Report 341

The High Plains Aquifer System of Texas, 1980 to 1990 Overview and Projections

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The High Plains Aquifer System of Texas, 1980 to 1990 Overview and Projections

by
Darrell S. Peckham, Geologist
and
John B. Ashworth, Geologist

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ABSTRACT

Recent geological and hydrological studies have furthered our knowledge of the High Plains aquifer system in Texas. Based on outcrop and core studies, the Ogallala Formation is most recently described as consisting of "alluvial sediments that partly fill paleovalleys and widespread thick eolian sediments capping paleouplands and most fluvial sections." Recharge rates to the aquifer system are somewhat higher than earlier estimated, and playa lakes appear to play a more important role in the recharge estimate.

In 1989, 4.69 million acre-feet of ground water was pumped for irrigation purposes on the Texas High Plains. This represents a 17 percent reduction in pumpage since 1979. Surveys also identify a reduction of about 1.39 million irrigated acres during the past decade. Because of reduced pumpage and increased recharge due to above-average annual precipitation, net water-level rises occurred over approximately 40 percent of the region between 1980 and 1990.

The recoverable volume of water in storage in the High Plains aquifer system in 1990 is estimated to be 417 million acre-feet. An additional 36 million acre-feet in the basal 10 feet of the aquifer is assumed to be economically unrecoverable.

Underground water conservation districts have played a significant role in the management of the aquifer. The number of operating districts has grown to nine in recent years and now encompass most of the Texas High Plains region.

An aquifer simulation model of the High Plains aquifer system, originally constructed in the early 1980s, was updated and revised in 1990 and was applied to predict future aquifer conditions. Current model projections indicate a slight increase in future water availability over 1980 projections; but, withdrawal of water will continue to exceed recharge, and water levels will continue to decline. Because of the large volume of water in storage, the aquifer can continue to support the various water needs of the High Plains region for many years.

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INTRODUCTION

The High Plains aquifer system underlies approximately 35,450 square miles of the Texas High Plains (Figure 1), the southernmost extension of the Great Plains physiographic province of North America. In Texas, the High Plains is the most extensive region irrigated with ground water and has historically experienced the greatest reductions in saturated thickness in the entire eight-state extent of the aquifer.

The Ogallala Formation is the principal water-bearing unit of the High Plains aquifer system that consists of the saturated sediments of the Ogallala and those geologic units in hydraulic continuity with the Ogallala that contain potable water (Table 1). Hydraulic continuity occurs between the Ogallala Formation and the underlying Cretaceous, Jurassic, and Triassic rocks in many areas of the Texas High Plains (Figure 2) and the overlying Quaternary deposits where present (Knowles and others, 1984).

Because of its economic importance to the state, the Texas Water Development Board (TWDB) has monitored the condition of the High Plains aquifer system since the 1950s. Some of their activities include the following:

(1) Water levels are measured annually in more than 3,100 wells by the TWDB and the underground water conservation districts within the area. The measurements are used to calculate storage depletion and to estimate expected ground-water reserves.

(2) Chemical quality analyses of water samples from approximately 5,000 wells have been conducted. The analyses are used to characterize the aquifer and detect human-induced water-quality changes. More than 700 analyses have been added to the TWDB ground-water database since 1989 (Hopkins, 1993).

(3) Surveys of irrigation are conducted every five years by the TWDB in cooperation with the U. S. Department of Agriculture Soil Conservation Service and the Texas State Soil and Water Conservation Board.

(4) An aquifer simulation model of the High Plains aquifer system constructed by the Texas Department of Water Resources in the early 1980s is being applied to predict future aquifer conditions. The model is periodically evaluated, revised, and updated.

In recent years, several geological and hydrological studies have refined our knowledge of the physical and mechanical makeup of the aquifer system. Also, monitored water-level changes have deviated somewhat from previously projected trends. The purpose of this report is to document the changes that have occurred in the aquifer from 1980 to 1990, summarize the more relevant advances toward understanding the hydrology of the aquifer system, and attempt to verify these findings or suggest alternative explanations.

