3.4 GROUND-WATER RESOURCES PERSPECTIVE

The Texas Water Development Board has identified and characterized nine major and 20 minor aquifers in the State, based on the quantity of water supplied by each (see Figures 2-4 and 2-5). A major aquifer is generally defined as supplying large quantities of water over large areas of the State. A minor aquifer typically supplies large quantities of water in small areas or relatively small quantities of water over large areas. The major and minor aquifers underlie approximately 81 percent of the State. Lesser quantities of water may also be found in the remainder of the State.

The surface extent, or outcrop, of each aquifer is the area in which the host geological formations are exposed at the land surface. This area corresponds to the principal recharge zone for the aquifers. Groundwater within this area normally reflects unconfined water-table conditions and is most susceptible to contamination. Some water-bearing formations dip below the surface and are covered by other formations. Aquifers with this characteristic are common. Aquifers covered with less permeable formations, such as clay, are confined under artesian pressure.

Exhibit 3-3
Classification of Aquifer Water Quality
(milligrams per liter or mg/l)

Fresh	less than 1,000 mg/l
Slightly Saline	1,000-3,000 mg/l
Moderately Saline (brackish)	3,000-10,000 mg/l
Very Saline*	10,000-35,000 mg/l

* Sea water is typically about 35,000 mg/l.

Aquifer water quality is described in terms of dissolved-solids concentrations (see Exhibit 3-3). Delineation of the downdip boundaries of each aquifer is based on chemical water quality criteria. The quality limit for most aquifers is 3,000 milligrams of dissolved solids per liter (mg/l). However, the limit for the Edwards (BFZ) is 1,000 mg/l, and can range up to 5,000 mg/l in the Dockum and Rustler and 10,000 mg/l in the Blaine for specific irrigation and industrial uses. Some aquifers, such as the Hueco Bolson and Lipan, have depth limitations at which water of acceptable quality can be obtained.

The average annual ground-water availability reported for each aquifer is comprised of the annual effective recharge plus, in some cases, an amount that can be recovered from storage. The estimated total amount of water in storage is also reported for some aquifers.

Recharge is the addition of water to an aquifer. This water may be absorbed from precipitation, streams, and lakes either directly into a formation or indirectly from another formation. Generally, only a small portion of the total precipitation seeps down through the soil cover to reach the water table.

Changes in water levels indicate a change in ground-water storage in an aquifer. These changes can be due to many causes, with some regionally significant and others confined to more local areas. In short, water-level fluctuations are caused by changes in recharge and discharge.

When recharge is reduced, as in the case of a drought, or when pumpage is greater than recharge, some of the water discharged from the aquifer must be withdrawn from storage, resulting in a decline of water levels. If water levels are lowered excessively, springs and shallow wells may go dry. However, when sufficient precipitation resumes or pumpage is reduced, the volume of water drained from storage may be replaced, and water levels will rise accordingly. Changes in water levels in water table aquifers are generally less pronounced than in artesian aquifers.

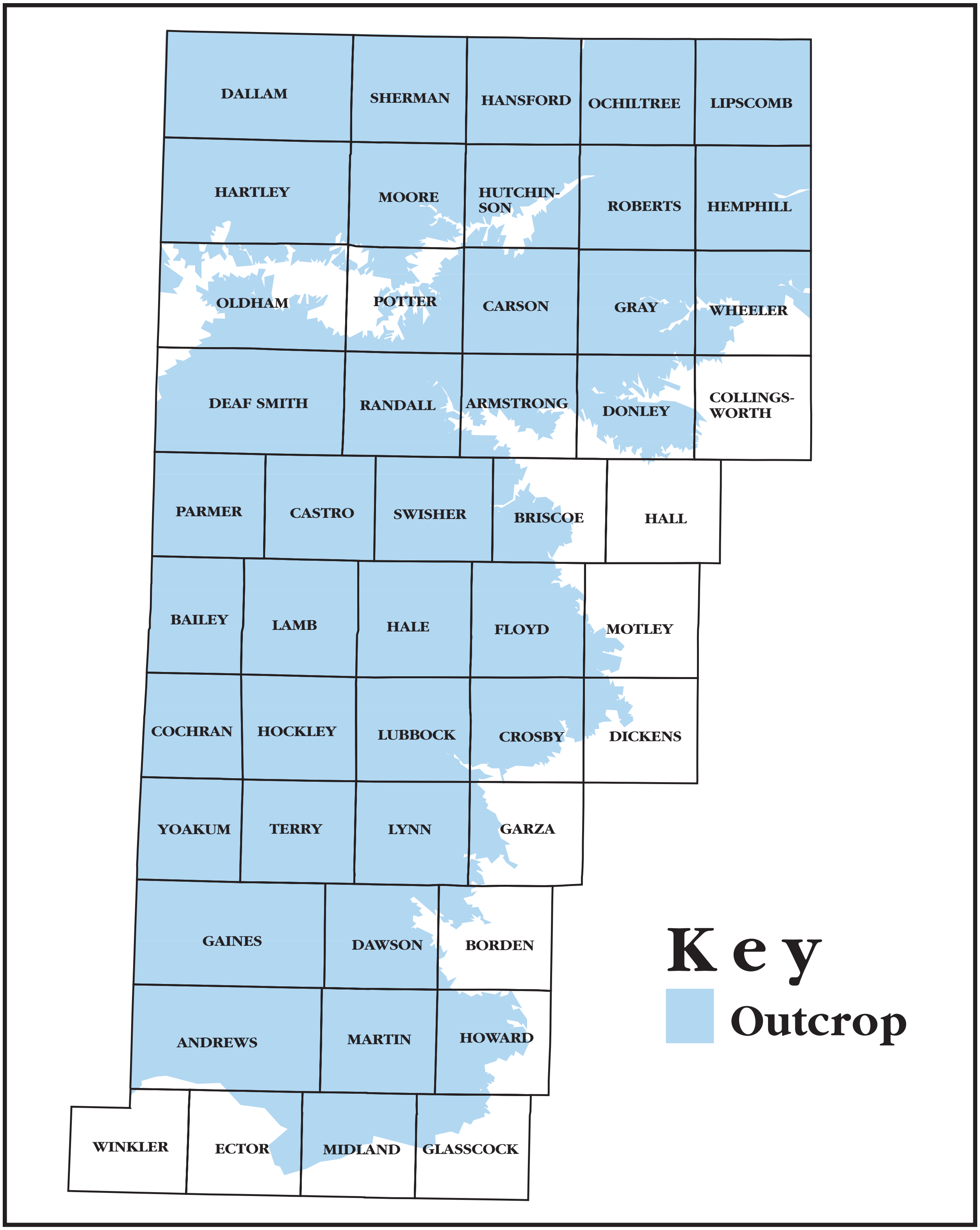

Figure 3-73
Ogallala Aquifer

3.4.1 Major Aquifers

3.4.1.1 Ogallala Aquifer

Location and Use. The Ogallala Aquifer covers more than 35,000 square miles of the High Plains in the Texas Panhandle, providing water to all or parts of 46 counties (see Figure 3-73). Extending through eight states northward to South Dakota, the Texas High Plains is the southernmost extension of the Great Plains physiographic province, often referred to as the "breadbasket" of North America. More water is pumped from the Ogallala in Texas than from any other aquifer. Total pumpage from the Ogallala in 1994 was approximately 5.9 million acre-feet (ac-ft), of which 96 percent was used for irrigation. Many communities use the Ogallala Aquifer as their sole source of drinking water supply.

Hydrogeology. Water-bearing areas of the Ogallala are laterally connected except where the Canadian River has eroded through the formation, thereby forming the boundary between two separate flow systems referred to as the Northern and Southern High Plains. Vertical hydrologic communication also occurs between the Ogallala and the underlying Cretaceous, Jurassic, and Triassic formations in many areas and between the overlying Quaternary Blackwater Draw Formation where present.

The Ogallala is primarily composed of sand, gravel, clay, and silt deposited during the Tertiary Period. Groundwater moves slowly through the Ogallala Formation in a southeastward 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 less in the south where the formation overlaps Cretaceous rocks. The saturated thickness ranges up to approximately 600 feet and is greatest where sediments have filled previously eroded drainage channels. Coarse-grained sediments in these channels also have the greatest permeability and supply water to wells with yields as high as 2,000 gal/min.

Water Quality. The chemical quality of the water in the aquifer is generally fresh; however, both dissolved solids and chloride concentrations increase from north to south. In the Northern High Plains, dissolved solids are typically less than 400 mg/l. Dissolved solids range from less than 1,000 to over 3,000 mg/l in the Southern High Plains, and chloride concentrations typically range from less than 300 to over 1,000 mg/l. The chemical quality is substantially influenced by upward leakage and subsequent mixing of water from the underlying Cretaceous aquifers, resulting in increased concentrations of sodium and chloride in Ogallala water. Fluoride content is commonly high and selenium concentrations locally exceed drinking-water standards.

Some ground-water contamination from past oil field practices has occurred mostly in the Southern High Plains. Dissolved-solids concentrations in excess of 3,000 mg/l suggest that the greatest cause of contamination was by oil field brines, particularly the disposal of oil field brines into unlined surface pits prior to the statewide "no pit" order of the Railroad Commission of Texas. Much of the water discharged into these pits probably seeped into the ground and eventually into the ground-water system. Additional brine contamination may be resulting from abandoned oil, gas, and injection wells and wells with broken or poorly cemented casings.

Availability. Total recoverable water in storage within the Ogallala, as calculated by a regional computer flow model, is 385 million ac-ft. Total ground-water availability for the aquifer also includes the annual effective recharge of 438,910 ac-ft. Recharge occurs principally by infiltration of precipitation on the surface and, to a lesser extent, by upward leakage from underlying formations. Only about 1 inch of the precipitation actually reaches the water table because annual rainfall is low, evaporation rate is high, and infiltration rate is low. Highest recharge infiltration rates occur in areas overlain by sandy soils and in playa-lake basins.

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, heavily irrigated areas have experienced water-level declines, some in excess of 100 feet. Reduced pumpage in other areas has resulted in a reduction of water-level declines and, in some cases, water-level rises.

Resource Management. Underground water conservation districts (UWCDs) have played a significant role in the management of the Ogallala Aquifer. By 1955, five districts had been established on the High Plains ranging in size from small parts of single counties to multi-county districts. Nine districts are currently in operation and some original districts have expanded to include additional territory. Currently active UWCDs include: Dallam County #1, Glasscock, High Plains #1, Mesa, North Plains #2, Panhandle #3, Permian basin, Sandy Land, and South Plains. In addition, the Garza County district was created in 1996. Most of these districts maintain well spacing rules to control density of pumping wells and have extensive water quality and water level monitoring networks. A majority of the districts have production regulation rules, and one district has a depletion rule. All of the above mentioned districts, except Garza, have submitted comprehensive management plans with Texas Natural Resource Conservation Commission (TNRCC). Counties experiencing water-level declines in the Ogallala that are not managed by UWCDs include Gaines, Swisher, and Briscoe.

Underground water conservation districts have led the way in encouraging conservation management practices. As a result of their efforts, irrigators are reporting water and labor savings of up to 50 percent. Many farmers are using more efficient irrigation systems such as surge valves and low energy precision application (LEPA) equipment. Also, soil moisture monitoring devices are being used to better schedule irrigation applications. Texas High Plains districts have also established programs such as water level and quality monitoring, public education, research, abandoned well closing, assistance to municipalities, and other programs that provide for the most effective conservation management.

In 1994, local water-related entities joined forces to address the problem of a diminishing resource. A process was begun to develop a regional water management plan that would examine alternatives for better, more efficient water use. The ultimate goal of this group is to achieve aquifer sustainability. Currently the group is trying to answer the question of whether aquifer sustainability can be achieved. If it is determined that full sustainability is not realistic, the question is "what level of aquifer depletion would be considered acceptable?"

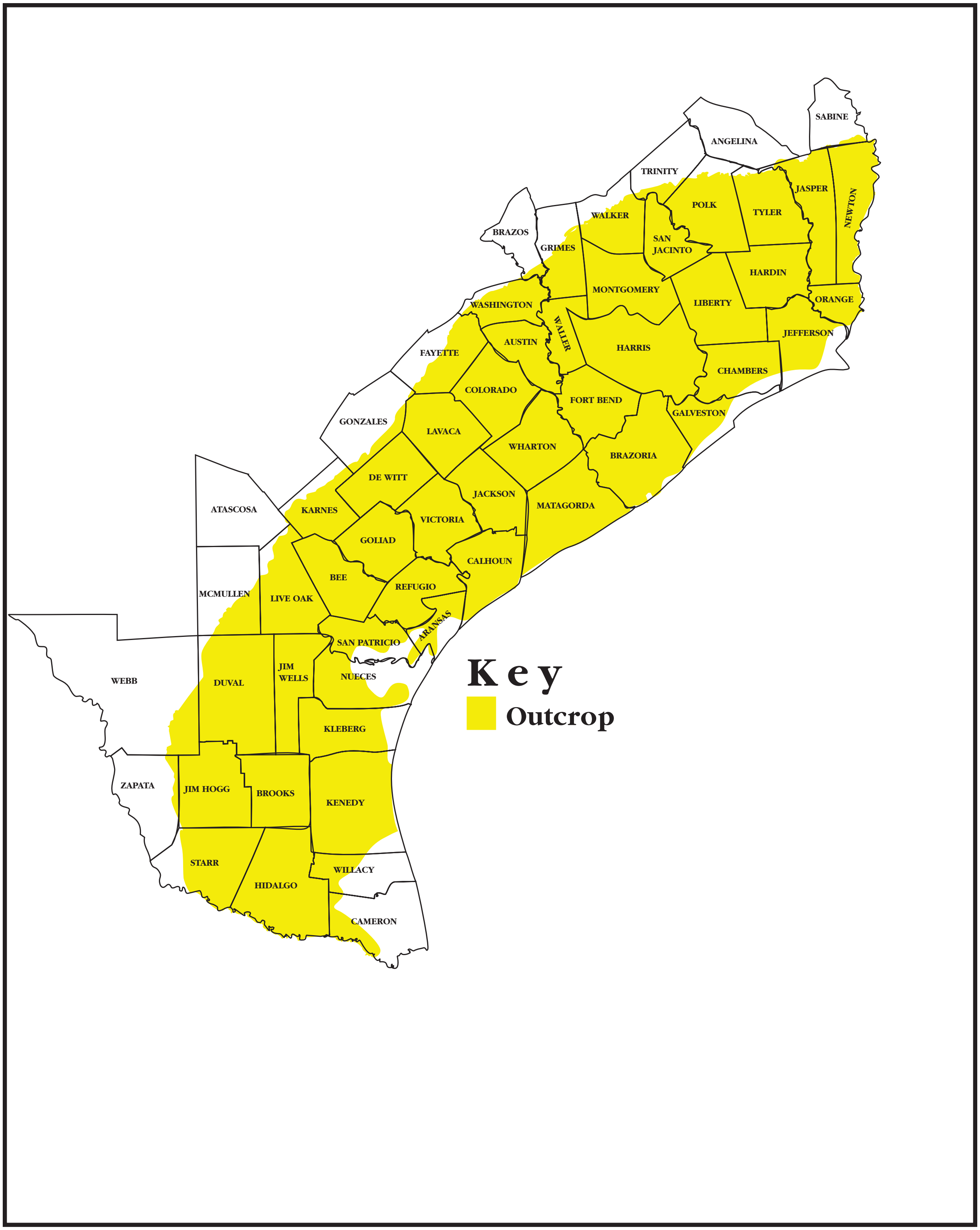

Figure 3-74
Gulf Coast Aquifer

3.4.1.2 Gulf Coast Aquifer

Location and Use. The Gulf Coast Aquifer forms an irregularly shaped belt along the Gulf of Mexico from Florida to Mexico. In Texas, the aquifer provides water to all or parts of 54 counties and extends from the Rio Grande northeastward to the Louisiana-Texas border (see Figure 3-74). Total pumpage was approximately 1.1 million acre-feet (ac-ft) in 1994. Municipal pumpage accounted for 51 percent of the total, irrigation accounted for 36 percent, and industrial accounted for 12 percent. The greater Houston metropolitan area, where well yields average about 1,600 gal/min, is the largest municipal user.

Hydrogeology. The aquifer consists of complex interbedded clays, silts, sands, and gravels, which are hydrologically connected to form a large, leaky artesian aquifer system. This system is comprised of four major components consisting of the following generally recognized water-producing formations. The deepest is the Catahoula, which contains groundwater near the outcrop in relatively restricted sand layers. Above the Catahoula is the Jasper Aquifer, primarily contained within the Oakville Sandstone. The Burkeville confining layer separates the Jasper from the overlying Evangeline Aquifer, which is contained within the Fleming and Goliad sands. The Chicot Aquifer, or upper component of the Gulf Coast Aquifer system, consists of the Lissie, Willis, Bentley, Montgomery, and Beaumont formations, and overlying alluvial deposits. Not all formations are present throughout the system, and nomenclature often differs from one end of the system to the other. Maximum total sand thickness ranges from about 700 feet in the south to 1,300 feet in the northern extent.

Water Quality. Water quality is generally good in the shallower portion of the aquifer. Groundwater containing less than 500 mg/l dissolved solids is usually encountered to a maximum depth of 3,200 feet in the aquifer from the San Antonio River basin northeastward to Louisiana. From the San Antonio River basin southwestward to Mexico, quality deterioration is evident in the form of increased chloride concentration and salt-water encroachment along the coast. Little of this groundwater is suitable for prolonged irrigation use due to either high salinity, or alkalinity, or both.

In several areas at or near the coast, including Galveston Island and the central and southern parts of Orange County in the northeastern part of the aquifer, heavy municipal or industrial pumpage has caused an updip migration, or saltwater intrusion, of poor quality water into the aquifer. Recent reductions in pumpage here have resulted in a stabilization and, in some cases, even improvement of ground-water quality.

Availability. Years of heavy pumpage for municipal and manufacturing use in portions of the aquifer have resulted in areas of significant water-level decline. Historically, declines of 200 to 300 feet have been measured in some areas of eastern and southeastern Harris and northern Galveston counties. Other areas of significant water-level decline include the Kingsville area in Kleberg County and portions of Jefferson, Orange, and Wharton counties. Some of these declines have resulted in compaction of dewatered clays and significant land-surface subsidence. Subsidence is generally less than 0.5 foot over most of the Texas coast, but has been as much as nine feet in Harris and surrounding counties. As a result, structural damage and flooding have occurred in many low-lying areas in Baytown and Texas City along Galveston Bay, and within the City of Houston.

Although water levels continued to decline in both the water-table and artesian portions of the Gulf Coast Aquifer in certain areas during the 1980 - 1990 decade, the rate of those declines has decreased when compared to historical trends through increased use of available surface-water supplies. Water-table decline in the Chicot Aquifer occurred in five isolated areas in western Harris and northeastern Fort Bend counties during this period. Decline in the Evangeline Aquifer also occurred, but at a faster rate than in the shallower Chicot. In northwest Harris County, a 50-foot decline in water level occurred over approximately a third of the area between 1980 and 1990.

Historical declines have also ended around the City of Kingsville in Kleberg County. Water levels have been rising and will most likely continue to do so as the City's dependence on groundwater is curtailed by increased use of surface water from nearby reservoirs owned by the City of Corpus Christi. Reductions in rice-farming operations in Orange County and near Wharton in Wharton County have also caused a slowdown or halt of localized historical water-level declines. In these areas, as well as in Harris County, controlling or reversing water-level declines has served to minimize or eliminate land-surface subsidence and saline-water encroachment as well.

In South Texas the utilization of groundwater has been greatly reduced and/or restricted, due to relatively poor quality. Use for municipal and livestock supplies has declined significantly, while use for irrigation and industrial supplies has almost ceased, especially in Cameron and Willacy counties. Also, along the coast in areas of saline-water intrusion caused by heavy pumpage and the accompanying water-level declines, long-term development of groundwater is impossible without desalination.

Annual availability of groundwater for the Gulf Coast Aquifer is determined with the application of a regional computer flow model developed for the aquifer. The model simulates the aquifer's response to changes in stress, such as recharge and pumpage, and predicts how the aquifer water levels and flows will change under potential future conditions. Model output indicates areas of the aquifer that are unable to or can be expected to experience problems supplying the demands that may be placed upon it.

The criteria for ground-water availability for future development of the Gulf Coast Aquifer considers issues such as future demand, historic and projected water-level declines and associated land-surface subsidence, potential quality deterioration, depletion of aquifer storage, and alternate supplies. These criteria allow for the lowering of water-levels to meet demands, but not total depletion of water-table or artesian storage and not to a level that would result in unacceptable land-surface subsidence during the planning period. For irrigation demands only, water levels are allowed to decline to a maximum of 400 feet below the land surface. Also, the criteria incorporates the management plan developed by the Harris-Galveston Coastal Subsidence District for development of water resources in Harris and Galveston counties.

Model simulations for the Gulf Coast Aquifer are made incorporating ground-water use based on the ratio of groundwater to surface water reportedly used in 1990 and the projected 2040 ratio from the 1990 State Water Plan. This ratio is then interpolated for the intervening years and applied to current projected demands through year 2050. With the exception of an area in the northeast part of the aquifer in southern Jasper and Newton counties, model output indicates that ground-water demands can be met with Gulf Coast Aquifer water through the year 2050 without violating the development criteria established for the aquifer. In the area unable to meet ground-water demands, additional supplies of surface water will be needed to meet this demand in the future.

Resource Management. Important management issues for the Gulf Coast Aquifer include controlling water-level declines and minimizing the related land-surface subsidence, and determination of usable ground-water resources in areas with quality problems. With over 1 million ac-ft of annual pumpage from the aquifer, only the Ogallala Aquifer is more heavily utilized in Texas.

In response to historical water-level declines, the Harris-Galveston Coastal Subsidence District was established in 1975 to regulate ground-water withdrawals in Harris and Galveston counties for the purpose of slowing or preventing subsidence and its associated problems. In 1992, a comprehensive management plan was introduced. In general, the district's management plan calls for the systematic conversion, over time, from ground-water to surface-water supplies to meet demands with no more than 20 percent of total water use from groundwater by the year 2030. The result has been that much of the City of Houston is now using surface water for municipal supply. This has resulted in water-level rises in the Chicot and Evangeline aquifers in parts of southeast Harris County and northern Galveston County. However, data indicate that continued ground-water pumpage for municipal, manufacturing, and irrigation purposes in northwestern Harris County and adjacent areas is going to occur, and this will result in additional water-level declines in the future.

Managing future useable ground-water resources in South Texas should begin with a comprehensive determination of the location and amount that can be developed. Except for relatively small areas, little data is currently available delineating the complicated horizontal and vertical distribution of usable quality water in the aquifer. Therefore, it is difficult to make accurate estimates of the available supplies to meet potential future demands.

Although ground-water conditions were evaluated, South Texas was not designated as critical by the State under the critical area process. Considering this is one of the fastest growing areas in Texas, it would be advisable to re-evaluate water supplies to better determine if future demands are capable of being met. Results of this evaluation can be used to determine if recommending creation of one or more ground-water districts could help to address the management issues related to this region of the Gulf Coast Aquifer.

In addition to the Harris-Galveston Coastal Subsidence District, two ground-water conservation districts are currently operating in the Gulf Coast Aquifer area. They are the Fort Bend

Subsidence District in Fort Bend County and the Live Oak UWCD in Live Oak County. All three districts have filed comprehensive management plans with the TNRCC.

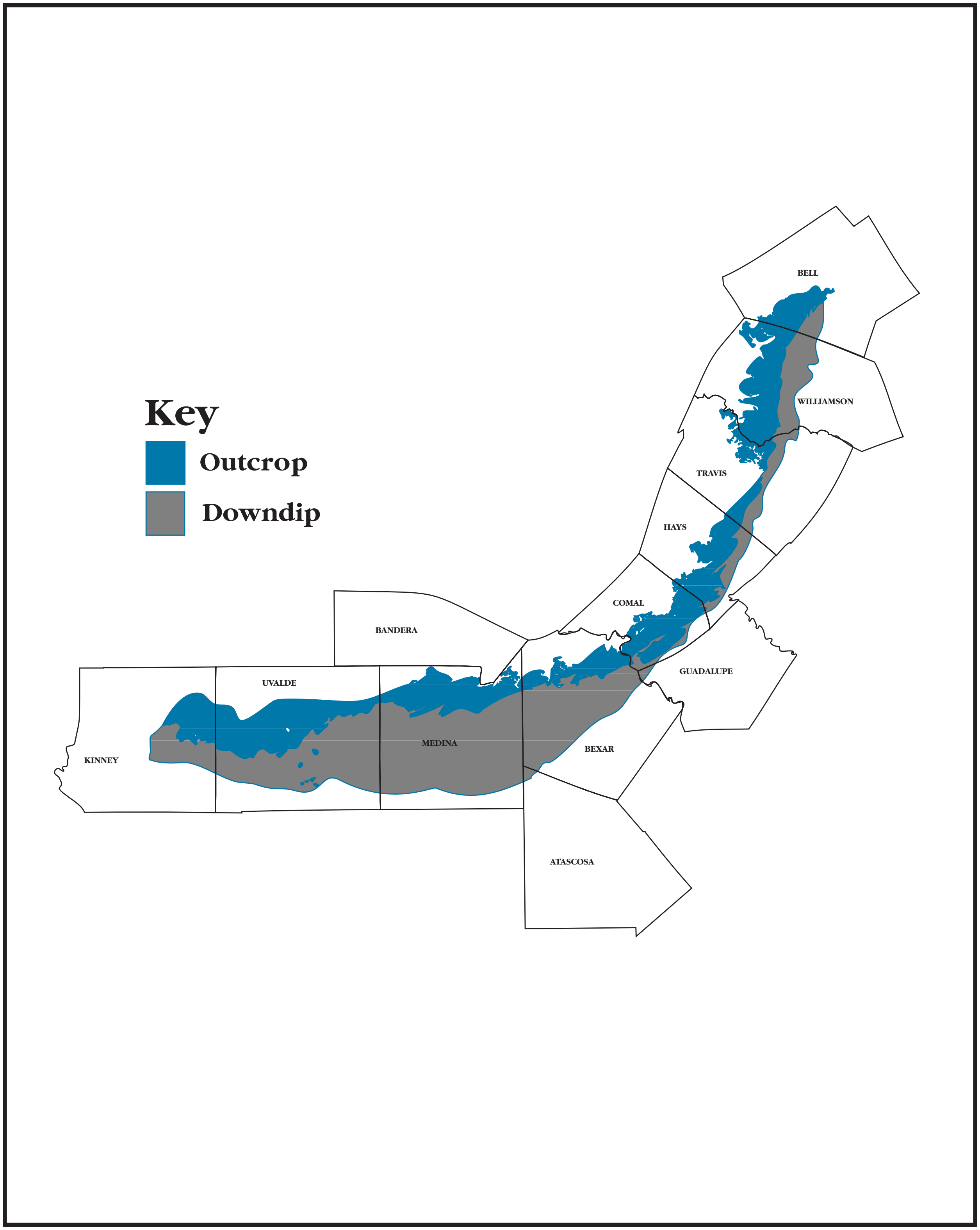

Figure 3-75
Edwards (BFZ) Aquifer

3.4.1.3 Edwards (BFZ) Aquifer

Location and Use. The Edwards (Balcones Fault Zone, or BFZ) Aquifer covers approximately 4,350 square miles in parts of 11 counties (see Figure 3-75). It forms a narrow belt extending from a ground-water divide in Kinney County through the San Antonio area northeastward to the Leon River in Bell County. A poorly defined ground-water divide near Kyle in Hays County hydrologically separates the aquifer into the San Antonio and Austin regions. The Austin region is further divided into the Barton Springs and Northern regions which are also hydrologically separate. The Edwards Aquifer Authority is the water management entity for the southern portion of the aquifer. The Barton Springs/Edwards Aquifer Conservation District is the management authority for the Barton Springs region. Management of the Northern region defaults to the TNRCC in the absence of a ground-water management district. The name Edwards (BFZ) distinguishes this aquifer from the Edwards-Trinity (Plateau) and Edwards-Trinity (High Plains) aquifers.

