Report 313

Evaluation of Ground-Water Resources in Briscoe, Hale, and Swisher Counties, Texas

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Texas Water Development Board

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Evaluation of Ground-Water Resources In Briscoe, Hale, and Swisher Counties, Texas

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ABSTRACT

The evaluation of ground-water conditions in all or parts of Briscoe, Hale, and Swisher Counties is in response to the 1985 passage of House Bill 2 by the Sixty-ninth Texas Legislature, which called for the identification and study of areas in the state that are experiencing or expected to experience within the next 20 years, critical underground water problems. The study area is located on the southern High Plains between Lubbock and Amarillo, in northwest Texas, and has a semi-arid climate that is characterized by low rainfall and high rate of evaporation. The economy is dominated by agricultural endeavors.

Water needs for the study area are supplied almost entirely from the High Plains aquifer which occurs primarily in the Ogallala Formation of Tertiary age, and, where hydrologically connected, in water-bearing units of Triassic and Cretaceous age. Average recharge to the High Plains aquifer is about 9,300 acre-feet per year in the three county area and is derived principally from precipitation that falls on the aquifer. Water-level declines of over 140 feet have occurred since irrigation development boomed in the 1940's. In areas of heavy pumpage, water-level declines of approximately 4.5 feet per year have been recorded.

In 1985, the total pumpage of ground water within the study area was about 615,717 acre-feet, of which 98 percent was used for irrigation. This amount is projected to decrease to about one-half million acre-feet by the year 2010. The average annual effective recharge to the aquifer is much less than the present and projected water demand; therefore, water will be drawn from storage in the aquifer. By the year 2010, using Texas Water Development Board projected High Per Capita with Conservation Series Model, dated September 1988, approximately 62 percent of the water held in storage in the aquifer in 1985 will have been used. Projected water use will result in significant water-level and well-yield declines.

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INTRODUCTION

Purpose

In 1985, the Sixty-ninth Texas Legislature recognized that certain areas of the state were experiencing or were expected to experience within the next 20 years, critical ground-water problems. House Bill 2 was enacted, which in part, directed the state water agency to identify the critical ground-water areas, conduct studies in the areas, and submit its findings and recommendations on whether a ground-water district should be established in the respective areas to address the ground-water problems (Subchapter C, Chapter 52, Texas Water Code).

This study by the Texas Water Development Board (TWDB) focuses on western Briscoe, Hale, and Swisher Counties, Texas, where water levels in the High Plains aquifer have been steadily declining for several decades.

Location and Extent

The study area is located in all or parts of Briscoe, Hale, and Swisher Counties on the southern High Plains in northwest Texas (Figure 1). Hale and the southwestern corner of Swisher County lie within the Brazos River basin, while the remainder of the area is located in the Red River basin. Cities in the area include Abernathy, Hale Center, Plainview, Silverton, and Tulia. The area studied in Briscoe County lies on the elevated plateau region, which encompasses approximately the southwestern third of the county. In order to completely describe the aquifer, data on the maps extend into that part of Hale County (southeastern quarter) which is part of the High Plains Underground Water Conservation District No. 1.

Geographic Setting

Western Briscoe, Hale, and Swisher Counties are located on the southern High Plains of Texas, an elevated plateau region characterized by relatively flat, treeless terrain, numerous shallow playa depressions, and occasional sand dunes. The plains slope imperceptibly to the southeast and are generally devoid of major drainage systems. Farm crops are cultivated over much of the study area, primarily during late spring and summer months.

In recent times, semiarid climatic conditions have generally prevailed over the study area, with precipitation as recorded by the National Weather Service measuring between 16 and 20 inches per year. Precipitation in the region is usually light during winter months, increasing in the late spring and early fall. Temperatures in the study area typically range from the low to mid-90's (degrees F) in the summer and from the low to mid-40's in the winter (Larkin and Bomar, 1983).

Weather patterns can be extreme over western Briscoe, Hale, and Swisher Counties. Temperatures drop as much as 60 degrees F over short periods of time when "blue northers" blow across the region, sometimes depositing light snows in the winter. Low humidity and strong southwesterly breezes commonly accompany higher summer temperatures, resulting in high surface evaporation rates and generating periodic dust storms across the Plains.

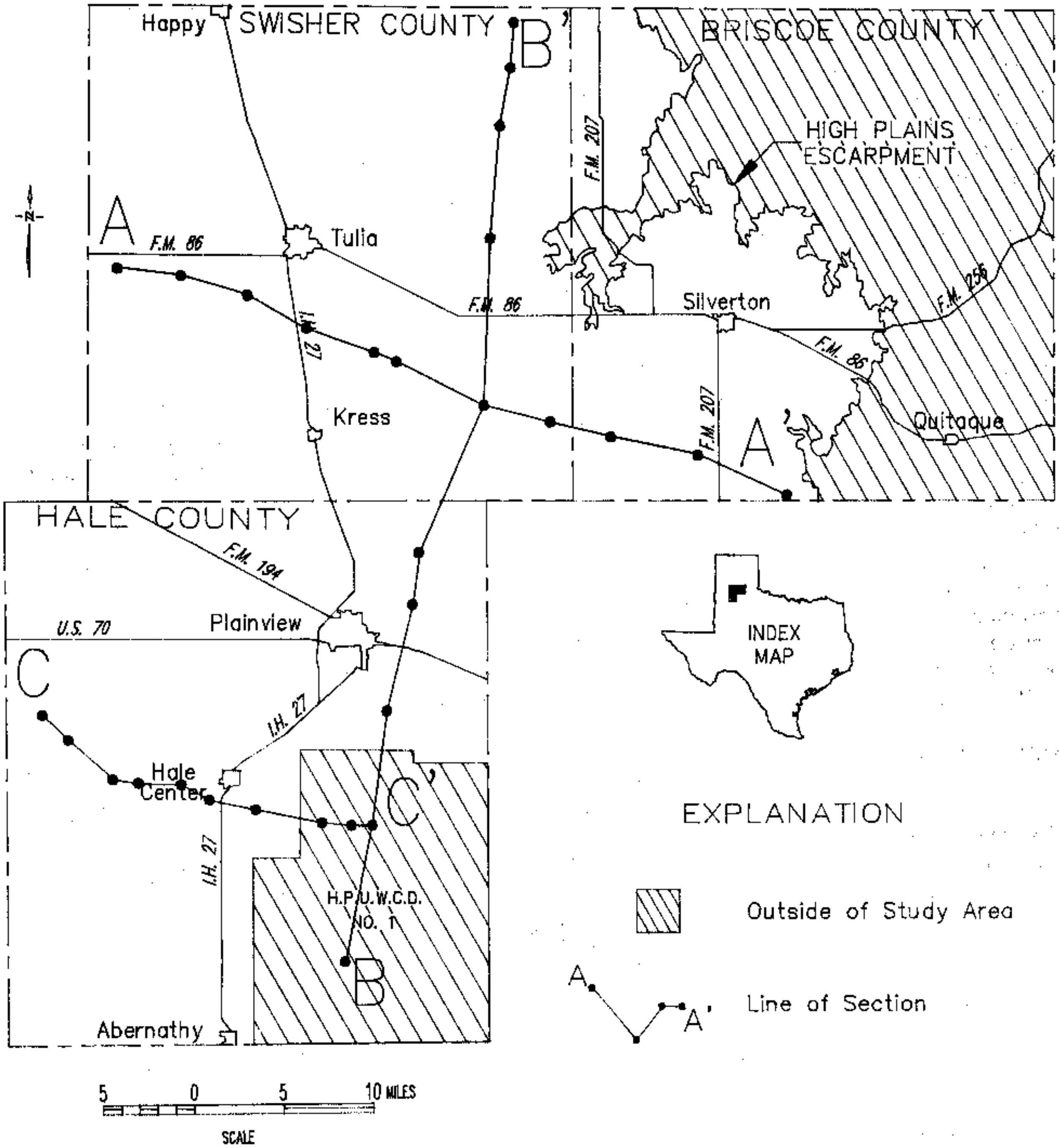

Figure 1

LOCATION OF STUDY AREA AND GEOLOGIC SECTIONS

The average annual gross lake evaporation is approximately 70 inches, an amount more than three times the average annual precipitation in the same region (Dougherty, 1975). Evaporation rates are highest in summer months when soil moisture demand by plants is also at its highest.

The economy in Briscoe, Hale, and Swisher Counties is based largely on agricultural development (Figure 2). Irrigation farming began in the region, and on the southern High Plains as a whole, with the completion of the first successful irrigation well four miles west of Plainview, Hale County, in 1911 (Cronin and Wells, 1960). Irrigation well development progressed slowly at first, then expanded over the study area in the late 1930's with the improved efficiency of pumps and power units. By the late 1960's and early 1970's, more than one million acre-feet of ground water per year was being withdrawn from the High Plains aquifer to irrigate almost one million acres of cropland in Briscoe, Hale, and Swisher Counties (TWDB, 1986). Higher energy costs, declining well yields, and a depressed farm economy have since prompted irrigation farming cutbacks, with approximately 720,000 acre-feet of ground water being used to irrigate approximately one-half million acres in the study area in 1984 (TWDB, 1986). Major crops cultivated include cotton, wheat, corn, and grain sorghum.

