Chapter 8

The Lipan Aquifer

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Introduction

The Lipan aquifer is classified as a minor aquifer by the Texas Water Development Board (TWDB) (Ashworth and Hopkins, 1995) and covers parts of three counties in west-central Texas (Figure 8-1). The Lipan aquifer comprises saturated alluvial deposits and the updip portions of the underlying Permian age limestones, dolomites, and shales that are hydrologically connected to the alluvium. Groundwater in the Lipan aquifer naturally discharges to the Concho River and by evapotranspiration in areas where the water table is at or near land surface. The aquifer contains fresh to moderately saline water.

The Lipan aquifer provides water to support irrigated farming as well as a small amount of groundwater that is used for livestock, municipal, rural domestic supply, and manufacturing. The heaviest groundwater usage from the aquifer has been in the Lipan Flats agricultural area of eastern Tom Green and western Concho counties. In the 1950s, row irrigation began in the Lipan Flats area and increased moderately until the mid to late 1980s. In the late 1980s, pivot irrigation systems came into use and groundwater pumping for irrigation increased from about 15,000 to over 70,000 acre-feet (AFY) per year by the late 1990s.

Historical well records show a dramatic increase in the number of irrigation wells in the Lipan aquifer during the 1990s. The number of irrigation wells increased from approximately 200 in 1990 to over 1,000 wells by the year 2000. Due to drought and heavy irrigation pumpage in the late 1990s, water levels decreased significantly in some areas and pumps in irrigation wells could not be run through the entire irrigation season. Wells in other areas continue to produce through the irrigation season, but at a reduced pumping rate.

General Description

West-central Texas is generally characterized by hot, dry summers and moderate winters. There is generally more precipitation in the spring and fall. However, summertime

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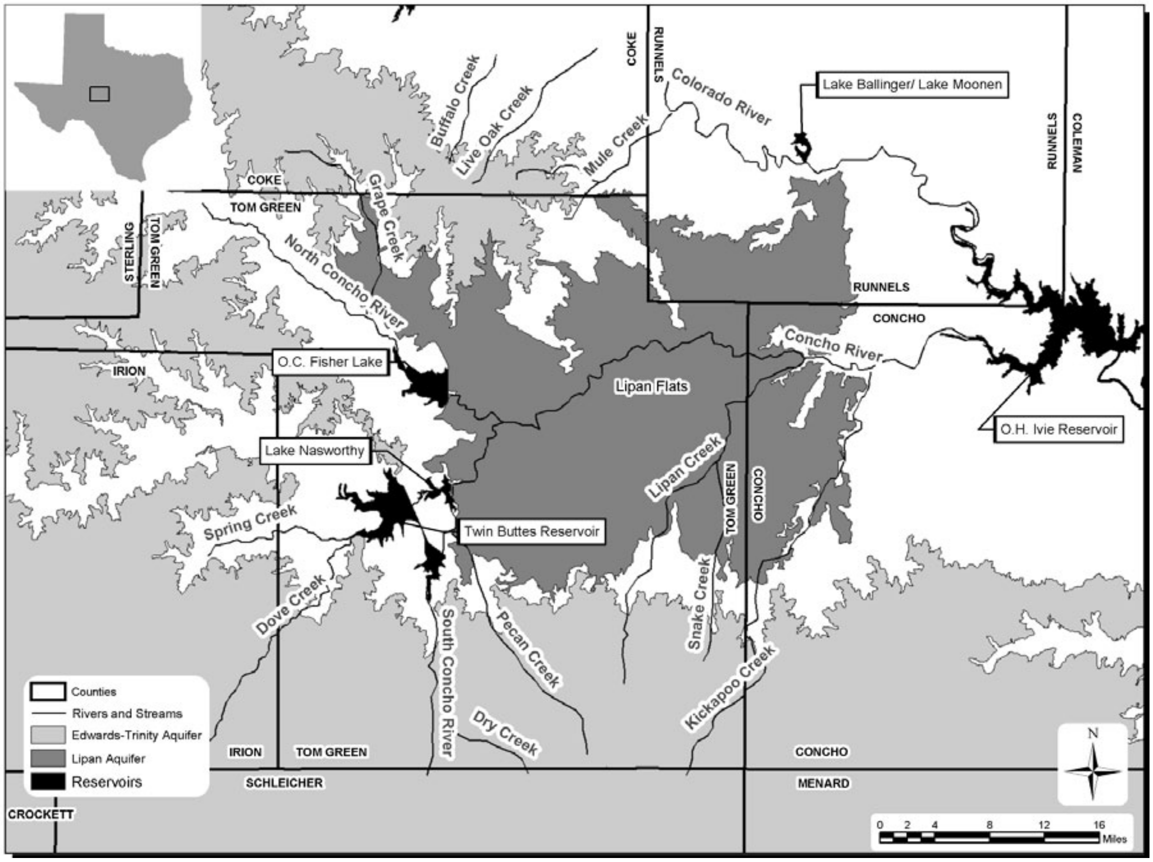

Figure 8-1: Location of the Lipan Aquifer.

thunderstorms can produce locally large amounts of rainfall in a short amount of time. San Angelo, the largest city near the aquifer, has an average annual rainfall of about 20.5 inches. Available records indicate that yearly precipitation can vary from 12 to 38 inches per year (Figure 8-2). On the eastern side of the aquifer, the precipitation averages about 25 inches per year and decreases to about 20 inches per year on the western side. The average annual lake evaporation is about 66 inches per year.