Principal uses of water from the Edwards (BFZ) Aquifer are for municipal and irrigation purposes. San Antonio, which obtains its entire municipal water supply from the aquifer, is the largest city in the United States and one of the largest in the world that relies solely on a single groundwater source. Of the total 488,691 acre-feet (ac-ft) pumped from the aquifer in 1994, 93 percent was for municipal and irrigation supplies. The Edwards (BFZ) also supplies industrial users in the San Antonio and Austin areas. Large springs feed several well-known recreational areas and serve as habitat to several endangered species of plants and animals. Major river systems also derive a significant amount of baseflow from Edwards (BFZ) spring flows that, in turn, is utilized outside the Edwards Region mainly for industrial and agricultural needs.

Hydrogeology. The aquifer, composed predominantly of limestone formed during the early Cretaceous Period, exists under water-table conditions in the outcrop and under artesian conditions where it is confined below the overlying Del Rio Clay. The Edwards (BFZ) Aquifer consists of the Georgetown Limestone, formations of the Edwards Group (the primary water-bearing unit) and their equivalents, and the Comanche Peak Limestone where it exists. Thickness ranges from 200 to 600 feet.

Recharge to the aquifer occurs primarily by the downward percolation of surface water from streams draining off the Edwards Plateau to the north and west and by direct infiltration of precipitation on the outcrop. This recharge reaches the aquifer through crevices, faults, and sinkholes in the unsaturated zone. Unknown amounts of groundwater enter the aquifer as lateral underflow from the Glen Rose Formation. Water in the aquifer generally moves from the recharge zone toward natural discharge points such as Comal, San Marcos, Barton, and Salado springs. Water is also discharged artificially from hundreds of pumping wells, particularly municipal supply wells in the San Antonio region, and irrigation wells in the western extent.

In the updip portion, groundwater moving through the aquifer system has dissolved large amounts of rock to create highly permeable solution zones and channels which facilitate rapid flow and relatively high storage capacity within the aquifer. Highly fractured strata in fault zones have also been preferentially dissolved to form conduits capable of transmitting large amounts of water. Due to its extensive honeycombed and cavernous character, the aquifer yields moderate to large quantities of water. Several wells yield in excess of 16,000 gal/min, and one well drilled in Bexar County flowed 37,000 gal/min from a 30-inch diameter casing. The aquifer is significantly less permeable farther downdip where the concentration of dissolved solids in the water exceeds 1,000 mg/l.

Water Quality. The chemical quality of water in the aquifer is typically fresh, although hard, with dissolved solids concentrations averaging less than 500 mg/l. The downdip interface between fresh and slightly saline water represents the extent of water containing less than 1,000 mg/l. Within a short distance down gradient of this "bad water line," the groundwater becomes increasingly mineralized.

Availability. Due to its highly permeable nature in the fresh water zone, the Edwards (BFZ) Aquifer responds quickly to changes and extremes in stress placed upon the system. This is indicated by the rapid fluctuations in water levels over relatively short periods of time. During times of adequate rainfall and recharge, the Edwards (BFZ) is able to supply sufficient amounts of water for all demands as well as sustain spring flows at many locations throughout its extent. However, when discharge is low or exceeds recharge, water withdrawn from wells and water discharged at the springs comes mainly from aquifer storage. If these conditions persist, water in storage within the aquifer continues to be depleted with corresponding water-level declines and reduced spring flows.

When an extended drought occurred in Texas during the 1950s, water levels in the Edwards (BFZ) showed large declines and spring flows were greatly reduced. Eventually water levels near Comal Springs fell to a point below the level of the spring outlets causing all flow to cease for several months. During that period severe damage may have occurred to the spring ecosystem, including damage to what are now recognized to be several endangered species of plants and animals. Drought conditions have also occurred in recent years characterized by below average rainfall and recharge. Combined with increased aquifer pumpage, these conditions resulted in significantly lowered water levels and spring flows that were potentially detrimental to the environment, leading to water use restrictions by many entities throughout the Edwards (BFZ) region.

Estimates of annual ground-water availability for the Edwards (BFZ) Aquifer in the Austin region of Texas are based on minimum spring flows and ground-water withdrawals that occurred in the Colorado and Brazos river basins during the long drought of the 1950s. In the Colorado River basin the estimate is based on minimum spring flow at Barton Springs in Travis County which, during the drought, was water supplied by effective recharge to the aquifer and not from water in storage. In the Brazos River basin the availability estimate is based on minimum spring flow at Salado Springs in Bell County and the estimated Edwards (BFZ) withdrawals for 1956 within the basin.

The criteria for ground-water availability for future development of the Edwards (BFZ) in the Austin region involves consideration of issues such as future demand, water-level declines, potential quality deterioration, depletion of aquifer storage, and the availability of alternate surface-water supplies. It allows for some increase in ground-water development to meet a portion of future demands, but utilizes available surface water to meet the majority of demands in order to minimize or eliminate any negative effects on the aquifer system.

In the San Antonio region, annual ground-water availability for the Edwards (BFZ) Aquifer is determined with the application of a regional computer flow model developed for the aquifer. The model is used to evaluate different management scenarios for the region by simulating the aquifer's response to changes in stress, such as recharge and pumpage placed upon the flow system. It simulates how the aquifer water levels, regional flow patterns, and spring flows will change under potential future conditions. Model output can roughly indicate areas of the aquifer that are unable to supply or can be expected to experience problems supplying the demands that may be placed upon it.

Establishing the criteria for ground-water availability for future development involves consideration of issues including future demand, historic and projected water-level declines, potential quality deterioration, depletion of aquifer storage, and spring flow requirements. A plan for future development of the Edwards (BFZ) in the San Antonio region was produced by the Texas Legislature in 1993 and is outlined in Senate Bill 1477. This plan calls for a maximum regional pumpage from the aquifer of 450,000 ac-ft per year through the year 2007, at which time it would be reduced to a maximum annual total of 400,000 ac-ft through the year 2012. From this time on, pumpage levels must be kept at a level to protect endangered species to the extent required by Federal law at Comal Springs in Comal County and San Marcos Springs in Hays County. To determine this level, application of the computer flow model for the Edwards (BFZ) was made assuming protection of the springs as established by Federal mandate in the bill. Model results currently indicate that a regional level of pumpage of 225,000 ac-ft per year is required to protect endangered species under historic recharge conditions, including a recurrence of the drought of record. Final pumping limits after the year 2012 have not been finalized and are subject to revision as better information becomes available or conditions change.

Resource Management. Important management issues for the Edwards (BFZ) Aquifer include establishing a level of ground-water withdrawals to ensure adequate water levels and at least minimum spring flows, developing a plan for the acceptable and equitable distribution of pumping among the numerous users involved, and securing additional supplies to meet projected demands in excess of allowable pumping limits.

As the primary source of water to approximately 1.5 million people in the San Antonio region alone, the aquifer supplies high quality water to urban, agricultural, industrial, and recreational users. Increasing ground-water demands in the entire Edwards (BFZ) region combined with recent drought conditions and the sensitive hydrologic and environmental nature of the aquifer have created a need for regional management of the resource.

In the Austin region the Barton Springs/Edwards Aquifer Conservation District was formed in 1987 by the Texas Legislature to address management issues for the aquifer. The district includes portions of Travis, Hays, Bastrop, and Caldwell counties covering an area between the City of Kyle in Hays County and the Colorado River in central Travis County. A comprehensive management plan has been developed by the district and is filed with the TNRCC. It outlines programs and activities covering areas such as water-level and water-quality monitoring, well construction and spacing standards, production regulations for permitted wells, and public education in conservation and protection of groundwater.

Management of the Edwards (BFZ) in the San Antonio region has long been a controversial and diverse issue. In 1959, after the severe drought from 1950-1957 that lowered water levels in the aquifer to record lows and caused Comal Springs in Comal County to go dry for several months, the Texas Legislature created the Edwards Underground Water District. The district included Bexar, Comal, Hays, Medina, and Uvalde counties and was charged with conserving, protecting, and recharging the underground water-bearing formations within the district, and preventing waste and pollution of such underground water. In 1989, Medina and Uvalde counties withdrew from the district and eventually formed two separate county-wide districts. For years various plans to manage ground-water withdrawals from the aquifer have been unsuccessful as bitter conflicts have erupted between the many diverse users and also between those living in the San Antonio region and those living downstream from the major spring outlets. Then, in 1993, while under threat of federal intervention for alleged failure to protect federally protected species that rely on spring flows from the Edwards (BFZ), the Texas Legislature enacted a management plan for the aquifer.

The plan, outlined in Senate Bill 1477, abolished the Edwards Underground Water District while creating a new entity, the Edwards Aquifer Authority. It calls for the Authority to implement a comprehensive management plan for the aquifer that regulates pumpage (see availability section) while taking into consideration the interests and needs of all the individuals and entities that rely on the aquifer as a water source and maintains the delicate relationship between spring flows and the environment. The boundary of the Authority contains all of Uvalde, Medina, and Bexar counties and parts of Atascosa, Caldwell, Comal, Guadalupe, and Hays counties. The Authority is to be governed by a board consisting of fifteen elected directors and two appointed non-voting members. Under the provisions of SB 1477, the Authority is given power to manage, protect, conserve, and prevent waste or pollution of the aquifer, and to hold and retire water rights. Through a permitting system, the Authority regulates the withdrawal of groundwater from the aquifer. All withdrawals of water must be authorized by the Authority unless the user is exempt (domestic and livestock use of 25,000 gal/day or less). In connection with permits, users may be required to submit conservation and reuse plans.

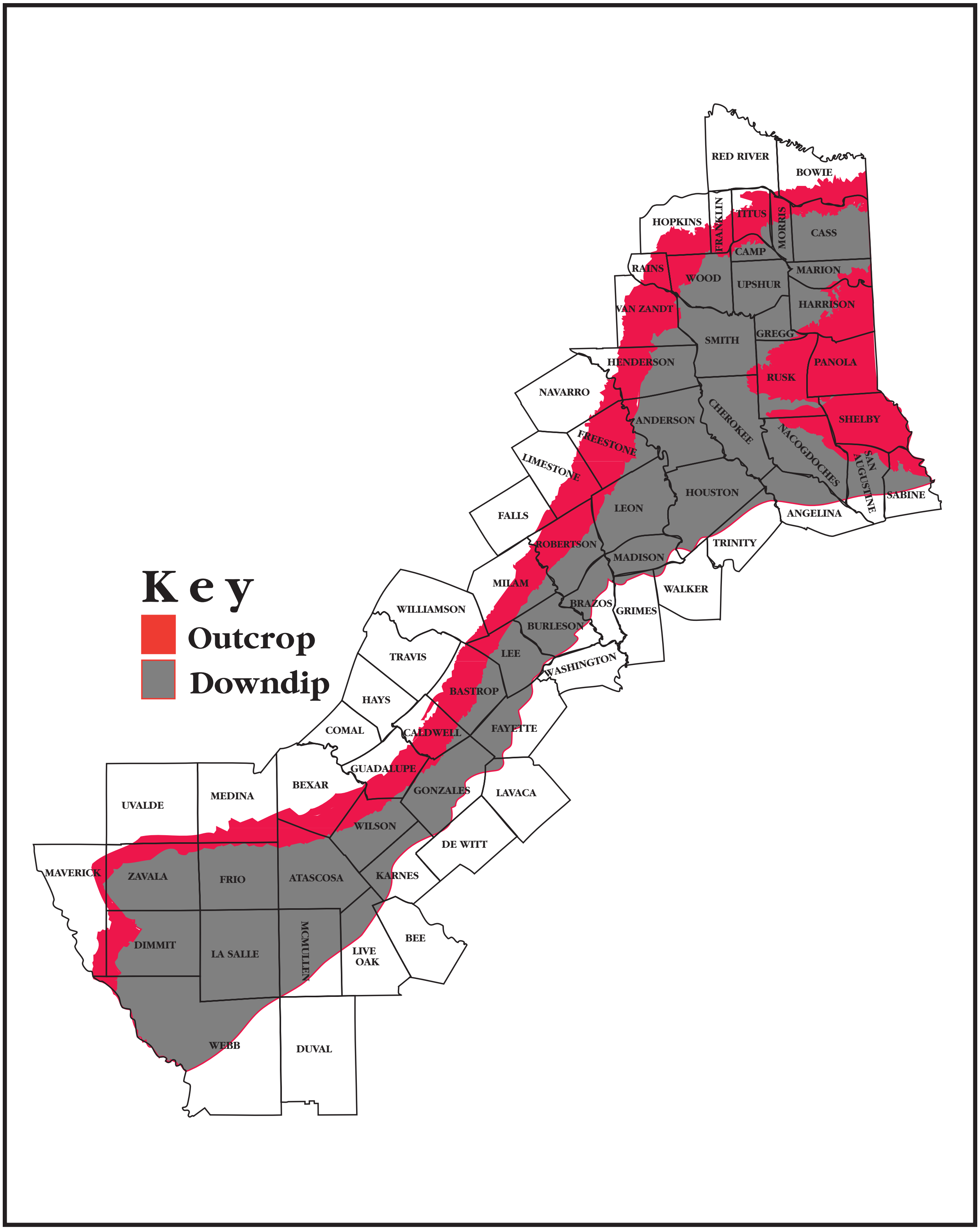

Figure 3-76
Carrizo-Willcox Aquifer

3.4.1.4 Carrizo-Wilcox Aquifer

Location and Use. The Wilcox Group and the overlying Carrizo Formation of the Claiborne Group form a hydrologically connected system known as the Carrizo-Wilcox Aquifer. This aquifer extends from the Rio Grande in south Texas northeastward into Arkansas and Louisiana, providing water to all or parts of 60 counties in Texas (see Figure 3-76). The Carrizo Sand and Wilcox Group occur at the surface along a narrow band that parallels the Gulf Coast and dip beneath the land surface toward the coast, except in the East Texas structural basin adjacent to the Sabine Uplift where the formations form a trough.

Total ground-water pumpage from the Carrizo-Wilcox in 1994 was 488,802 acre-feet (ac-ft). Municipal pumpage accounted for 31 percent of the total and irrigation accounted for 51 percent. The largest metropolitan areas dependent on groundwater from the Carrizo-Wilcox are located in central and northeast Texas and include Bryan-College Station in Brazos County, Lufkin and Nacogdoches in Angelina and Nacogdoches counties, and the City of Tyler in Smith County. Irrigation is the predominant use in the Winter Garden region of South Texas.

Hydrogeology. The Carrizo-Wilcox Aquifer is predominantly composed of sand, locally interbedded with gravel, silt, clay, and lignite deposited during the Tertiary Period. South of the Trinity River and north of the Colorado River, the Wilcox Group is divided into three distinct formations. From oldest to youngest these are the Hooper, Simsboro, and Calvert Bluff. Of the three, the Simsboro typically contains the most massive and coarsest sands. Division into three formations cannot be made outside this area due to the absence of the Simsboro as a distinct unit. Aquifer thickness in the downdip artesian portion ranges from 200 feet in Dimmit County to more than 3,000 feet in Atascosa County.

Where it is found at the surface, the aquifer exists under water-table conditions and in the subsurface it is under artesian conditions. Yields of wells are commonly 500 gal/min and some may reach 3,000 gal/min downdip where the aquifer is under artesian conditions. Some of the greatest yields are produced from the Carrizo Sand in the southern, or Winter Garden, area of the aquifer. Yields of greater than 500 gal/min are also obtained from the Carrizo and the Simsboro formations in the central region.

Water Quality. Regionally, water from the Carrizo-Wilcox is fresh to slightly saline with quality problems limited to localized areas. In the outcrop, the water is hard yet usually low in dissolved solids. Downdip, the water is softer, has a higher temperature, and contains more dissolved solids. Hydrogen sulfide and methane may occur locally. Excessively corrosive water with a high iron content occurs naturally throughout much of the northeastern part of the aquifer. In this area, some instances of relatively high concentrations of dissolved solids, sulfate, and chloride have also been reported. Some of these sites are in or near areas where lignite is known to occur and may be due to 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.

Localized contamination of the aquifer in the Winter Garden region is associated with extensively faulted areas and heavy irrigation pumping that has facilitated downward leakage of saline water from the overlying Bigford Formation. Some recently sampled wells in Dimmit and Zavala counties were found to contain high concentrations of dissolved solids, chloride, and/or sulfate. Downward leakage of more highly-mineralized water from overlying strata through the uncemented annular space between the well casings and the boreholes of such wells is considered to be the most likely cause.

Availability. Significant historic water-level declines have developed in the semi-arid Winter Garden portion of the southern Carrizo Aquifer, as the region is heavily dependent on groundwater for irrigation purposes. Even though these declines have not exceeded the development criteria (discussed further below), since 1920 they have reached 100 feet in much of the area and over 250 feet in the Crystal City area of Zavala County. From 1980 to 1990, water-level declines in the artesian portion of the aquifer in excess of 50 feet affected parts of Frio and Atascosa counties. Localized water-quality deterioration, as discussed in the previous section, has also been associated with water-level declines in this area.

Extremely large water-level declines have occurred in northeast Texas around Tyler and the Lufkin-Nacogdoches area. In many wells, declines in the artesian portion of the Carrizo-Wilcox in this area have exceeded 400 feet. In a few wells, declines have been as much as 500 feet since the 1940s. Much of this pumpage has been for municipal supply, but industrial pumpage is also significant, especially for the paper mills northeast of Lufkin. Fortunately, in this area the aquifer occurs at a depth in excess of 750 feet, which leaves a large amount of artesian storage available for additional development.

In the northeast part of the aquifer, the outcrop area has been dewatered in the vicinity of lignite surface mining operations. Water-table declines in excess of 20 feet covered parts of Van Zandt, Henderson, and Freestone counties in the Wilcox outcrop belt during the 1980 - 1990 period. A fourth area of water-level decline has affected parts of Robertson and Milam counties in the Simsboro Sand Member of the Wilcox.

Annual ground-water availability for the Carrizo-Wilcox in Texas is determined with the application of regional computer flow models developed for the aquifer. These models simulate the aquifer's response to changes in stress, such as recharge and pumpage placed upon the flow system, and predict how the aquifer water levels and flows will change under potential future conditions. Model output indicates areas of the aquifer that are unable to or can be expected to experience problems supplying the demands that may be placed upon it.

The criteria for ground-water availability for future development of the Carrizo-Wilcox varies for different geographic regions of the aquifer. Establishing this criteria involves consideration of issues such as future demand, historic and projected water-level declines, pumping lift costs, potential quality deterioration, and depletion of aquifer storage. In the Winter Garden area, these criteria allow for the lowering of water levels to a maximum of 400 feet below the land surface or to the top of the aquifer depending upon which level is reached first during the planning period. In central and northeast Texas, where pumping levels are already more than 400 feet below the land surface in some areas, development criteria allow additional water-level declines, but not total depletion of aquifer water-table or artesian storage during the planning period.

With the development criteria in place, model simulations for the Carrizo-Wilcox Aquifer were made assuming all future demands would be met with ground-water supplies. This places the maximum amount of stress on the system and represents a "worst case scenario". Model output indicates that these demands can be met with Carrizo-Wilcox water through the year 2050 without violating the development criteria established for the aquifer. Additionally, in northeast Texas, surface-water supplies are also currently available to meet demands. Therefore, in this area future dependence on groundwater will be less than assumed in the model simulations and negative effects on the system due to heavy long-term pumpage will be diminished.

Resource Management. From a management standpoint, the most pressing ground-water issue associated with the Carrizo-Wilcox Aquifer in Texas is water-level declines in areas of concentrated municipal, industrial, and agricultural pumpage. In some areas, pumping levels have fallen as much as 500 feet due to heavy pumpage from numerous wells located within relatively small areas.

Large water-level declines are being addressed in East Texas through reduced ground-water pumpage and conjunctive use of surface-water supplies. In some of the most significant areas, recent reductions of ground-water pumpage have resulted in slowing of annual water-level decline rates and in some cases even water-level rises. Such pumpage 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 reduction of ground-water pumpage by the paper industry northeast of Lufkin in the late 1970s and again in 1988. The City of Tyler has been practicing conjunctive use of surface and ground water for many years and has reduced groundwater to less than 20 percent of its total use.

In addition to numerous cities with plans to manage water needs for future growth and development, there are currently four underground water conservation districts in the Carrizo-Wilcox Aquifer area. These districts include the Evergreen UWCD covering Atascosa, Frio, and Wilson counties; Plum Creek Conservation District in Caldwell County; Gonzales UWCD in Gonzales County; and Anderson UWCD covering a small area near Palestine in Anderson County. At this time, only the Evergreen UWCD has filed a comprehensive management plan with the TNRCC. It outlines specific goals and activities of the district in areas such as water-level and water-quality monitoring, public education in conservation and protection of ground-water, well construction standards, well spacing requirements, and production limits.

In the agricultural areas of South Texas, conjunctive use of surface and groundwater is possible only on a limited, localized basis. Therefore, in this area, any future development from the Carrizo-Wilcox where significant water-level declines have occurred should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage.

Although this area has not been designated as critical by the state under the critical area process, formation of one or more ground-water districts could help to address the management issues related to the Carrizo-Wilcox Aquifer. In the absence of such an entity, implementation of management policy and methods will fall to individual land owners.

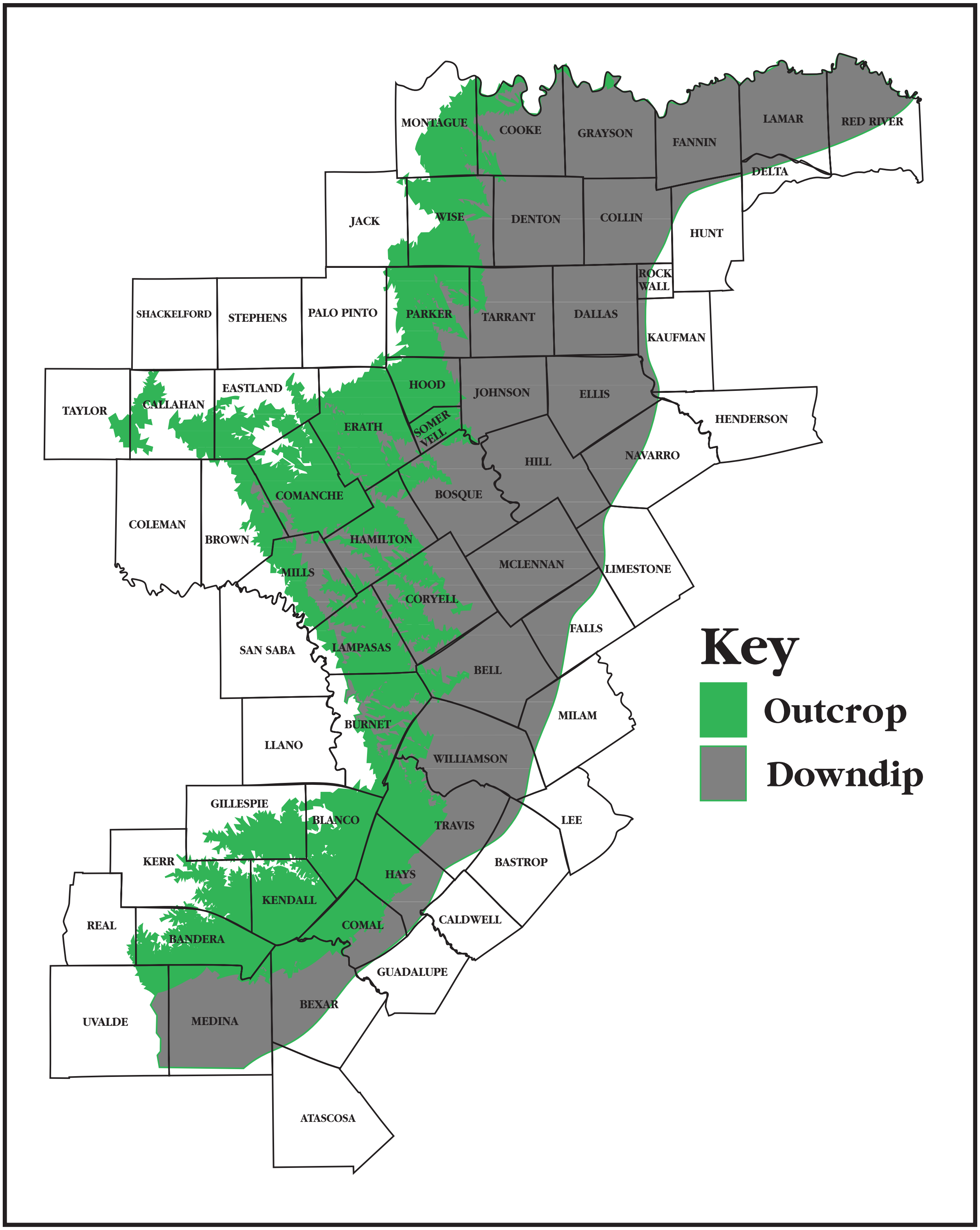

Figure 3-77
Trinity Aquifer

3.4.1.5 Trinity Aquifer

Location and Use. The Trinity Aquifer consists of early Cretaceous age rocks of the Trinity Group formations which occur in a band from the Red River in North Texas to the Hill Country of south-central Texas and provides water in all or parts of 55 counties (see Figure 3-77). Trinity Group deposits also occur as far west as the Panhandle and Trans-Pecos regions where they are included as part of the Edwards-Trinity (High Plains) and Edwards-Trinity (Plateau) aquifers.

Water from the Antlers portion of the Trinity Aquifer is mainly used for irrigation in the outcrop area of North and Central Texas, although Sherman and Gainesville are two large public supply users. Elsewhere, water from the Trinity is used extensively for municipal supply and other uses. Total water pumped from the Trinity in 1994 was 192,961 acre-feet (ac-ft). Of this total, 55 percent was used for municipal purposes and 29 percent was used for irrigation.

Hydrogeology. The Trinity Aquifer is composed of sand, clay, and limestone deposited during the Cretaceous Period. Formations comprising the aquifer include, in ascending order, the Twin Mountains-Travis Peak, Glen Rose, and Paluxy. In the northern part of the extent where the Glen Rose thins or is missing, the Paluxy and Twin Mountains coalesce to form the Antlers Formation. The Antlers consists of up to 900 feet of sand and gravel; the Paluxy of up to 400 feet of sand interbedded with clay and shale; and the Glen Rose of up to 1,500 feet of limestone with interbedded shale, marl, and occasional anhydrite. Usable quality water (containing less than 3,000 mg/l dissolved solids) occurs to depths of up to about 3,500 feet. Wells completed in the Paluxy and Glen Rose aquifers yield small to moderate amounts of water; while those completed in the Antlers and Twin Mountains yield larger quantities.

In the southern extent, the Trinity includes the Glen Rose and underlying Travis Peak Formation. The Travis Peak contains sands, clays, and limestones, and is subdivided into water-bearing members of the Hensell, Cow Creek, and Hosston. Trinity well yields are rarely more than 100 gal/min in the southern Hill Country area.

Water Quality. Water quality from the Trinity Aquifer is acceptable for most municipal and industrial purposes, however, excess concentrations of certain constituents in many places exceed drinking-water standards for municipal supplies. Although the Twin Mountains is the most prolific of the Trinity Aquifers in North-Central Texas, the quality of the water is generally not as good as that from the Paluxy or Antlers formations. Heavy pumpage and water-level declines in this region have contributed to deteriorating water quality in the aquifer. Dissolved solids in water pumped from municipal wells in the community of Blum increased from approximately 900 mg/l in 1980 to 1500 mg/l in 1986 as a result of water-level declines. This change is indicative of inter-formational leakage from the more highly mineralized overlying Glen Rose Formation. The potential for updip movement of poor quality water also exists where large and ongoing water-level declines have reversed the natural water-level gradient and have allowed water of elevated salinity to migrate back updip toward pumpage centers. In some instances, excess levels of constituents are naturally occurring. For example, several wells completed in the Hensell Member of the Travis Peak Formation exhibit higher levels of sodium, sulfate, and chloride which are believed to be the result of leakage from the overlying Glen Rose. This is less likely to happen in the Hosston Member where the overlying Hammett Shale acts as an aquitard to prevent leakage from occurring. In the southern Hill Country region, the primary contribution to poor quality occurs in wells that have not adequately cased off water in evaporite beds in the upper part of the Glen Rose. Water quality naturally deteriorates in the downdip direction of all the Trinity water-bearing units.