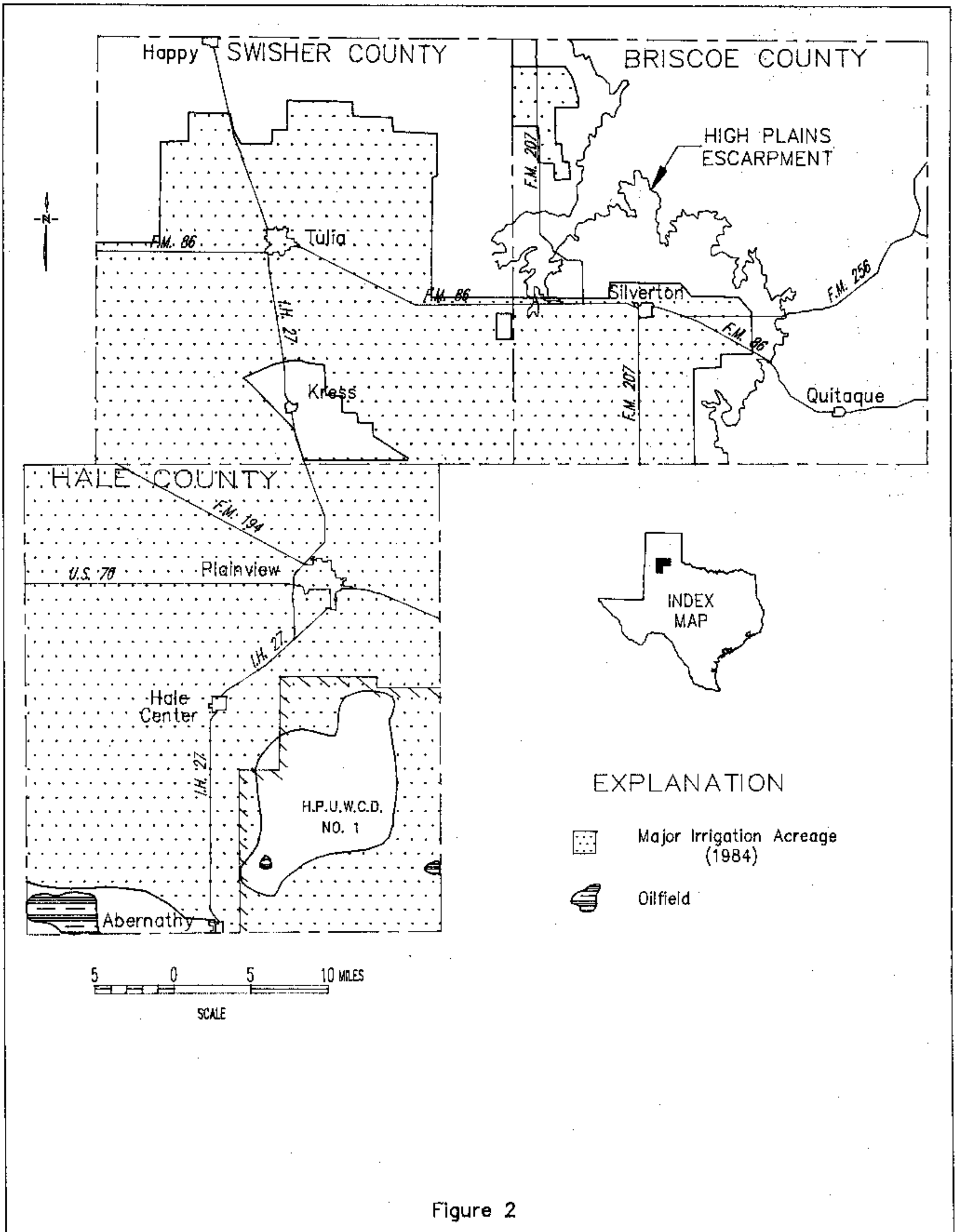

Figure 2

LAND USE, 1984

Table 1

IRRIGATION SUMMARY FOR BRISCOE, HALE, AND SWISHER COUNTIES

Ground-Water Supplied

County	Year	Acres	Acre-feet	Wells
Briscoe[1]	1958	55,000	38,817	539
	1964	70,200	111,348	607
	1969	63,970	96,069	650
	1974	66,196	103,045	821
	1979	65,776	95,350	815
	1984	60,133	45,644	746
Hale[2]	1958	533,455	575,752	4,500
	1964	461,800	1,105,616	4,378
	1969	352,520	680,167	4,400
	1974	430,595	824,614	4,600
	1979	386,891	356,949	4,463
	1984	354,000	525,273	4,700
Swisher	1958	319,200	265,026	2,630
	1964	279,012	471,623	3,608
	1969	245,840	363,920	4,596
	1974	316,800	474,878	4,600
	1979	132,624	157,952	4,900
	1984	125,425	150,758	3,800

Source: TWDB Report 294

[1] These data for Briscoe County include irrigated acreage not within in the study area. In 1984, over 6,000 acres outside the study area was irrigated with approximately 8,000 acre-feet of ground water from about 100 wells.

[2] These data for Hale County include that part within the High Plains Underground Water Conservation District No. 1.

There is also limited oil and gas development in southern Hale County around Anton-Irish, Lutrick, and Arick oilfields. However, very little ground-water depletion from the High Plains aquifer has resulted from this development.

Previous and Current Investigations

Numerous ground-water investigations have been published by the TWDB and its predecessor agencies that address the geohydrology of the study area. The most extensive investigation (Knowles, Nordstrom, and Klemt, 1982) included this three -county area in a regional study of the entire High Plains aquifer. Many studies addressing each county are also available. Publications containing information relating to the geohydrology of the aquifer in the study area are listed in the selected references of this report.

Geologic mapping in the study area is best presented on the Lubbock and Plainview Geologic Atlas Sheets published by the University of Texas, Bureau of Economic Geology (BEG). The base map for this report was adapted from these sheets.

The Board has maintained a water-level and water-quality monitoring network within the study area since the 1940's. The network consists of 238 water-level observation wells measured annually and 440 chemical analyses of water samples taken from 330 wells in the three-county area. Monitoring of the aquifer is also being done in surrounding counties lying in the High Plains Underground Water Conservation District (HPUWCD) No. 1 by their personnel.

Acknowledgements

The authors thank the numerous individuals for their cooperation in providing information on the aquifer in their area. More specifically, appreciation is extended to city and water supply company officials who furnished information concerning their municipal water-supply systems, and to the many property owners who allowed access to their wells to measure water levels and sample for chemical quality.

Additionally, special thanks are given to a group of individuals who served on an advisory committee that was formed by the Board to provide input by those most affected by the conditions of the High Plains aquifer in the study area. The committee consisted of concerned and knowledgeable citizens who represent public supply and irrigation users of the ground water in the study area.

GEOHYDROLOGY

Irrigation water for crops in Briscoe, Hale, and Swisher Counties is drawn mostly from the High Plains aquifer that is broadly developed in strata of Mesozoic and Cenozoic age. In the study area, coarse- to medium-grained fluvial deposits that form basal and lower-middle parts of the Ogallala Formation generally form the most effective ground-water conduits in the High Plains aquifer. The fluvial deposits are thickest (Figure 3) and best developed where they fill paleovalley courses that were scoured into underlying strata in pre-Ogallala time (Figure 4) (Knowles and others, 1982).

Wind-deposited cover sands and loess (Blackwater Draw Formation - Illinoian age) and fine-grained playa deposits (Tahoka and Double Lakes Formations) cover more than 98 percent of the southern High Plains surface in Briscoe, Hale, and Swisher Counties (BEG, 1967 and 1968). The deposits are locally more than 40 feet thick and include interbedded soil horizons at most locations.

Lower Cretaceous strata underlie the Ogallala Formation in southern Hale County (Knowles and others, 1982). The Lower Cretaceous strata have a maximum thickness of 100 feet and include a basal sand deposit (Antlers Formation) overlain by marls (Walnut Formation) and associated limestones (Comanche Peak and Edwards Formations) (Fallin, 1987).

Triassic strata underlie and subcrop below the Ogallala Formation in the study area, except where Cretaceous strata are present (Knowles and others, 1982). The Triassic strata thicken to the west, ranging from less than 300 feet thick along the southern High Plains escarpment in parts of Briscoe County to more than 1,000 feet thick under western Hale and Swisher Counties. A typical Triassic section in the study area includes thick clay and shale intervals, with coarser-grained sandstone facies becoming more prominent in lower parts of the section. Thick Paleozoic and Precambrian rock assemblages underlie the Triassic strata (Table 2).

Figures 5, 6, and 7 show the relationships of the various formations within the High Plains aquifer. The cross-section locations are indicated on Figure 1.

Saturated intervals in the southern High Plains aquifer are thickest where the Ogallala Formation fills and immediately overlies pre-Ogallala valley systems under the southern High Plains. In 1980, zones of saturation in the aquifer ranged from 60 to more than 200 feet thick over paleovalley trends in the study area (Figure 8) (Knowles and others, 1982). At the same time, saturated intervals in other parts of the High Plains aquifer were rarely more than 60 feet thick throughout Briscoe, Hale, and Swisher Counties.