Ground surface elevations vary across the aquifer from about 2,500 feet above mean sea level (AMSL) in the west and north to about 1,500 feet AMSL in the east (Figure 8-3). The Lipan Flats, a broad, flat plain dominated by farmland, lies in the center of the Lipan aquifer. Cotton, grain sorghum and wheat are the main crops grown in the Lipan Flats. Gently sloping hills, entrenched by seasonal spring fed streams, rise up from the Lipan Flats to the north, west, and south. Mesquite, juniper, and grasslands make up a large portion of the vegetation in the rangeland areas, which are mainly used for raising cattle, sheep, and goats. The Lipan aquifer lies partially in the physiographic area known as the Central Texas Plains province and partially in the Edwards Plateau province of Texas. The North, South, and Middle Concho watersheds all drain to the San Angelo area to form the Concho River, which dissects the Lipan Flats area and joins the Colorado River

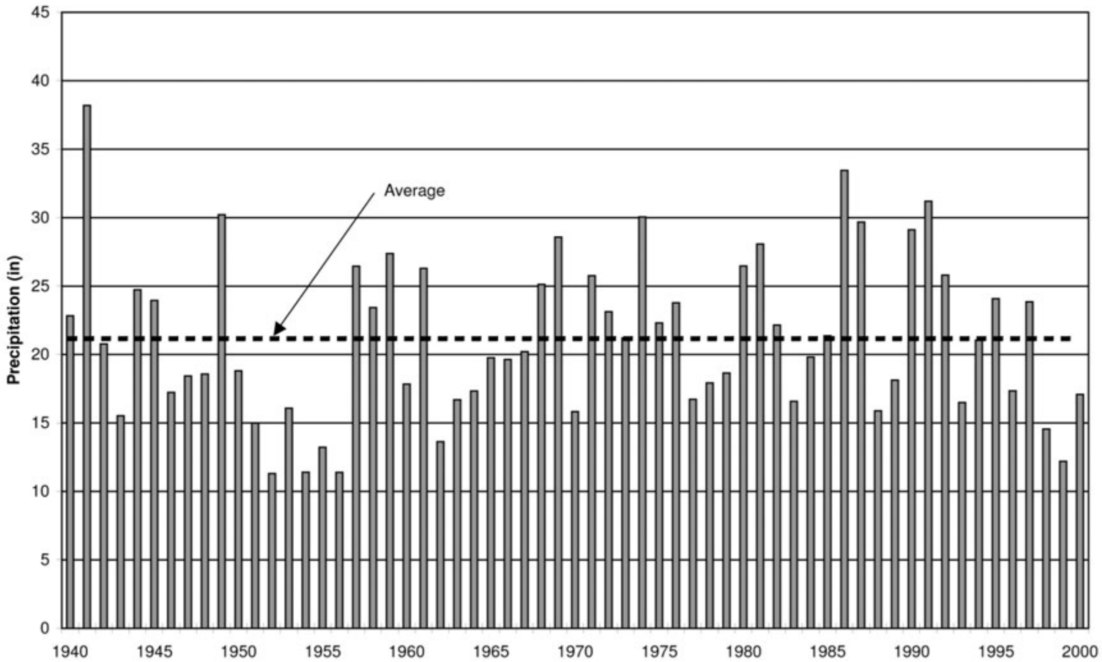

Figure 8-2: Historical precipitation.

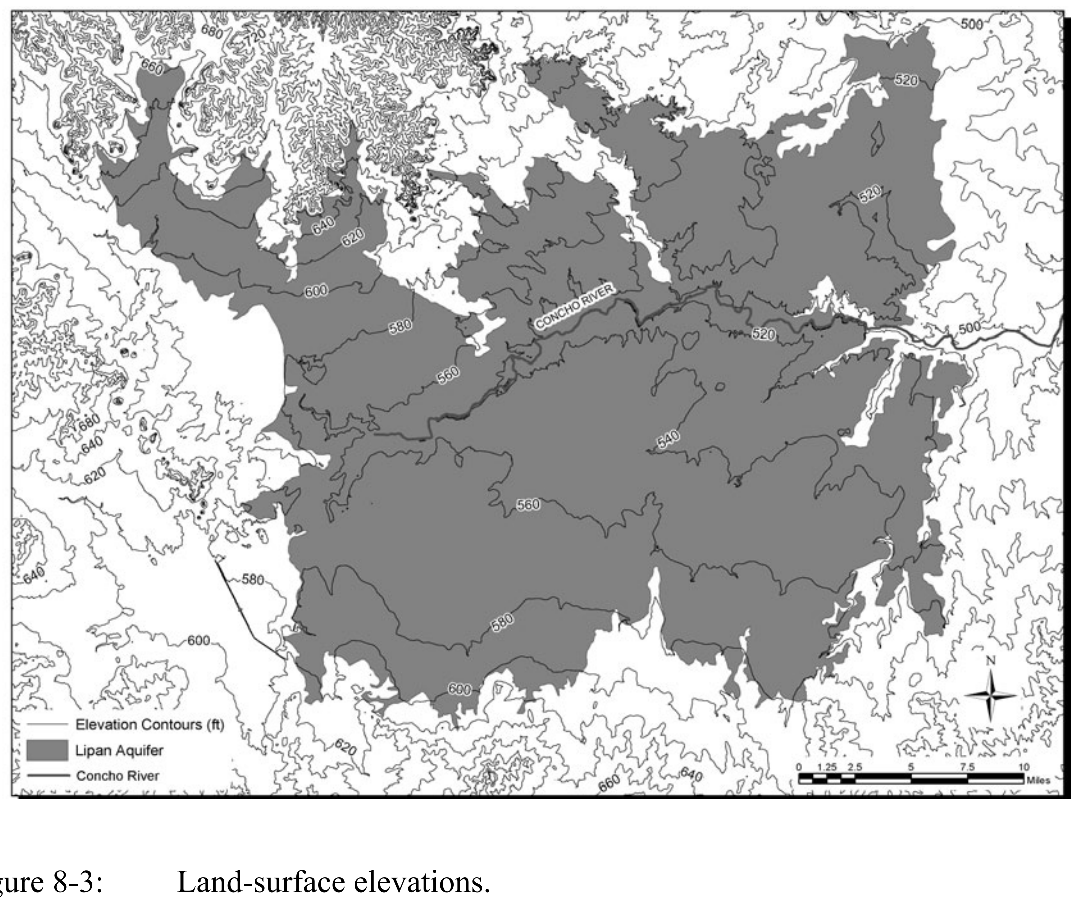

Figure 8-3: Land-surface elevations.