Availability. Estimated future ground-water availability from the Trinity Aquifer is calculated as a combination of annual depletion from storage in the northern region and effective recharge throughout the entire extent. Total ground-water storage in the Trinity Aquifer is 750,450 ac-ft. Recharge to the Trinity occurs primarily from precipitation on the outcrop. Lesser amounts of water may enter from surface streams and lakes on the outcrop and possibly through inter-formational leakage. The annual effective recharge to the aquifer is 95,100 ac-ft or approximately 1.5 percent of the average annual precipitation.

Extensive development of the Paluxy Aquifer has occurred in the Tarrant and Dallas counties region where water levels have historically dropped as much as 350 feet. Water levels in the Twin Mountains Aquifer have historically declined by as much as 550 feet in the Dallas-Fort Worth area, however, these declines are currently more concentrated in Denton and Johnson counties. The Travis Peak is extensively developed from the Hensell and Hosston in the Waco area where historically the water level has declined as much as 400 feet. In the southern Hill Country, Trinity water levels fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions.

Water-level declines during the 1985 -1995 period continued to decrease as public supply wells were abandoned in favor of surface-water supplies. Some isolated areas of Central and North Texas continued to experience declines in excess of 50 feet in the artesian portion of the Trinity. Declines of at least 100 feet affected the following areas:

In the Twin Mountains Aquifer, declines occurred in the southwest corner of Dallas County and east of Alvarado and Grandview in Johnson County. In the central region, a small area of declines centered around Itasca in Hill County was the extension of the Johnson County area of decline. Another small area of declines included the communities of Aquilla (Hill County) and Laguna Park (Bosque County). A third area occurred in northwest Limestone County and east-central McLennan County. Two other very small areas of decline occurred at Round Rock in central Williamson County and near Pflugerville in north-central Travis County.

Water-table declines affected much smaller areas in the outcrop portion of the Trinity between 1985 and 1995. Declines continued in Somervell, Hood, and Bosque counties where groundwater is mainly pumped for irrigation, and in western Williamson and Travis counties and in eastern Kerr and Bandera and southern Kendall counties where water use is for domestic and livestock purposes. Several water-level declines occurred in this region during the 1996 drought. The Hill Country area from Austin to San Antonio is experiencing some of the most rapid growth of population in the state, and groundwater from the Trinity Aquifer, which is very limited in this area, is almost the only viable supply.

Resource Management. The most important Trinity Aquifer management issues to be addressed in north-central Texas are the water level declines in the Dallas-Fort Worth and Waco areas and around the smaller municipal use centers in between. Significant declines continue despite a considerable shift of use from groundwater to surface sources for municipal and industrial demands. Increased emphasis on conservation programs would benefit this area.

In the Hill Country of Central Texas, limited ground-water availability in areas of continuing rapid population growth is an increasing problem since there are few, if any, surface water supplies available. As a result of this area's difficulty in meeting future water demands, the TNRCC declared all or parts of eight counties in the Hill Country critical, but has yet to initiate creation of underground water conservation districts. In response to the critical area concerns, three districts have been formed: Hill Country UWCD in Gillespie County, Headwaters UWCD in Kerr County, and Springhills Water Management District in Bandera County. All three districts have submitted comprehensive management plans with TNRCC, however, only the Hill Country District has well spacing and production regulations.

Because of the critical nature of the ground-water resource in the Hill Country area, management considerations should include several important components. Where appropriate, surface water supplies should be extended to populated areas that have already exceeded available ground-water supplies. New subdivisions should be designed with adequate water-supply sources as a primary consideration and small lots with individual wells should be discouraged. Rainwater harvesting and water conservation practices such as landscape Xeriscaping should be promoted. Drought contingency and water-supply drought monitoring plans should be established. Additional underground water conservation districts should be established where appropriate, and district management plans should be developed that reflect a coordinated regional effort between districts, county commissioners courts, and municipalities.

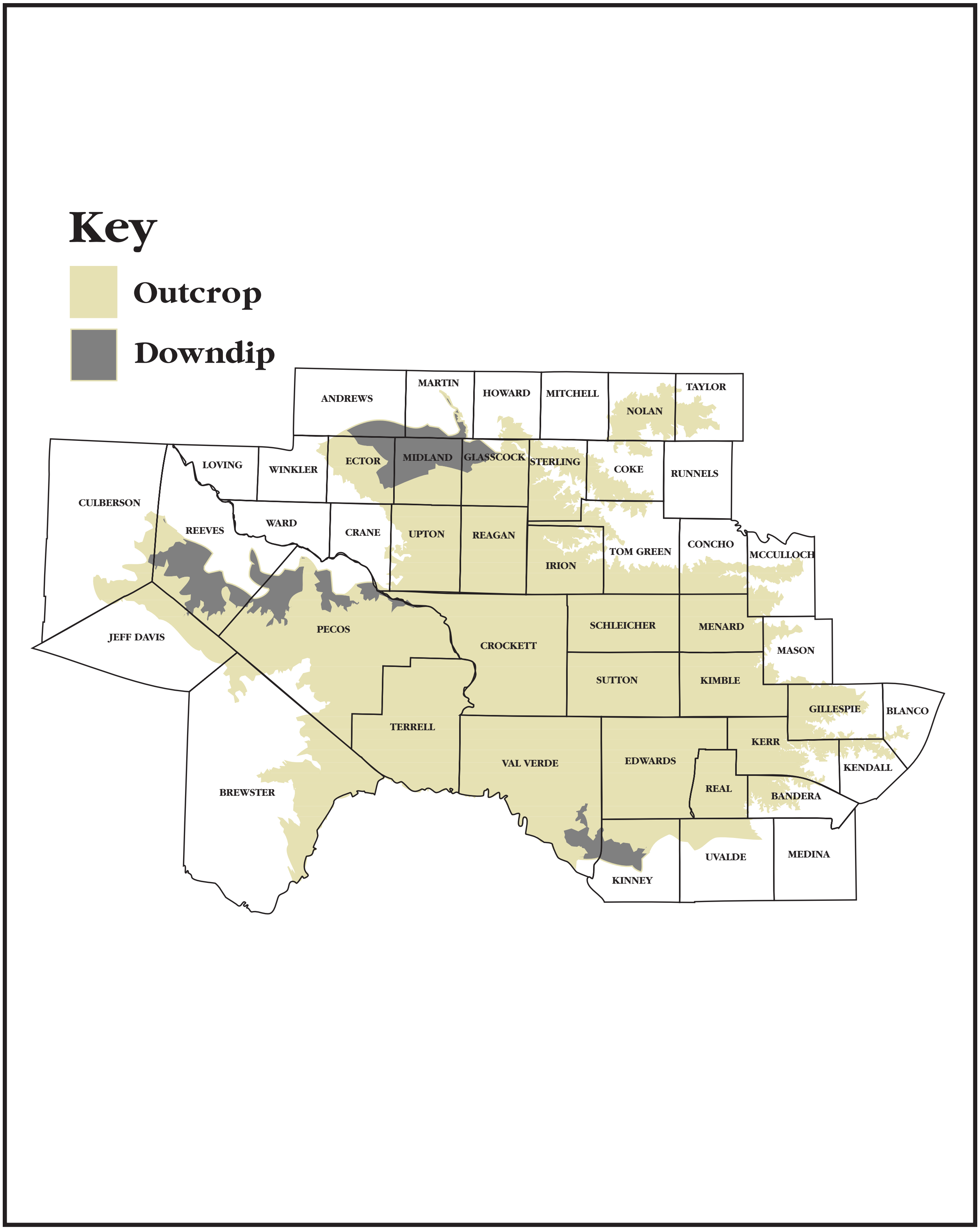

Figure 3-78
Edwards-Trinity (Plateau) Aquifer

3.4.1.6 Edwards-Trinity (Plateau) Aquifer

Location and Use. The Edwards-Trinity (Plateau) Aquifer underlies the Edwards Plateau east of the Pecos River and the Stockton Plateau west of the Pecos River, providing water to all or parts of 38 counties (see Figure 3-78). The aquifer extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas. Total pumpage from the aquifer was 214,900 acre-feet (ac-ft) in 1994, with irrigation pumpage accounting for 79 percent of the total.

Hydrogeology. The aquifer consists of saturated sediments of lower Cretaceous age Trinity Group formations and overlying limestones and dolomites of the Comanche Peak, Edwards, and the Georgetown formations. The Glen Rose Limestone is the primary unit in the Trinity in the southern part of the plateau and is replaced by the Antlers Sand north of the Glen Rose pinch-out. In the northwestern region, the aquifer may be hydrologically connected to other aquifers such as the Ogallala, Dockum, Rustler, and Cenozoic Pecos Alluvium. Springs issuing from the aquifer form the headwaters for several eastward and southerly flowing rivers.

The aquifer generally exists under water table conditions, however, where the Trinity is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards, artesian conditions may exist. Reported well yields commonly range from less than 50 gal/min where saturated thickness is thin to more than 1,000 gal/min where large-capacity wells are completed in jointed and cavernous limestone.

Water Quality. Natural chemical quality of Edwards-Trinity (Plateau) water ranges from fresh to slightly saline. The water is typically hard and may vary widely in concentrations of dissolved solids made up mostly of calcium and bicarbonate. The salinity of the groundwater tends to increase toward the west. Water-quality deterioration in the northern part of the aquifer resulted from the disposal of oil-field brines into unlined pits prior to the Railroad Commission's "no pit" order in 1969. Groundwater in these areas contain high levels of chloride. Water quality of springs issuing from the aquifer in the south and eastern border areas is typically excellent.

Availability. The total quantity of water in storage in the aquifer is about 145 million ac-ft, however, this amount is not considered developable in part because extensive withdrawals from storage would deplete available surface-water supplies and adversely affect natural recharge to the Edwards (BFZ) Aquifer. The quantity of groundwater that is considered available is expressed in terms of annual effective recharge and equates to 776,000 ac-ft.

There is little pumpage from the aquifer over most of its extent, and water levels have generally remained constant or have fluctuated only with seasonal precipitation. In some instances water levels have declined as a result of increased pumpage. Although historical declines have occurred in the northwestern part of the aquifer in Reagan, Upton, Midland, and Glasscock counties as a result of irrigation, none of the areas supplied by groundwater from the Edwards-Trinity (Plateau) Aquifer have experienced declines greater than 20 feet since 1980.

Resource Management. Due to the sparse population and limited pumpage, there has been little effect on water levels and water quality over a majority of the Plateau region. However, in the northwest segment, the aquifer has been altered by irrigation and previous oil-field activities. Because of these problems, an area including parts of Midland, Reagan, and Upton counties was declared critical in 1990 by the TNRCC. Underground water conservation district creation under this process has not been initiated. The Glasscock County UWCD was previously formed to address similar problems and has since incorporated some irrigated farm land in northern Reagan County. The Santa Rita UWCD has more recently been formed by local initiative to address the remaining area of Reagan County.

Other UWCDs in the northern part of the Plateau region include Coke County, Irion County, Sterling County, Sutton County, Emerald (Crockett County), and Plateau (primarily Schleicher County). Most of these districts maintain well spacing rules to control density of pumping wells and have an extensive water quality and water level monitoring network.

Hill Country (Gillespie County), Headwaters (Kerr County), and Springhills (Bandera County) UWCDs are located along the southeast border of the Plateau and incorporate part of the Trinity Aquifer. These three districts are mostly concerned with water quantity and quality problems (primarily related to the Trinity Aquifer) resulting from the rapid population migration from the cities of Austin and San Antonio. The districts, however, do monitor the condition of the Edwards-Trinity (Plateau) Aquifer as it affects spring flow that forms the headwaters of the Guadalupe and Medina rivers and other tributaries. All the districts mentioned above have submitted comprehensive management plans with TNRCC.

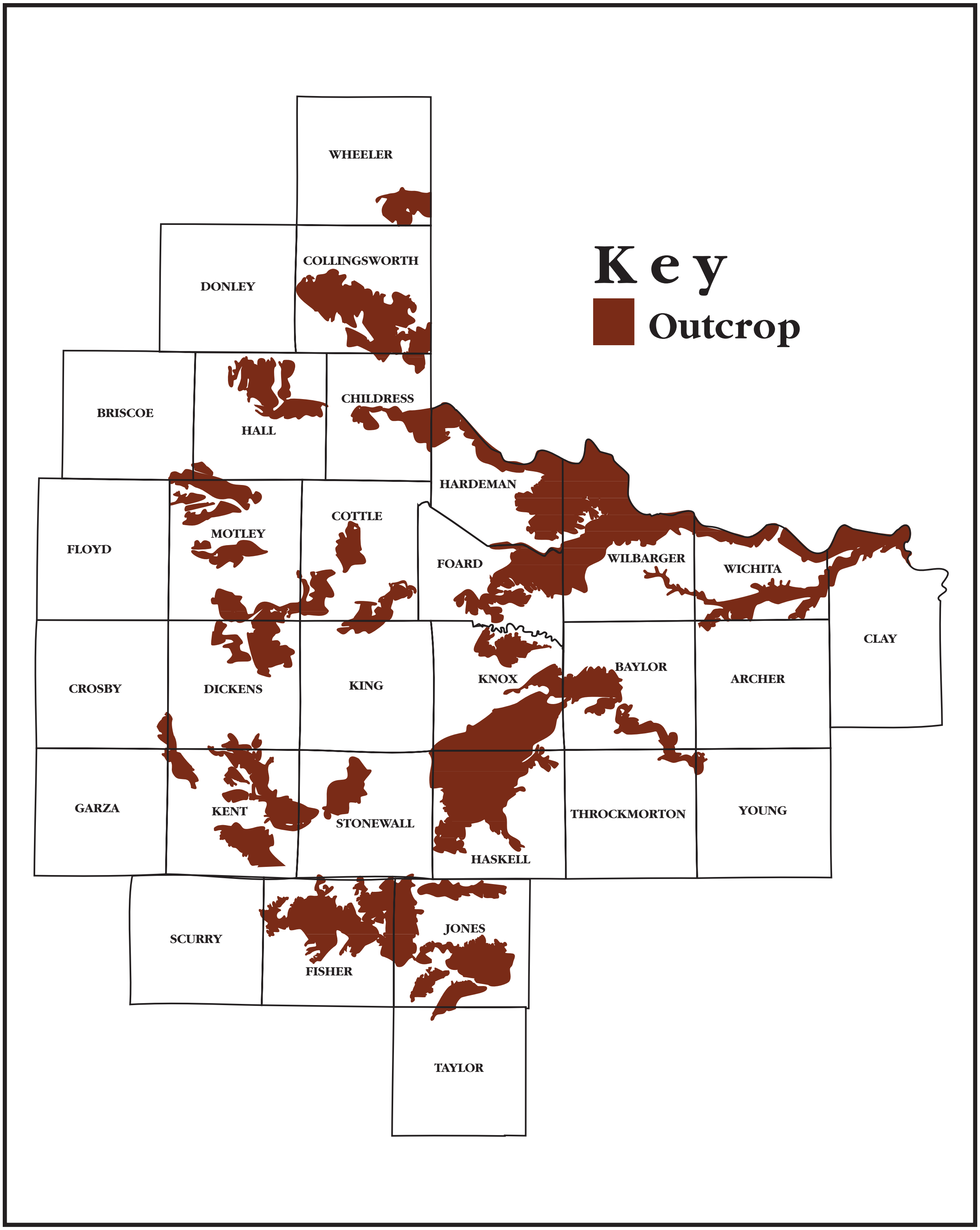

Figure 3-79
Seymour Aquifer

3.4.1.7 Seymour Aquifer

Location and Use. The Seymour Formation consists of isolated areas of alluvium that are erosional remnants of a larger area or areas. The aquifer is found in parts of numerous north-central and Panhandle counties (see Figure 3-79). About 93 percent of the 151,765 acre-feet (ac-ft) of water pumped from this aquifer in 1994 was used for irrigation. Municipal pumpage, primarily for the cities of Vernon, Burkburnett, Electra, and Seymour, accounted for about 5.5 percent.

Hydrogeology. The Seymour consists of discontinuous beds of poorly sorted gravel, conglomerate, sand, and silty clay deposited during the Quaternary Period by eastward-flowing streams. Individual accumulations vary greatly in thickness, although most are less than 100 feet thick. In a few isolated spots in Collingsworth County, formation thickness may exceed 300 feet. These thick accumulations overlie buried stream channels or sinkholes in underlying formations. This aquifer is under water-table conditions in most of its extent, but artesian conditions may occur where the water-bearing zone is overlain by clay. The lower, more permeable part of the aquifer produces the greatest amount of groundwater. Yields of wells range from less than 100 gal/min to as much as 1,300 gal/min depending on saturated thickness. Yields average about 300 gal/min.

Water Quality. Water quality in these alluvial remnants generally ranges from fresh to slightly saline, although a few higher salinity problems may occur. The salinity has increased in many heavily-pumped areas to the point where the water has become unsuitable for domestic uses. Natural salt pollution in the upper reaches of the Red and Brazos River basins precludes the full usage of these water sources without desalination. Brine pollution from earlier oil-field activities has resulted in localized contamination of formerly fresh ground- and surface-water supplies. Nitrate concentrations in excess of drinking-water standards are widespread in Seymour groundwater. Sources of the nitrate are both naturally occurring and through contamination by man's activities.

Availability. Fresh to slightly saline groundwater recoverable from storage from these scattered alluvial aquifers is estimated to be 3.18 million ac-ft based on 75 percent of the total storage. Annual effective recharge to the aquifer is approximately 215,200 ac-ft or 5 percent of the average annual precipitation that falls on the aquifer outcrop. No significant long-term water-level declines have occurred in areas supplied by groundwater from the Seymour Aquifer.

Resource Management. Basic management issues for the Seymour Aquifer are the prevention of overuse and the determination of water quality. Additional future surface water supplies are unlikely in the Seymour area, so it is very important to protect this aquifer, which supplies most of the water for all uses within the area.

Two underground water conservation districts were created within the area of the Seymour Aquifer by the Texas Legislature. The Collingsworth County UWCD has been confirmed. The Haskell/Knox UWCD was not confirmed by local vote. The Collingsworth District submitted a management plan to the TNRCC in 1994.

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Any future high capacity development from the Seymour Aquifer should be based on sound hydrologic and geologic principles. Well and well field sites should be determined based on test holes and should be constructed and completed using accepted standards and spacing requirements to provide the most efficient well possible. Good planning and optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage.

Figure 3-80
Hueco-Mesilla Bolson Aquifers

3.4.1.8 Hueco-Mesilla Bolson Aquifers

Location and Use. The Hueco and Mesilla Bolson aquifers are located in El Paso and Hudspeth counties in the far western tip of Texas (see Figure 3-80). The aquifers are composed of Tertiary and Quaternary basin-fill (bolson) deposits that extend northward into New Mexico and westward into Mexico. The Hueco Bolson, principal aquifer in the El Paso area, is located on the eastern side of the Franklin Mountains; to the west is the Mesilla Bolson. Of the total 97,257 acre-feet (ac-ft) of groundwater pumped from the aquifers in 1994, 89 percent was used for municipal supply, primarily for the City of El Paso. Across the international border, water for Ciudad Juarez is supplied from the Hueco Bolson.

Hydrogeology. The Hueco Bolson, approximately 9,000 feet in total thickness, consists of silt, sand, and gravel in the upper part and clay and silt in the lower part. Only the upper several hundred feet of the Bolson contain fresh to slightly saline water.

The Mesilla Bolson consists of approximately 2,000 feet of clay, silt, sand, and gravel. Three water-bearing zones in the Mesilla (shallow, intermediate, and deep) have been identified based on water levels and quality. The shallow water-bearing zone includes the overlying Rio Grande Alluvium.

Water Quality. The chemical quality of the groundwater in the Hueco Bolson differs according to its location and depth. Dissolved-solids concentrations in the upper, fresher part of the aquifer range from less than 500 to more than 1,500 mg/l and average about 640 mg/l. Quality of Hueco Bolson water in Mexico is slightly poorer.

Chemical quality of groundwater in the Mesilla Bolson ranges from fresh to saline, with salinity generally increasing to the south along the valley. The water is commonly freshest in the deep zone of the aquifer and contains progressively higher concentrations of dissolved solids in the shallower zones. Increasing deterioration of quality of these aquifers is the result of large-scale ground-water withdrawals which are depleting the aquifers of the freshest water.

Availability. Approximately 9 million ac-ft of recoverable fresh water is estimated to be in storage in the Hueco Bolson, the majority of which occurs in the El Paso metropolitan area. Very little usable quality water occurs in the Hueco Bolson in Hudspeth County. Under the Texas part of the lower Mesilla Valley, Mesilla Bolson deposits and the Rio Grande Alluvium together contain approximately 560,000 ac-ft of fresh water in storage.

The average annual effective recharge to the Hueco Bolson is approximately 18,000 ac-ft and to the Mesilla, recharge is approximately 6,000 ac-ft. The amount of fresh groundwater available on an annual basis from the aquifers is equivalent to their annual effective recharge, induced recharge, and depletion of water recoverable from storage. Years in which pumpage exceeds recharge result in water-table declines.

Historical large-scale ground-water withdrawals, especially from municipal well fields in the downtown area of El Paso and Ciudad Juarez, have caused major water-level declines. These declines in turn have significantly changed the direction of flow, rate of flow, and chemical quality of groundwater in the aquifers. Declining water levels have also resulted in a minor amount of land-surface subsidence.

Resource Management. The amount of groundwater needed to supply projected future demands in the El Paso area exceeds the estimated annual effective recharge to the aquifers and, therefore, a large portion will continue to be drawn from storage. Because of historical water-level declines and the potential for depletion of the Hueco Bolson Aquifer, the El Paso area was selected for critical area evaluation. A proposed designation of the El Paso area as critical by the TNRCC was considered in 1990, however, the Commission agreed to take the proposed designation under advisement until the completion of a regional water-supply study by local governments. The study has been completed, however, the Commission has yet to take action on the designation.

The City of El Paso, the principal user of the Hueco Bolson Aquifer, has an aggressive water resource management plan which includes stringent water conservation ordinances, a rate structure designed to encourage conservation, blending of fresh and brackish water, an aquifer recharge project, a desalinization pilot project, expansion of the Mesilla Bolson Aquifer well field, wastewater reuse, acquisition of additional surface water rights, and most important, ongoing studies and negotiations to maximize development of the Rio Grande Project in New Mexico to bring El Paso a year- round supply of surface water in the future. The City has recently instituted a policy of extending water distribution outside the City which will provide for better regional management of the limited resource.

Across the border, Ciudad Juarez is reliant on the Hueco Bolson Aquifer for its municipal supply. Like El Paso, Cd. Juarez is growing rapidly and will soon outgrow its ground-water reserves. The City is investigating ground-water sources west of the Sierra Juarez mountains and the potential for future surface-water supplies. The cities of El Paso and Juarez should continue to share information on the condition of the aquifer for common benefit.

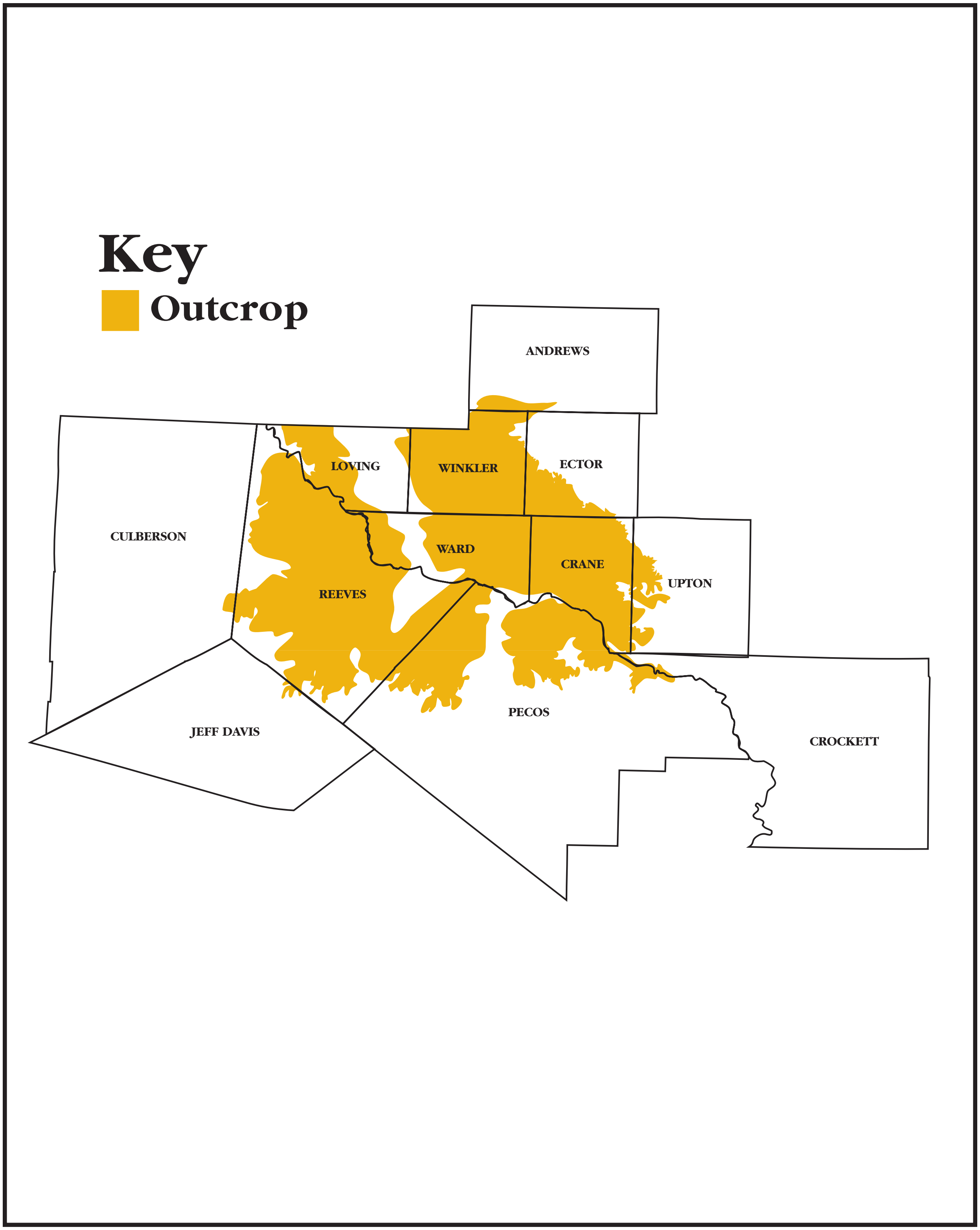

Figure 3-81
Cenozoic Pecos Alluvium Aquifer

3.4.1.9 Cenozoic Pecos Alluvium Aquifer

Location and Use. The Cenozoic Pecos Alluvium Aquifer, located in the upper part of the Pecos River Valley of west Texas, provides water to parts of Crane, Loving, Pecos, Reeves, Ward, and Winkler counties (see Figure 3-81). The aquifer is the principal source of water for irrigation in Reeves and northwestern Pecos counties and for industrial, power generation, and public supply use elsewhere. Water is exported from Ward County to the City of Odessa by the Colorado River Municipal Water District. Of the total 152,290 acre-feet (ac-ft) of groundwater pumped in 1994, 83 percent was used for irrigation.

Rapid development of irrigation farming in Reeves County began in the late 1940s, peaked in 1953 with 525,000 ac-ft of pumpage, and remained at a rate above 300,000 ac-ft annually until the mid 1970s. Since that time, irrigation pumpage has decreased substantially.