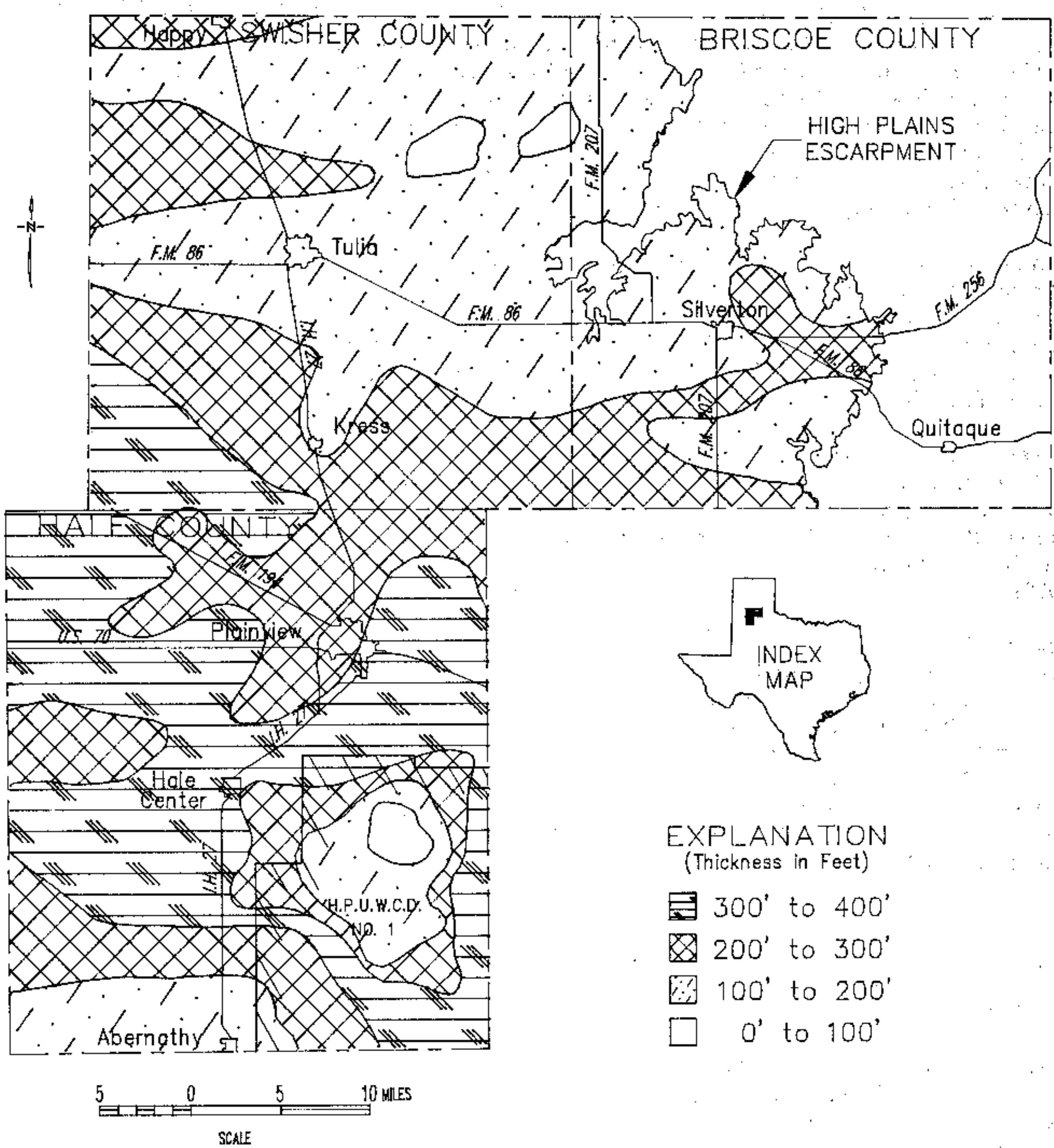

Figure 3

THICKNESS OF THE OGALLALA FORMATION

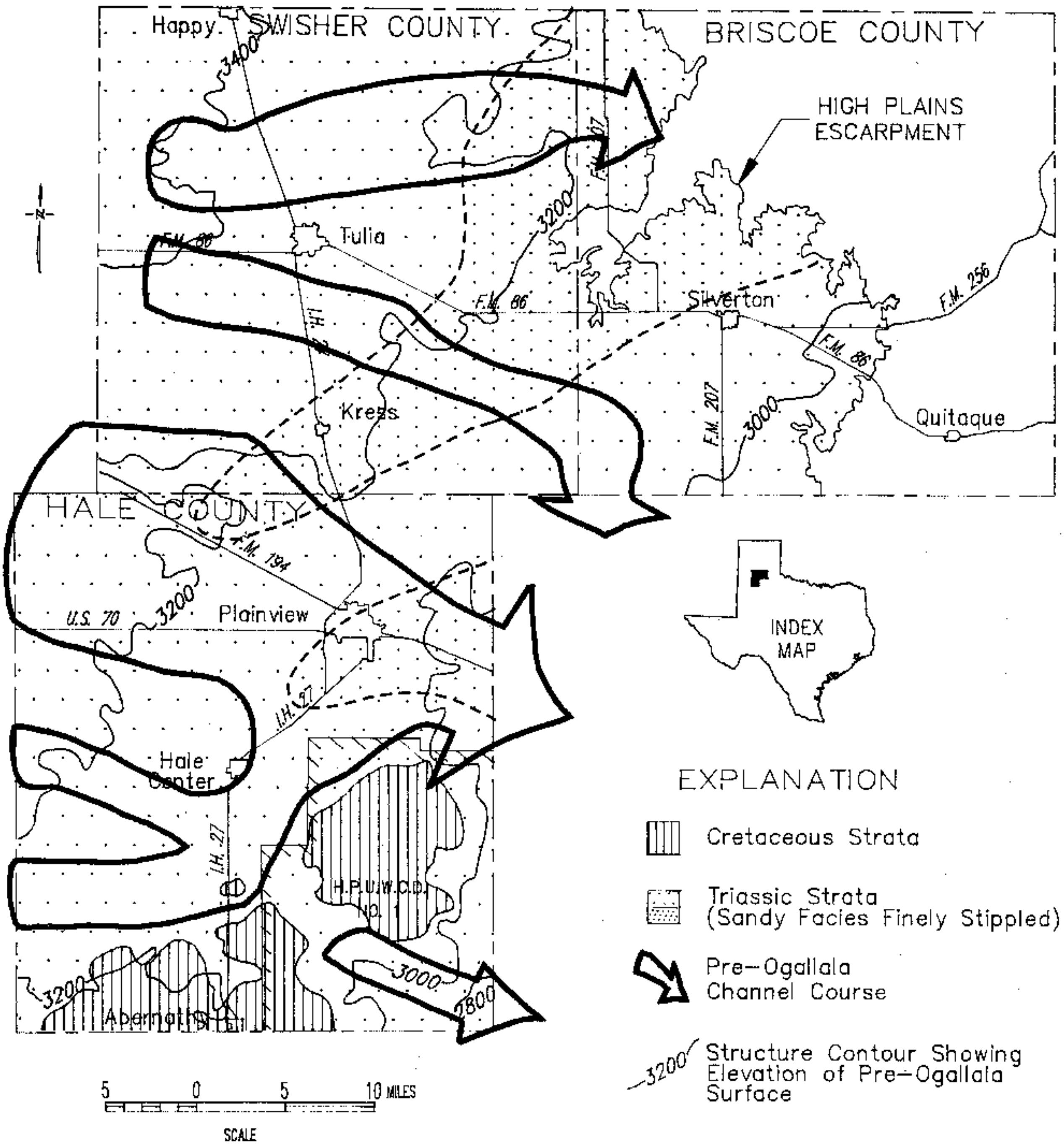

Figure 4

PRE–OGALLALA SUBCROP GEOLOGY AND TOPOGRAPHY

Table 2. - *Geologic Units and Their Water-Bearing Characteristics*

System	Series	Group	Formation	Approximate maximum thickness (feet)	Physical character of rocks	Water-bearing characteristics*
Quaternary	Pleistocene to Recent		Alluvium, eolian and lacustrine deposits	40	Windblown sand and silt, fluvial flood plain deposits, and silt and clay playa lake deposits.	Yields small amounts of water to wells.
Tertiary	Late Miocene to Pliocene		Ogallala	400	Tan, yellow, and reddish-brown, silty to coarse-grained sand mixed or alternating with yellow to red silty clay and variable sized gravel. Caliche layers common	Yields moderate to large amounts of water to wells. The principal aquifer in the study area with yields of some wells in excess of 800 gal/min.
Cretaceous	Comanche	Fredericksburg	Edwards	100	Light-gray to yellowish-gray, thick bedded to massive, fine- to coarse-grained limestone.	Yields small amounts of water to wells.
			Comanche Peak		Light-gray to yellowish-brown, irregularly bedded, argillaceous limestone and thin interbeds of light-gray shale.	
			Walnut		Light-gray to yellowish-brown, fine- to medium-grained, argillaceous sandstone; thin bedded, gray to grayish-yellow, calcareous shale; and light-gray to grayish limestone.	Not known to yield water to wells.
		Trinity	Antlers		White, gray, yellowish-brown to purple, fine- to coarse-grained, argillaceous, loosely cemented sand, sandstone, and conglomerate with interbeds of siltstone and clay.	Yields small to moderate amounts of water to wells in the southern edge of the study area.
Triassic	Upper	Dockum	Undivided	1,000+	Vari-colored, fine- to medium-grained sandstone with some claystone and interbedded shale.	Yields small amounts of water to wells. Water quality variable with stratigraphic position and depth.
Permian	Upper		Undivided	1,000+	Very fine- to fine-grained, red sandstone and shale; white to brown gypsum, anhydrite, and dolomite.	Not known to yield water to wells.

* Yields of wells: small = <50 GPM, moderate = 50-500 GPM, large = >500 GPM.

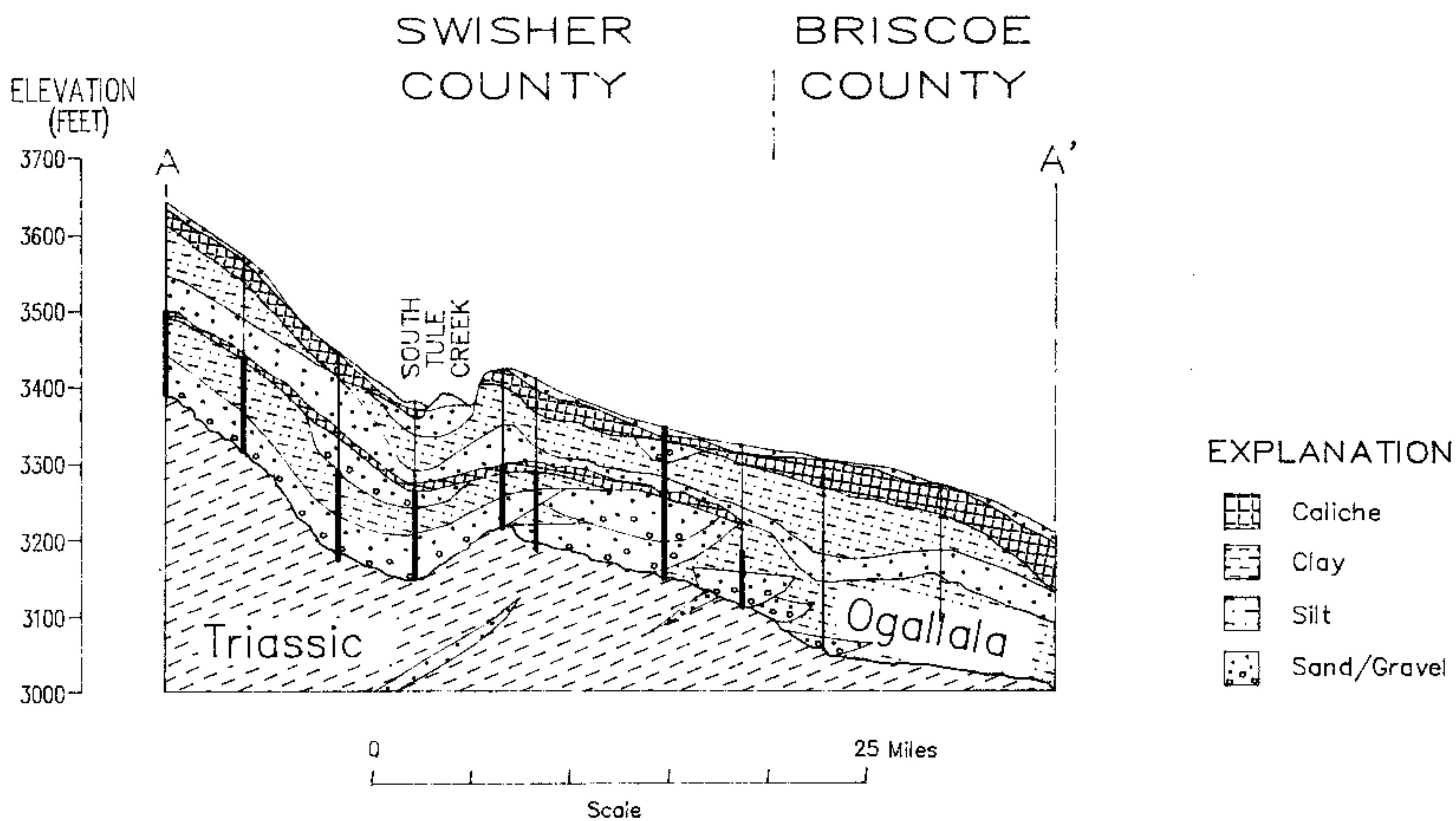

Figure 5

GEOLOGIC SECTION A—A'

