Reservoir which would provide more than 100,000 acre-feet per year of additional water.

**Table 6.  
Present Conjunctive Ground-Water and Surface-Water  
Use for Municipal Supply, 1980 and 1985  
(in acre-feet)**

City	1980			1985		
	Ground Water	Surface Water	Total	Ground Water	Surface Water	Total
Jacksonville	2,157	862	3,019	1,530	722	2,252
Kilgore	2,661	0	2,661	1,735	670	2,405
Liberty City	127	0	127	151	22	173
Nacogdoches	3,074	2,416	5,490	3,476	2,200	5,676
Tyler	2,927	12,603	15,530	2,212	13,638	15,850

## SUMMARY

Water demands of the study area are supplied from both surface-water and ground-water sources. In 1985, total water use was 101,712 acre-feet. About 63 percent or 64,465 acre-feet was ground water, mostly from the Carrizo-Wilcox aquifer. Almost 95 percent of total water use in this area is for municipal and industrial use.

The most pressing ground-water problem of the area is water-level declines in the Tyler area and in the area between Lufkin and Nacogdoches. In both areas, pumping levels have fallen 500 feet or more due to extremely heavy pumpage from numerous wells located within relatively small areas. A relatively recent switch to conjunctive use of ground and surface water by Tyler, Nacogdoches, and large industrial pumpers in the Lufkin area seems to have slowed, if not stabilized, these declines, however.

In some areas, outside of the influence of these large concentrations of wells, there is adequate ground water available from the Carrizo-Wilcox aquifer to supply the projected needs of many of the smaller public supply entities through 2010 and beyond. In these areas, future well sites should be determined based on test holes and the new wells should be constructed in a manner to provide the most efficient well possible. Some suggested methods, under-reaming, gravel packing, etc. are outlined within the report.

Significant amounts of surface water, well above the current use, are available from numerous reservoirs within or near the study area. This includes some water rights which are owned by entities within the area, but not in use at this time, such as Lufkin's rights to water in Sam Rayburn Reservoir. There appears to be an adequate amount available to provide for the additional water demands projected for municipal and industrial use through 2010 and well beyond.

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