Hydrogeology. Consisting of up to 1,500 feet of alluvial fill, the Cenozoic Pecos Alluvium occupies two hydrologically separate basins: the Pecos Trough in the west and the Monument Draw Trough in the east. The aquifer is hydrologically connected in different areas to underlying water-bearing strata, including the Cretaceous in Pecos and Reeves counties and the Triassic in Ward and Winkler counties.

Groundwater in the Cenozoic Pecos Alluvium Aquifer occurs under semi-confined or unconfined (water-table) conditions, although confining clay beds may create localized artesian conditions. Moderate to large yields can generally be expected from wells completed in this aquifer.

Water Quality. The chemical quality of water in the aquifer is highly variable, differing naturally with location and depth, and is generally better in the eastern Monument Draw Trough. Water from the aquifer is generally hard and contains dissolved-solids concentrations ranging from less than 300 to more than 5,000 mg/l. Sulfate and chloride are the two prominent anions. A natural deterioration of quality occurs with increasing depth of the water-bearing strata.

Even though the natural quality of the groundwater in parts of the aquifer has been relatively poor since before its early development by man, certain areas have experienced a definite deterioration in quality as a result of human activity. This quality deterioration is primarily the result of petroleum industry activities in Loving, Ward, and Winkler counties and irrigation practices in Pecos, Reeves, and Ward counties.

Availability. Water-level declines in excess of 200 feet historically have occurred in south-central Reeves and northwest Pecos counties, but have moderated since the mid 1970s with the decrease in irrigation pumpage. Groundwater that once rose to the surface and flowed into the Pecos River now flows in the subsurface toward areas of heavy pumpage. As a consequence, baseflow to the Pecos River has declined. Elsewhere, only moderate water-level declines have occurred as a result of less intense pumpage for industrial and public supply use in Ward and Winkler counties.

In areas that are suitable for ground-water withdrawal, more than 30 million ac-ft of fresh to slightly saline groundwater is estimated to be in storage in the Cenozoic Pecos Alluvium Aquifer. Of this amount, only about 9.48 million ac-ft can be withdrawn by wells without significant ground-water quality degradation. Average annual effective recharge to the Cenozoic Pecos Alluvium Aquifer, calculated to be 70,800 ac-ft, is derived principally from precipitation and irrigation return flow.

Resource Management. Due to historical water-level declines and documented cases of water- quality degradation, the Cenozoic Pecos Alluvium area was evaluated for critical area designation. In 1990, the TNRCC ruled against critical designation for the region, but expressed the need for continued monitoring. Local attempts to create an underground water conservation district in Winkler County have failed.

The current level of irrigation occurring in Reeves and northwest Pecos counties is not excessively overdrafting the aquifer and, therefore, additional management is not necessary. However, if irrigation development should increase to the level experienced in the 1950s and 60s, then management techniques similar those used by underground water conservation districts on the High Plains would be of benefit. Current well spacing, pumpage limitations, and land use management imposed on municipal well fields in Ward County have allowed these areas to withdraw water without creating significant water-level declines or quality deterioration. Additional water-resource management is not currently necessary for this area. Oil field operations, that in the past led to ground-water contamination problems, are still active in Loving and Winkler counties. These operations should be monitored closely, especially where they occur in the vicinity of municipal well fields.

Figure 3-82
Bone Spring-Victorio Peak Aquifer

3.4.2 Minor Aquifers

3.4.2.1 Bone Spring-Victorio Peak Aquifer

Location and Use. The Bone Spring-Victorio Peak Aquifer underlies a small area in the northeastern corner of Hudspeth County known as Dell Valley (see Figure 3-82). The valley lies between the Guadalupe Mountains on the east and the Diablo Plateau on the west. The aquifer extends northward into the Crow Flats area of New Mexico and is primarily used for irrigation. In 1994, the 172,979 acre-feet (ac-ft) of groundwater pumped for irrigation was significantly more than in previous years. The remaining 41 ac-ft of pumpage from the aquifer was for public water supply use by Dell City.

Hydrogeology. The Bone Spring-Victorio Peak Aquifer is contained in limestone beds of early Permian age. Groundwater in the aquifer occurs under water-table conditions in joints, fractures, and cavities in the limestone. Permeability of the limestones is highly variable and well yields differ widely from about 150 gal/min to more than 2,200 gal/min. The thickness of the aquifer may be as much as 2,000 feet.

Water Quality. Groundwater withdrawn from the aquifer commonly contains between 2,000 and 6,000 mg/l dissolved solids. Because the water does not meet drinking water standards, the community of Dell City must use a demineralization process.

The groundwater is acceptable for irrigation use because of the high permeability of the soil. However, the quality of the aquifer water is deteriorating as agricultural chemicals and salts are leached from surface soils by irrigation return flow. No indication of saline water encroachment from the nearby salt flats to the east has been noted.

Availability. The average annual amount of ground-water available, calculated as effective annual recharge and irrigation return flow to the aquifer, is 90,000 ac-ft. Based on a comparison of pumpage and water levels, it is estimated that a yearly pumpage of 90,000 ac-ft would not cause a decline in water levels. Annual measurements from 1983 through 1993 indicate that water levels remained relatively constant suggesting that recharge through irrigation return flow and seasonal precipitation kept pace with the water being withdrawn.

Resource Management. Water from this aquifer is used almost exclusively for irrigation of agricultural crops, therefore, management of the aquifer relates to this principal function. The water level in the aquifer continuously declined from the advent of irrigation pumpage in the 1940s to the early 1980s when the rate of water withdrawal reached its highest level. The following 10 years witnessed a reduction in annual pumpage and a resulting water-level recovery. However, the past few years have seen a resurgence of pumpage and, as expected, water levels have reacted in a downward trend. Water quality has, likewise, deteriorated over time. Water-level declines, although not as threatening to irrigation activities as is quality deterioration, do serve as an indicator of aquifer conditions.

The Hudspeth County UWCD No.1 was created in 1957 and serves only the Dell Valley area of Hudspeth County. District management policy is primarily centered around the establishment of an allowable production rate of 5 ac-ft per acre serviced per year. Rules are also in place concerning aquifer recharge operations. At the present time, a district management plan has not been filed with the TNRCC. Because of the potential for salt water encroachment from the adjacent salt flats to the east, the district should maintain a monitoring network to warn of significant water-level declines and be prepared to limit pumpage in affected areas.

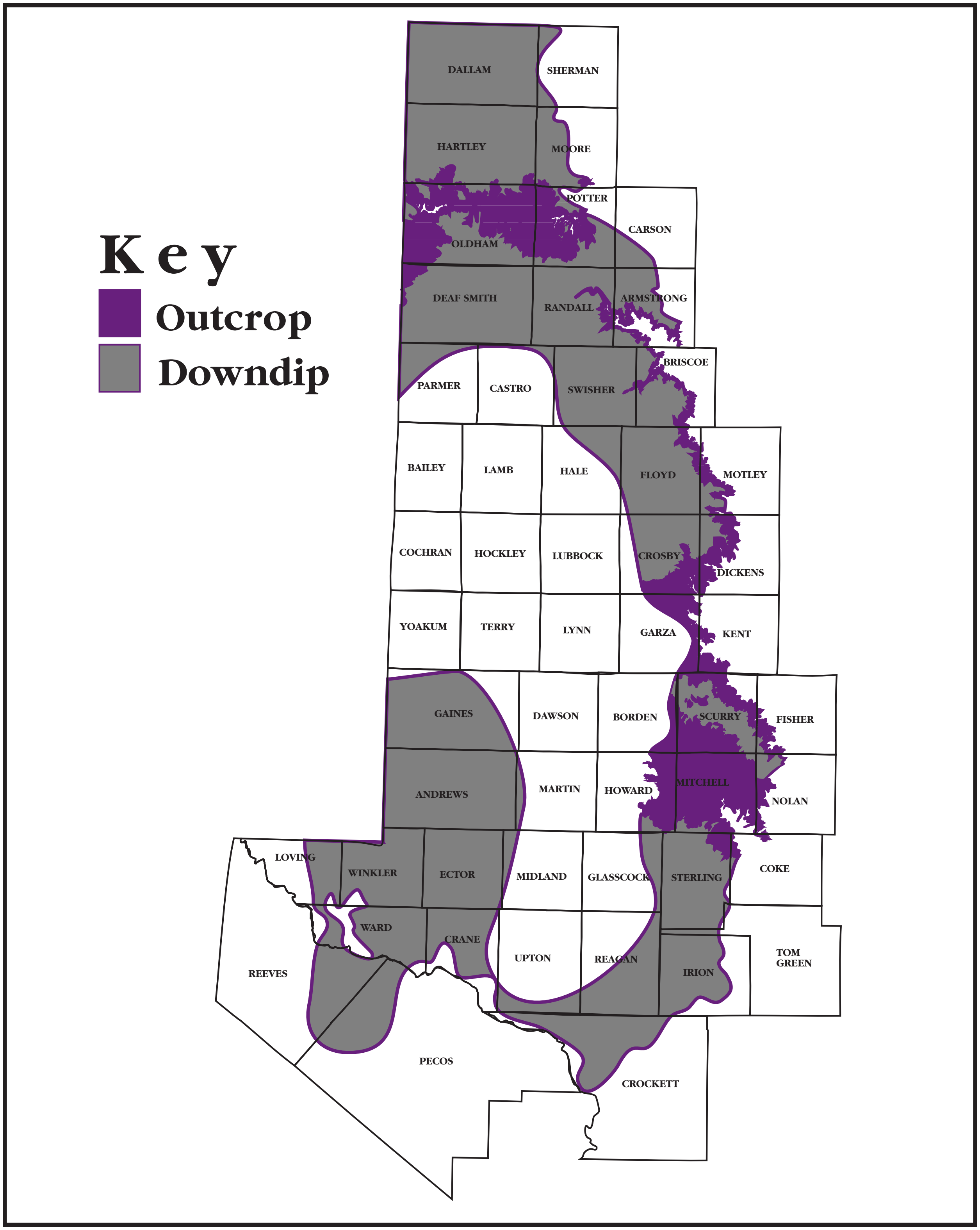

Figure 3-83
Dockum Aquifer

3.4.2.2 Dockum Aquifer

Location and Use. The Dockum Group of Triassic age underlies the Ogallala Aquifer in much of the Texas Panhandle and is exposed along the eastern edge of the caprock escarpment and in the Canadian River basin (see Figure 3-83). It underlies the Cenozoic Pecos Alluvium in the middle Pecos River basin and Cretaceous formations in the northwestern Edwards Plateau region. The aquifer provides water in all or parts of 44 counties.

Dockum groundwater is used for irrigation in the eastern outcrop area, primarily in Mitchell and Scurry counties, and in combination with Ogallala water north of the Canadian River. Municipal-supply use occurs in the northern part of the Southern High Plains, the eastern outcrop area, and in Reeves and Winkler counties. Elsewhere, the aquifer is used extensively for oil field water-flooding operations. Total pumpage from the Dockum Aquifer was approximately 40,035 ac-ft in 1994. Of the total amount, irrigation pumpage was 58 percent, mining use was 23 percent, and municipal pumpage amounted to 13 percent.

Hydrogeology. The primary water-bearing zone in the Dockum Group, commonly called the "Santa Rosa", consists of up to 700 feet of sand and conglomerate interbedded with layers of silt and shale. Additional discontinuous sandstone lenses occur elsewhere within the Dockum that also produce water. Except in the outcrop area, this overlying confining bed causes artesian conditions to prevail. Where the "Santa Rosa" occurs at the top of the Dockum, the aquifer is hydrologically continuous with overlying, water-bearing formations. Aquifer permeability is typically low, and well yields normally do not exceed 300 gal/min.

Water Quality. Concentrations of dissolved solids in the groundwater range from less than 1,000 mg/l in the eastern outcrop of the aquifer to more than 20,000 mg/l in the deeper parts of the formation to the west. High sodium concentrations pose a salinity hazard for soils, thus limiting regional long-term use of the water for irrigation. Dockum water used for municipal supply by several cities often contains chloride, sulfate, and dissolved solids that are near or exceed safe drinking-water standards.

Availability. Recharge to the Dockum Aquifer is negligible except in the outcrop areas where approximately 23,500 ac-ft is estimated to occur annually. An additional small amount of recharge also occurs as leakage from overlying, water-bearing formations in the southern extent of the aquifer. In the artesian part of the aquifer, production generally exceeds recharge thus resulting in water-level declines and aquifer depletion.

Resource Management. Eight underground water conservation districts currently in operation in the Dockum Aquifer area were created primarily to protect the overlying Ogallala Aquifer and, therefore, have not developed management rules specific to the Dockum Aquifer. These districts are Dallam County #1, High Plains #1, Mesa, North Plains #2, Panhandle #3, Permian basin, Sandy Land, and South Plains. Six other districts in the Dockum Aquifer area south of the Ogallala include Coke County, Emerald (Crockett County), Glasscock County, Irion County, Santa Rita (Reagan County), and Sterling County. Of these six districts, five have well spacing requirements and three have pumping regulations.

In 1994, entities in the High Plains Ogallala Aquifer area joined to address the depletion of available water resources. A process was initiated to develop a regional water management plan and examine alternatives for more efficient use of the area's water resources. Within this area, the Dockum Aquifer is considered a secondary water source, and its use is encouraged over Ogallala water where quality constraints are not as rigid. Because of its potential for augmenting water supplies, the Dockum should be monitored by the underground water conservation districts.

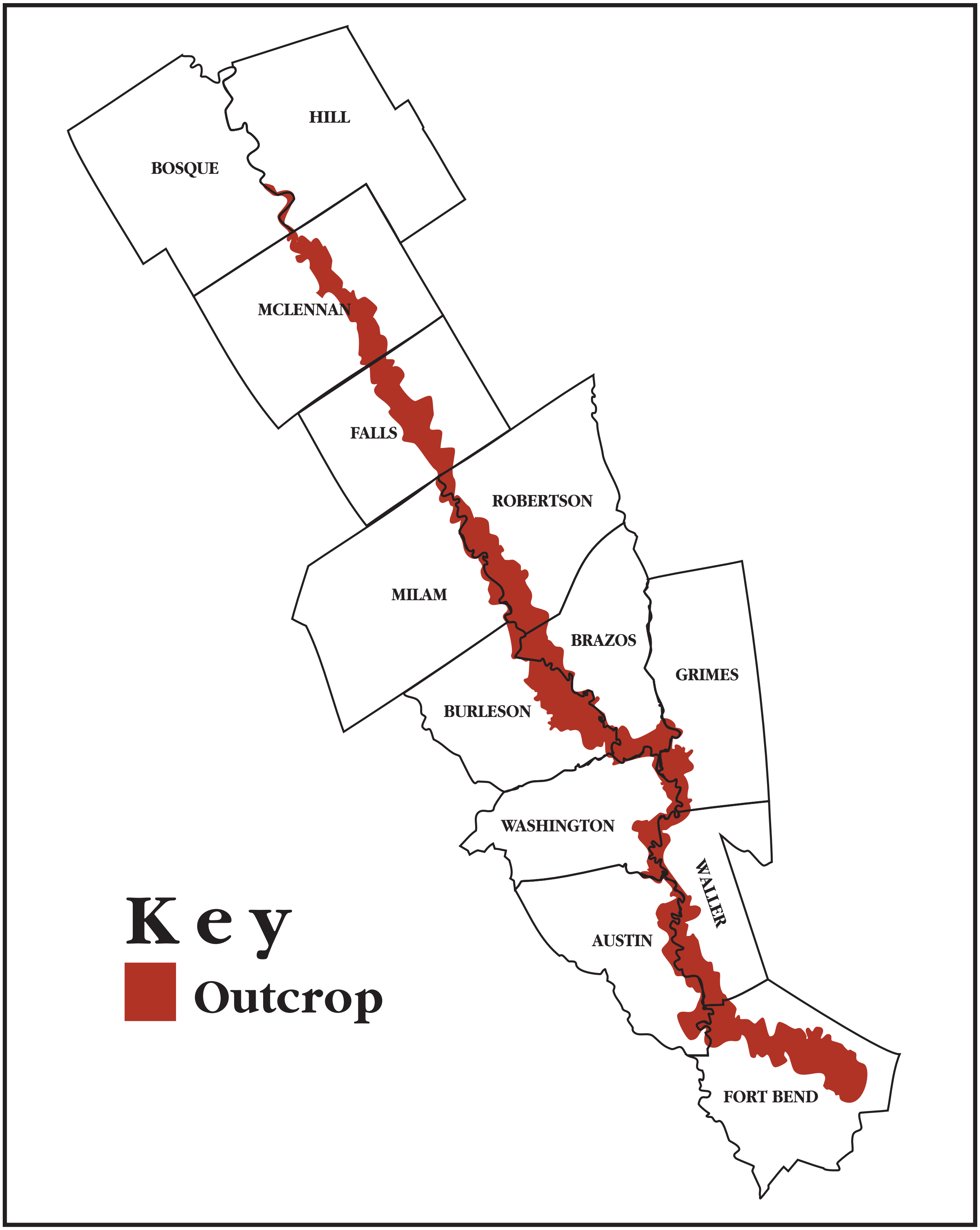

Figure 3-84
Brazos River Alluvium Aquifer

3.4.2.3 Brazos River Alluvium Aquifer

Location and Use. The Brazos River Alluvium Aquifer is composed of water-bearing alluvial sediments occurring in floodplain and terrace deposits of the Brazos River in southeast Texas (see Figure 3-84). Ranging from less than 1 mile to almost 7 miles wide, the aquifer stretches approximately 350 miles along the sinuous course of the river between southern Hill and Bosque counties and eastern Fort Bend County. In 1994, total aquifer pumpage was 30,021 acre-feet (ac-ft) of which 99 percent was for irrigation purposes.

Hydrogeology. Deposited during the Quaternary Period, the river alluvium forms the flood plain and a series of terraces. The flood plain is of primary significance as a source of groundwater in the Brazos River Valley, however, groundwater also may occur in the terrace alluvium. The river valley alluvium consists of clay, silt, sand, and gravel, and is generally coarsest and most water-bearing in the lower part of the aquifer. Water in the flood-plain alluvium usually exists under water-table conditions, although artesian conditions may occur locally where extensive lenses of clay are present. Saturated thickness of the alluvium is as much as 85 feet or more, with maximum thickness occurring in the central and southeastern parts of the aquifer. Wells can yield up to 1,000 gal/min, but the majority have yields ranging from 250 to 500 gal/min.

Water Quality. The chemical quality of the groundwater in the aquifer varies widely, even within short distances. In many areas, concentrations of dissolved solids exceed 1,000 mg/l. Most of the Brazos River Valley that is irrigated with this groundwater contains soils sufficiently permeable to alleviate any soil salinity problems. In some areas, the water from the aquifer is sufficiently fresh to meet safe drinking-water standards.

Availability. Annual availability for the Brazos River Alluvium consists of effective recharge and recoverable storage. Recharge to the alluvium is chiefly by precipitation on the flood plain surface. Water-level data indicate that the aquifer is readily replenished by rainfall. This is seen by record low water levels measured at the end of the 1950s drought recovering to pre-development levels in just a few years with above average rainfall. Total annual effective recharge to the Brazos River Alluvium is estimated to be 100,000 ac-ft. based on 75 percent of total storage, approximately 1.38 million ac-ft of water is estimated to be recoverable. Therefore, annual availability for the aquifer through the year 2050 is 134,500 ac-ft.

Resource Management. Water level and water quality data do not indicate any areas of quantity or quality problems for the Brazos River Alluvium. Total pumpage from the aquifer is much less than annual availability. Although historical declines have occurred where pumpage for irrigation purposes has exceeded local recharge, water level data indicate that lowering of the water table by large withdrawals will generally be offset by subsequent periods of normal or above normal rainfall when recharge increases and pumpage decreases.

Currently there is one underground water conservation district in the Brazos River Alluvium area, the Fort Bend Subsidence District covering Fort Bend County. The district has a comprehensive management plan filed with the TNRCC. Although management in addition to that currently being practiced is not necessary, programs that monitor aquifer conditions should be continued to provide data to evaluate potential problem areas in the future. Future high-capacity development from the Brazos River Alluvium Aquifer should incorporate sound investigative procedures. Wells should be constructed in a manner conforming to standards and spacing requirements that provide the most efficient well possible. Optimal pumping programs will help minimize long-term water level declines related to heavy pumpage. Also, conjunctive use of available surface-water supplies should be explored as an option for meeting future large-capacity demands.

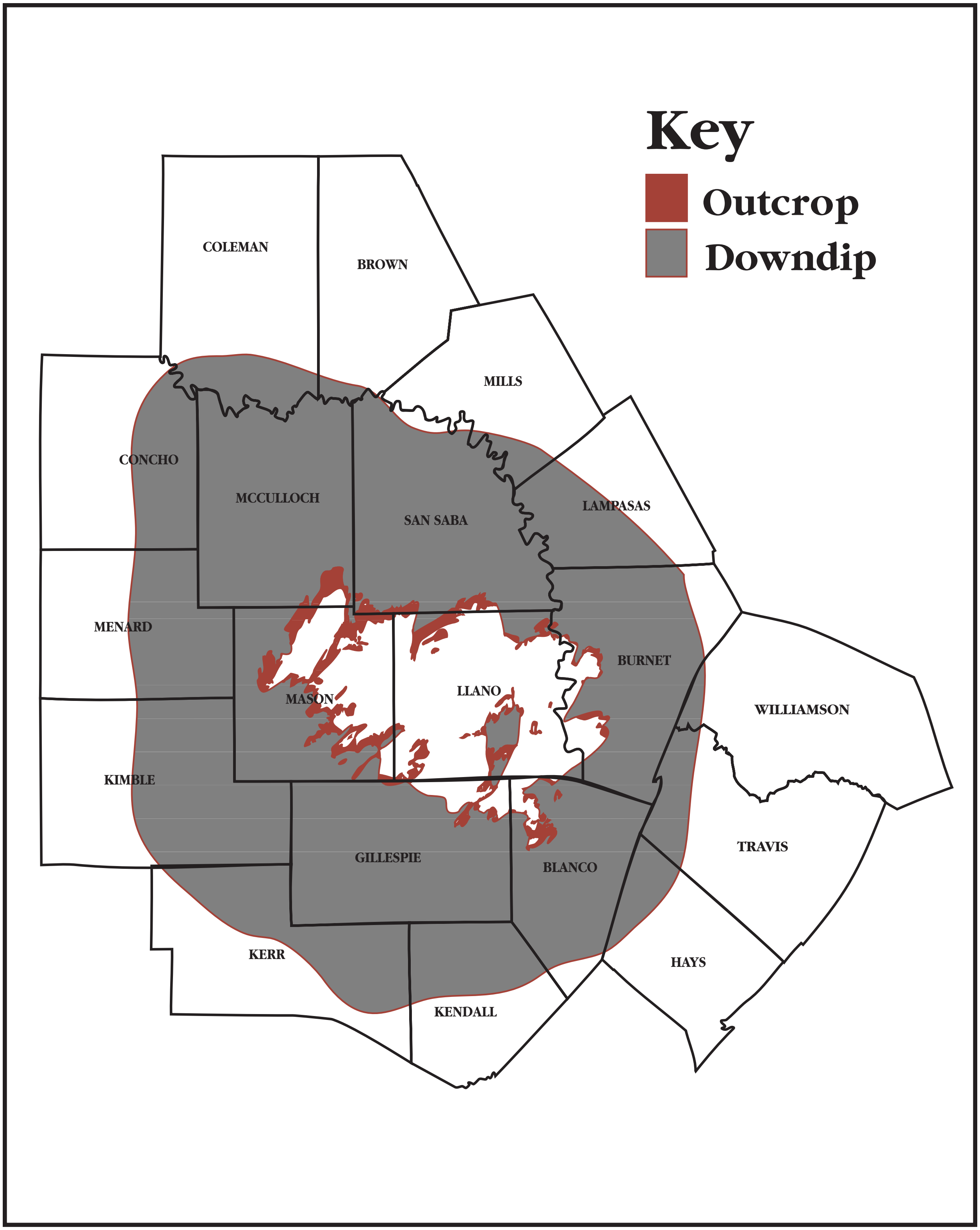

Figure 3-85
Hickory Aquifer

3.4.2.4 Hickory Aquifer

Location and Use. The Hickory Aquifer underlies approximately 5,000 square miles in parts of 19 counties within the Llano Uplift region of Central Texas (see Figure 3-85). Discontinuous outcrops of the Hickory sandstone overlie and flank the exposed Precambrian rocks that form the central core of the Uplift. The downdip artesian portion of the aquifer encircles the Uplift and extends to maximum depths approaching 4,500 feet.

In 1994, a total of 23,587 acre-feet (ac-ft) of water was pumped from the Hickory Aquifer. Of this total, 17,073 ac-ft, or 72 percent, was used for irrigation, primarily for cultivation of peanuts on the sandy soils of the Hickory outcrops in Mason, McCulloch, San Saba, and Llano counties. The largest capacity wells, however, have been completed for municipal supply purposes at Brady, Mason, and Fredericksburg. Many rural water supply corporations and rural residential subdivisions use water from the aquifer for domestic purposes. A significant part of the flow from San Saba Springs, which supplies water for the City of San Saba, is believed to be from the Hickory Aquifer.

Hydrogeology. The Hickory Sandstone Member of the Cambrian Riley Formation is composed of some of the oldest sedimentary rocks found in Texas. In most of the northern and western portions of the aquifer, the Hickory Sandstone Member can be differentiated into lower, middle, and upper units which reach a maximum thickness of 480 feet in southwestern McCulloch County. In the southern and eastern extent of the aquifer, the Hickory Sandstone Member consists of only two units which range in thickness from about 150 to 400 feet.

Block faulting has compartmentalized the Hickory Aquifer. Apparent vertical fault displacement ranges from a few feet to as much as 2,000 feet and apparent significant lateral fault displacement also occurs. Throughout its extent, the thickness of the aquifer is affected by the relief of the underlying Precambrian surface. Both faulting and relief have caused significant variations in the occurrence, availability, movement, productivity, and quality of groundwater within the aquifer.

The yields of large-capacity wells used for municipal and irrigation purposes usually range between 200 and 500 gal/min. However, some municipal wells have been reported to have yields exceeding 1,000 gal/min. The largest well yields are typically obtained where the aquifer has the greatest saturated thickness in the artesian portion of the aquifer northwest of the Llano Uplift.

Water Quality. Dissolved-solids concentrations of groundwater from the Hickory Aquifer generally range from 300 to 500 mg/l. Groundwater containing considerably less than 3,000 mg/l dissolved solids has been produced from depths greater than 2,500 feet in eastern Concho County and in northern portions of McCulloch and San Saba counties. Locally, the aquifer produces water with excessive alpha particle and total radium concentrations in excess of safe drinking water standards. The water can also contain radon gas. Most of the radioactive water produced from the aquifer is believed to be coming from the middle Hickory unit. The upper unit of the Hickory produces groundwater containing concentrations of iron in excess of safe drinking-water standards. Concentrations of nitrate in excess of safe drinking-water standards due to septic tanks and farming and ranching activities may be encountered in shallow Hickory wells in the outcrop area.

Availability. The artesian portion of the aquifer containing water with 3,000 mg/l or less dissolved solids has 110 million ac-ft of water in storage. Of this amount, approximately 10 million ac-ft is recoverable water in artesian storage above an arbitrary depth of 400 feet below land surface. An additional 100 million ac-ft is partly recoverable from artesian storage below 400 feet. In addition, an unknown large amount of partly recoverable water is in water-table storage in the outcrop portion of the aquifer. Approximately 160 million ac-ft of recoverable water is estimated to exist in the entire saturated portion of the aquifer from the outcrop areas to the downdip limit.

Recharge occurs as precipitation and infiltrates the discontinuous outcrops of Hickory Sandstone. The annual effective recharge to the aquifer is estimated to be 52,600 ac-ft. This amount equates to 10 percent of the mean annual precipitation. In much of its extent, Hickory Sandstone underlies the basal sandstones of the Trinity Group Aquifer system where it receives a significant but unknown amount of recharge by downward leakage from the Trinity.