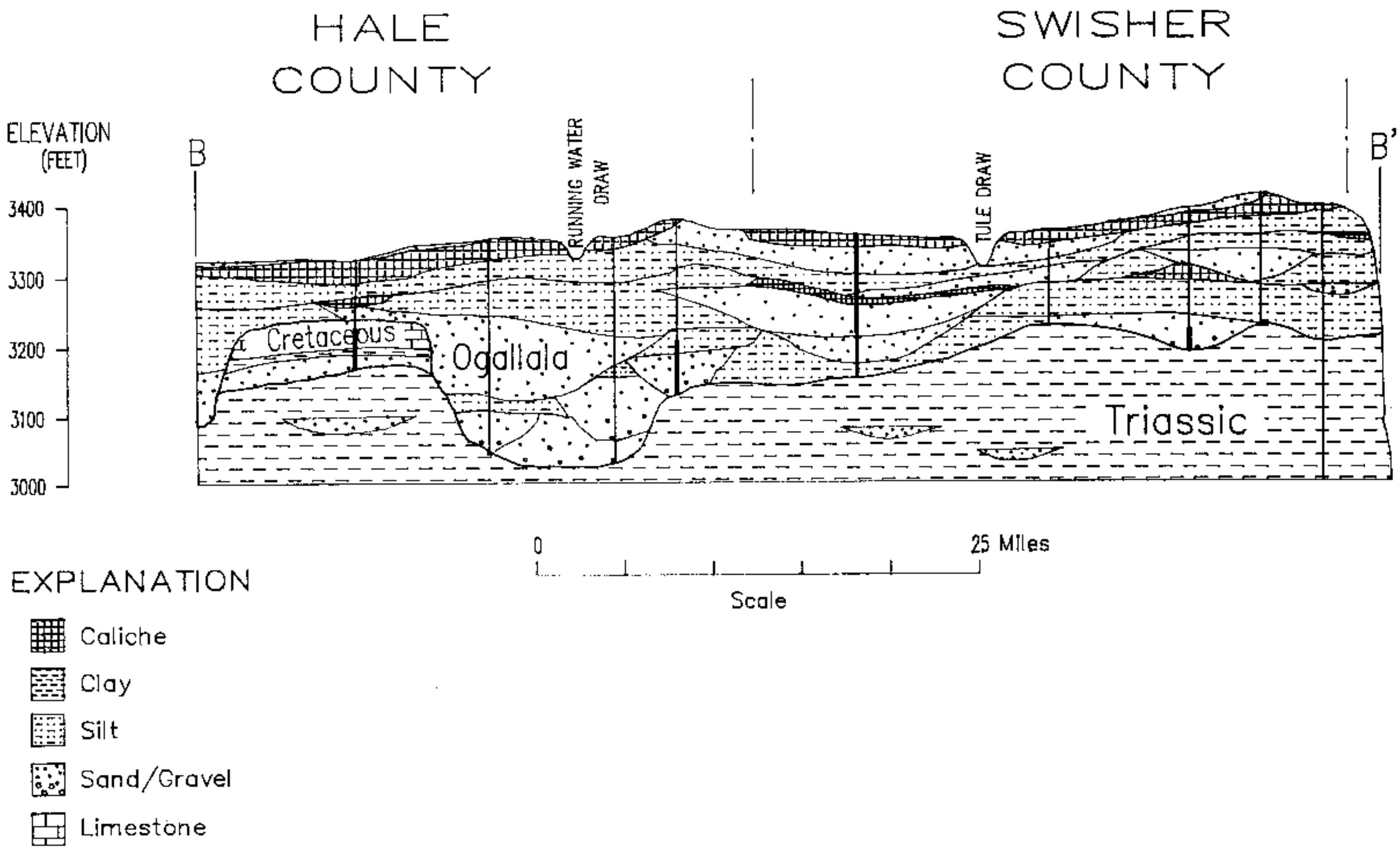

Figure 6

GEOLOGIC SECTION B—B'

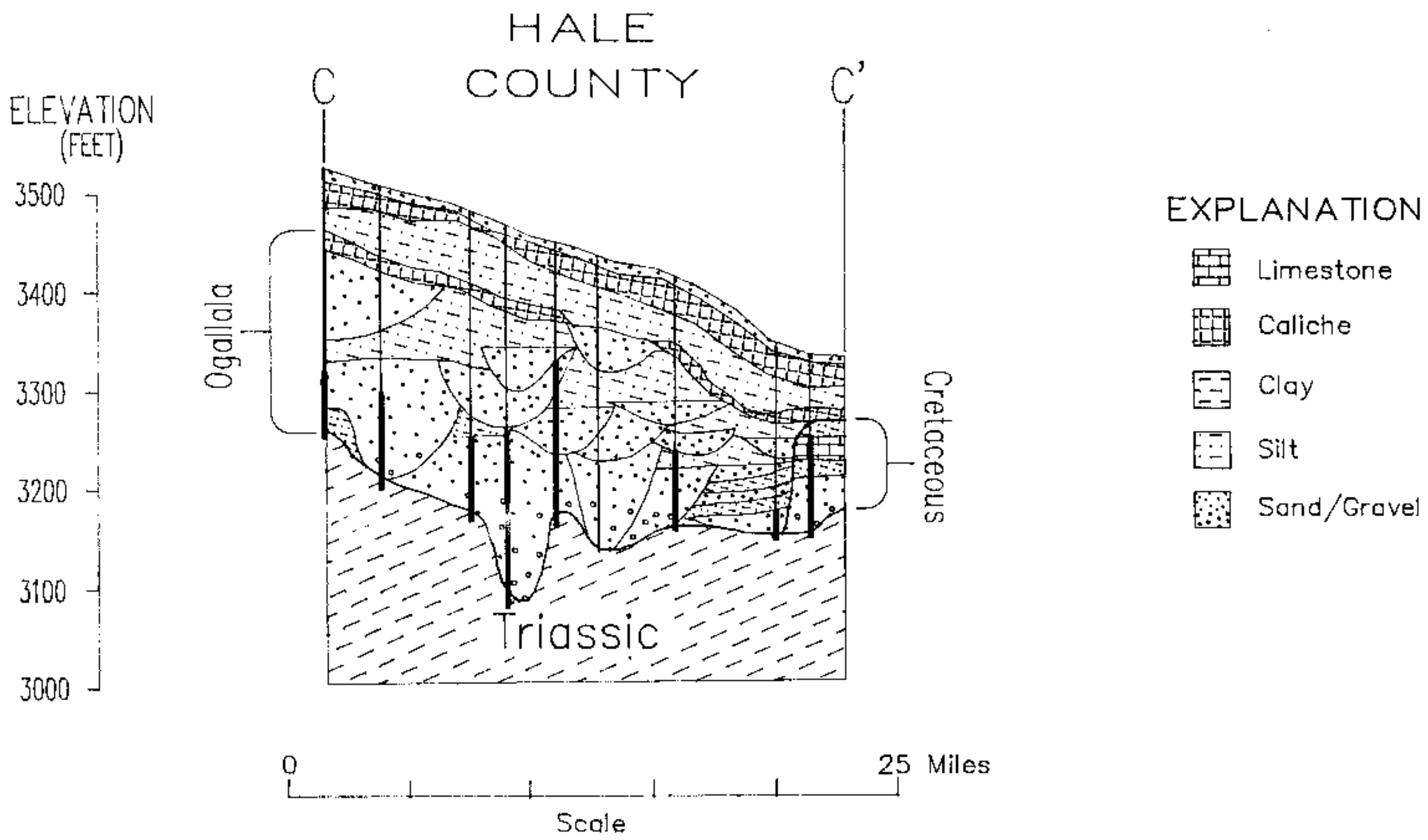

Figure 7

GEOLOGIC SECTION C–C'