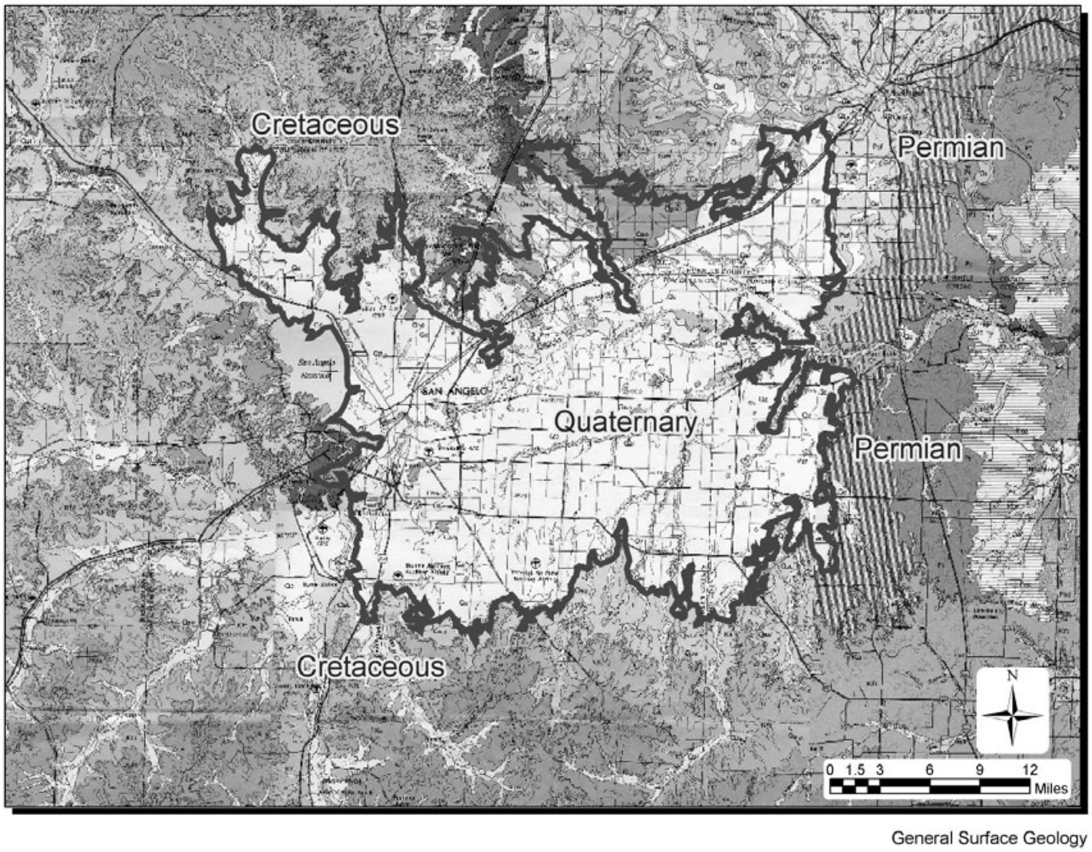

Figure 8-4: Surface geology.

east of the Lipan aquifer. The predominant soils in the study area are clays and sandy, silty clays with some small areas of silty gravels and silty sands. These soils generally thicken towards the Concho River and thin near the edges of the Lipan Flats. The Lipan-Kickapoo Groundwater Conservation District (LKGCD) covers parts of Tom Green, Runnels, and Concho counties.

Geology and Hydrogeology

The Lipan aquifer is primarily comprised of Quaternary aged alluvial deposits unconformably overlying Permian limestones and shales (Lee, 1986). Groundwater in the alluvial deposits and Permian limestones is hydraulically connected, and most wells in the area are completed in both units. An eroded paleo-surface on the Permian rocks forms the contact between the two units. This contact is an undulating erosional surface characterized by differential weathering of the Permian formations. Figure 8-4 illustrates the general surface geology in the study area.

Age	Formation	Maximum Thickness (feet)	Hydrologic Unit	Description and Water-Bearing Characteristics
Quaternary	Leona Formation and Alluvium	125	Leona aquifer	Gravel and stream channel deposits with conglomerate of limestone cemented with sandy lime. Yields sufficient water for irrigation where thickness is suitable.
Permian	**San Angelo Sandstone**	250	San Angelo aquifer	Bright red sandstone with some clay and gypsum. Conglomerate at base. Yields small quantities of water.
	Choza Formation	625	Choza aquifer	Gray dolomitic limestone with clay and some silty clay layers. Yields small quantities of water.
	Bullwagon Dolomite	75	Bullwagon aquifer	Massive yellow to gray dolomitic limestone and green and red shale layers. Yields sufficient water for irrigation.
	Vale Formation	140	Vale aquifer	Shale at top. Rest is red sandy shale with thin streaks of green shale. Yields small quantities of water.
	Standpipe Limestone	15	Standpipe aquifer	Yellowish to light gray marly limestone. Yields small quantities of water.
	Arroyo Formation	60	Arroyo aquifer	Alternating layers of shale and limestone. Yields small quantities of water from the limestone horizons.

Figure 8-5: Hydrostratigraphic section of the Lipan Aquifer (after Lee, 1986).

The Lipan aquifer covers most of Tom Green County and portions of Concho, Runnels, Irion, and Coke counties. The TWDB designated the Lipan as a minor aquifer due to its importance to the local economy. The TWDB delineation of the Lipan aquifer, as shown in Figure 8-4, is based on the lateral extent of Quaternary alluvial deposits (Ashworth and Hopkins, 1995). However, water-bearing Permian units under the alluvium extend beyond the boundaries of the alluvium to form a more extensive aquifer to the east and north. The alluvium and Permian units are also in hydrologic connection to the Cretaceous units of the Edwards-Trinity aquifer that lies to the west and south.