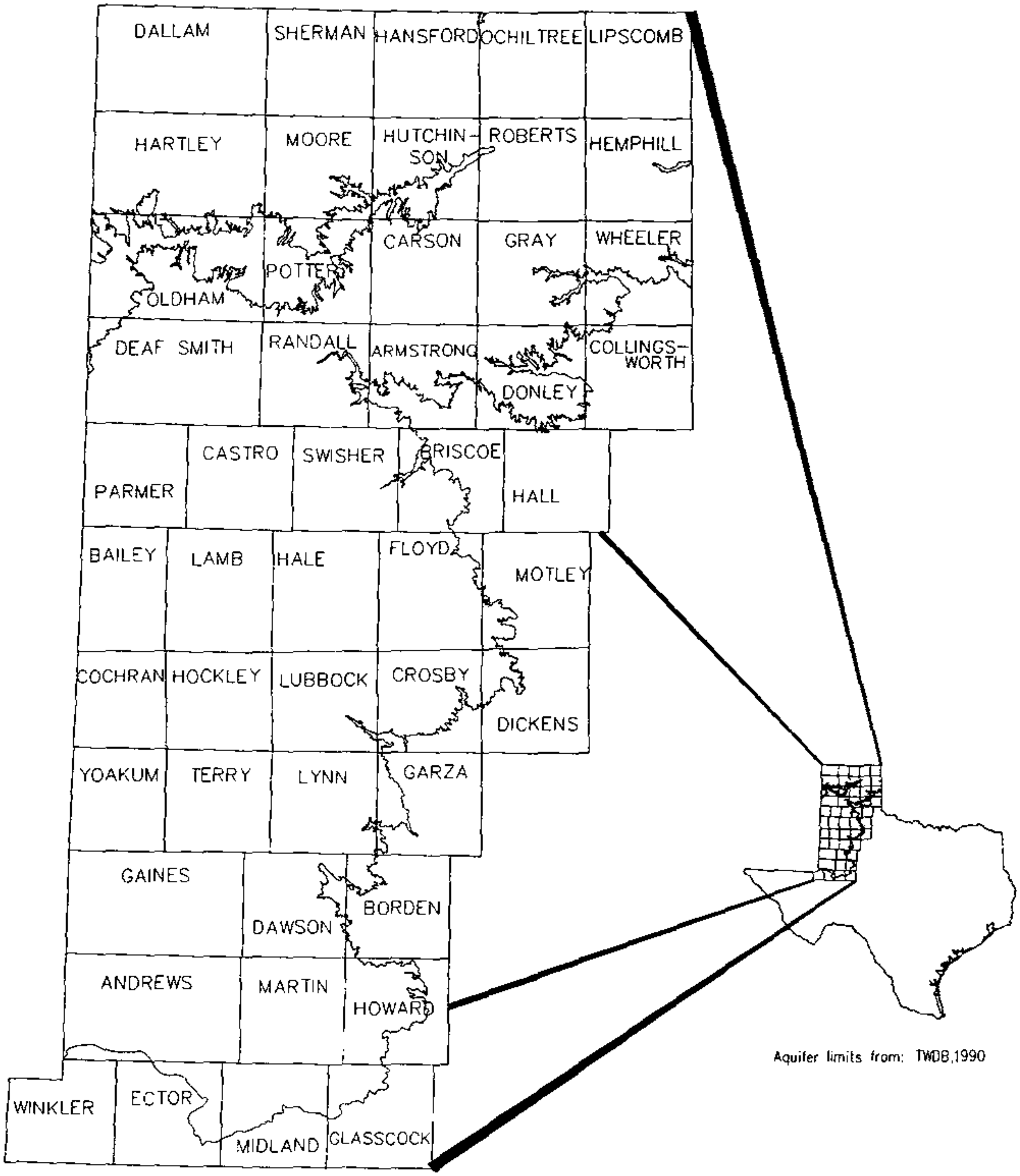


Figure 1

LOCATION OF THE HIGH PLAINS AQUIFER IN TEXAS

Table 1. - Water-Bearing Units Comprising the High Plains Aquifer System

System	Formation	Aquifer
Quaternary	Alluvium, eolian, and lacustrine deposits	
Tertiary	Ogallala	Ogallala
Cretaceous	Romeroville Sandstone	Rita Blanca
	Mesa Rica Sandstone	
	Lytle Sandstone	
	Duck Creek	Edwards-Trinity High Plains and Plateau
	Kiamichi	
	Edwards Limestone	
	Antlers	
Jurassic	Morrison	Rita Blanca
	Exeter Sandstone	
Triassic	Dockum	Dockum