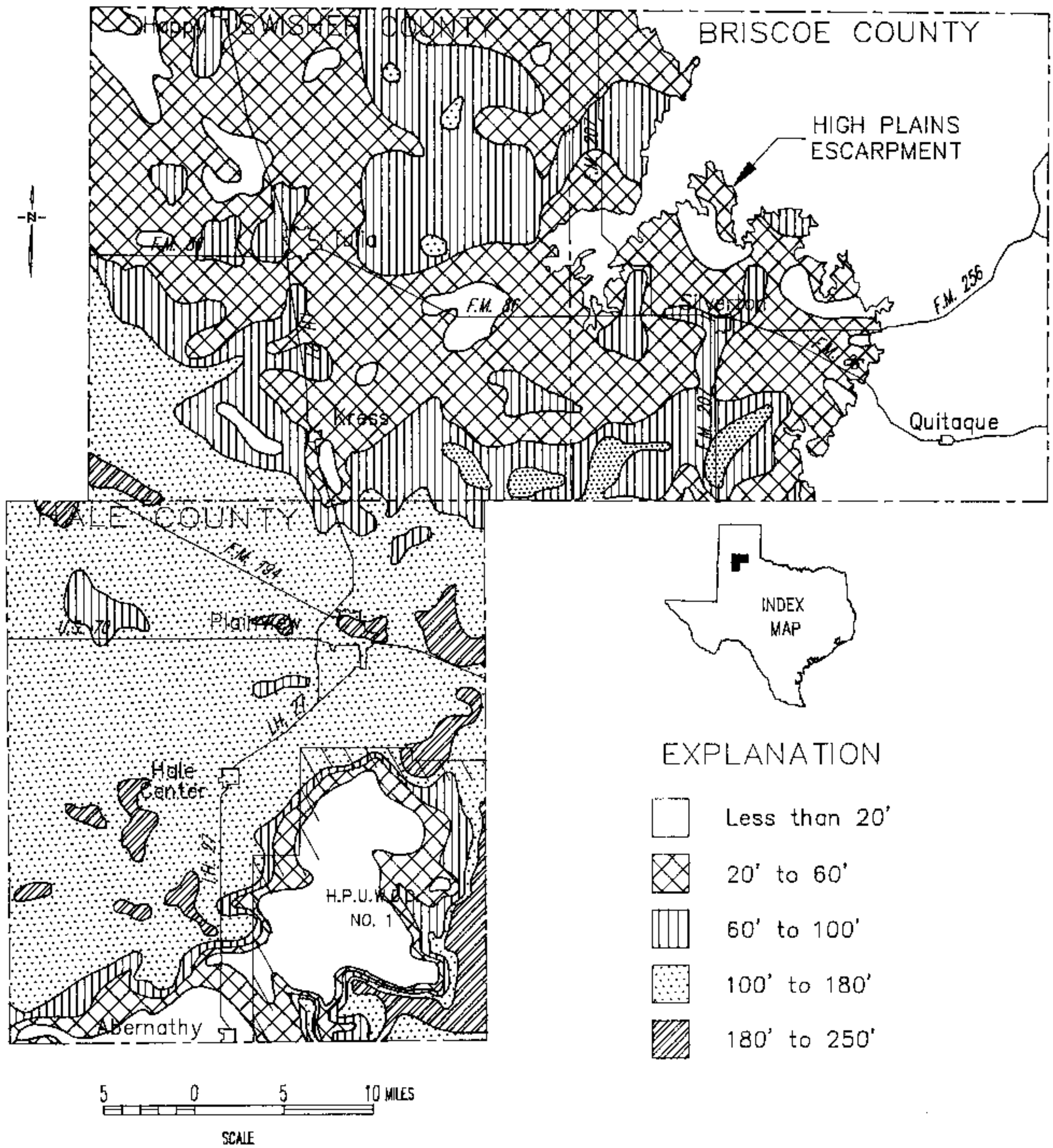

Figure 8

APPROXIMATE SATURATED THICKNESS
OF THE HIGH PLAINS AQUIFER, 1980

Ground-water movement through the High Plains aquifer in the study area is generally to the east-southeast. Flow rates are highest in the coarse- to medium-grained Ogallala deposits filling paleovalley courses, where hydraulic conductivity values usually range from 67 to 201 feet per day. Areas of high specific yield (16-20%) also delineate these paleovalley courses (Nordstrom, 1984). Actual water movement through the deposits is generally estimated to range from 0.5 to 1.0 foot per day along flow paths, with higher rates probably occurring locally when updip pressure heads are increased by above average recharge entering the system (Knowles and others, 1982).

Figure 9 is a map showing the 1987 static water level in wells completed in the High Plains aquifer. The water table regionally dips to the southeast at approximately 10 feet per mile. Local areas deviating from this pattern are mainly the result of heavy pumpage, which has lowered the water table in relation to the surrounding area. The water table has dropped since the 1940's when irrigation development started as shown on Figures 10 and 11.

Ground water in the High Plains aquifer also occupies porous and permeable intervals in Lower Cretaceous and Triassic strata that underlie the Ogallala Formation in the study area. Ground water in the Lower Cretaceous in southern Hale County occurs in basal sand deposits (Antlers Formation) and in overlying limestone strata (Comanche Peak and Edwards Formations), where fractures, bedding planes, and solution cavities influence ground-water movement (Fallin, 1987). In Triassic strata, the aquifer occurs in coarser-grained sandstone facies (Figure 4) that underlie the Ogallala Formation in northwest Briscoe, northeast Hale, and southeast Swisher Counties (Knowles and others, 1982).

Precipitation is the principal source of recharge to the High Plains aquifer. However, it is estimated that less than one percent of the average amount of precipitation that annually falls on the study area actually enters the aquifer (about 9,310 acre-feet per year for the three counties) (Knowles and others, 1982). Much of the precipitation that falls on the study area collects in the numerous playa lakes that dot the southern High Plains surface in the region, where silt and clay bottoms restrict infiltration and allow upwards to 60 percent of the moisture to evaporate back into the atmosphere (Nativ and Smith, 1985). Moisture that does enter the aquifer is usually absorbed in more porous soil zones that surround playa basin floors, and in more porous sand facies that bound surface drainages in the region.

Recharge via irrigation-water return flow would be similar to recharge by precipitation in that water in excess of evapotranspiration and plant needs would be allowed to enter the unsaturated zone and move downward toward the water table. Recent irrigation practices through the use of such things as soil moisture blocks, drip irrigation systems, etc., have probably reduced recharge by this mechanism. An estimation of the quantity of recharge via irrigation return flow is beyond the scope of this study, but as shown by water-level declines this amount plus meteoric recharge is insufficient to off-set pumpage.