A hydrostratigraphic section of the major formations associated with the Lipan aquifer is shown in Figure 8-5. The Quaternary Leona Formation deposits, which can be up to 125 feet thick, consist mostly of gravels and conglomerates cemented with sandy lime and layers of clay. However, analysis of well driller's logs indicates that significantly less sand is found in the Leona Formation than previously reported (UCRA, 2000). The Leona Formation generally fines upwards with conglomerates existing mainly in locations of thicker alluvium. The most abundant lithologic unit observed in the Leona

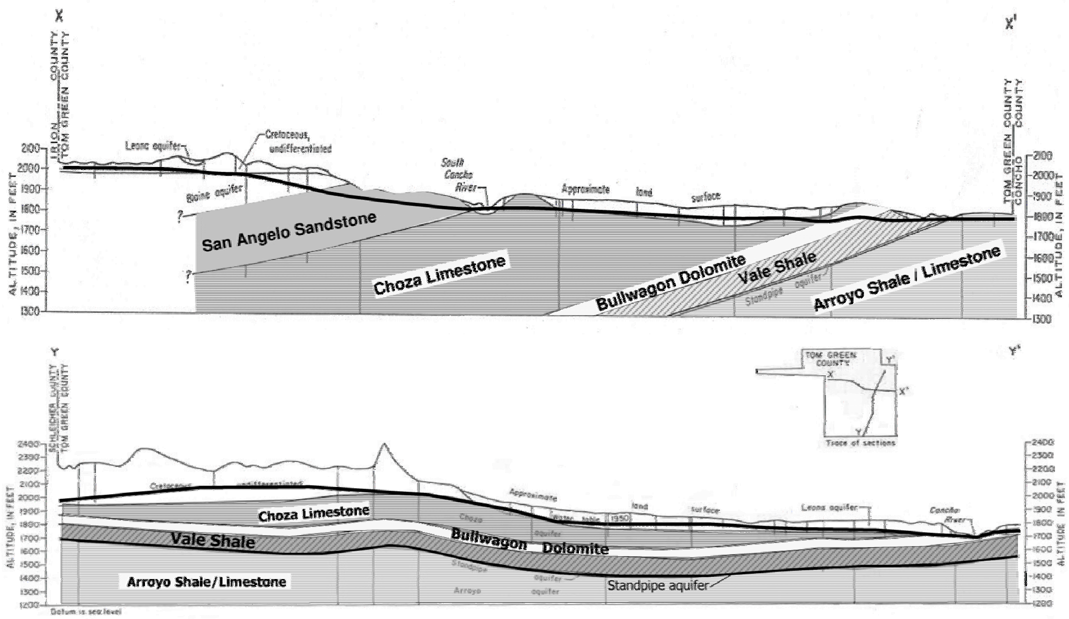

Figure 8-6: Geologic cross-sections of the Lipan Aquifer (after Lee, 1986).

Formation consists of consolidated alluvium and detritus. It mainly contains poorly sorted, rounded to sub-angular chert and limestone gravels. Fine to very fine sands occur in minor amounts (UCRA, 2000).

The Permian formations underlying the alluvium are predominantly limestones and shales of the Clear Fork Group. As shown in the cross-section in Figure 8-6, these formations, which dip westward towards the Permian Basin at about 50 feet per mile, include the Choza Formation, Bullwagon Dolomite Member, Vale Formation, Standpipe Limestone Member, and the Arroyo Formation (Lee, 1986). Willis (1954) also described the geology of Tom Green County and provided an inventory of existing wells and springs.

Edwards-Trinity aquifer formations of Cretaceous age outcrop to the north, west, and south and represent the lateral extent of the Lipan aquifer in those directions. The Cretaceous formations of the Edwards-Trinity (Plateau) aquifer consist mostly of massive limestones and unconsolidated to cemented gravels, sands, and clays (Lee, 1986). Springs are found along the contact between the Cretaceous and Quaternary, which drain the Edwards-Trinity aquifer and add a small amount of water to the Leona Formation. To the east, the Leona Formation thins and pinches out and represents the eastern extent of the TWDB-delineated Lipan aquifer. Other noncontiguous Quaternary alluvium deposits exist in Runnels, Concho, and western McCulloch counties and have similar characteristics as the Leona Formation in the Lipan Flats of Tom Green County, except that their extent is more limited.

An assessment of the wells in the Lipan aquifer indicates that the production capacity is spatially correlated to the strike orientation of the Permian formations that lie below the Leona gravels. Higher production wells appear to correspond to Leona alluvial deposits overlying the Choza, Bullwagon, and Vale formations. In these areas, there are generally thicker alluvial deposits with conglomerates near the contact with the Permian. The Permian formations in these areas, which outcrop to the east and north of the Lipan aquifer, are generally more productive than areas where the alluvial deposits are thinner. The Bullwagon Dolomite Member usually produces water in sufficient quantities for irrigation. Other Permian formations in the Clear Fork Group yield smaller amounts of water from limestone layers. The formations that comprise the Lipan aquifer are hydraulically connected and indistinguishable based on existing water-level observations. Well logs indicate that boreholes typically encounter small zones (one to three feet) in the Permian units that produce the majority of the water in the well. In addition, many logs note lost circulation, which may indicate karst development in the Permian units.

There is limited information on hydraulic properties in the Lipan aquifer. Well yields in the Lipan aquifer vary from less than 10 gpm to over 500 gpm. Reports from drillers generally indicate that most production comes from relatively small zones. Reported values of specific capacity from pump tests in the Lipan aquifer range from less than 5 to over 100 gpm/ft. Other tests may have been performed, but their results have not been published. The data from existing tests indicate the potential for large variations in the hydraulic conductivity of the aquifer over a relatively small distance. This finding is consistent with well production data, which can vary significantly over short distances.

Because there are a limited number of hydraulic conductivity estimates for the Lipan aquifer, available production data was used to estimate hydraulic properties, as discussed below. In the Lipan Flats area, air rotary drilling rigs are normally used to drill wells. After boreholes are drilled to total depth, drillers will usually perform a production capacity test on the borehole by “blowing” the well and estimating the flowrate. In the Lipan aquifer, there are over 1,300 wells where production capacity tests have been completed and reported. This production capacity data was used to estimate specific capacity values. Specific capacity is the ratio of the production rate in a well to the drawdown in a well during pumping. To estimate this ratio from the production test performed by blowing the well, it was assumed that the entire depth of the well is dewatered, and thus the drawdown in the well was equal to the thickness of the static water column in the well. The specific capacity was then estimated by dividing the amount of water produced during the test by the drawdown. The results are shown in Figure 8-7. This methodology assumes complete drawdown of the aquifer to produce the measured production rate. In most cases this is probably an overestimate of the drawdown, which consistently underestimates the specific capacity.