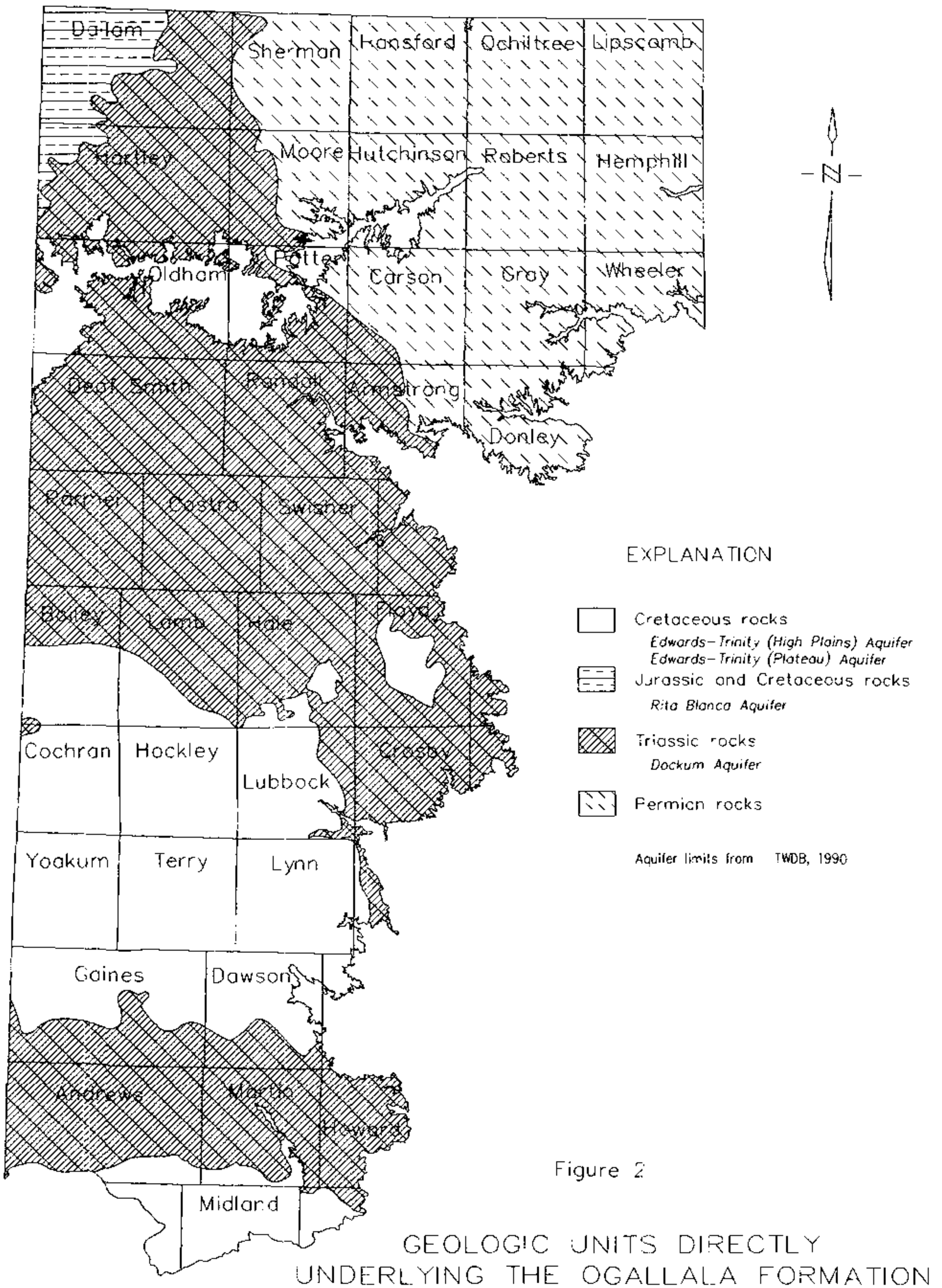


Figure 2

GEOLOGIC UNITS DIRECTLY UNDERLYING THE OGALLALA FORMATION

HYDROGEOLOGY

Geology

In 1990, the TWDB published revised maps of the major and minor aquifers in the state (TWDB, 1990; and Ashworth and Flores, 1991). These new maps more clearly establish the extent of aquifers underlying the Ogallala and, in hydrologic combination with the Ogallala, form the High Plains aquifer system. Water-bearing units of Cretaceous and Jurassic ages combine to form the Rita Blanca aquifer in the western part of Dallam and Hartley counties (Christian, 1989). Lower Cretaceous units form two separate subcrops within the Texas High Plains, the Edwards-Trinity (High Plains) and the Edwards-Trinity (Plateau). Underlying these three aquifers and much of the Ogallala are Triassic (Dockum aquifer) and Permian formations.