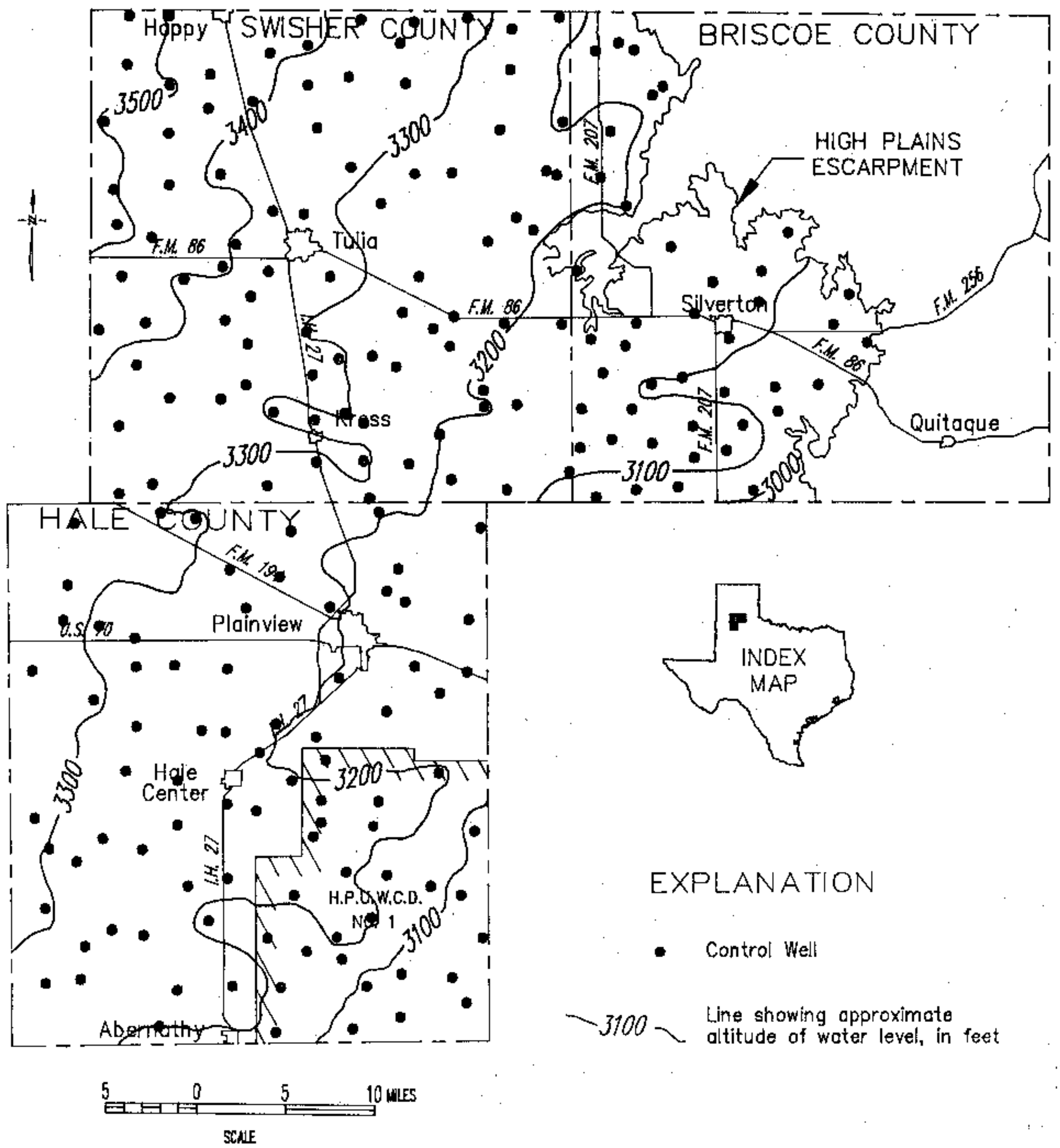

Figure 9

APPROXIMATE ALTITUDE OF WATER LEVELS IN THE HIGH PLAINS AQUIFER, WINTER 1987–88

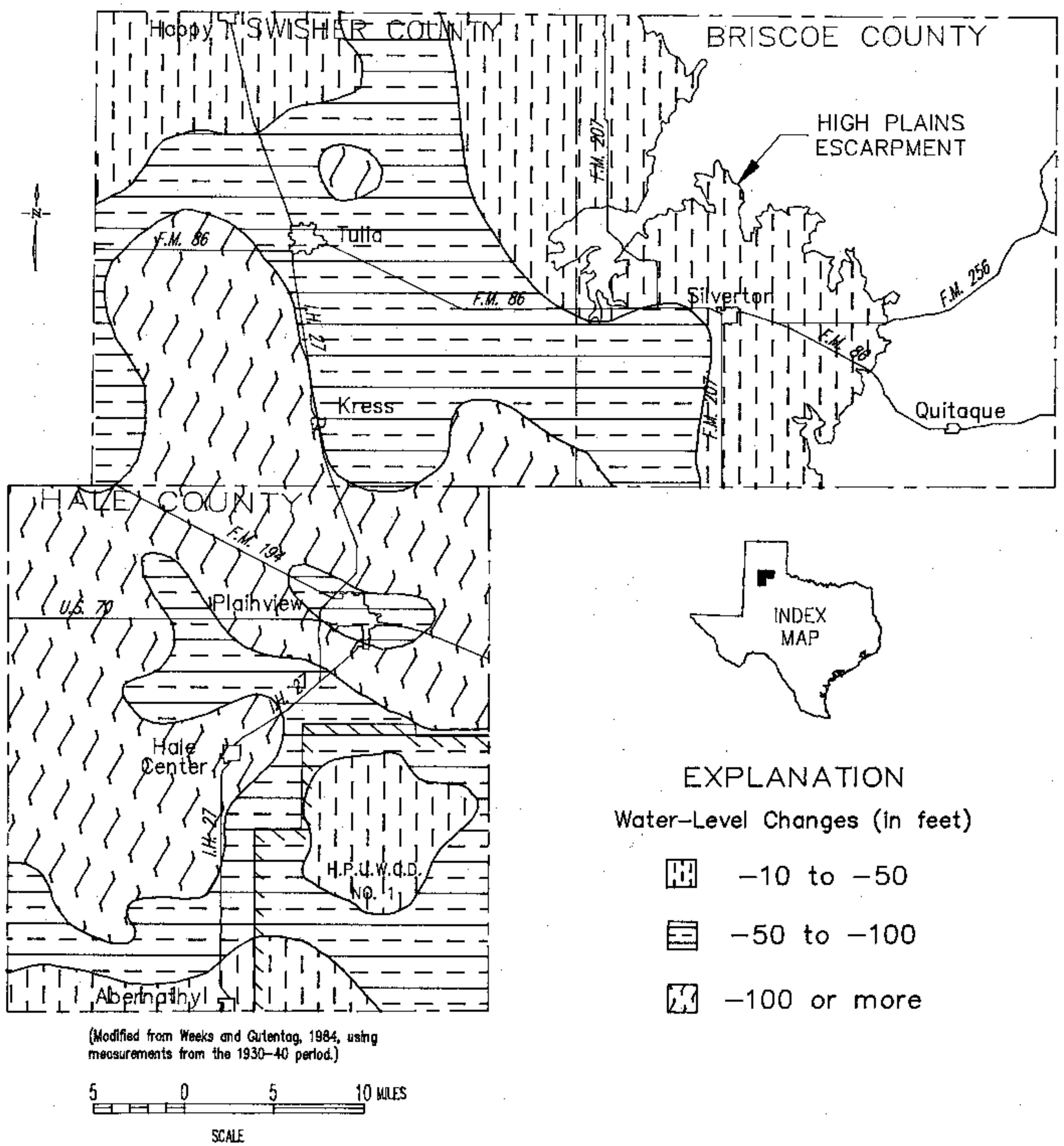

Figure 10

CHANGES IN WATER LEVELS, PREDEVELOPMENT TO 1988

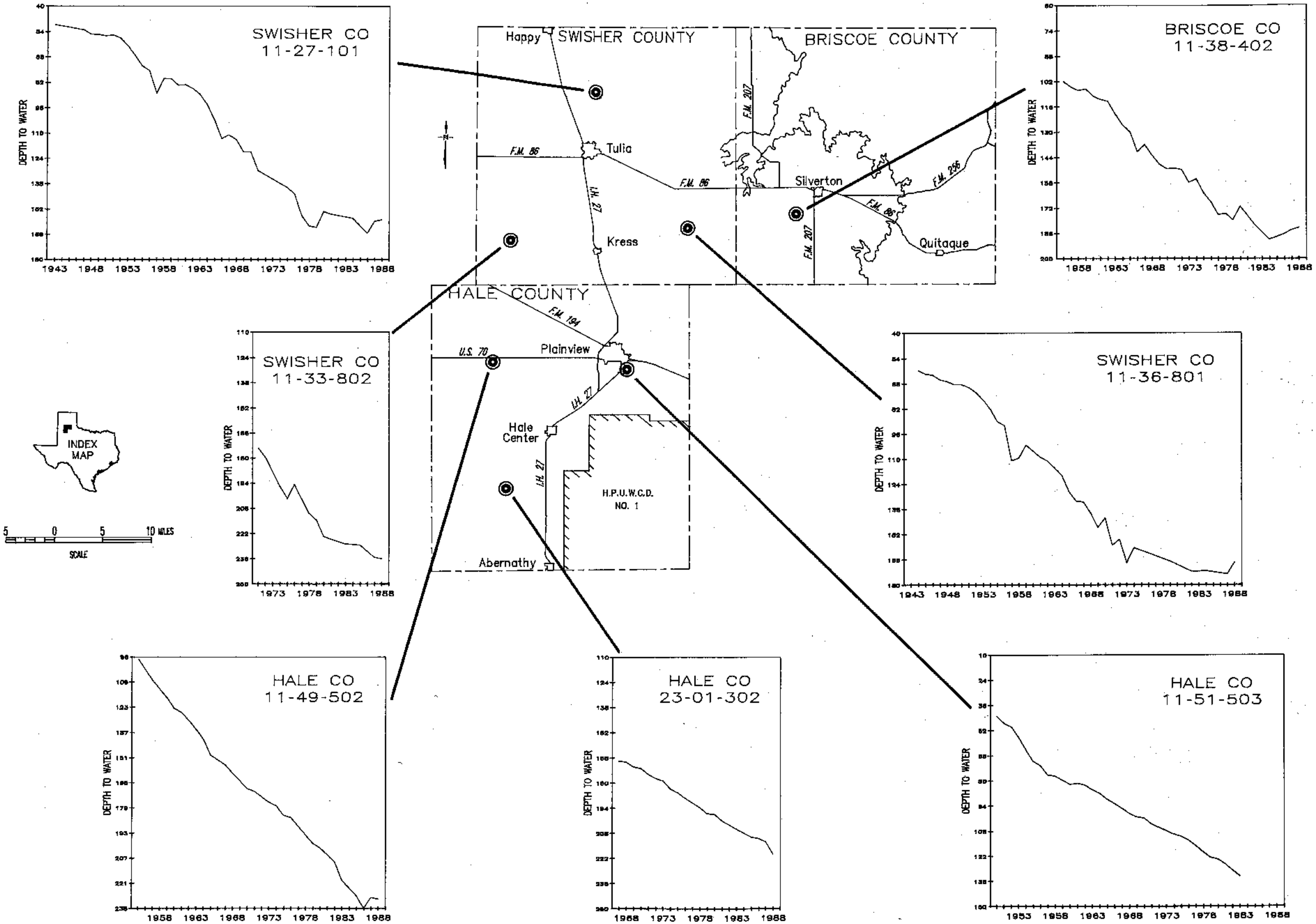

Figure 11

HYDROGRAPHS OF SELECTED WELLS COMPLETED IN THE OGALLALA FORMATION

Discharge from the High Plains aquifer in Briscoe, Hale, and Swisher Counties is to springs, seeps, and producing well heads. Springflow has been most common along the southern High Plains escarpment in Briscoe County, particularly where Tule Creek drains off the escarpment to merge with Prairie Dog Town Fork Red River. No more than 3,250 acre-feet of ground water is estimated to be discharged from the aquifer by springs and seeps each year (Nativ and Smith, 1985). Discharge along the escarpment in Briscoe County is possible, but springs have ceased flowing in recent years (Brune, 1981). As previously indicated, annual pumpage in recent years has totaled over half a million acre-feet per year in the study area (Table 1), a figure far exceeding annual recharge to the aquifer.

Yields from wells completed solely in the High Plains aquifer in the study area have ranged from less than 100 gallons per minute to more than 800 gallons per minute. Highest yielding wells are completed generally in areas where aquifer porosities and permeabilities are highest and saturated intervals are thickest in Ogallala sediments filling pre-Ogallala valley courses.

In regards to chemical quality, ground water in the southern High Plains aquifer under Briscoe, Hale, and Swisher Counties is: 1) fresh, generally containing less than 500 milligrams per liter (mg/l) dissolved solids; 2) slightly basic, with a pH range between 7.1 and 8.1; 3) very hard, with equivalent concentrations of calcium carbonate ($CaCO_3$) usually ranging between 200 and 300 mg/l; and 4) characterized almost exclusively by a mixed cation-bicarbonate hydrochemical signature that suggests some silicate mineral weathering in the system. The actual amount of dissolved solids in the aquifer increases from 300 to 500 mg/l in an easterly, downdip direction under Swisher and Briscoe Counties in the Ogallala Formation, while remaining relatively constant (less than 400 mg/l) in northern Hale County where coarse-grained valley-fill deposits in the Ogallala permit more fluid flow.

Ground water in Lower Cretaceous strata that underlie the Ogallala Formation in southern Hale County is slightly poorer in quality, containing upwards to 700 mg/l dissolved solids. The Lower Cretaceous ground water has a pH range between 8.1 and 8.4 and a mixed cation-bicarbonate hydrochemical signature. Similarly, ground water in Triassic strata that are included in the High Plains aquifer usually has more solutes than ground water in the overlying Ogallala Formation, with local exceptions occurring near the southern High Plains escarpment where meteoric recharge to the Triassic occurs.

Ground-Water Problems

Water-Level Declines

Water levels in wells completed in the High Plains aquifer have declined substantially in Briscoe, Hale, and Swisher Counties since irrigation pumpage began in the early 1900's. The declines have been prominent in northern Hale and southern Swisher Counties, measuring more than 100 feet at many locales as depicted in Figure 10 (Weeks and Gutentag, 1984).

Hydrographs for select wells in the study area (Figure 11) show that the rate of water-level declines in the High Plains aquifer have been relatively constant since the late 1940's, with perhaps some leveling off (rate decreases) in certain areas during the 1980's due to such things as cut backs in pumpage and employment of improved irrigation methods. During the same time period, wells completed in other parts of the High Plains aquifer have registered turnarounds from water-level declines to water-level rises (Fallin and others, 1987). Figure 12 shows the approximate change in water levels between the winter 1979-1980 and winter 1987-1988 measurements.

If annual pumpage rates continue to exceed annual recharge rates in a manner similar to what they have over the past 40 years, saturated thicknesses in the High Plains aquifer will decrease by more than 100 feet in certain parts of the study area over the next 40 years (Knowles and others, 1982). At the same time, costs to bring deeper water to the surface will rise, and well yields will continue to decrease. Figure 13 (after Knowles and others, 1982) depicts the approximate saturated thickness of the High Plains Aquifer, 2030.

To avert water-level declines in the High Plains aquifer, and maintain agricultural development in the study area, specific water management strategies need to be employed. Increased recharge to the aquifer may be implemented through the development of drain fields and artificial recharge wells around selected playas in the region. Also, impoundment reservoirs along specific drainages in the region, especially Running Water Draw in northern Hale County, might be constructed to catch precipitation runoff for both surface use and recharge by well and surface infiltration methods.