Figure 8-7 indicates that there are two areas of the Lipan aquifer that are typically more productive than others. As discussed previously, the orientation of these high production zones is parallel to the strike of the geologic units and indicates that the underlying geology impacts the permeability of the aquifer units.

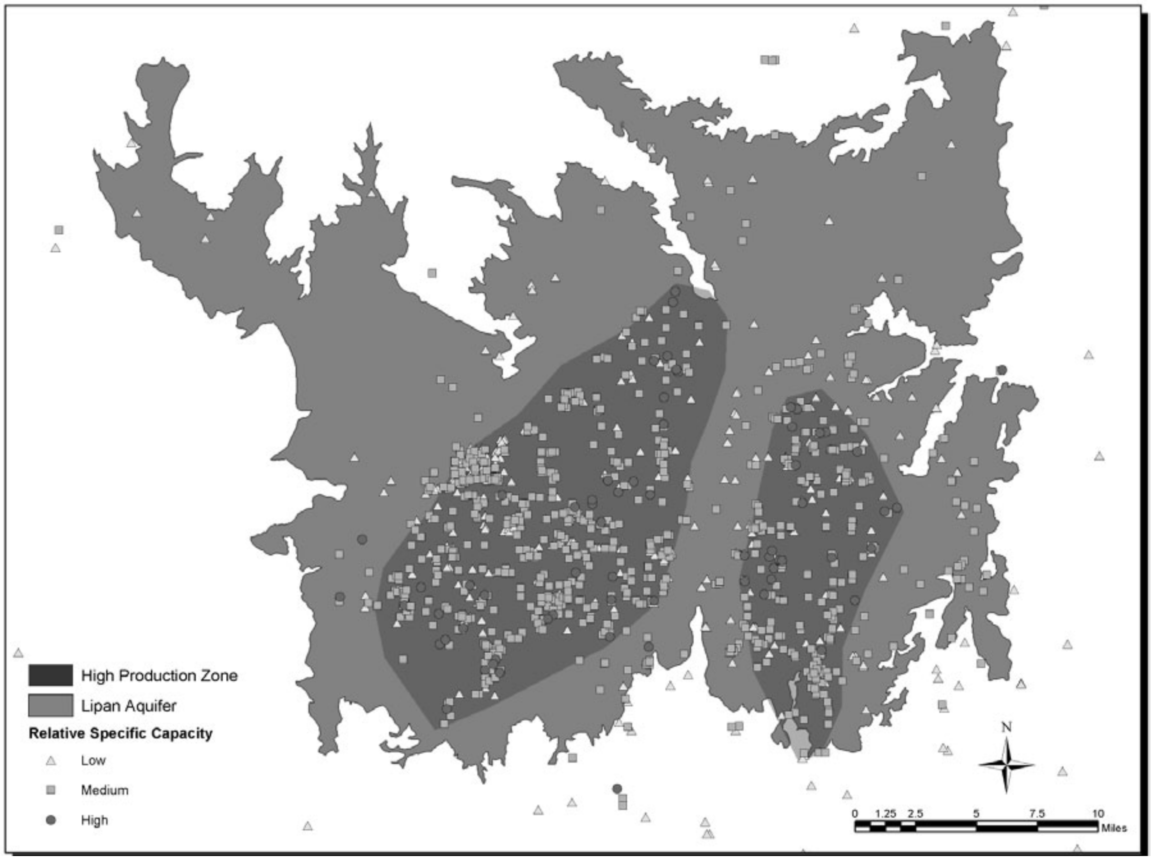

Figure 8-7: Distribution of specific-capacity values calculated from production capacity (ft^2/day) and the log distribution of these values in the Lipan aquifer.

Mace (2001) published a method for estimating transmissivity values from specific capacity. Using this method, values of transmissivity were estimated for the 1,333 production capacity tests. This resulted in transmissivity values ranging from 0.25 ft^2/day to over 4,400 ft^2/day. The arithmetic and geometric mean are 331 ft^2/day and 167 ft^2/day, respectively. Assuming an average saturated thickness of 150 feet, the average hydraulic conductivity would be 2.2 ft/day and have a geometric mean of 1.1 ft/day. There are no documented estimates of specific yield for the Lipan aquifer. The specific yield of other dolomite and limestone aquifers varies from 0.1 to 0.2 (Freeze and Cherry, 1979).

Regional Groundwater Flow

Water levels recorded in the first three months of 1950 were used to develop the potentiometric surface map shown in Figure 8-8. Although there was some pumping prior to 1950, these water levels are assumed to represent relatively stable, predevelopment conditions in the aquifer. Figure 8-8 indicates that the Concho River is the natural