Resource Management. There are currently five underground water conservation districts in the Hickory Aquifer area. These districts include the Hickory UWCD #1 covering parts of Concho, Kimble, Mason, McCulloch, Menard, and San Saba counties; the Fox Crossing Water District in Mills County; the Headwaters UWCD in Kerr County; the Hill Country UWCD in Gillespie County; and the Saratoga UWCD in Lampasas County. The Hickory, Headwaters, and Hill Country districts have filed comprehensive management plans with the TNRCC. Management plans for the Hickory and Hill Country districts both contain guidelines for aquifer pumpage, and the plan for the Hill Country district also sets well spacing requirements.

Water-level data do not indicate any areas of quantity problems for the Hickory. This can be attributed to the relatively small amount of pumpage compared to the annual effective recharge and recoverable storage. Also, naturally elevated concentrations of some water quality constituents appear to be local in nature. Even though overdrafting of the aquifer has not occurred, programs that monitor aquifer conditions should be continued to provide data to evaluate potential problem areas in the future.

At this time, no additional aquifer management is necessary for the Hickory Aquifer. However, any future high capacity development should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines related to heavy pumpage.

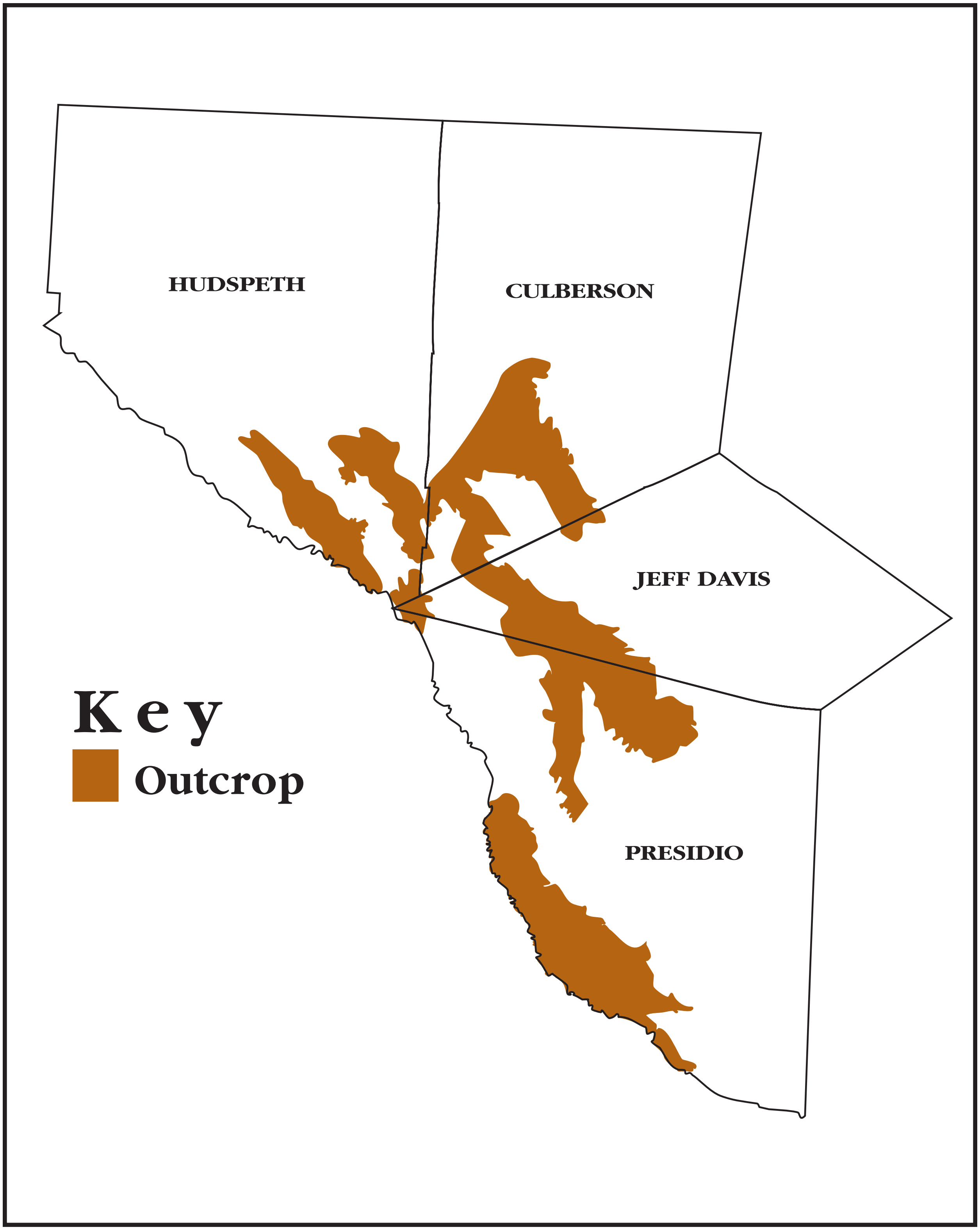

Figure 3-86
West Texas Bolson Aquifers

3.4.2.5 West Texas Bolson Aquifers

Location and Use. In the western part of the Trans-Pecos region of Texas, several deep basins have been filled by erosional material which contains quantities of varying quality groundwater (see Figure 3-86). These filled basins, or bolsons, include the Red Light Draw, Eagle Flat, Green River Valley, Presidio-Redford Bolson, and Salt basin. The Salt basin can be subdivided into the Salt, Wild Horse, Michigan, Lobo, and Ryan Flats. These bolsons provide water mainly used for irrigation purposes in parts of Hudspeth, Culberson, Jeff Davis, and Presidio counties. The communities of Sierra Blanca, Valentine, and Van Horn use these aquifers for municipal supply. In 1994, total pumpage from all the West Texas bolsons was 10,975 acre-feet (ac-ft), 62 percent of which was used for irrigation. A large majority of the irrigation occurs in the Salt basin.

Hydrogeology. Bolson deposits in each of these basins differ according to the type of rock material that was eroded from the adjacent uplands and the manner in which this material was deposited. Sediments range from coarse-grained volcanic and limestone detritus redeposited as alluvial fans to fine-grained silt and clay lake deposits. Water in the aquifer generally occurs under water-table conditions. Yields of some irrigation wells exceed 3,000 gal/min, however, most wells do not exceed 1,000 gal/min. Well depths range from very shallow to over 4,000 feet in some irrigation wells.

Water Quality. Water quality characteristics differ from basin to basin, ranging from fresh in the higher elevations to brine in the Salt Flat where very shallow groundwater continuously evaporates. Typically, in basins where the aquifers are capable of producing large quantities of water, the quality is sufficient to support irrigated agriculture, as well as meet drinking-water quality standards,

Availability. Recharge to the bolsons results from precipitation that falls directly on the basins and the surrounding uplands. The average annual effective recharge for the combined West Texas bolson aquifers is approximately 24,000 ac-ft (greater than half is in the Salt basin) or 1 percent of the mean annual precipitation on the outcrop. Recharge is minimal in this region due to low annual rainfall and high evaporation rate. A total of approximately 7 million ac-ft of fresh to slightly-saline groundwater is in storage in the bolsons.

Resource Management. The vast West Texas region is characteristically rural, with large land tracts and small population. Regional water resource management is adequately maintained by landowners. The recent acquisition of properties and associated ground-water reserves by the City of El Paso could result in future large-scale pumpage with the capability of effecting regional water levels. This occurrence has brought to the forefront the desire of local citizens to establish regional ground-water management.

The Jeff Davis County UWCD was formed in 1994 and serves the southern portion of the Salt Basin Aquifer. The district was created to address management issues concerning outside influences on their local ground-water resources. The district has adopted rules for the purpose of conserving, preserving, and protecting groundwater. A Presidio County district was legislatively authorized in 1993 but has not been confirmed by local election.

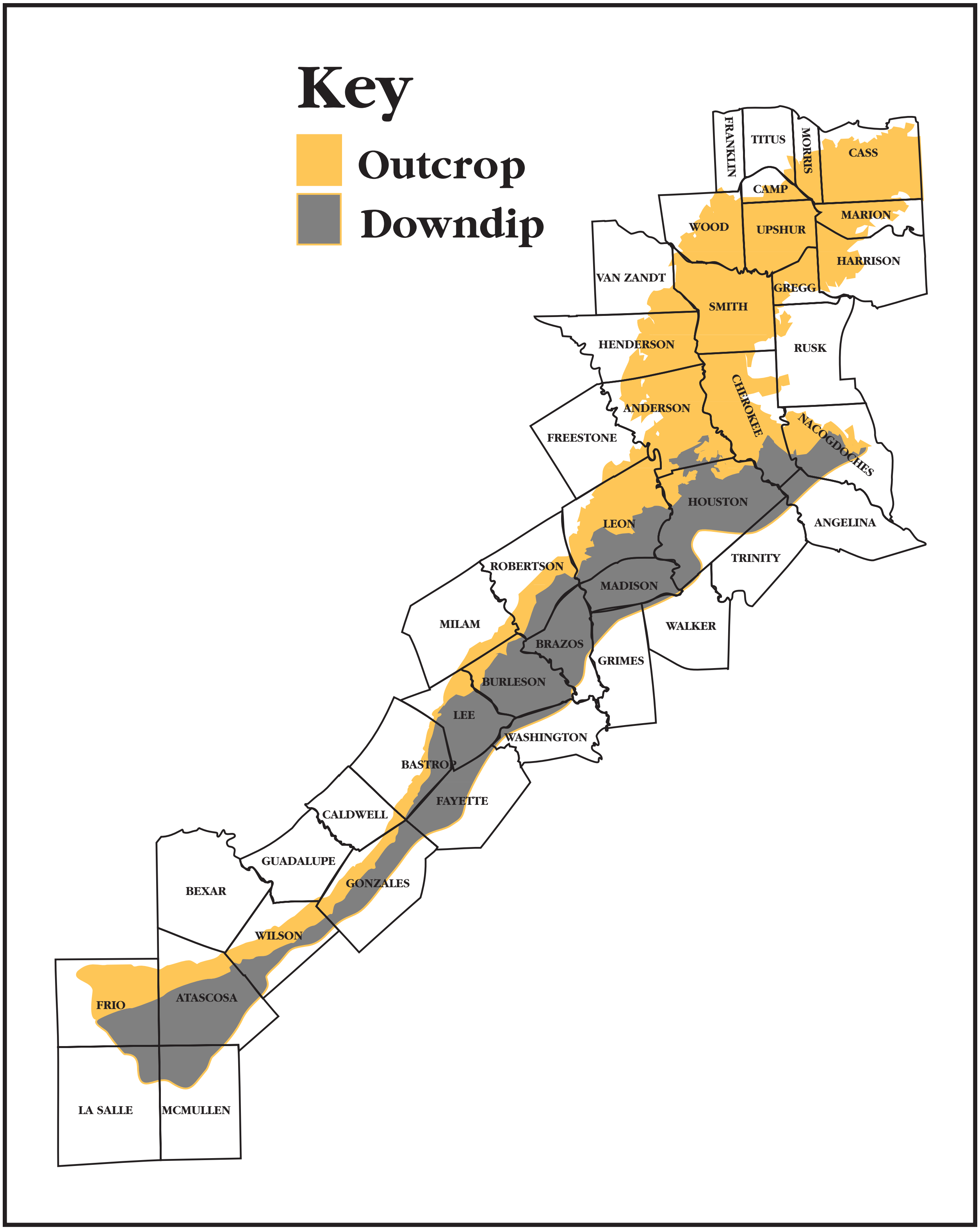

Figure 3-87
Queen City Aquifer

3.4.2.6 Queen City Aquifer

Location and Use. The Queen City Aquifer extends in a band across most of the State from the Frio River in South Texas northeastward into Louisiana (see Figure 3-87). The southwestern boundary is placed at the Frio River because of a facies change in the formation. This facies change results in reduced amounts of poorer quality water produced from this interval southwest of the Frio River. The aquifer provides water for domestic and livestock purposes throughout most of its extent, significant amounts of water for municipal and industrial supply in northeast Texas, and water for irrigation in Wilson County. Total pumpage for all uses in 1994 was 16,319 acre-feet (ac-ft).

Hydrogeology. Sand, loosely cemented sandstone, and interbedded clay units of the Queen City Formation of the Tertiary Claiborne Group make up the aquifer as delineated within Texas. These rocks dip gently to the south and southeast toward the Gulf Coast. Although total aquifer thickness is usually less than 500 feet, it can approach 700 feet in some areas of northeast Texas. In the outcrop area, water occurs under water-table conditions while in the downdip subsurface, where the Queen City is covered by younger, non water-bearing rocks, the water is under artesian conditions. Usable quality water is generally found within the outcrop and for a few miles downdip, but in some areas it may occur down to depths of approximately 2,000 feet. Yields of individual wells are commonly low, but a few exceed 400 gal/min.

Water Quality. Throughout most of its extent, the chemical quality of the Queen City Aquifer water is excellent, however, quality deteriorates with depth in the downdip direction. The water may have high acidity (low pH) in much of northeast Texas and relatively high iron concentrations in localized areas. Hydrogen sulfide gas is sometimes present. Fortunately, each of these naturally occurring conditions may be treated relatively easily and economically.

Availability. While large amounts of usable quality groundwater are contained within the rocks of the Queen City, yields are low. Estimates of the availability of water from the Queen City Aquifer are based on recharge to the aquifer. Because of differences in topography, vegetative cover, and other factors, only 2 percent of the annual rainfall is estimated recharge in the Trinity, Colorado, Guadalupe, San Antonio, and Neches River basins. Approximately 5 per cent is estimated recharge in the Neches, Sulphur, Sabine, and Cypress Creek basins. Total annual effective recharge to the aquifer is estimated to be 682,100 ac-ft.

Resource Management. Basic management issues for the Queen City Aquifer include prevention of excessive water-level declines and water-quality deterioration and development of future supply options to meet potential demands. The keys to accomplishing these tasks are to avoid overdrafting the aquifer and to utilize appropriate methods for developing new water supplies.

Water-level and quality data does not indicate any areas of problems for the Queen City Aquifer. This can be attributed partly to the relatively small amount of aquifer pumpage compared to total annual recharge and partly to management practices already in place by entities that utilize the aquifer for their water supply. Overdrafting of the aquifer has not occurred and, therefore, additional management is not currently necessary. However, programs that monitor aquifer conditions should be continued to provide data that is essential to evaluate potential problem areas in the future.

Any future high capacity development from the Queen City Aquifer should incorporate sound investigative procedures. Wells should be constructed in a manner conforming to standards and spacing requirements to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage. Also in East Texas, conjunctive use of available surface-water supplies should be explored as an option for meeting future large- capacity demands.

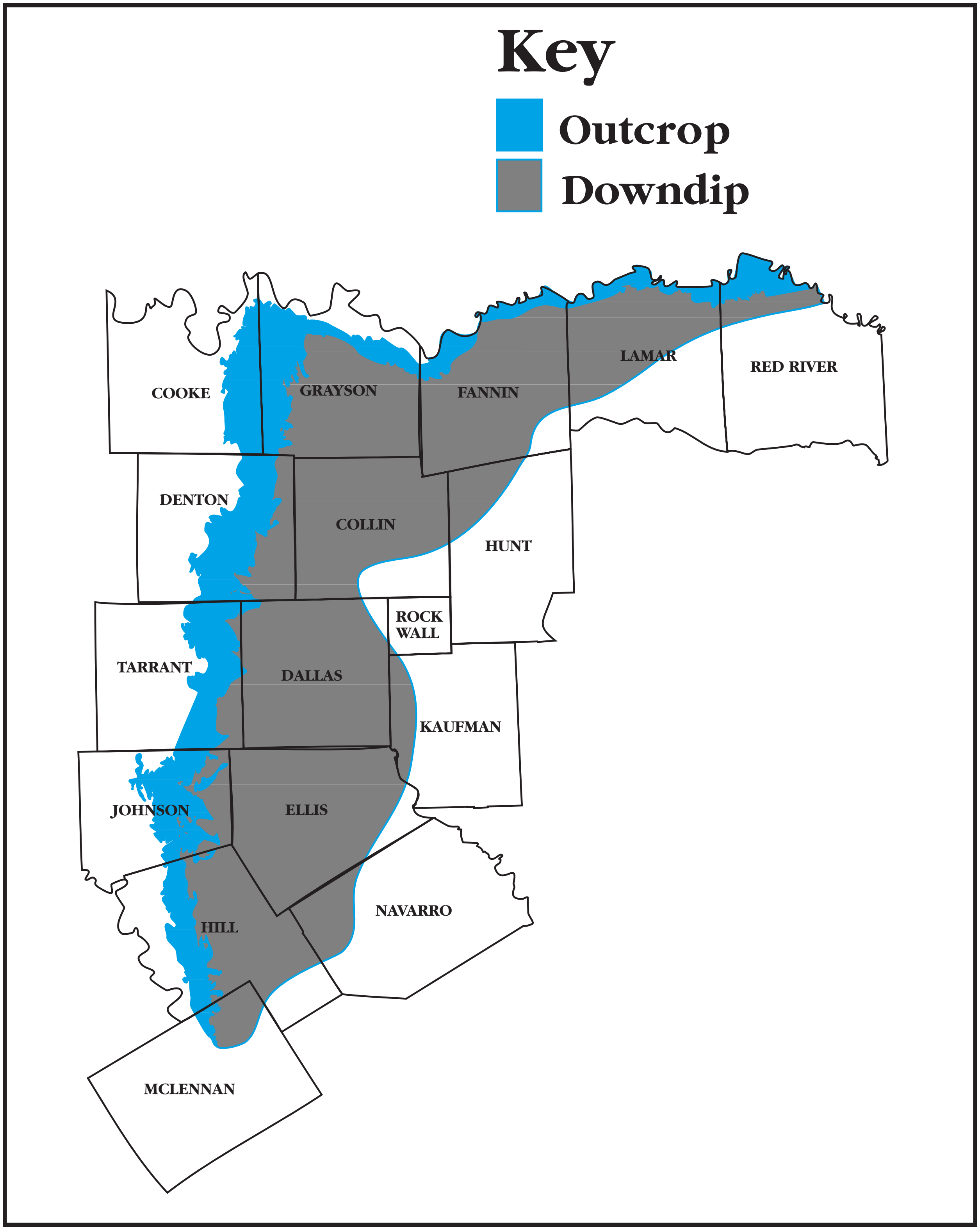

Figure 3-88
Woodbine Aquifer

3.4.2.7 Woodbine Aquifer

Location and Use. The Woodbine Aquifer extends from McLennan County in North-central Texas northward to Cooke County and eastward to Red River County, paralleling the Red River (see Figure 3-88). Water produced from the aquifer furnishes municipal, industrial, domestic and livestock, and small irrigation supplies throughout this extensive North Texas region. Total pumpage for all purposes in 1994 was 15,572 acre-feet (ac-ft). The largest user of groundwater for public supply purposes is the City of Sherman which pumped 6,604 ac-ft.

Hydrogeology. The Woodbine Aquifer of Cretaceous age is composed of water-bearing sand and sandstone beds interbedded with shale and clay. The Woodbine Group is divided into three water-bearing parts that differ considerably in productivity and quality. Usually the lower part of the aquifer is developed to supply water for domestic and municipal wells.

The water in storage is under water-table conditions in the outcrop and under artesian conditions in the subsurface. The aquifer dips eastward into the subsurface where it reaches a maximum depth of 2,500 feet below land surface and a maximum thickness of approximately 700 feet. Yields of wells completed in the Woodbine Aquifer range from less than 100 gal/min to about 700 gal/min.

Water Quality. Chemical quality of water deteriorates rapidly in well depths below 1,500 feet. In areas between the outcrop and this depth, quality is considered good overall as long as groundwater from the upper Woodbine is sealed off. The upper Woodbine contains water of extremely poor quality in downdip locales and contains excessive iron concentrations along the outcrop. Water from the artesian portion in Dallas, Ellis, and Navarro counties is characterized by high concentrations of sulfate. Several wells in the outcrop portion of the aquifer in Johnson and Tarrant counties contain sulfate concentrations in excess of drinking-water standards and are apparently associated with extensive non-commercial lignite beds. Relatively high boron concentrations, derived from ancient volcanic sediments, render the groundwater in these areas unsuitable for irrigation due to the boron-toxicity to plants.

Availability. The average annual ground-water availability for the Woodbine, equivalent to the transmission capacity of the aquifer, is estimated to be 26,100 ac-ft. Less than 1 inch of the average annual precipitation of 35 inches is necessary as effective recharge to supply that total.

Since the 1970s, in areas where heavy municipal and industrial pumpage has exceeded local recharge, significant water-level declines within the Woodbine have occurred. This area of regional water-level decline extends from the Sherman-Denison area in Grayson County into eastern Grayson, southwestern Fannin, and northern Collin counties. Declines in excess of 100 feet have been measured near the City of Sherman and the largest net decline, measuring 159 feet for the period 1976 to 1989, is centered beneath the City of Randolph in Fannin County. Fortunately, in this area the top of the Woodbine occurs at depths ranging from 400 to greater than 1,000 feet below the land surface and, therefore, additional amounts of artesian storage continue to be available for development.

Resource Management. The primary management issue for the Woodbine Aquifer is minimization or prevention of additional water-level declines in areas of concentrated pumpage mainly in the northern portion of the aquifer. In these areas where overdrafting of the aquifer has occurred, supply problems are accompanied by potential quality problems. This is due to an increased chance of up-dip movement of saline water resulting from reversals of the regional gradient associated with continued water-level declines.

To address both supply and potential quality problems, entities have utilized available surface-water supplies to supplement or replace demands that, in the past, have been met with groundwater. For example, the City of Sherman, historically the largest user of groundwater from the Woodbine, has used surface water to meet almost half of its municipal needs since 1993. The result of this, and other efforts at conjunctive use of surface and groundwater, has been a stabilization of water levels in the region. Data does not indicate any significant water-level declines for the aquifer since 1985, and there is no evidence of quality deterioration along the slightly saline (3,000 mg/l) line.

Most of the Woodbine Aquifer was included as part of a critical area study completed in 1990. From the results of that study the TNRCC determined the area was not critical. However, it was recommended that monitoring of aquifer conditions be continued in order to provide essential data to evaluate any potential problem areas in the future.

Future high-capacity development from the Woodbine Aquifer should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements that provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage. Conjunctive use of available surface-water supplies should be explored as an important option for meeting future large-capacity demands. This will also minimize potential negative impacts on the aquifer system resulting from increased pumpage.

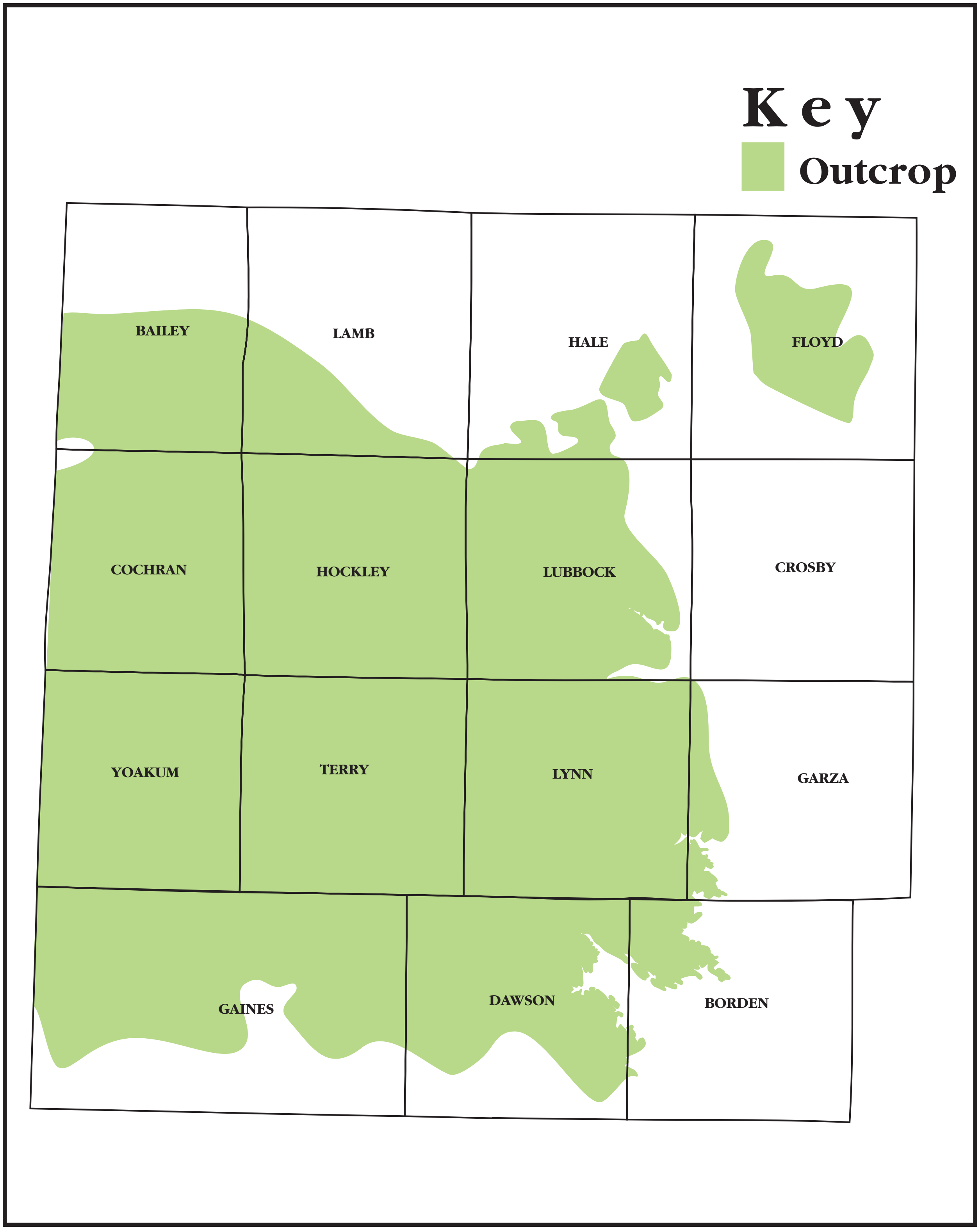

Figure 3-89
Edwards-Trinity Aquifer (High Plains)

3.4.2.8 Edwards-Trinity Aquifer (High Plains)

Location and Use. The Edwards-Trinity (High Plains) Aquifer occurs in 14 counties in the South- Central part of the Texas High Plains and extends westward into New Mexico (see Figure 3-89). Wells drilled into the Edwards-Trinity are often dual-completed with the overlying Ogallala Aquifer. In 1994, of the total 2,186 acre-feet (ac-ft) pumped from the aquifer, 66 percent was used for irrigation. Lesser amounts were used for municipal supply and livestock.

Hydrogeology. The aquifer occurs in two distinct water-bearing zones in formations of the Cretaceous Fredericksburg and Trinity groups. One zone occurs in the basal sand and sandstone deposits of the Antlers Formation (Trinity Group) and is almost always under artesian pressure. The other water-bearing zone occurs primarily in joints, solution cavities, and along bedding planes in limestones of the Comanche Peak and Edwards formations. In much of the area, this upper zone is hydrologically connected to the overlying Ogallala Aquifer.

Groundwater in the aquifer generally moves toward the east-southeast and naturally discharges from springs along the eastern High Plains escarpment. In many places the ground-water potentiometric surface in the aquifer is higher than in the overlying Ogallala Aquifer, resulting in the upward migration of water from these formations. Well yields generally range between 50 and 200 gal/min.

Water Quality. Water 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 areas where these formations are overlain by saline lakes and the gypsiferous Tahoka and Double Lakes formations.