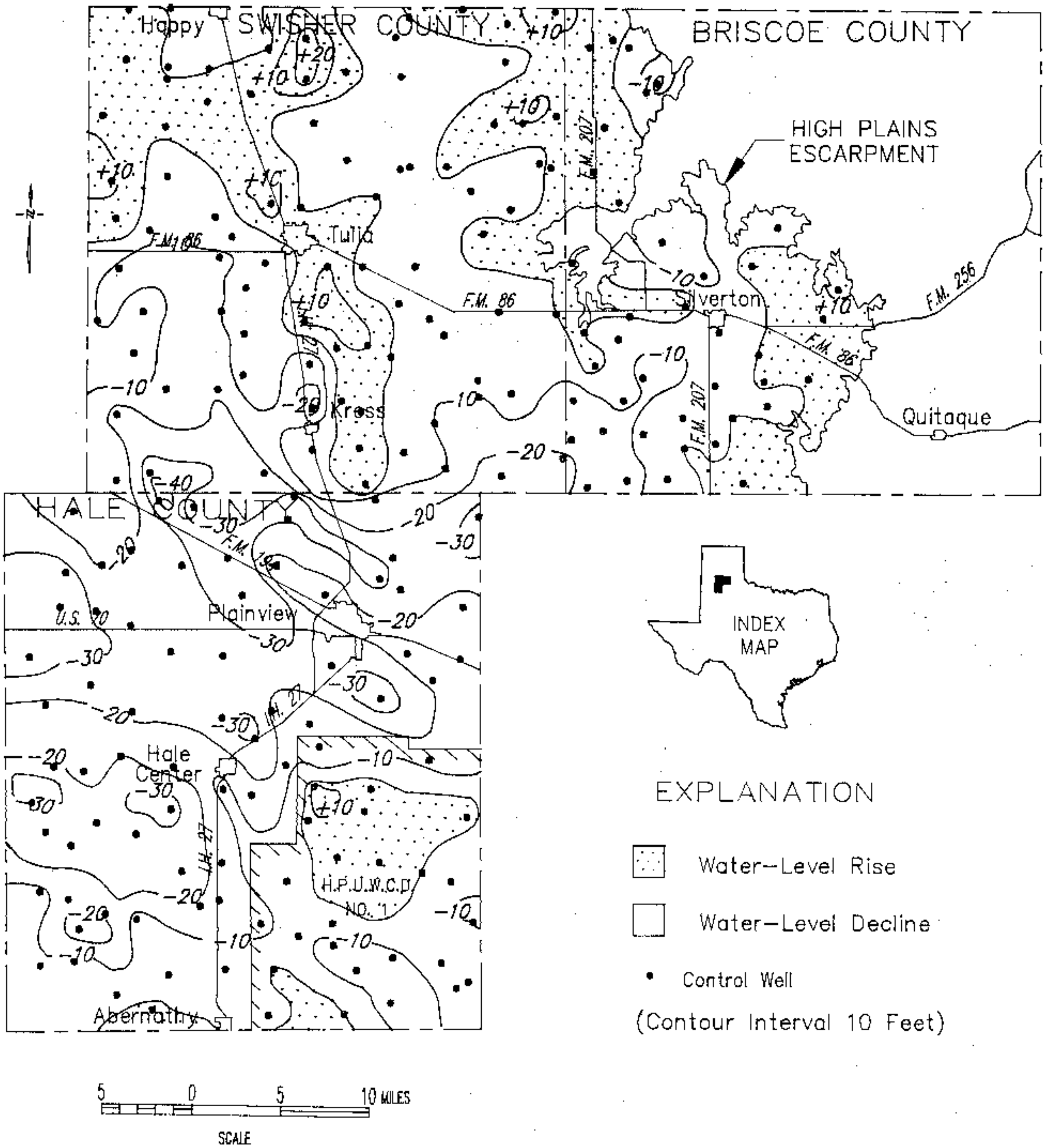

Figure 12

APPROXIMATE CHANGES IN WATER LEVELS
1980–1988

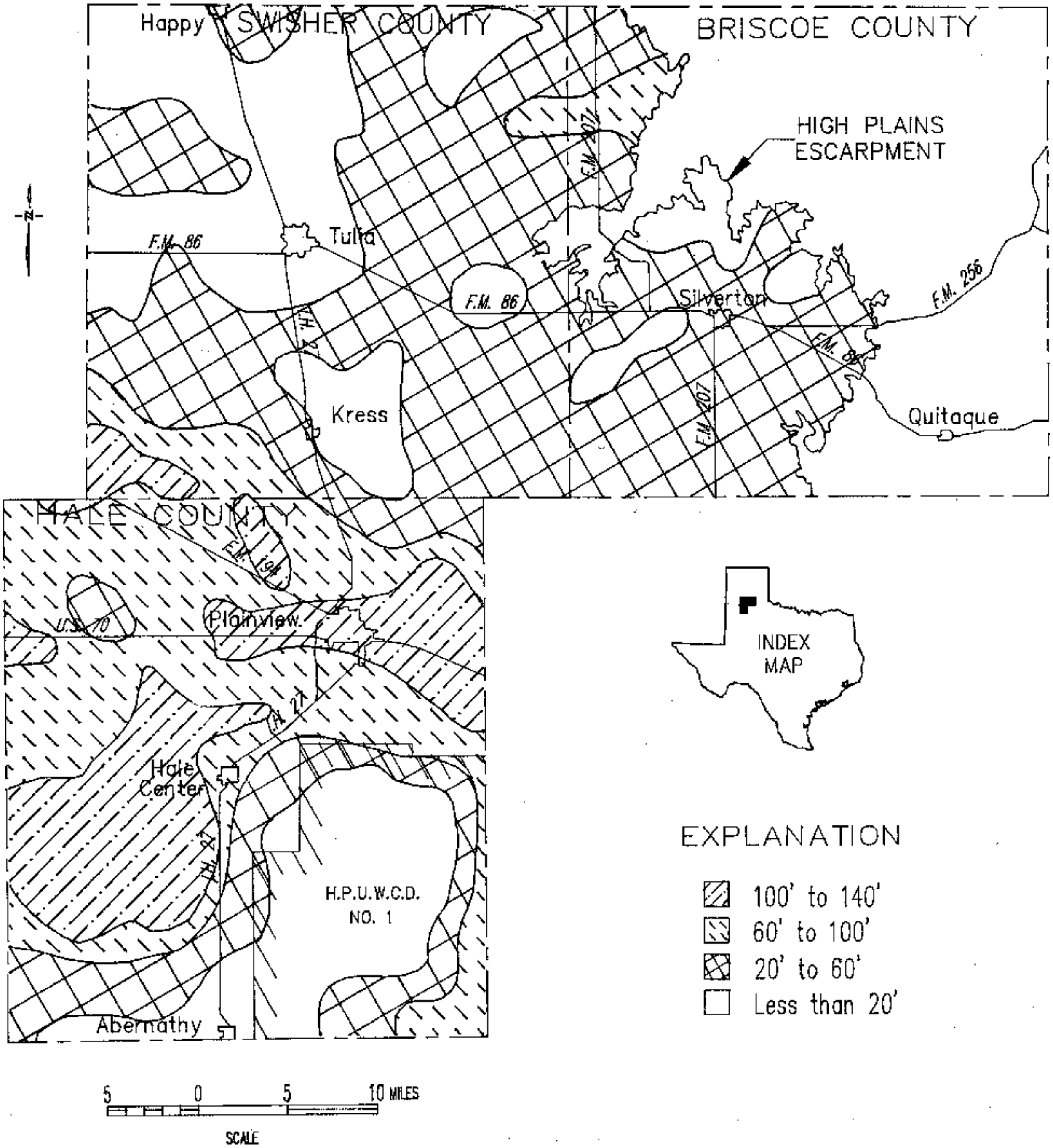

Figure 13

APPROXIMATE SATURATED THICKNESS OF THE HIGH PLAINS AQUIFER, 2030

(From Knowles, and Nordstrom and Klemt, 1982)

Projected Water Demand

Population

With the exception of Plainview, the regional population is generally sparse and is heavily dependant on agricultural economic conditions. The major cities of Abernathy, Hale Center, Plainview, Silverton, and Tulia had a combined population of 32,739 in 1985, which represents a decrease of approximately three percent from the 1980 level. The population for these cities is projected to increase to 46,034 by the year 2010 (TWDB, 1988).

The population of the rural area in 1985 was 12,958, which is projected to increase to 18,055 by the year 2010. The 1980 and 1985 population for cities and rural areas along with projected estimates for the years 1990, 2000, and 2010 are shown in Table 3. Population projections for the study area were estimated using the Texas Water Plan High Series population projection methodology (September, 1988 Preliminary Draft).

Water Use

In 1985, the total pumpage of ground water within the study area (Figure 1) was about 615,717 acre-feet. About 98 percent of this amount was used for irrigation being pumped from approximately 8,000 irrigation water wells. Land being irrigated in 1984 is depicted on Figure 2. The amount of water used in 1980 and 1985 is shown on Table 4 by county and use.

Municipal ground-water use is augmented by surface water purchased by Plainview, Tulia, and Silverton. About 40 percent (3,138 acre-feet) of water used for municipal purposes in 1985 was surface water. Presently, over 90 percent of municipal water use is supplied by surface water. Even though used for municipal, industrial, and livestock purposes, surface water only accounts for about one percent of total water use.

Water Demands, 1990-2010

Current and projected water demands in the study area are shown by use category on Table 4. Projections of future municipal requirements are based upon Texas Water Development Board Projected High Per Capita with Conservation Series (TWDB, 1988). Future projections of irrigation, industrial, and livestock use are based on the Board's High Series Preliminary Draft projected demands (dated September, 1988) and the apportioned share of total county demands. High series projections take into account the demands that are likely to occur during drought conditions. While future water requirements are expected to be met largely from ground-water supply, some surface-water supplies have been allocated to cities in the study area and will be discussed in the section on availability.

Under High Series projection conditions, the total annual water requirement for the study area is expected to decrease by 20 percent from 1985 to the year 2010, to an estimated 491,579 acre-feet. Municipal requirements will increase by 3,715 acre-feet in 2010, while irrigation use will decrease by 128,000 acre-feet. The estimated annual effective recharge to the aquifer is much less than the amount needed to meet present and future demands. Accordingly, water supply for the study area will continue to be drawn from storage within the aquifer, and water levels will continue to decline.

Table 3
Current and Projected Population [1]

County [2]	Year	Cities [3]	Rural [4]	Total
Briscoe	1980	918	684	1,602
	1985	756	618	1,374
	1990	687	570	1,257
	2000	730	606	1,336
	2010	778	644	1,422
Hale	1980	27,388	7,986	35,374
	1985	27,489	7,995	35,484
	1990	27,820	7,705	35,525
	2000	32,533	9,027	41,560
	2010	38,036	10,566	48,602
Swisher	1980	5,033	4,690	9,723
	1985	4,494	4,345	8,839
	1990	4,375	4,146	8,521
	2000	5,638	5,344	10,982
	2010	7,220	6,845	14,065
Study Area Total	1980	33,339	13,360	46,699
	1985	32,739	12,958	45,697
	1990	32,882	12,421	45,303
	2000	38,901	14,977	53,878
	2010	46,034	18,055	64,089

[1] 1980 and 1985 populations are based on Bureau of Census statistics. 1990, 2000, and 2010 populations are based on High Series population projection (TWDB, 1988).

[2] Population estimates are for the area in each county that is on the High Plains and excludes that portion of Hale County that is in the High Plains Underground Water Conservation District No. 1 (Figure 1).

[3] Cities include Silverton in Briscoe County; Abernathy, Hale Center, and Plainview in Hale County; and Tulia in Swisher County.

[4] Rural includes unincorporated areas and all rural population.