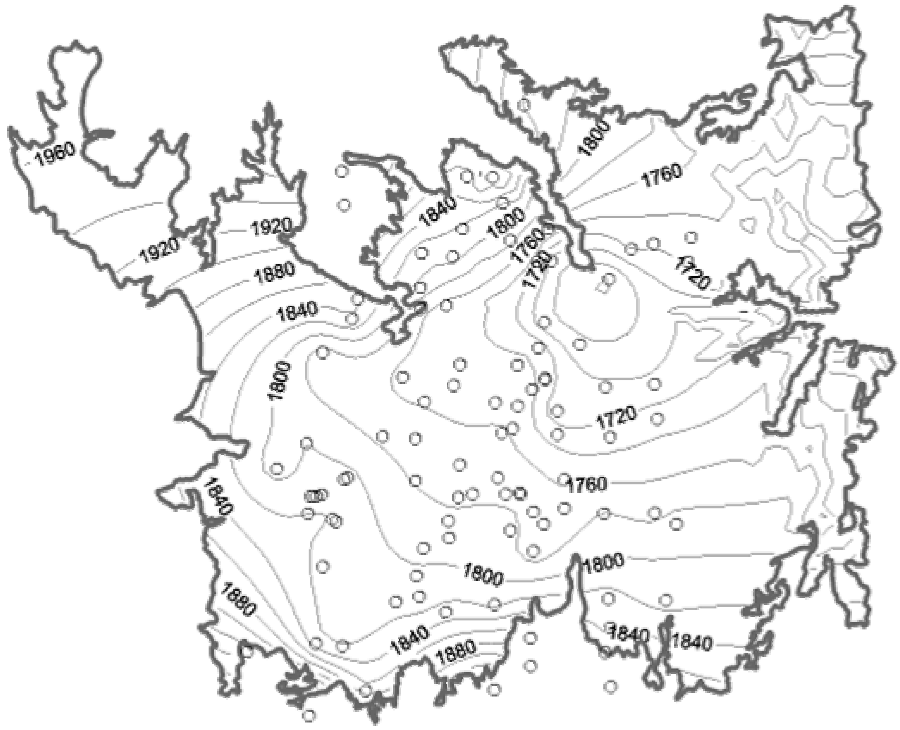

Figure 8-8: Water levels in 1950.

discharge point for some groundwater in the Lipan aquifer that enters from the north, west and south. Richter and others (1990) indicate that there is also a small upward component of flow from the deeper regional flow system that comes from the northwest. Groundwater that is not discharged from the Lipan aquifer naturally through seeps, springs, or evapotranspiration moves east through Permian units.

Figure 8-9 shows the potentiometric surface map estimated from water-level measurements collected in 2000. When comparing the 1950 and 2000 maps, a general decrease in water levels is observed in the center of the Lipan Flats area. However, water levels near the edges of the Lipan aquifer and in Edwards–Trinity wells do not change significantly between 1950 and 2000. When groundwater levels are relatively low near the Concho River, surface water may recharge the aquifer in local proximity to the stream.

Hydrographs for wells in the Lipan aquifer are shown in Figure 8-10. These hydrographs indicate that wells outside the Lipan Flats area have experienced relatively small water level declines as compared to the wells in the middle of the Lipan Flats area. During the drought of the late 1990s, as irrigation pumping increased, water levels in many wells in the Lipan Flats area decreased from 30 to 60 feet and some decreased over 100 feet.

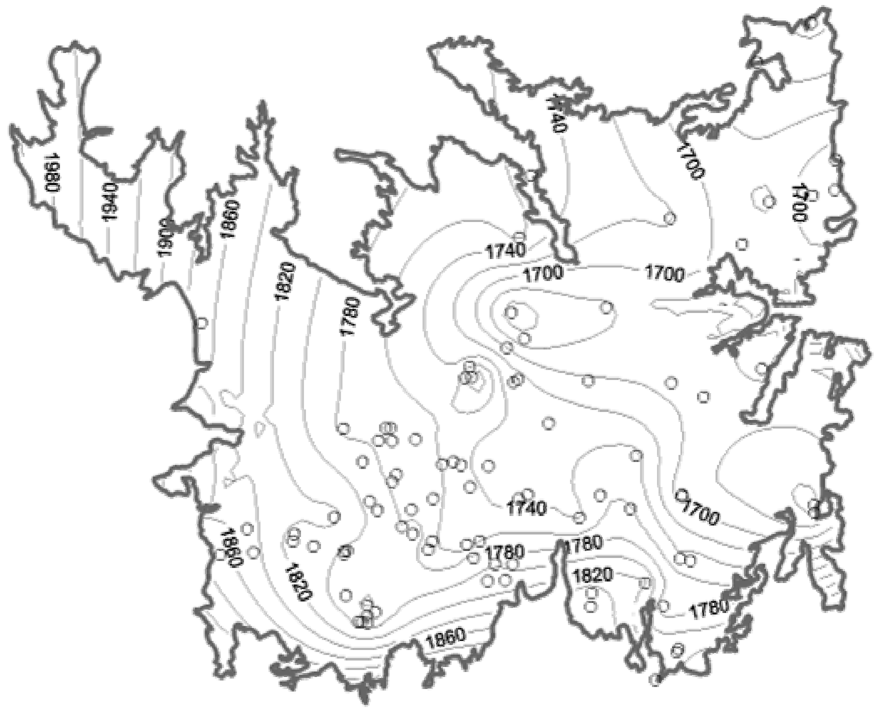

Figure 8-9: Water levels in 2000.

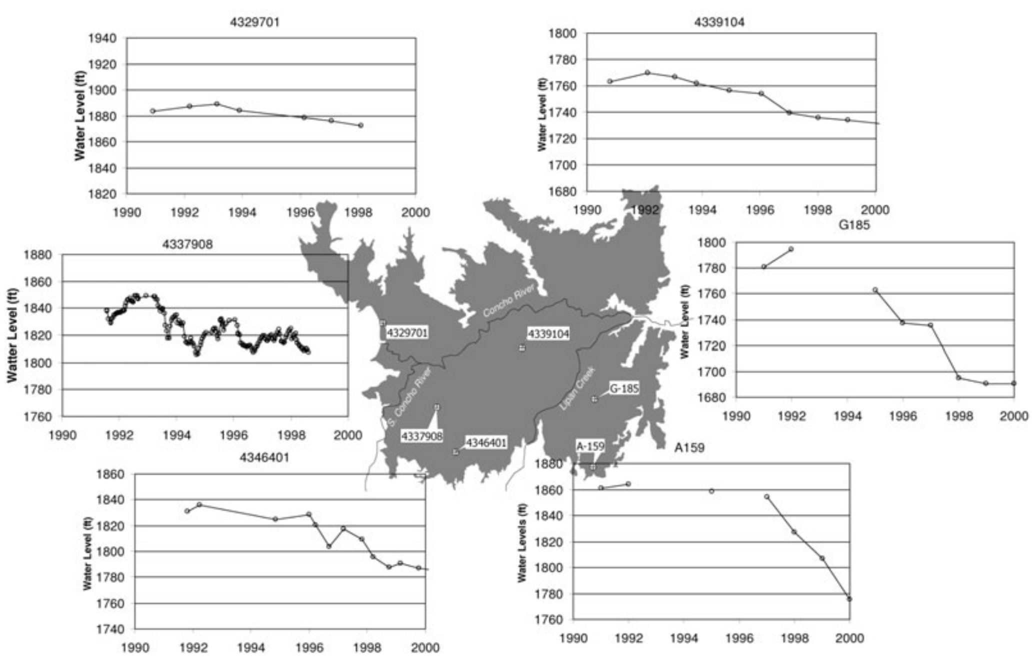

Figure 8-10: Selected well hydrographs.