The Ogallala Formation of late Miocene to early Pliocene age generally consists of heterogeneous sequences of coarse-grained sand and gravel in the lower part grading upward into fine clay, silt, and sand. Previously, the Ogallala was described as fluvial sediments deposited as a series of coalescing alluvial fans or plains with only minor amounts of eolian sediments (Seni, 1980). However, Reeves (1972), Hawley and others (1976), and Hawley (1984) recognize the Ogallala as predominately eolian sediments in parts of Texas and southeastern New Mexico. Outcrop and core studies by Gustavson and Winkler (1987) indicate the Ogallala in Texas and New Mexico consists of "alluvial sediments that partly fill paleovalleys and widespread thick eolian sediments capping paleouplands and most fluvial sections." Calcic paleosols and fossil evidence suggest a depositional environment in a mostly semiarid to subhumid climate (Winkler, 1990; Schultz, 1990; and Thomasson, 1990).

Recharge

Early irrigators believed the body of water underlying the Texas High Plains was inexhaustible and was being continuously replenished by snowmelt from the Rocky Mountains. Geologic and hydrologic studies later led to an understanding that recharge to the aquifer primarily occurs by infiltration of precipitation on the surface.

Only a small portion of water from precipitation percolates to the water table due to a combination of high evaporation and slow infiltration rates. The semi-arid climate of the High Plains results in an average annual gross lake evaporation rate of 72 to 81 inches, which is three to six times the average annual rainfall (Larkin and Bomar, 1983). The formation of caliche also suggests the dominance of evaporation over deep percolation. Estimates of annual recharge rates for the aquifer vary considerably. Studies have suggested recharge from diffused percolation ranging from 0.01 (Stone, 1984) to 0.833 (Knowles and others, 1984) inches per year.

Recharge through the estimated 20,000 to 30,000 playa lakes has drawn the most controversy. Heavy precipitation runoff from approximately 89 percent of the Texas High Plains accumulates in these surface depressions. While some studies suggest that the silt and clay bottoms of the playas render them nearly impermeable, others indicate that leakage through the playas is the primary source of recharge to the entire aquifer. Nativ and Riggio (1990), using tritium as a tracer, calculated the recharge rate through the vadose zone as ranging from 0.5 to 3.24 inches per year. Based on the fast recharge rates and the slightly enriched values of oxygen and hydrogen isotopes, Nativ and Riggio concluded that "the most likely method of ground-water recharge is focused percolation of partly evaporated playa-lake water."

Average precipitation, as reported by the National Weather Service, increased dramatically between 1980 and 1990 in the Texas High Plains resulting in conditions favorable for increased recharge. The greatest precipitation increase occurred south of the Canadian River where approximately 50 percent of the southern region received between four and six inches of rainfall above the annual average. The remainder of the area received up to four inches above the annual average. Most of the precipitation increase occurred between 1985 and 1987.

Within the High Plains aquifer system, recharge to the Ogallala aquifer also occurs by upward leakage from the underlying Cretaceous (Edwards-Trinity High Plains aquifer) and Triassic (Dockum aquifer) formations that, in places, have a higher water level than the Ogallala (Nativ, 1988). Flow from the Triassic into the Ogallala occurs in only a few places along the eastern escarpment. Flow from a large portion of the Cretaceous into the Ogallala is possible wherever permeable contacts are available. This mixing of Cretaceous and Ogallala waters is indicated by hydrochemical similarities in these areas.

The 1990 revision of the TWDB High Plains aquifer model resulted in an increased awareness that, especially in the southern region, recharge to the aquifer is more variable than previously envisioned. Further study is needed to improve simulation of the various recharge mechanisms that occur within the aquifer.