Availability. The amount of groundwater recoverable from storage is estimated to be between 1 and 3 million ac-ft. Recharge to the aquifer occurs laterally from the bounding Ogallala Formation along northern and western parts of the subcrop and by downward percolation from overlying units elsewhere. Upward ground-water movement from the underlying Triassic Dockum Aquifer into the Edwards-Trinity may also occur in some areas.

Since little water is produced from the aquifer, declines are restricted to the immediate areas of water use. Only limited quantitative data on the interaction between the Cretaceous and Ogallala formations are available; however, recent studies have indicated that the Edwards-Trinity (High Plains) has a significant impact on the water level and quality of the Ogallala.

Resource Management. Four underground water conservation districts currently in operation in the Edwards-Trinity (High Plains) Aquifer area were created primarily to protect the overlying Ogallala Aquifer and, therefore, have not developed management rules specific to the Edwards-Trinity. These districts are the High Plains #1, Mesa, Sandy Land, and South Plains.

In 1994, water-related entities in the High Plains Ogallala Aquifer area joined to address the problem of the depletion of available water resources. A process was initiated to develop a regional management plan to examine alternatives for more efficient use of the area's water resources.

Within the Ogallala area the Edwards-Trinity is considered a secondary water source, and its use is encouraged instead of Ogallala water where quality constraints are not as rigid. Because of its potential for augmenting Ogallala water supplies, the Edwards-Trinity should be monitored by the underground water conservation districts.

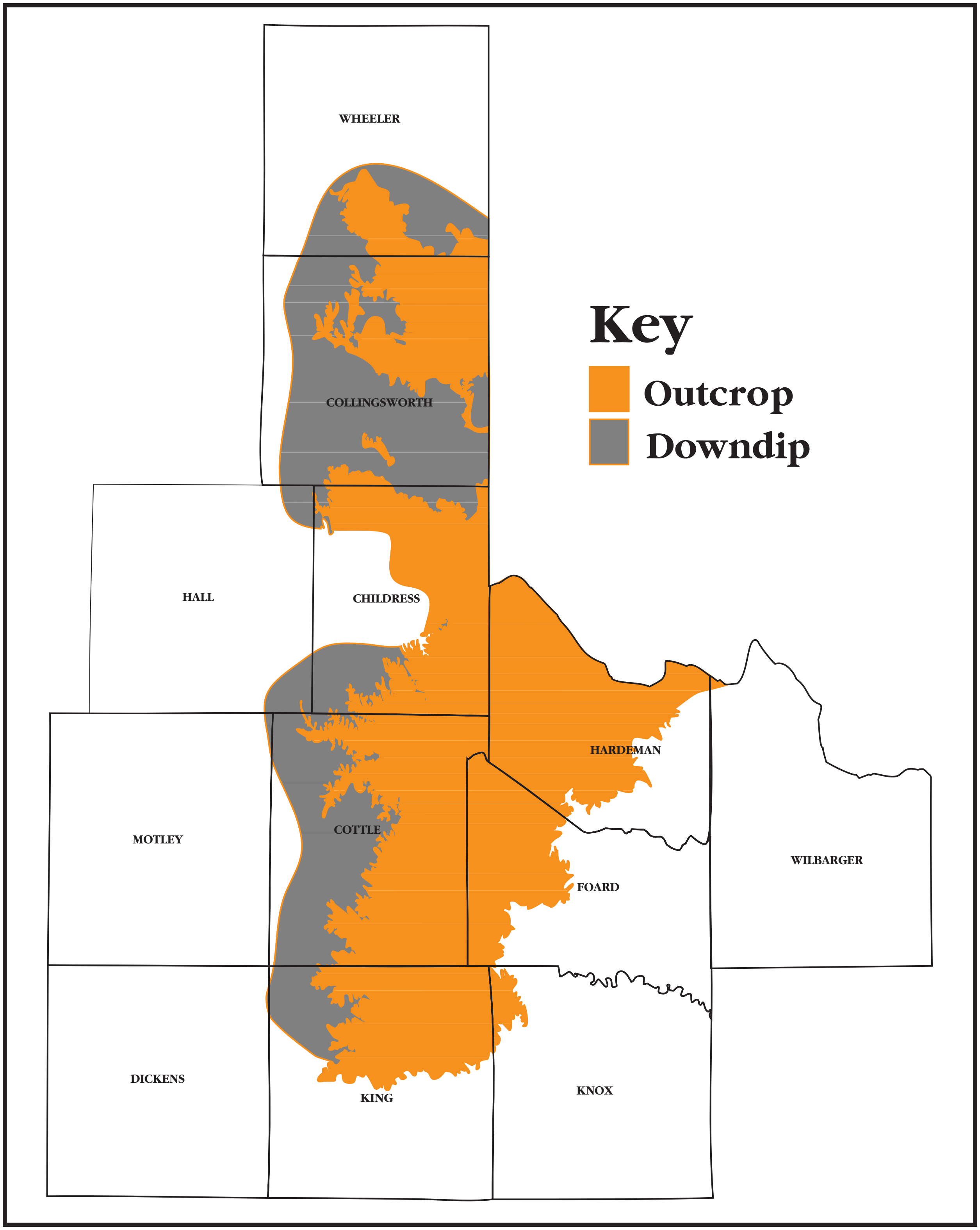

Figure 3-90
Blaine Aquifer

3.4.2.9 Blaine Aquifer

Location and Use. The Blaine Formation crops out in a band from Wheeler County to King County and extends westward in the subsurface to adjacent counties (see Figure 3-90). The aquifer provides water for all or parts of 9 counties in West-Central Texas. Although the formation is present farther south, the limited use of its water does not justify its inclusion as a minor aquifer. In 1994, total aquifer pumpage was 24,094 acre-feet (ac-ft) of which 98 percent was for irrigation purposes. In addition to this amount, a relatively small amount of water was pumped for secondary recovery of oil and gas, municipal, stock, and domestic needs.

Hydrogeology. The Blaine Formation of Permian age is composed of anhydrite and gypsum with interbedded dolomite and clay. Water occurs primarily in the numerous solution channels of the Blaine under water-table conditions. The saturated thickness of the aquifer approaches 300 feet in its northern extent.

Well yields vary from a few gal/min to more than 1,500 gal/min. Although water in storage is generally under water-table conditions, larger yields are associated with the few areas of the aquifer that are confined by relatively impervious beds. Dry holes or wells of low yield are commonly found adjacent to wells of moderate to high yields because of the uneven nature in confining beds and the occurrence of the water in solution zones. Groundwater not intercepted by wells tends to discharge naturally in areas of lower topography through seeps and springs.

Water Quality. The concentration of dissolved solids in the Blaine increases with depth of the aquifer and along surface drainages in natural discharge areas. The extent of the aquifer, based upon usage, includes water containing less than 10,000 mg/l dissolved solids and excludes portions that exceed this limit. In addition to natural contamination of the Blaine by halite dissolution and upward migration of deeper waters, nitrates and pollution associated with the production of oil and gas represent significant sources of contamination to the aquifer. The salinity of the water can also increase during periods of sustained pumpage as saline waters underlying the fresh water-bearing sections are drawn into wells through the extensive network of fractures and solution channels within the aquifer.

Availability. Annual availability for the Blaine, as effective recharge, is estimated to be 142,600 ac-ft. The primary source of recharge to the Blaine is precipitation on the outcrop area. Annual effective recharge is estimated to be 5 percent of the mean annual precipitation with the highest rates of infiltration occurring in areas overlain by sandy soils. Water recharged to the aquifer moves along solution channels and caverns dissolving evaporitic deposits of anhydrite and massive halite which, in turn, contribute to the overall poor quality of water.

Resource Management. To date, no significant regional water level declines have been noted for the Blaine Aquifer. Measured declines are limited to areas dependent upon groundwater for irrigation purposes, however, in these areas recovery of levels is usually quick in response to seasonal rainfall.

Currently, only the Collingsworth County UWCD in Collingsworth County is located in the Blaine Aquifer area. The district has filed a comprehensive management plan with the TNRCC. Additional aquifer management is not considered necessary at this time. Due to the naturally occurring poor water quality and the erratic occurrence of usable quality water, the Blaine Aquifer is not considered a viable source for any municipality with a growing population.

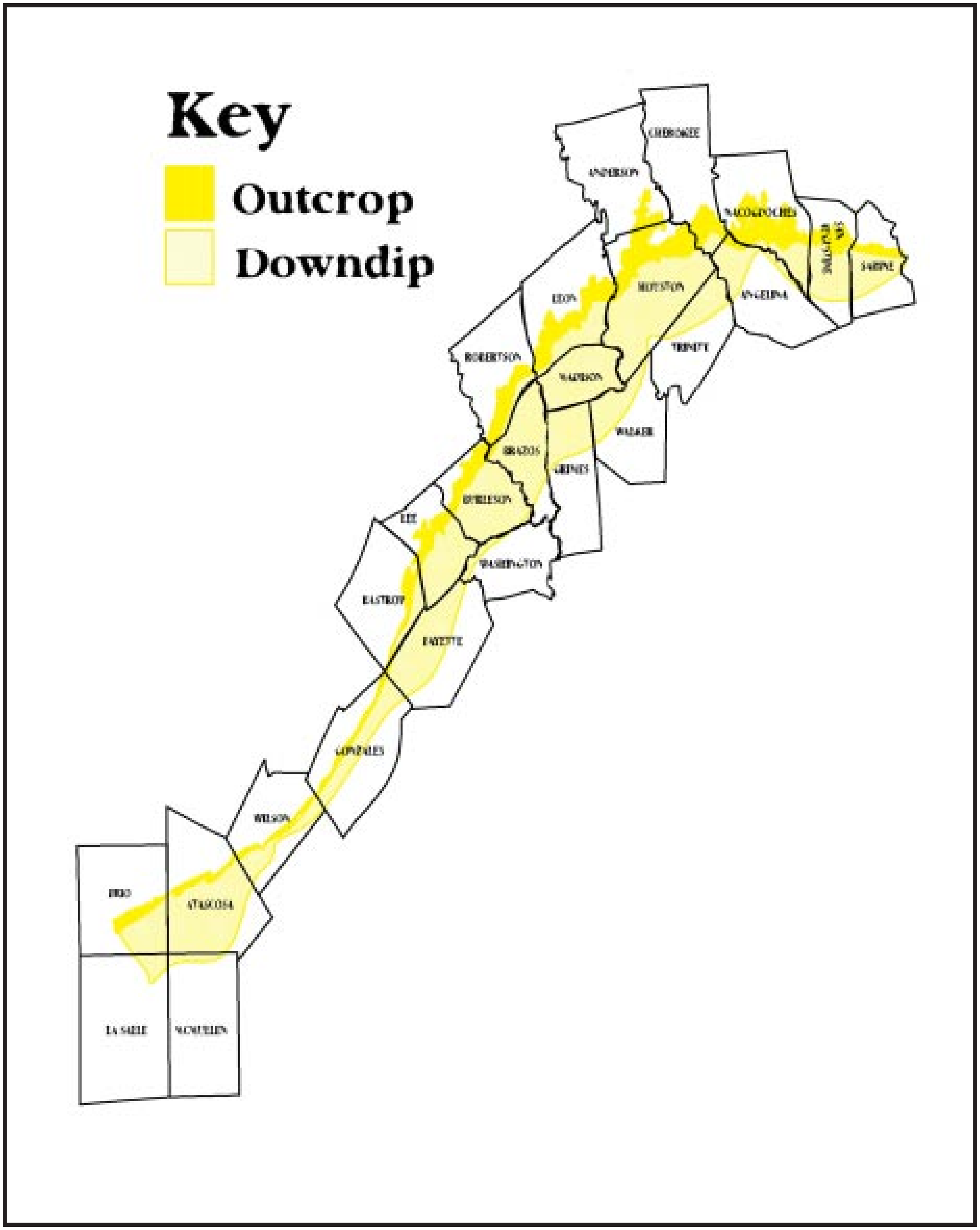

Figure 3-91
Sparta Aquifer

3.4.2.10 Sparta Aquifer

Location and Use. The Sparta Aquifer extends in a narrow band across the state from the Frio River in South Texas northeastward to the Louisiana border in Sabine County (see Figure 3-91). The southwestern boundary is placed at the Frio River because of a facies change in the formation which makes it difficult to delineate the boundaries of the Sparta and contiguous formations southwestward. The facies change results in reduced amounts of water and poorer quality water produced from the interval. The Sparta provides water for domestic and livestock supply throughout its extent and, in much of the region, it also provides water for municipal, industrial, and irrigation purposes. Total pumpage for all uses in 1994 was 6,827 acre-feet (ac-ft).

Hydrogeology. The Sparta Formation is part of the Claiborne Group deposited during the Tertiary Period. As delineated within Texas, the aquifer consists of sand and interbedded clay with more massive sand beds in the basal section. These rocks dip gently to the south and southeast toward the Gulf Coast and reach a total thickness ranging up to 300 feet. Usable quality water is commonly found within the outcrop and for a few miles downdip, but in some areas may occur down to depths approaching 2,000 feet. Yields of individual wells are generally low to moderate, although most high-capacity wells average 400 to 500 gal/min. A few wells may produce as much as 1,200 gal/min. Water occurs under water-table conditions in the outcrop and under artesian conditions downdip where the Sparta is covered by younger, non water-bearing rocks.

Water Quality. The Sparta Aquifer produces water of excellent quality throughout most of its extent in Texas, however, water quality deteriorates with depth in the downdip direction. Locally, water within the aquifer contains iron concentrations in excess of drinking water standards, but this iron may be removed easily and economically.

Availability. Relatively large amounts of usable quality groundwater are contained within the rocks of the Sparta Aquifer. The average annual ground-water availability in the Sparta Aquifer is 163,800 ac-ft. Availability is considered to be 5 percent of the average annual rainfall on the aquifer in the Neches and Sabine River basins and, elsewhere, is based on the ability of the aquifer to transmit water from the outcrop to discharge areas downdip.

Resource Management. Basic management issues for the Sparta Aquifer include prevention of excessive water-level declines and water-quality deterioration and development of future supply options to meet potential demands. The keys to accomplishing these tasks are to avoid overdrafting the aquifer and to utilize appropriate methods for developing new water supplies.

Current and historic water-level and water-quality data does not indicate any areas of quantity or quality problems for the Sparta. This can be attributed partly to the relatively small amount of aquifer pumpage compared to total annual recharge and partly to management practices already in place by entities that utilize the aquifer for their water supply. Overdrafting of the aquifer has not occurred and, therefore, additional management is not currently necessary. However, programs that monitor aquifer conditions should be continued to provide data that is essential to evaluate potential problem areas in the future.

Any future high capacity development from the Sparta Aquifer should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage. Also in East Texas, conjunctive use of available surface-water supplies should be explored as an option for meeting future large-capacity demands.

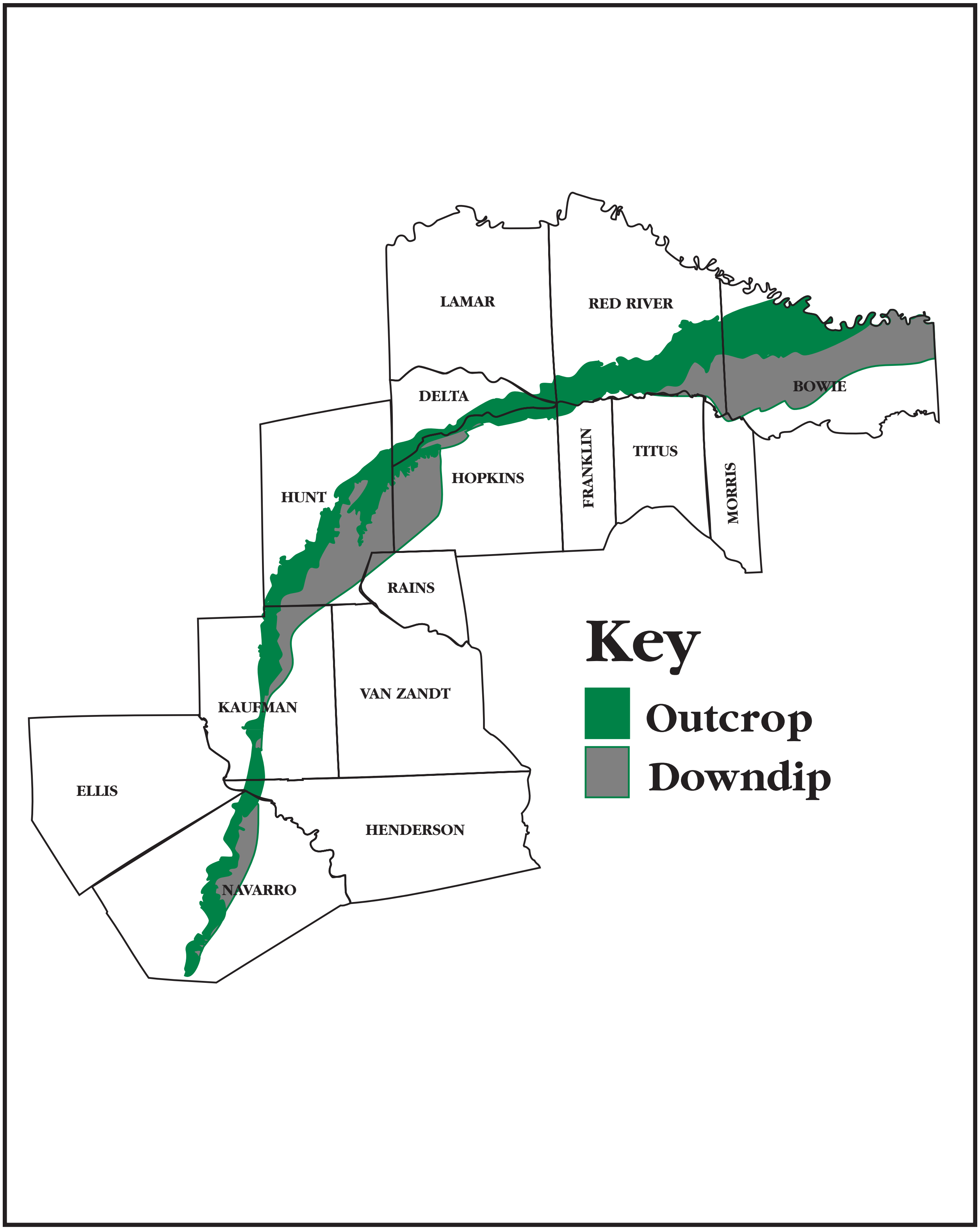

Figure 3-92
Nacatoch Aquifer

3.4.2.11 Nacatoch Aquifer

Location and Use. The Nacatoch Aquifer occurs in a narrow band in northeast Texas and extends eastward into Arkansas and Louisiana (see Figure 3-92). Pumpage from the aquifer totaled 3,484 acre-feet (ac-ft) in 1994, 74 percent of which was used for municipal purposes. The City of Commerce is the largest community pumping from the aquifer for municipal supply, however, significant amounts of water from the Nacatoch are also used for rural domestic and livestock purposes.

Hydrogeology. The Nacatoch Formation, composed of one to three sequences of sands separated by impermeable layers of mudstone or clay, was deposited in the East Texas basin during the Cretaceous Period. The aquifer also includes a hydrologically connected mantle of alluvium up to 80 feet thick where it covers the Nacatoch along major drainage ways. The south and east basinward dip of the formation is interrupted by the Mexia-Talco fault zone, which alters the normal flow direction and adversely affects the chemical quality of the groundwater. Groundwater in this aquifer is usually under artesian conditions except in shallow wells on the outcrop where water-table conditions exist. Well yields are generally low, less than 50 gal/min, and rarely exceed 500 gal/min.

Water Quality. The quality of groundwater in the aquifer is generally alkaline, high in sodium bicarbonate, and soft. Dissolved-solids concentrations increase in the downdip portion of the aquifer and are significantly higher downdip of faults. In areas where the Nacatoch occurs as multiple sand layers, the upper layer contains the best-quality water. The water quality is generally acceptable for most uses, however, the high degree of mineralization precludes its use for irrigation in some areas.

Availability. Annual availability, equivalent to annual effective recharge, for the Nacatoch Aquifer is estimated to be 3,030 ac-ft. Recharge to the aquifer occurs mainly from precipitation on the outcrop. Aquifer water levels have been significantly lowered in some areas as a result of pumpage exceeding the effective recharge. For example, long term municipal pumpage in past years has resulted in water level declines around the City of Commerce in Delta and Hunt counties. Fortunately, these declines have been stabilized with conjunctive use of available surface-water supplies. Although water level data does not indicate any significant declines for the Nacatoch since 1985, aquifer storage will be depleted if future pumpage exceeds effective recharge.

Resource Management. Basic management issues for the Nacatoch Aquifer include minimization or prevention of excessive water-level declines and development of future supply options to meet potential demands. The keys to accomplishing these tasks are to avoid overdrafting the aquifer and to utilize appropriate methods for developing new water supplies.

Water-level and water-quality data do not currently indicate any new areas of quantity or quality problems for the Nacatoch. This can be attributed partly to the relatively equal amount of aquifer pumpage compared to total annual recharge and partly to management practices already in place by entities that utilize the aquifer for their water supply. Where overdrafting of the aquifer has occurred in the past, conjunctive use of surface water has reduced or stabilized water-level declines. Therefore, additional management is not currently necessary. However, programs that monitor aquifer conditions should be continued to provide data that is essential to evaluate potential problem areas in the future.

Future high-capacity development from the Nacatoch Aquifer should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements that provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines and reduce quality problems related to heavy pumpage. Also, conjunctive use of available surface-water supplies should be explored as an option for meeting future large-capacity demands. This will also minimize potential negative impacts on the aquifer system resulting from increased pumpage.

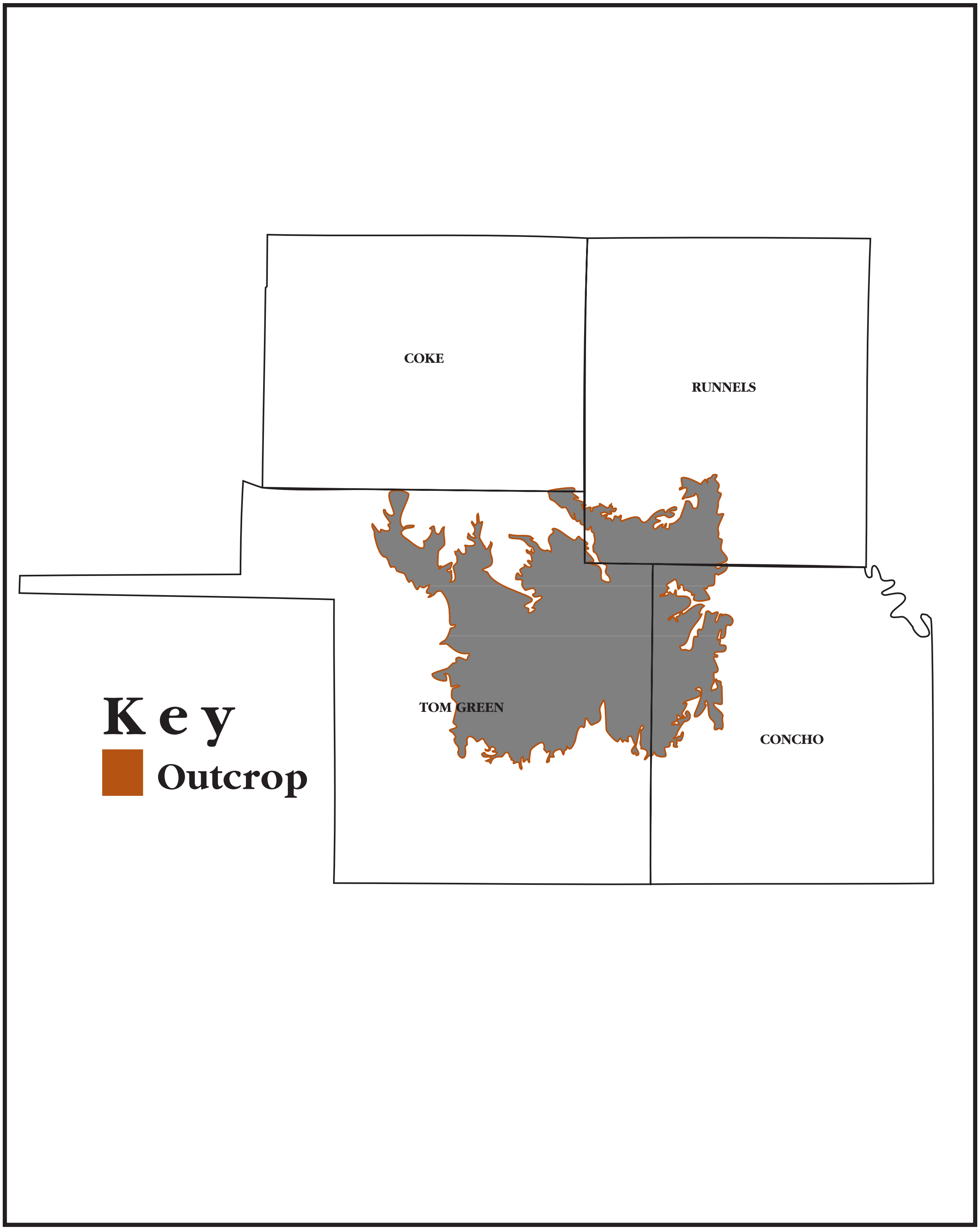

Figure 3-93
Lipan Aquifer

3.4.2.12 Lipan Aquifer

Location and Use. The Lipan Aquifer is located in the Lipan Flats area of eastern Tom Green, western Concho, and southern Runnels counties (see Figure 3-93). Groundwater from the aquifer is used principally for irrigation with very limited amounts used for rural domestic and livestock purposes.

Hydrogeology. The Lipan Aquifer is comprised of saturated alluvial deposits of the Leona Formation of Pleistocene age. Total thickness of the alluvium ranges from a few feet to about 125 feet. Also included in the aquifer are the updip portions of the underlying Choza Formation and Bullwagon Dolomite of Permian age that are hydrologically continuous with the Leona and contain fresh to slightly-saline water. Groundwater in the Lipan Aquifer exists under water-table conditions. It naturally discharges by seepage to the Concho River and by evapotranspiration in areas where the water table is at or near land surface. Saturated thickness of the Leona alluvial sediments ranges from zero to over 100 feet. Well yields generally range from 100 to over 1,000 gal/min.

Water Quality. Groundwater in the Leona Formation ranges from fresh to slightly saline and is very hard. Water in the underlying updip portions of the Choza and Bullwagon tends to be slightly saline. The chemical quality of groundwater in the Lipan Aquifer often does not meet drinking water standards; however, it is generally suitable for irrigation. Nitrates are also a problem. The CRMWD reports that virtually all of the 600 wells they sampled in the past year had nitrate levels in excess of ten parts per million, and some far exceeded those levels.

The quality of the groundwater in the Lipan Aquifer has been affected by two man-induced conditions, oil field activities and irrigation practices. Leaking abandoned oil wells have allowed brine to infiltrate into fresh-water zones in local areas. Seasonal heavy irrigation pumpage has encouraged the upward migration of poorer quality water from deeper zones. Additionally, irrigation return flow has concentrated minerals in the water through evaporation and the leaching of natural salts from the unsaturated zone.

Availability. The calculated availability of water from the Leona part of the aquifer is 130,000 ac-ft which includes a specified volume in storage that is allowed to be depleted and average annual effective recharge. This quantity does not include usable quality water in the underlying Choza and Bullwagon. The actual annual volume of recoverable water has been demonstrated to be variable and dependent on annual recharge.

Recharge to the aquifer primarily results from the infiltration of local precipitation. Lesser amounts of recharge are derived from lateral underflow from adjacent water-bearing formations, seepage from the Tom Green County Water Control and Improvement District No. 1 water conveyance structures, irrigation return flow, and seepage below the three surface-water reservoirs near San Angelo. The average annual effective recharge to the aquifer is estimated to be 60,000 ac-ft. The average annual ground-water availability from the Lipan aquifer is considered to be the water extracted from the aquifer during normal precipitation years for the combined usage in Tom Green, Concho and Runnels counties.