During the same period, well yields generally decreased (significantly in some areas) where water levels decreased (personal communication with Allan Lange, 2003).

Recharge

As previously discussed, the Concho River is a natural discharge feature of the Lipan aquifer system. Although the Concho River is classified as a perennial river, stream gage data indicate that stretches of the river between San Angelo and Paint Rock have ceased to flow during the summer months during recent dry years. Two gain-loss studies along the Concho River between San Angelo and Paint Rock have been documented (Slade and others, 2000). These studies were completed in 1918 and 1925, prior to impoundment of the reservoirs west of San Angelo and development of the Lipan aquifer. These studies indicate that the Concho River naturally receives discharge from the Lipan aquifer between San Angelo and Paint Rock. The studies in 1918 and 1925 show a net gain of 5.4 cubic feet/second (cfs) (3,912 acre-feet per year (AFY)) and 5.2 cfs (3,767 AFY), respectively.

Spring and Dove Creeks, located south and southwest of San Angelo, emanate from the contact between the Edwards–Trinity aquifer and the Lipan aquifer and have historically provided a consistent base flow for the Concho River. There are several other small springs that emanate from the Lipan aquifer. Most of the springs are located in small streams and creeks, which are usually dry. When these springs do flow, the water typically moves only a short distance downstream before infiltrating back into the aquifer or being evapotranspirated.

The primary sources of recharge to the Lipan aquifer are the infiltration of precipitation and lateral cross-formational flow. Lateral cross-formational flow from the Edwards–Trinity aquifer and other water-bearing formations located north of the Lipan aquifer is a source of recharge to the Lipan aquifer. The amount of lateral inflow has not been estimated. Leakage from the lakes west of San Angelo is another source of potential recharge to an aquifer. A small amount of irrigation return flow may occur where row watering is practiced. Return flow from pivot irrigation systems is probably insignificant. Localized stream loss may also provide a small amount of recharge under certain conditions.

Scanlon and others (2002) compiled recharge estimates for the major aquifers in Texas. Recharge estimates have never been published for the Lipan aquifer. Major aquifers where recharge has been estimated and that are located in areas with similar climatic conditions and aquifer properties are the Edwards–Trinity (to the south and west), and the Seymour and Ogallala (located to the north). Average recharge rates compiled for these aquifers range from about 1.2 to 2 inches per year, or about 5 to 10 percent of average annual precipitation (Scanlon and others, 2002). Based on this range of estimates, vertical recharge from precipitation could range from about 0.6 to 3.8 inches per year (about 2,000 to 15,000 AFY).

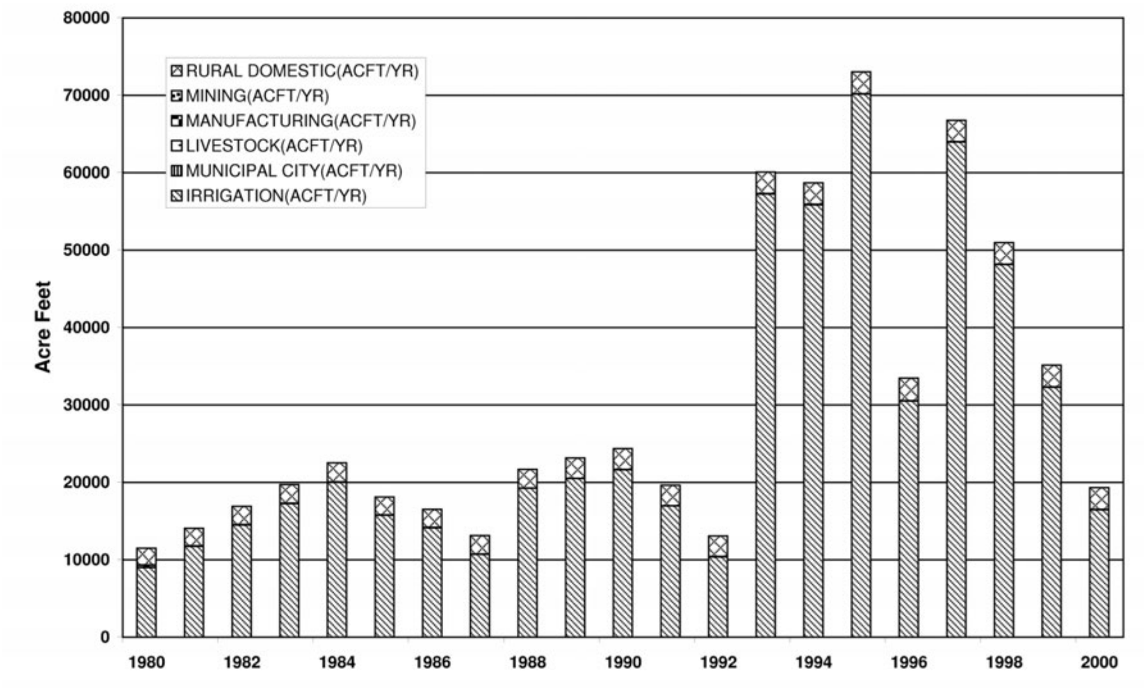

Figure 8-11: Historical pumping from the Lipan Aquifer

Discharge

The TWDB estimates groundwater pumping for seven water use categories: irrigation, municipal, rural domestic, manufacturing, power generation, livestock operations, and mining. Historical pumping estimates for 1980 through 1997 are available for all of these categories except power generation, which did not have any reported groundwater use during this time. Figure 8-11 shows the historical pumping from the Lipan aquifer between 1980 and 2000.