Table 4. Current and Projected Water Demand by Use in the Study Area [1]
(Units in Acre-feet)

County [2]	Year	Municipal [3]	Irrigation	Industrial	Livestock [4]	Total
Briscoe	1980	185	45,467	--	351	46,003
	1985	197	33,414	--	51	33,662
	1990	194	37,886	--	418	38,498
	2000	195	37,886	--	484	38,565
	2010	197	37,886	--	484	38,567
Hale	1980	6,979	613,995	2,440	1,327	624,741
	1985	5,986	418,065	1,992	1,347	427,390
	1990	7,088	291,816	2,244	1,574	302,722
	2000	7,867	291,816	2,571	1,823	304,077
	2010	8.704	291,816	3,049	1.823	305,392
Swisher	1980	1,683	212,835	---	2,963	217,481
	1985	1,440	147,123	9	6,093	154,665
	1990	1,645	141,100	---	3,523	146,268
	2000	2,011	141,100	---	4,083	147,194
	2010	2,437	141,100	---	4,083	147,620
Total	1980	8,847	872,297	2,440	4,641	888,225
	1985	7,623	598,602	2,001	7,491	615,717
	1990	8,927	470,802	2,244	5,515	487,488
	2000	10,073	470,802	2,571	6,390	489,836
	2010	11,338	470,802	3,049	6,390	491,579

[1] 1980 and 1985 water demands are based on reported and site-specific computed use; 1990, 2000, and 2010 water demands are based on TWDB High Series Preliminary Draft projected demands dated September 1988.

[2] Water demand estimates are for the study area only and do not include that part of Hale County in HPUWCD No. 1 nor that part of Briscoe County outside the study area.

[3] Surface water is supplied to Silverton and Tulia by the Mackenzie Municipal Water Authority (971 acre-feet in 1985) and to Plainview by Canadian River Municipal Water Authority (2,167 acre-feet). Municipal includes rural public-supply systems and domestic use.

[4] Livestock includes surface water (about 20 percent) supplied from local sources such as creeks, stock tanks, playa lakes and run of the river.

Availability of Water

Current Availability of Ground Water

The recoverable volume of fresh to slightly saline ground water in storage within the study area was approximately 15 million acre-feet in 1980, with an estimated recharge to the aquifer of 9,300 acre-feet per year (Knowles and others, 1982). Comparing these values with the over 600,000 acre-feet of ground water pumped in 1985, shown in Table 4, illustrates the fact that annual withdrawal by pumpage far exceeds the replenished quantity, resulting in the net water-level declines shown in Figure 11.

Potential for Conjunctive Use of Ground and Surface Water

Surface water is currently being used in conjunction with ground water to provide for municipal needs within the study area. Surface water is supplied to Silverton and Tulia by Mackenzie Municipal Water Authority and to Plainview by the Canadian River Municipal Water Authority. This supply amounted to 3,138 acre-feet in 1985, or 40 percent of total municipal use. In 1988, approximately 98 percent of the water used by Silverton and Tulia was surface water.

Data from the files of the Board indicate that Silverton and Tulia are each allocated about 1,300 acre-feet per year of water from Mckenzie Reservoir. Based on data from Tables 3 and 4, this is of sufficient quantity to provide their water needs through 2010. Plainview has an allocation of 2,600 acre-feet per year from the Canadian River Water Authority (Lake Meredith) which would leave Plainview a deficit of about 3,700 acre-feet in the year 2010. This amount can be derived from the cities well fields, which currently produce over 2,000 acre-feet per year to meet their present-day needs.

However, 98 percent of water use in the study area is for irrigation purposes, and no surface-water allocations have been made for this purpose. A very small amount can be accountable to pumpage from playa lakes, but for the most part, almost all water used in the study area is ground water.

Potential for Additional Ground-Water Development

Areas most favorable for additional ground-water development are dependent on saturated thickness, specific yield, and history of water-level declines. The study area, consisting mostly of farming enterprises, is presently near, or at, maximum development. The three-county area had 9,200 irrigation wells in operation in 1984 (TWDB, 1986).

Additional development of the Dockum sand units and Cretaceous strata may provide additional quantity of water for irrigation purposes, but not in sufficient quantities or areal extent to prevent overdraft of the aquifer as is currently happening or projected in the future (Fallin, 1987).

Potential Methods of Increasing Aquifer Recharge

Recharge is the process by which water is absorbed and added to the zone of saturation and can occur both naturally and artificially. As described earlier, natural recharge to the aquifer primarily occurs as water, derived from precipitation, percolates downward from the surface. Any activity by man, either intentional or unintentional, that increases or supplements the rate of replenishment to the aquifer, is called artificial recharge.

Numerous methods of artificially recharging aquifers have been studied (O'Hare and others, 1986), but the following discussion will focus on methods applicable to the primary study area (Figure 1) which consists mostly of a farming region of the High Plains. Increased recharge would benefit the area by increasing the amount of water in storage in the aquifer in an area that has experienced significant water-level declines. The following discussion on increasing aquifer recharge is an excerpt from a press release issued by the HPUWCD No. 1 in March, 1988.

> *"Why the reduction in pumpage and the increase in the recharge to the aquifer? There are many factors. The principal factor has been the poor economic conditions of the farming industry. This has resulted in reduced amounts of water pumped for irrigation throughout most of the area.*
>
> *Those who have continued to irrigate have made serious efforts to improve their irrigation efficiency. Furrow irrigators utilize such practices as pipelines to transport the water from the wells to the fields. Pipelines reduce losses from 10 to 30 percent per 1,000 feet as compared to open, unlined ditches. Time controlled surge valves increase efficiency savings an additional 10 to 30 percent of water pumped. Elimination of irrigation tailwater through tailwater return systems has saved as much as 20 percent of water pumped. Water savings of 10 percent or more have been achieved by utilizing moisture sensors to determine when the field needs to be irrigated and how much water needs to be applied to wet the field to field capacity. Using plant growth regulators on field crops results in more efficient use of water by crops, which in turn, results in more pounds of fruit per inch of water used by the plant. Using furrow dikes to harvest precipitation reduces irrigation requirements by as much as three inches per acre on farms with three percent slope.*
>
> *Other irrigators have converted from furrow irrigation to center pivot drop line systems. In instances where open, unlined earthen ditches were previously used, water savings of 50 percent or more have been achieved. Also, many older center pivot systems which operated under high pressure with water discharges above the center line have been*

converted to partial drops, reducing water losses by 20 percent or more. Those systems which have been converted to full drops have reduced losses by as much as 35 percent. Some irrigators with center pivot systems maximize these water savings by minimum tillage farming, which maximizes their utilization of precipitation and irrigation water by greatly reducing evaporation from the soil surface.

Above average precipitation during the past few years not only has reduced irrigation water demand, but also provided an above average water supply source for natural recharge to the aquifer. Ninety-seven percent of the precipitation runoff which occurs on the High Plains is collected in the playa basins. The construction of pits and sumps in the bottom of 65 percent or more of the 17,000 playa basins in the High Plains has increased the opportunity for natural recharge to the aquifer. These modifications are carved through the almost impermeable clay beds which line most of these lakes into the more porous caliche material. Not only is the natural recharge potential increased, but the runoff water is confined to a smaller surface area which reduces the evaporation losses. Most of the natural recharge occurs through the sides of the modification, as the clays suspended in the runoff water seal the bottoms of the modified structures. The sealed bottom prevents all the water from being recharge d from the modification. However, on the plus side, the water remaining in the modifications provides a water supply for wildlife long after the majority of the unmodified basins have gone dry.

Economic opportunities in the farming community undoubtedly will dictate how much water is pumped for irrigation in the future. Improvements in irrigation equipment and technology will continue to be made, because of cost effectiveness. A large amount of acreage has been enrolled in the 10-year Conservation Reserve Program (CRP), which will eliminate the need to irrigate this acreage for a least the next 10 years. This will reduce the demand on the aquifer.

Future farm programs will also influence pumpage, as will the amounts and timeliness of precipitation occurring in the area in future years. The prospects look good for reduced demands on the aquifer."

An additional source of surface water that might be available for infiltration through spreading basins is sewage effluent from the various municipal water systems. Factors that must be carefully analyzed before using this process include: (1) the cost of transporting the effluent to the spreading basin, (2) the infiltration capability of the spreading basin, and (3) the chemical quality effect that the effluent will have on the present quality of the ground water and land surface.

Recharge wells have successfully been used to inject water directly into underground water-bearing zones. The nature of the water sources, such as treated sewage effluent in El Paso, storm runoff near Dell City, and playa lakes near Lubbock, along with an understanding of the geohydrological characteristics of the formation into which the water will be injected, determines the technology necessary to construct recharge wells (O'Hare and others, 1986). In the study area, water collected in surface depressions and storm-runoff structures represents the most viable source for injection. Precaution must be given to injecting only water that is silt free and chemically fresh.

An investigation of the feasibility of secondary recovery of ground water (HPUWCD, 1982) concluded that depending on site selection, the cost of such recovery is economically feasible only for municipalities whose existing water supply is almost exhausted. Continuing studies of secondary recovery of capillary water by the District (1985) concluded that this method is both economically and technologically feasible. However, additional scientific research must be undertaken to improve upon the mechanical efficiency of the technology and to advance the understanding of complex ground-water and capillary-water environments.

Projected Availability Through the Year 2010

The amount of ground water needed to supply projected demands through the year 2010 is in excess of the estimated annual effective recharge to the aquifer. Therefore, the water supply for the study area will continue to be drawn from storage within the aquifer. Based on the storage depletion rate shown below, by the year 2010 approximately 62 percent of the water held in storage in the aquifer in 1985 will have been used with approximately 7.82 million acre-feet remaining.

Year	Pumpage[1]	Average Annual Effective Recharge[2]	Storage Depletion[3]	Water Remaining in the Aquifer
1985	612,579	9,300	603,279	20,364,000
1990	483,741	9,300	464,441	17,347,605
2000	485,857	9,300	476,557	12,603,195
2010	487,567	9,300	478,267	7,820,525

Water quantity in acre-feet.

[1] Ground-water portion of demand listed in Table 4.

[2] This quantity does not take into account irrigation return flow.

[3] Pumpage minus recharge.

It is important to remember that the model used to obtain these data is basing future projections upon high series projected demands and takes into account that demands are likely to occur during drought conditions. An adequate quantity of ground water for irrigation use should be available through the year 2010, although heavy pumpage in this area, especially during drought periods, will probably result in significant water-level and well-yield declines.

SUMMARY

The High Plains aquifer provides the major source of water for irrigation and municipal use in the study area. Pumpage far in excess of recharge has resulted in declining water levels and that trend is expected to continue. Future pumpage at this rate will result in higher irrigation costs and declining well yields.

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