Resource Management. The Lipan-Kickapoo Water Conservation District is the primary resource management entity for the aquifer. The district maintains rules addressing well spacing to control density of pumping wells, well permitting, well construction, and nonpoint source and point source pollution protection. The district has led the way in encouraging conservation management practices and has a water quality and water level monitoring system. It has established public education, research, and abandoned well closure programs and has been very diligent in its resource protection efforts in regards to the man-induced water-quality degradation concerns. The district has submitted a comprehensive management plan with TNRCC.

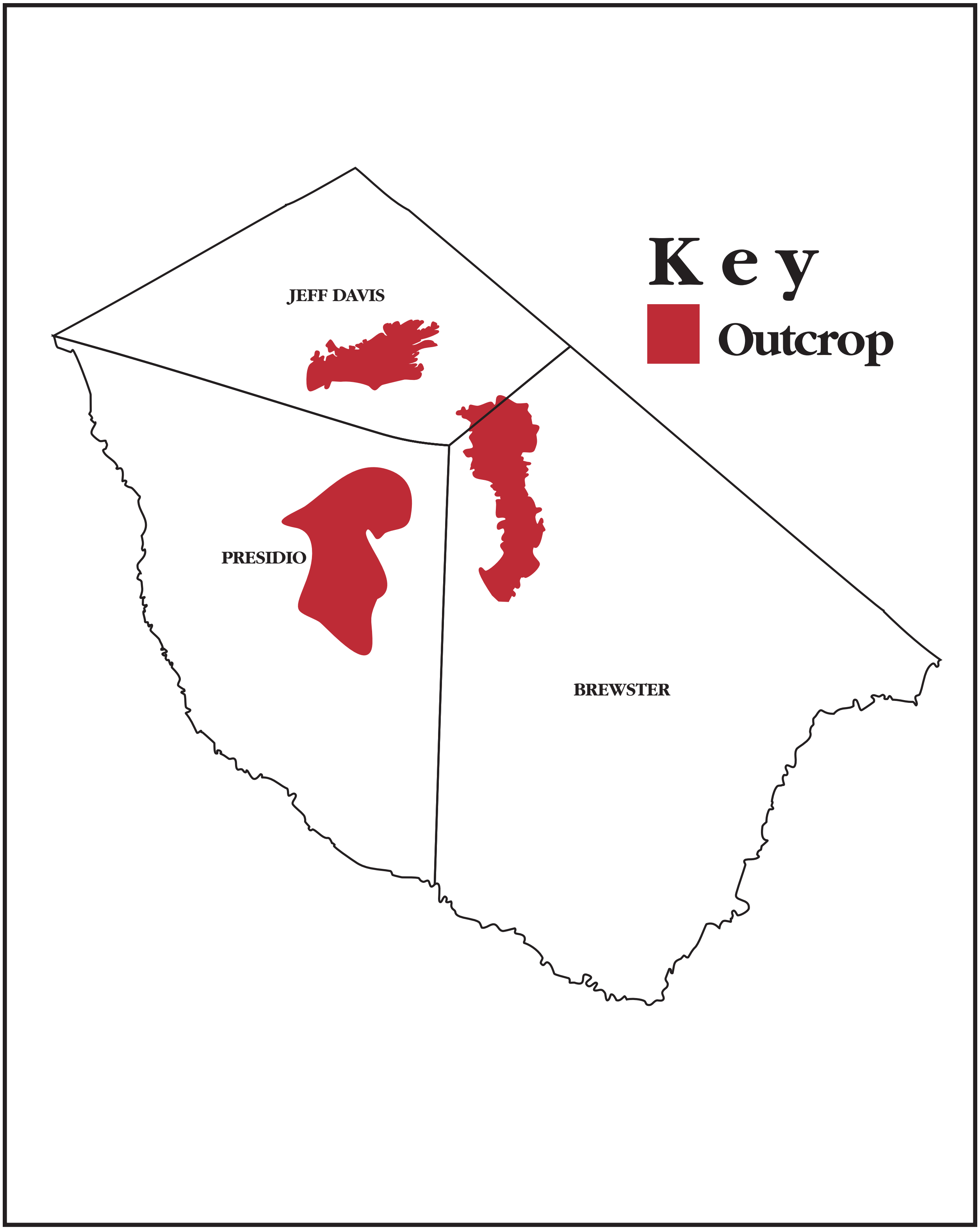

Figure 3-94
Igneous Aquifer

3.4.2.13 Igneous Aquifer

Location and Use. The Igneous Aquifer occurs in three separate areas in the arid Trans-Pecos region of West Texas within Brewster, Presidio, and Jeff Davis counties (see Figure 3-94). In 1994, total aquifer pumpage was 4,291 acre-feet (ac-ft) of which 57 percent was for municipal supplies, primarily for the cities of Alpine, Fort Davis, and Marfa. Water is also produced for domestic, livestock, and mining uses.

Hydrogeology. The aquifer occurs in intrusive and extrusive igneous rocks of Tertiary age which contain useable quantities of good-quality groundwater. Groundwater occurs under water-table conditions in fissures and fractures in lava flows, tuffs, and related igneous rocks. Average thickness is 900 to 1,000 feet.

Water-bearing formations in the Alpine area include the Cottonwood Springs basalt, Sheep Canyon basalt, Crossen Trachyte, and associated alluvium. Of these, the principal water-bearing units are the Cottonwood Springs and Sheep Canyon basalt. Principal water-bearing units in the Marfa area include parts of the Petan basalt and the Tascotal Formation. The aquifer in the Davis Mountains area includes the Barrel Springs Formation and associated alluvium.

Well yields are moderate to large in the Marfa area and small to moderate in the Alpine and Fort Davis areas. Well yields vary due to a wide range in permeability. Lower permeabilities generally occur in the lower sections of the aquifer, and moderately high permeabilities occur in the faulted and fractured upper layers.

Water Quality. Water quality of the Igneous Aquifer is acceptable for municipal and domestic uses. Although dissolved solids, sulfate, and chloride content are within recommended safe drinking-water standards, elevated levels of silica and fluoride that reflect the igneous origin of the rock have been found in some wells.

Availability. The average annual availability, calculated as effective recharge to the Igneous Aquifer near Alpine, Marfa, and the Davis Mountains, is estimated to be about 14,300 ac-ft. This estimate is based on 2.5 percent of the mean annual precipitation. Recharge to the aquifer is from precipitation on the outcrop area and runoff from the adjacent mountains, particularly through permeable alluvial fans overlying the aquifer at the base of the mountains.

Resource Management. The greatest use of water from the Igneous Aquifer is for public supply by the cities of Alpine, Fort Davis, and Marfa. Therefore, management of the aquifer is the principal responsibility of the cities. Increased agricultural water use in the Fort Davis area and potentially in the Marfa area should be monitored for long-term effect. Water shortages occasionally occur in the Alpine water system during prolonged dry periods, thus, the City should establish efficient water use policies and plan for future expanded needs.

The Jeff Davis County UWCD addresses management needs in the Fort Davis part of the Igneous Aquifer. The district is relatively new and only recently adopted rules that address well permitting. A Presidio County district that would have included the Marfa area was legislatively authorized in 1993 has not been confirmed by local election.

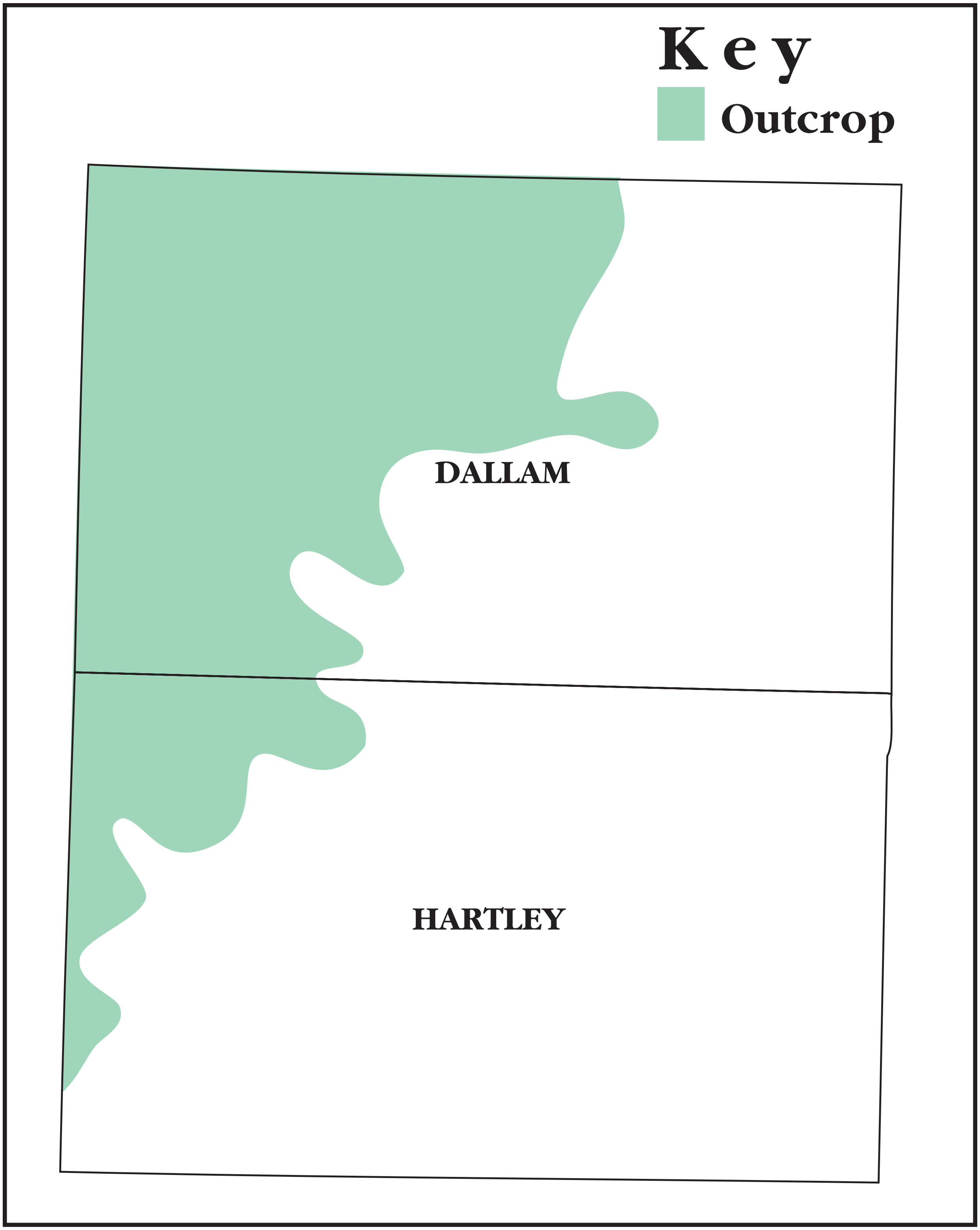

Figure 3-95
Rita Blanca Aquifer

3.4.2.14 Rita Blanca Aquifer

Location and Use. The Rita Blanca Aquifer underlies the Ogallala Formation in western Dallam and Hartley counties in the northwest corner of the Texas Panhandle and makes up a small part of a large aquifer system that extends into Oklahoma, Colorado, and New Mexico (see Figure 3-95). Total pumpage from the Rita Blanca in 1994 was 4,573 acre-feet (ac-ft) of which 98 percent was for irrigation purposes. Texline is the only community that uses the aquifer for municipal supply.

Hydrogeology. Groundwater in the Rita Blanca occurs in sand and gravel formations of Cretaceous and Jurassic age. Flow intervals in the Cretaceous Mesa Rica and Lytle Sandstones are capable of yielding small to large quantities of water while the Romeroville Sandstone of the Dakota Group yields small quantities. Groundwater also occurs in small quantities in the Jurassic Exeter Sandstone and sandy sections of the Morrison Formation. Highest yields of between 600 and 800 gal/min are obtained from wells completed in the Mesa Rica and Lytle Sandstones.

Water Quality. Water quality in the Cretaceous formations is usually fresh, but very hard, with concentrations of dissolved solids less than 300 mg/l. Some wells, however, produce water that is slightly saline, which is unsuitable for irrigating most crops grown in the region. Groundwater produced from wells completed in Jurassic formations within the Rita Blanca Aquifer is moderately to very hard and fresh to slightly saline. Dissolved-solids concentrations range from 400 mg/l to approximately 1,100 mg/l.

Availability. Water available for development from the aquifer on an annual basis consists of a combination of effective recharge and recoverable storage. Recharge to the aquifer in Texas occurs by leakage through the Ogallala and by lateral flow from portions of the aquifer system in New Mexico and Oklahoma. Effective recharge and recoverable storage for the Rita Blanca have not been quantified but, historically, have been included with regional recharge and storage estimates for the Ogallala Aquifer.

Aquifer water-level declines in excess of 50 feet have occurred in some irrigated areas from the early 1970s to the middle 1980s. These declines are the result of pumpage exceeding effective recharge and storage being depleted and are evident by the disappearance of many springs in the northern part of Dallam County that once contributed to the constant flow in creeks that are now ephemeral. Since the middle 1980s, the rate of decline has generally slowed and, in some areas, have reversed and water-level rises have occurred. However, water levels will continue to decline in areas where recharge is exceeded by pumpage of water from the aquifer.

Resource Management. The primary management issue for the Rita Blanca Aquifer is controlling water-level declines in areas of concentrated agricultural pumpage. In some areas, water levels have fallen over 50 feet since the 1970s. The key to accomplishing this task is to avoid overdrafting the aquifer and to utilize appropriate methods when developing additional groundwater supplies.

There are currently two underground water conservation districts in the Rita Blanca Aquifer area, the Dallam County UWCD #1 covering the northern part of Dallam County, and the North Plains Ground Water Conservation District #2 covering Sherman, Hansford, Ochiltree, Lipscomb, and portions of Dallam, Hartley, Moore, and Hutchinson counties. The North Plains district management plan contains well spacing, production, and aquifer depletion regulations. Both districts have filed comprehensive management plans with the TNRCC, however, neither district is currently active in the High Plains Ogallala Area Regional Water Management Plan. At this time no additional aquifer management is necessary for the Rita Blanca Aquifer.

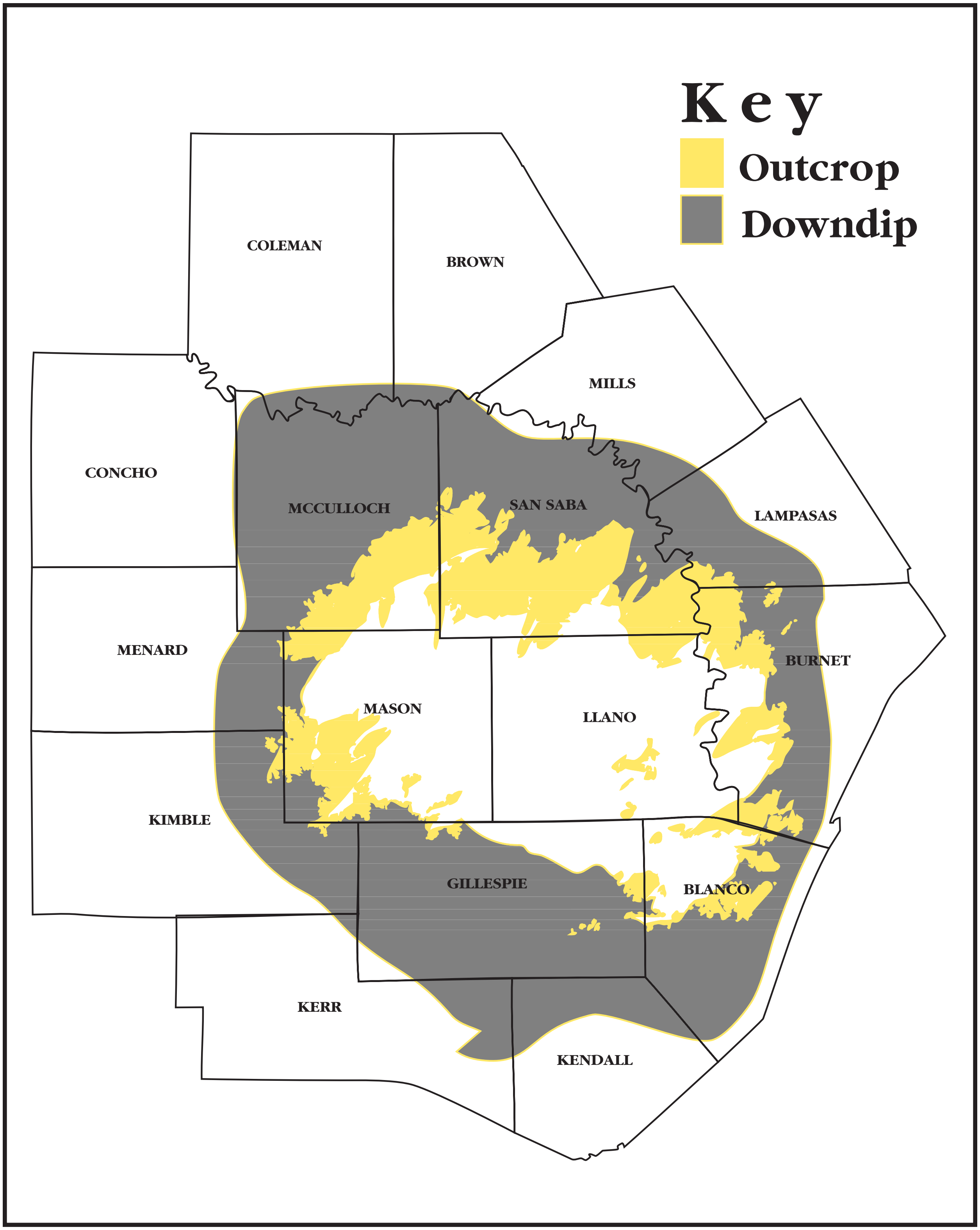

Figure 3-96
Ellenburger-San Saba Aquifer

3.4.2.15 Ellenburger-San Saba Aquifer

Location and Use. The Ellenburger-San Saba Aquifer underlies about 4,000 square miles in parts of 15 counties in the Llano Uplift area of Central Texas (see Figure 3-96). Discontinuous outcrops of the aquifer generally encircle older rocks in the core of the Uplift. The remaining downdip portion contains fresh to slightly-saline water to depths of approximately 3,000 feet below land surface.

In 1994, 61 percent of the 5,518 acre-feet (ac-ft) of water pumped from the aquifer was used for municipal supplies including the Cities of Fredericksburg, Johnson City, Bertram, and Burnet. Most of the deep municipal wells which supply the City of Brady also produce an unknown amount of water from the Ellenburger-San Saba sequence of rocks. A large portion of water flowing from San Saba Springs, which is the water supply for the City of San Saba, is believed to be from the Ellenburger-San Saba and Marble Falls aquifers.

Hydrogeology. The aquifer occurs in the various limestone and dolomite facies of the San Saba Member of the Wilberns Formation of Late Cambrian age, and in the Honeycut, Gorman, and Tanyard Formations of the Ellenburger Group of Early Ordovician age. In the southeastern portion of the aquifer, these units have a combined maximum thickness of about 2,700 feet while in the northeastern portion of the aquifer, the combined maximum thickness is about 1,100 feet. In some areas, where the overlying beds are thin or absent, the Ellenburger-San Saba Aquifer may be hydrologically connected to the Marble Falls Aquifer.

Groundwater in the aquifer is mostly under artesian pressure, even in much of the outcrop areas where relatively impermeable carbonate rocks of the thick Ellenburger-San Saba sequence function as confining layers. Local and regional block faulting has significantly compartmentalized the Ellenburger-San Saba. Dissolution along such faulting and related fractures has formed various-sized cavities which are the major water-bearing features of the aquifer.

The maximum yields of large capacity wells used for municipal and irrigation purposes generally range between 200 and 600 gal/min. Most other wells generally yield less than 100 gal/min. The anisotropic nature of the aquifer makes it difficult to obtain desired well yields in some areas, particularly in Fredericksburg and Bertram.

Water Quality. Water produced from the aquifer has a range in dissolved solids between 200 and 3,000 mg/l, but is usually less than 1,000 mg/l. The quality of water, however, deteriorates rapidly away from outcrop areas. Approximately 20 miles or more downdip from the outcrop, water is typically unsuitable for most uses. In the northwestern portion of the aquifer, water quality deterioration increases with depth due to excess sodium and chloride. In the southeastern portion, deterioration is due to increases in calcium and sulfate. All of the groundwater produced from the aquifer is inherently hard. Some wells in the Pedernales River Valley between Fredericksburg and Johnson City produce water from the aquifer with nitrate concentrations exceeding safe drinking- water standards.

Availability. Approximately 20 million ac-ft of fresh to slightly-saline groundwater is estimated to be in storage in the aquifer. Recoverable storage above a depth of 400 feet is estimated to be 8 million ac-ft. The remaining 12 million ac-ft in storage below this depth is only partly recoverable by wells.

An estimated 29,400 ac-ft of water is being discharged annually from the aquifer in its outcrop areas and represents the average annual effective recharge to the aquifer. This amount was determined from spring flow measurements and equates to about 2 percent of the mean annual precipitation on the outcrop. Where the aquifer is overlain by saturated basal sands and sandstones of the Trinity Aquifer system, the Ellenburger-San Saba Aquifer also receives a significant, but unknown, amount of recharge.

Resource Management. There are currently five underground water conservation districts in the Ellenberger-San Saba Aquifer area. These districts include: the Hickory UWCD #1 covering parts of Concho, Kimble, Mason, McCulloch, Menard, and San Saba counties; the Fox Crossing Water District in Mills County; the Hill Country UWCD in Gillespie County; the Saratoga UWCD in Lampasas County; and the Headwaters UWCD in Kerr County. The Hickory, Hill Country, and Headwaters districts have filed comprehensive management plans with the TNRCC. Plans for the Hickory and Hill Country districts contain guidelines for aquifer pumpage. The plan for the Hickory district also sets limits on maximum allowable water-level declines while the plan for the Hill Country district sets well spacing requirements.

Water-level data do not indicate any areas of quantity problems for the Ellenberger-San Saba. This can be attributed to the relatively small amount of pumpage compared to the annual effective recharge and recoverable storage. Even though overdrafting of the aquifer has not occurred, programs that monitor aquifer conditions should be continued to provide data to evaluate potential problem areas in the future.

At this time no additional aquifer management is necessary for the Ellenberger-San Saba Aquifer. However, any future high capacity development should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines related to heavy pumpage. Also, conjunctive use of available surface-water supplies should be explored as an option for meeting future large-capacity demands. This will minimize potential negative impacts on the aquifer system resulting from increased pumpage.

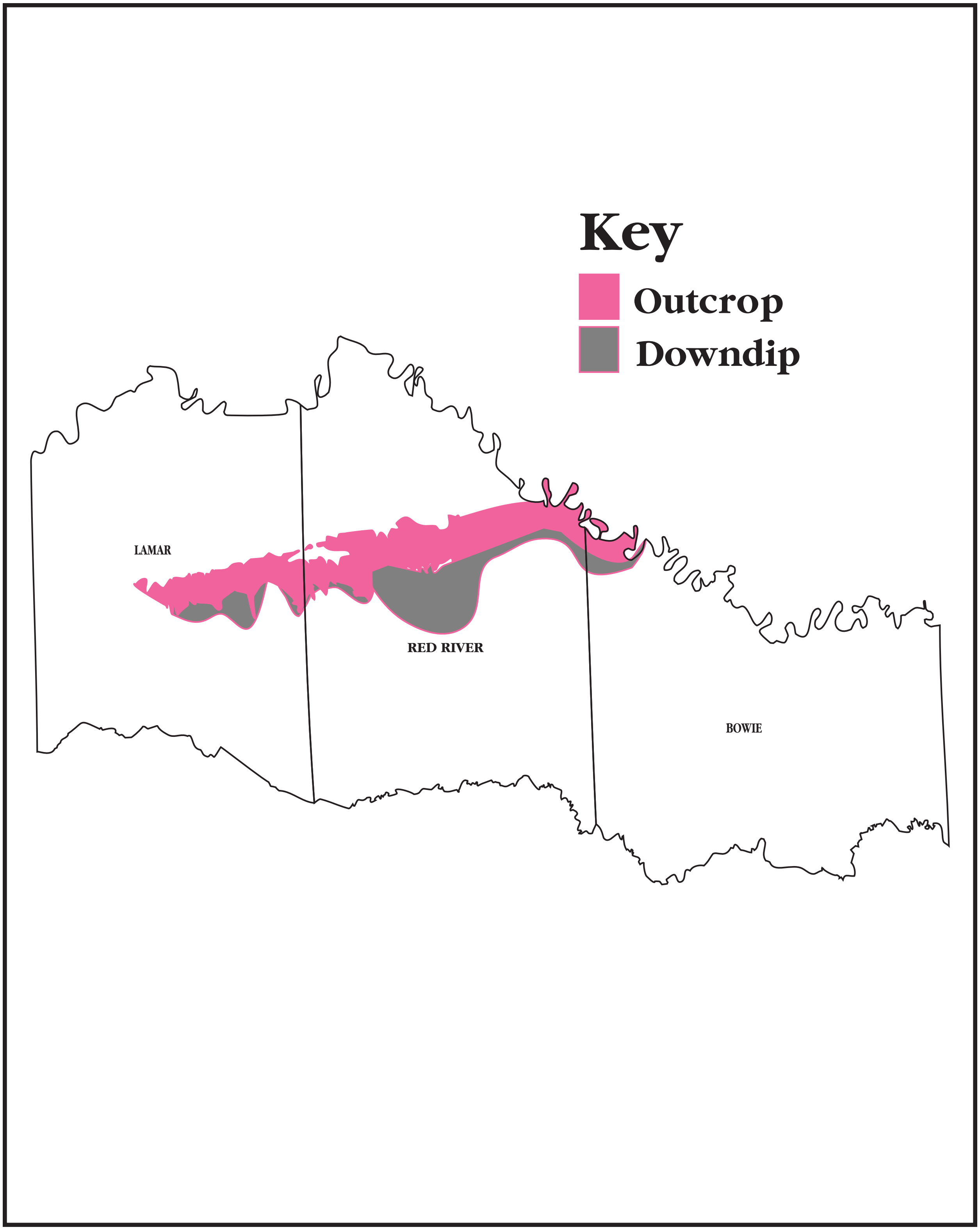

Figure 3-97
Blossom Aquifer

3.4.2.16 Blossom Aquifer

Location and Use. The Blossom Aquifer occupies a narrow east-west band in parts of Bowie, Red River, and Lamar counties in the northeast corner of the State (see Figure 3-97). In 1994, municipal pumpage accounted for 80 percent of the total pumpage of 986 acre-feet (ac-ft) from the Blossom. The majority of groundwater pumped for municipal use is provided by the City of Clarksville and the Red River Water Supply Corporation.

Hydrogeology. The Blossom Sand formation consists of alternating sequences of sand and clay deposited during the Cretaceous Period along the northern edge of the East Texas basin. In places it attains a thickness of 400 feet, although no more than 29 percent of this thickness consists of water-bearing sand.

The Blossom Aquifer yields water in small to moderate amounts over a limited area on and south of the outcrop area. Most of the water in storage is under water-table conditions. The largest known yields of 650 gal/min occur in Red River County where production is greatest. Production decreases in the western half of the aquifer where yields of 35 to 85 gal/min are more typical.

Water Quality. Wells producing fresh to slightly-saline water are located on the formation outcrop in northwestern Bowie and eastern Red River counties and in the City of Clarksville. The groundwater is generally soft, slightly alkaline and, in some areas, high in sodium, bicarbonate, and iron. Water quality, although not acceptable for irrigation due to high mineralization, is generally acceptable for most non-industrial uses.