Irrigation pumping began in the 1940s and increased slowly until the late 1980s, when it began to increase significantly. TWDB reported that the total groundwater pumping in 1974 for Tom Green, Concho, and Runnels counties was 14,902 AFY, of which 10,657 AFY was for irrigation. In 1977, these totals rose to 17,080 AFY total withdrawal with 14,050 AFY used for irrigation.

Historical well records show a dramatic increase in the number of irrigation wells in the Lipan aquifer during the 1990s. The number of irrigation wells increased from approximately 200 in 1990 to over 1,000 by the year 2000. In 1997, irrigation pumping from the Lipan aquifer totaled 65,000 AFY. All other pumping in the Lipan aquifer for that year totaled just over 2,600 AFY. Municipal, industrial, and domestic pumping accounts for less than five percent of the total pumping in 1997. San Angelo, the largest city in the area, has not used any groundwater from the Lipan aquifer to date. The second

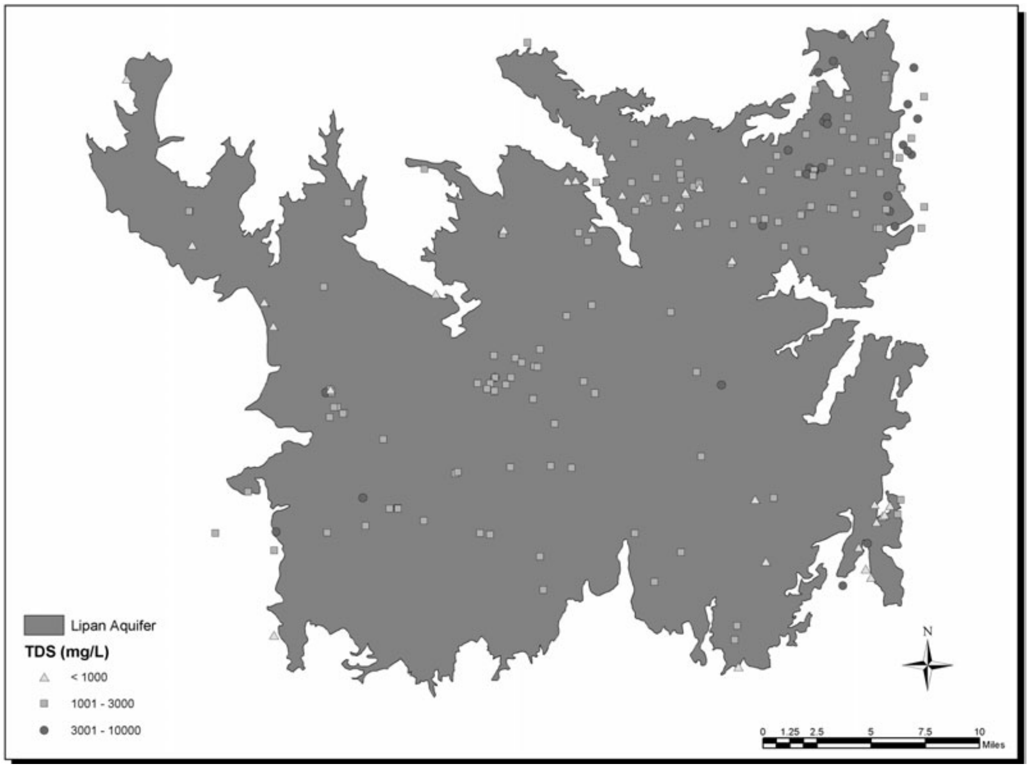

Figure 8-12: Total dissolved solids in the Lipan Aquifer

largest user of groundwater after irrigation is rural domestic pumping, accounting for almost four percent of the total pumping.

Water Quality

The amount of total dissolved solids (TDS) in groundwater is one measure of water quality and is the sum of the concentrations of all of the dissolved ions, mainly sodium, calcium, magnesium, potassium, chloride, sulfate, and bicarbonate. The TCEQ has defined aquifer water quality in terms of dissolved-solids concentrations expressed in milligrams per liter (mg/L) and has classified water into four broad categories:

- fresh (less than 1,000 mg/L);
- slightly saline (1,000 - 3,000 mg/L);
- moderately saline (3,000 - 10,000 mg/L); and
- very saline (10,000 - 35,000 mg/L).

Water-quality data was compiled from the TWDB groundwater database and the Texas Commission on Environmental Quality (TCEQ) public water-supply well database. A total of 199 TDS measurements were available for the Lipan aquifer. As indicated in Figure 8-8, water quality in the Lipan is typically slightly saline, but varies from fresh to moderately saline. A significant percentage of the sampled wells contain water with nitrate, chloride, and sulfate concentrations above the drinking water standards.

Groundwater Availability

There are many ways to define groundwater availability of an aquifer. The combination of recent drought and increased irrigation pumping has proven that there is a practical limit to the availability of groundwater from the Lipan aquifer. Because the Lipan aquifer is relatively small and the wells are relatively shallow, water levels near heavy pumping can decline significantly during drought periods. During the late 1990s, the combined impacts of drought and increased irrigation demand (65,000 AFY) resulted in decreased water levels and reduced productivity in many wells in the Lipan aquifer. However, before the mid-1990s, when production was estimated at 30,000 to 40,000 AFY, consistently low water levels and reduced well production was not a common problem.

During the previous drought of record (1950 through 1955), the demand on the Lipan aquifer was significantly smaller than it was during the drought that started in the late 1990s and continued through 2002. It remains to be seen how the Lipan aquifer will respond when more average climatic conditions emerge and irrigation demands remain greater than 65,000 AFY. The response of the aquifer will provide important information as to the average groundwater availability of the Lipan aquifer. In addition, the completion of the TWDB Lipan groundwater availability model (currently under development) should provide a useful tool for evaluating technical and policy decisions regarding groundwater availability and aquifer management.

Acknowledgments

We appreciate the help we have received from several people who have worked diligently to document, study, and conserve the water resources of the Lipan aquifer. Allan Lange, general manager of the Lipan-Kickapoo Water Conservation District has been especially helpful. We also thank Scott McWilliams, Allan Standen, Michael Hoelscher and Allan Lange for their practical insight and historical perspective of the Lipan aquifer.

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