Availability. Annual availability for the Blossom Aquifer is equal to the annual effective recharge which occurs mainly through infiltration of rainfall on the outcrop. Because deep loamy soils containing significant amounts of clay overlie most of the Blossom outcrop area, only one-half of one percent of the mean annual precipitation that falls on the sandy rechargeable portion of the formation outcrop is considered effective recharge. The average annual effective recharge for the aquifer is estimated to be 811 ac-ft.

Pumpage near the City of Clarksville has caused significant historical water-level declines. However, since 1988 when the City began conjunctive use of surface and groundwater, water levels have risen nearly 100 feet. Because of accessibility to public water supply systems (including surface water), many individual wells have been abandoned resulting in water level rises in other areas. Water-level data do not indicate any significant declines in the Blossom since 1985, however, aquifer storage will again be depleted if future pumpage exceeds effective recharge.

Resource Management. Basic management issues for the Blossom Aquifer include minimization or prevention of excessive water-level declines and development of future supply options to meet potential demands. The keys to accomplishing these tasks are to avoid overdrafting the aquifer and to utilize appropriate methods for developing new water supplies.

Water-level and water-quality data do not currently indicate any new areas of quantity or quality problems for the Blossom. This can be attributed to the management practices already in place by entities that use the aquifer for their water supply. Where overdrafting of the aquifer has occurred in the past, conjunctive use of surface water has stabilized or reversed water-level declines. Therefore, additional management is not currently necessary. However, programs that monitor aquifer conditions should be continued to provide data that is essential to evaluate potential problem areas in the future.

Future high-capacity development from the Blossom Aquifer should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements that provide the most efficient well possible. Optimal pumping programs will help minimize long-term water-level declines and reduce quality problems related to heavy pumpage. Also, conjunctive use of available surface-water supplies should be explored as an option for meeting future large-capacity demands. This will also minimize potential negative impacts on the aquifer system resulting from increased pumpage.

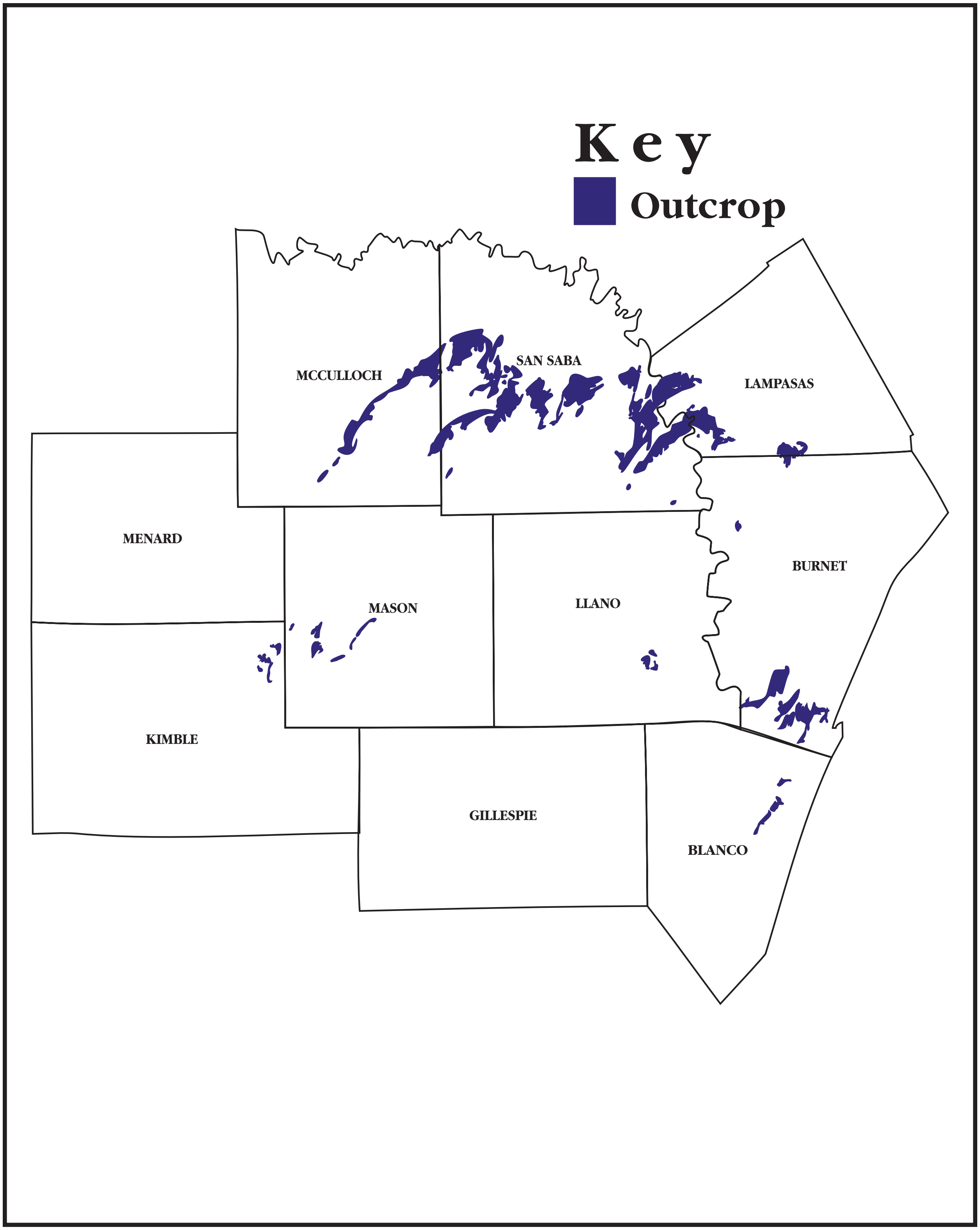

Figure 3-98
Marble Falls Aquifer

3.4.2.17 Marble Falls Aquifer

Location and Use. The Marble Falls Aquifer occurs in several separated outcrops, primarily along the northern and eastern flanks of the Llano Uplift region of Central Texas (see Figure 3-98). The downdip portion of the aquifer is of unknown extent. It provides water to parts of McCulloch, San Saba, Lampasas, Burnet, and Blanco counties, and to smaller parts of Kimble, Llano, and Mason counties. In 1994, a total of 1,524 acre-feet (ac-ft) of water was pumped from the aquifer with 1,051 ac-ft, or 69 percent, for municipal needs. San Saba and Rochelle are the two largest communities that withdraw water from the aquifer for public supply use. Smaller amounts of water are also used for rural domestic supplies, watering of livestock, and irrigation.

Hydrogeology. Groundwater occurs in fractures, solution cavities, and channels in the limestones of the Marble Falls Formation of the Pennsylvanian Bend Group. Maximum thickness of the formation is 600 feet. Numerous large springs issue from the aquifer and provide a significant part of the baseflow to the San Saba River in McCulloch and San Saba counties and to the Colorado River in San Saba and Lampasas counties. The aquifer contributes a significant portion of the flow at San Saba Springs, the source of drinking water for the City of San Saba. Where underlying beds are thin or absent, the Marble Falls and Ellenburger-San Saba aquifers may be hydrologically connected. Wells completed in these limestones have been reported to yield as much as 2,000 gal/min, however, most wells produce substantially less due to the anisotropic condition of the aquifer.

Water Quality. The quality of water produced from the aquifer is generally suitable for most purposes. However, wells in Blanco County have produced water having nitrate concentrations in excess of drinking water standards. The downdip artesian portion of the aquifer in most areas is not extensive and water becomes significantly mineralized within relatively short distances downdip from the outcrop recharge area. Because the fractured and dissolutioned limestones of the Marble Falls are relatively shallow, the aquifer is quite susceptible to pollution by the activities of man.

Availability. The quantity of groundwater available as annual effective recharge has been estimated to be 26,400 ac-ft based on spring flow data. This amount equates to approximately 5 percent of the mean annual precipitation on the outcrop of the aquifer.

Resource Management. There are currently two underground water conservation districts in the Marble Falls Aquifer area. These districts include the Hickory UWCD #1 covering parts of Concho, Kimble, Mason, McCulloch, Menard, and San Saba counties, and the Saratoga UWCD in Lampasas County. The Hickory UWCD #1 has filed a comprehensive management plan with the TNRCC. The plan contains guidelines for aquifer pumpage and also sets limits on maximum allowable water-level declines.

Water-level data do not indicate any areas of quantity problems for the Marble Falls. This can be attributed to the relatively small amount of pumpage compared to the annual effective recharge. Even though overdrafting of the aquifer has not occurred, programs that monitor aquifer conditions should be continued to provide data to evaluate potential problem areas in the future.

At this time no additional aquifer management is necessary for the Marble Falls Aquifer. However, any future high capacity development should incorporate sound investigative procedures. Well sites should be determined based on test holes and wells should be constructed in a manner conforming to standards and spacing requirements to provide the most efficient well possible. Optimal pumping programs will help to minimize long-term water-level declines related to heavy pumpage. Also, safeguards should be instituted to ensure future development and associated activities do not place the aquifer at risk of pollution.

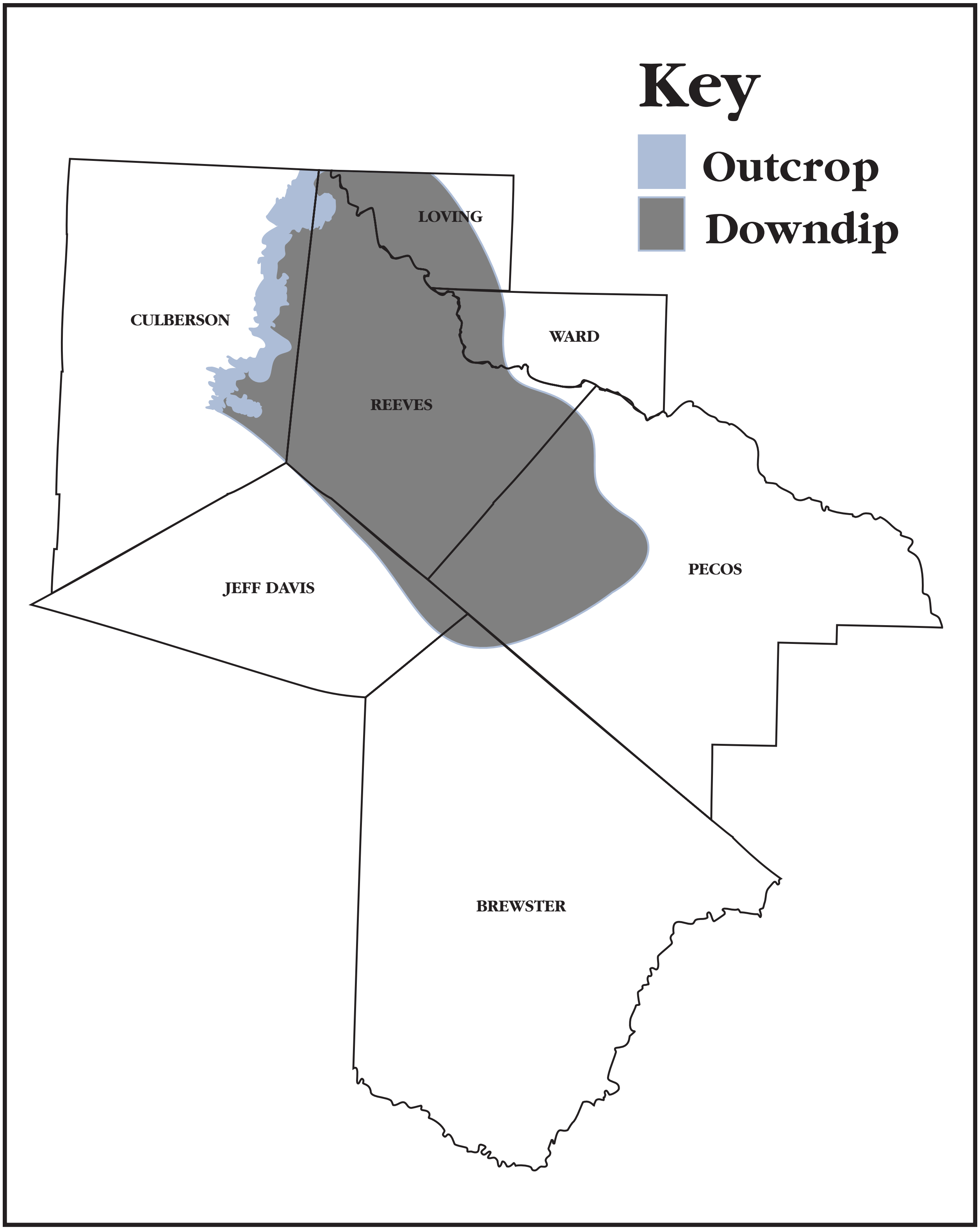

Figure 3-99
Rustler Aquifer

3.4.2.18 Rustler Aquifer

Location and Use. The Rustler Aquifer crops out in a north-south band in eastern Culberson County in the Trans-Pecos region of West Texas and extends downdip into Reeves, Loving, Ward, and Pecos counties (see Figure 3-99). In 1994, total aquifer pumpage of 1,486 acre-feet (ac-ft) was used for irrigation, livestock, and water-flooding operations in oil-producing areas. High dissolved-solids concentrations render water from the Rustler unsuitable for human consumption.

Hydrogeology. Dolomite, limestone, and gypsum beds of the Rustler Formation were deposited in the Delaware basin during the Permian and reach a maximum thickness of 500 feet. Water is produced primarily from highly permeable solution channels, caverns, and collapsed breccia zones.

The aquifer exists under water-table conditions where it crops out in Culberson County and under artesian conditions throughout the remainder of its extent. Except where the porosity is well developed in the solution zones in the formation, storage capacity is relatively low. Acidizing wells usually results in yields ranging from 300 to 1,000 gal/min.

Water Quality. Groundwater from the Rustler Aquifer is generally unsuitable for human consumption because it contains from 2,000 to 6,000 mg/l dissolved solids. However, the water is suitable for other purposes including irrigation.

The dissolved-solids concentration increases down gradient, eastward into the basin, with a shift from sulfate to chloride as the predominant anion. Highly mineralized groundwater may be caused by the dissolution of evaporites within the Rustler due to local ground-water flow and/or mixing with brine which has migrated upward from saline aquifers underlying the Rustler. An area of greater than 10,000 mg/l dissolved solids occurs around the City of Pecos in Reeves County.

Less mineralized water, with a dissolved-solids content of less than 1,000 mg/l, occurs only in one area within the outcrop in southern Culberson County. An area of slightly-saline water (containing less than 3000 mg/l dissolved solids) in eastern Loving County corresponds to a portion of the aquifer that is relatively close to the surface and may be the result of recharge which has infiltrated through the overlying permeable cover.

Availability. The average annual ground-water availability from the aquifer as effective recharge is conservatively estimated to be 4,000 ac-ft. Recharge from the infiltration of precipitation on the outcrop moves eastward into the basin and may migrate upward into the overlying Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium. Due to limited pumpage from the Rustler, no regional water-level declines are evident.

Resource Management. A small portion of the southwestern extent of the Rustler is covered by the Jeff Davis County UWCD. At the present time, the district has not filed a comprehensive management plan with the TNRCC. Considering the amount and use of water from the aquifer, regional management of the resource is appropriately maintained by individual landowners with no additional measures being necessary at this time.

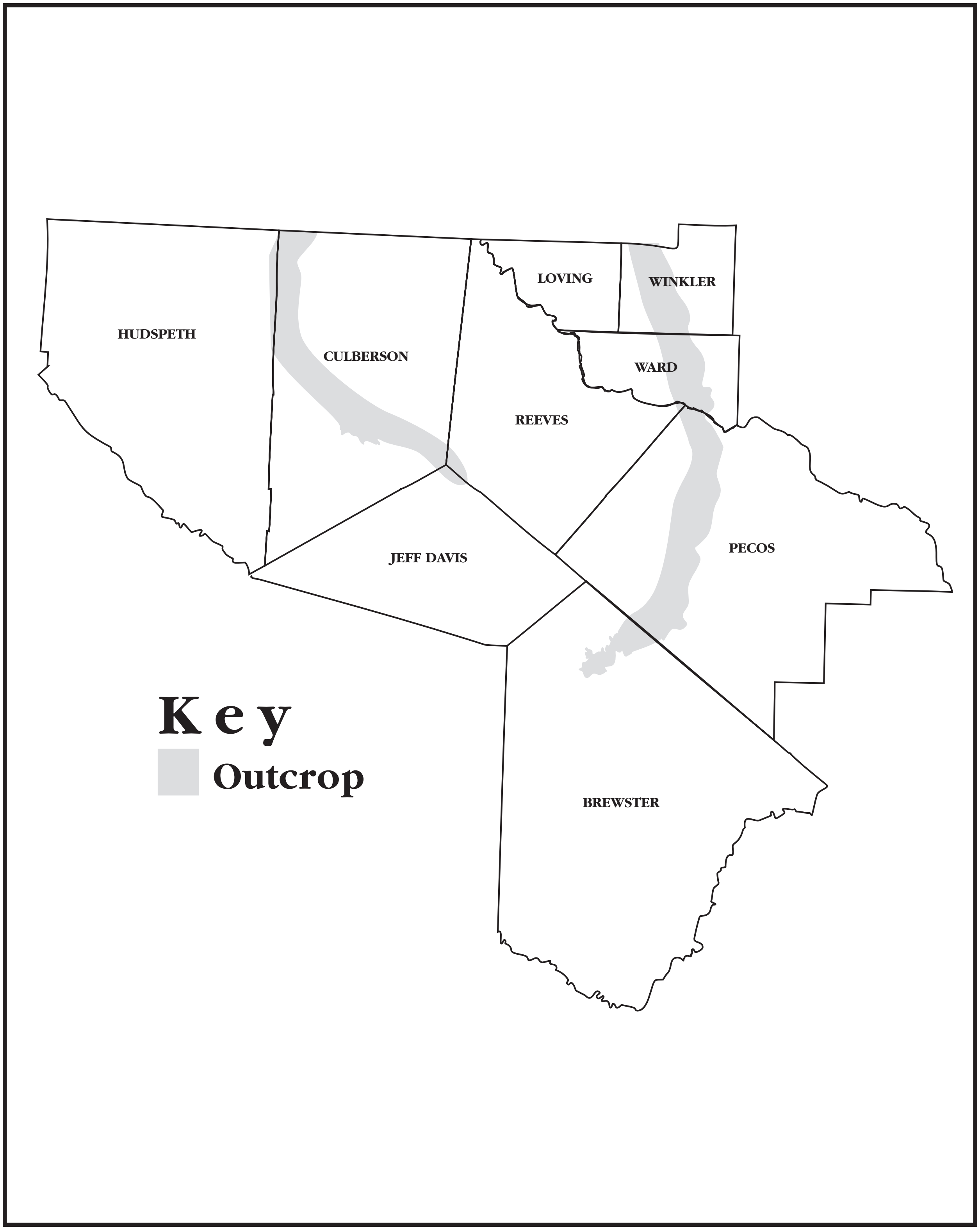

Figure 3-100
Capitan Reef Complex Aquifer

3.4.2.19 Capitan Reef Complex Aquifer

Location and Use. The Capitan Reef formed along the margins of the Delaware basin, an embayment covered by a shallow Permian sea. In Texas, the reef parallels the western and eastern edges of the basin in two arcuate strips 10 to 14 miles wide and is exposed in the Guadalupe, Apache, and Glass mountains (see Figure 3-100). Elsewhere, the reef occurs in the subsurface. The reef extends northward into New Mexico where it provides abundant fresh water to the City of Carlsbad. Most of the groundwater pumped from the aquifer in Texas is used for oil reservoir water-flooding operations in Ward and Winkler counties and agricultural irrigation in Pecos, Culberson, and Hudspeth counties. Total recorded pumpage from the aquifer in 1994 was 2,832 acre-feet (ac-ft), however, a significant amount of pumpage for water-flooding operations is unaccounted.

Hydrogeology. The aquifer is composed of up to approximately 2,000 feet of massive, vuggy to cavernous dolomite and limestone, bedded limestone, and reef talus. Water-bearing formations include the Capitan Limestone, Goat Seep Limestone, and most of the Carlsbad facies of the Artesia Group which includes the Grayburg, Queen, Seven Rivers, Yates, and Tansill formations. Yields of wells commonly are more than 1,000 gal/min in Culberson and Hudspeth counties; while in the Apache Mountains area, limited data indicate that yields are as high as 400 gal/min. One well in northern Pecos County flows at a rate of about 1,000 gal/min, and wells in Ward and Winkler counties, likewise, yield large quantities.

Water Quality. The aquifer generally contains water of marginal quality, with most wells yielding water with total dissolved solids ranging between 1,000 and 3,000 mg/l. High salt concentrations in some areas are probably caused by migration of brine water injected for secondary oil recovery. Freshest quality water is located near areas of recharge where the reef is exposed at the surface in the three mountain ranges. Many of the wells that exist in the aquifer are quite old and their casing is potentially in a state of deterioration. Artesian conditions in these wells allow water from the aquifer to migrate through casing ruptures and commingle with fresh-water zones.

Availability. Recharge to the aquifer occurs by precipitation and infiltration of surface water directly into cavernous reef deposits in outcrop areas in the Guadalupe Mountains along the Texas and New Mexico border, the Apache Mountains in southern Culberson County, and the Glass Mountains in Brewster and Pecos counties. The average annual ground-water availability from the aquifer has been estimated to be 12,500 ac-ft as effective recharge. In the Culberson County area south of the Guadalupe Mountains, 375,000 ac-ft of water is estimated to be recoverable from storage. In the Apache Mountains area, 10,000 ac-ft is estimated to be available. Elsewhere in Pecos, Ward, and Winkler counties, undetermined amounts of groundwater occur in storage.

Resource Management. Management issues for the Capitan Reef Complex Aquifer include prevention of excessive water-level declines and water-quality deterioration. Most of the pumpage from this aquifer is currently by a limited number of agricultural and industrial users. Management requirements are thus dictated by the economic value that the water from the aquifer brings for its intended use. The cost required to lift water from the aquifer for irrigation in Culberson and Hudspeth counties, will probably prevent the aquifer from ever being depleted. Likewise, the generally poor quality of the aquifer in Ward and Winkler counties limits the aquifer to specific quality-tolerant industrial uses.

The eastern extent of the aquifer occurs in a region that was evaluated during the critical area process, however, the primary study element was the overlying Cenozoic Pecos Alluvium Aquifer. Although water-related problems were found to exist, the area was not declared critical by the TNRCC. There are currently no underground water conservation districts located in areas overlying the Capitan Reef Complex Aquifer. Local attempts to create a district in Winkler County have failed.

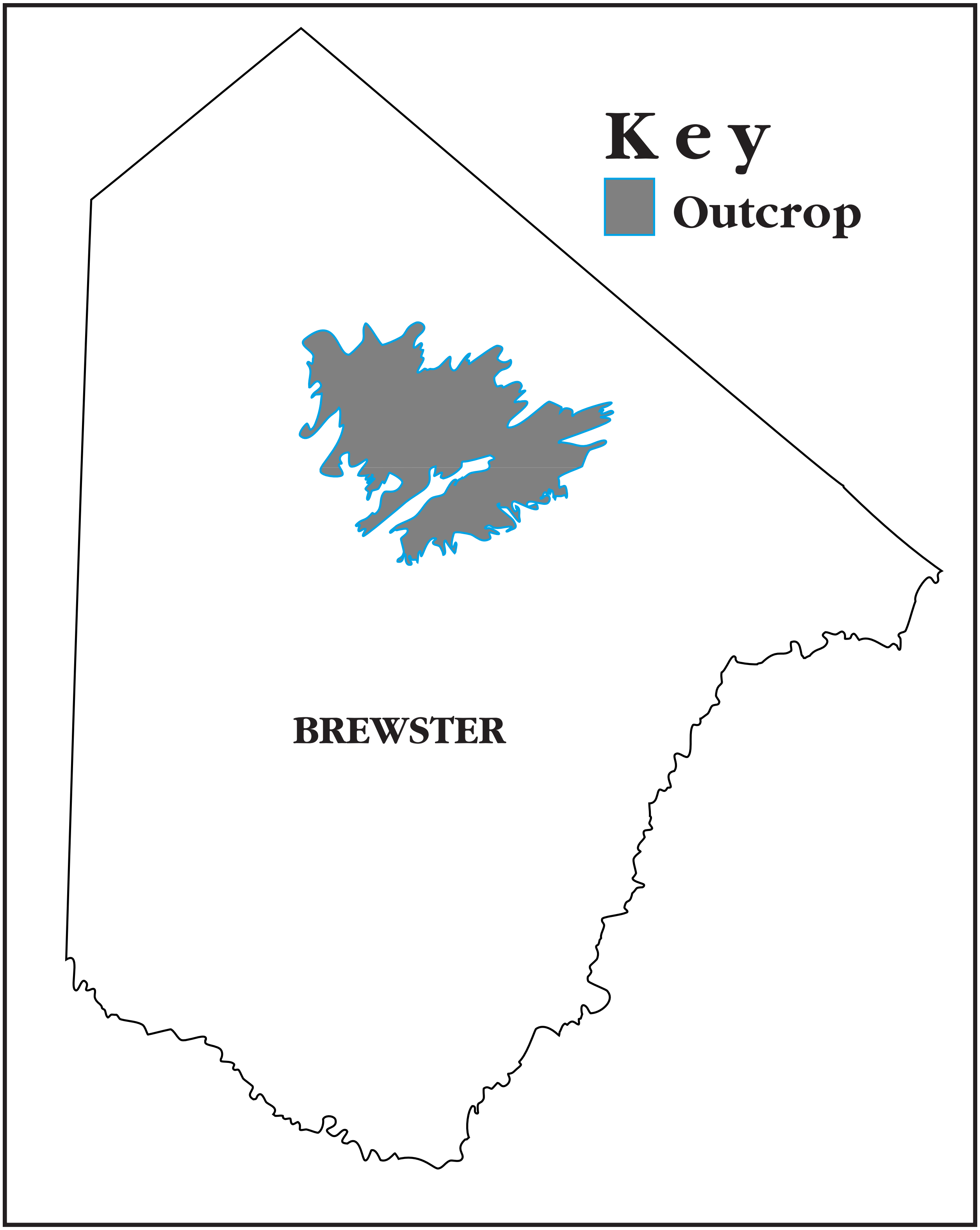

Figure 3-101
Marathon Aquifer

3.4.2.20 Marathon Aquifer

Location and Use. The Marathon Aquifer occurs entirely within the north-central portion of Brewster County in west Texas (see Figure 3-101). It is utilized primarily for municipal supply by the City of Marathon and for domestic and stock purposes. Total aquifer pumpage in 1994 was 117 acre-feet (ac-ft).

Hydrogeology. The Marathon Aquifer is contained within the Gaptank, Dimple, Tesnus, Caballos, Maraviallas, Fort Pena, and Marathon Limestone formations deposited during the Early Paleozoic Era. Of these, the Marathon Limestone is the most productive unit. Water in the Marathon is generally under water-table conditions and occurs in crevices, joints, and cavities associated with the complex folding and faulting that characterizes the Marathon Uplift region. Total aquifer thickness ranges from 350 to about 900 feet. Most wells are less than 250 feet deep and yield from less than 10 to more than 300 gal/min with the greatest yields occurring where aquifer formations are most fractured and faulted. Many of the shallow wells in the region actually produce from alluvial deposits that cover portions of the rock formations.

Water Quality. Water from the Marathon Aquifer, although hard, is typically of good quality. Dissolved solids usually range from 500 to 1,000 mg/l.

Availability. Annual availability of groundwater from the Marathon Aquifer is calculated as effective recharge derived from precipitation that falls on the outcrop and from runoff that flows off the surrounding highlands. Annual effective recharge is approximately 18,300 ac-ft which is equivalent to 2.5 percent of the mean annual precipitation.

Resource Management. The Marathon region is sparsely populated, and there is no expectation of major increases in water demand in the future. To date, no significant aquifer water-level declines have been noted. Therefore, additional aquifer management beyond what is currently in place at the local level is not necessary at this time. Even though overdrafting of the aquifer has not occurred, aquifer conditions should continue to be monitored for potential problems in the future.