Discharge

Prior to the influx of modern man to the High Plains with his means of artificially extracting water from underground sources, the High Plains aquifer system maintained a balance where recharge equaled discharge. Discharge was equal to the natural evapotranspiration of shallow ground water, flow from seeps and springs, and downward movement to underlying formations. The arrival of pioneering families intent on developing an agricultural economy changed the natural balance as substantially more water was withdrawn from the aquifer than was replaced.

Springs occur on the High Plains where the surface elevation intercepts the water table. Temporary springs may exist following significant rainfall when infiltrating water ponds at shallow depths and spills back onto the surface before it has a chance to migrate downward to lower depths.

A survey of springs by Gunnar Brune (1981) identified approximately 170 sites in the Texas Panhandle where seeps and springs once existed. Abandoned structures, weather-beaten by time and neglect, and dying cottonwood trees still mark many of these sites where early plains pioneers attempted to establish a homestead. Archeological artifacts found near many of the former spring sites also attest to the importance these "watering holes" once had to the early natives of this land. Longtime residents of the High Plains recall that some springs dried up early in the 20th century, while other springs ceased to flow by the 1950s and 1960s when irrigation pumpage had its greatest effect on water levels.

Brune also identified approximately 225 actively flowing seeps and springs, the majority of which occur along the eastern escarpment and in the Canadian River "breaks." Most of these springs have relatively low flows, with only 25 having a measured flow exceeding three cubic feet per second. Some of these springs are associated with saline lakes that occur primarily in the southern region of the aquifer in Texas and New Mexico (Wood and Jones, 1990).

Within the aquifer system, downward leakage of water from the Ogallala into underlying Cretaceous and Triassic formations occurs where Ogallala water levels are higher than water levels in the underlying units (Nativ, 1988). Probably very little ground water escapes from the entire system through downward leakage to deeper Permian formations because of the low permeability of these older units.

The greatest withdrawal of water from the aquifer occurs through the discharge of pumping wells. High Plains irrigation represents about 65 percent of the total irrigated acreage in the state, and 83 percent of the acres irrigated with ground water. Similarly, 4.69 million acre-feet of ground water was pumped for irrigation purposes from the High Plains aquifer system in 1989, which is a 17 percent reduction, or 0.98 million acre-feet less than the 1979 pumpage (TWDB, 1991). Only 14 of 46 High Plains counties showed an increase in irrigation water use from 1979 to 1989. The reduction of irrigation water use during the decade was the result of an increase in average annual precipitation, more extensive involvement with conservation practices, and a decrease in irrigated acreage.

In 1989, approximately 3.95 million acres were irrigated on the Texas High Plains, a reduction of about 1.39 million acres since 1979. Higher energy costs, declining well yields, unavailability of labor, and depressed farm prices account for this reduction (TWDB, 1991).

Water-Level Changes

Water levels in the High Plains aquifer system are controlled by the rate of recharge to and discharge from the aquifer. With the development of large-scale irrigation operations on the High Plains following World War II, pumpage from the aquifer far outpaced recharge. The declining water table appeared to be the result of mining that would eventually deplete the aquifer. Monitoring of the aquifer water level during the past decade, however, has indicated that this downward trend may not be as consistent as previously thought.

Water-level changes from 1980 to 1990 varied substantially from the generally consistent, decline-oriented trend prior to 1980. Figure 3 shows the 1990 elevation of the aquifer's water level. In approximately 40 percent of the area, declines reversed and water-level rises were observed (Ashworth, 1991) (Figure 4). This reversal was due to increased recharge and decreased pumpage caused by an increase in average annual precipitation, improved irrigation management practices that have resulted in less water applied per acre, and a decrease in irrigated acreage. During the 1980 to 1990 period, the largest area of water-level rise in excess of 20 feet occurred in the southern part of the region centered in Dawson and eastern Gaines counties (Ashworth, 1991) (Figure 4). The maximum rise observed was more than 60 feet in a small area in Dawson County.

Certain areas that had significant water-level declines from predevelopment to 1980 continued to show declines from 1980 to 1990 (Figure 5). In approximately 45 percent of the Texas High Plains, water levels continued to decline between 1980 and 1990 as a result of pumpage exceeding recharge (Ashworth, 1991). In the central part of the Panhandle, water-level declines in portions of Castro, Floyd, Hale, Lamb, Parmer, and Swisher counties exceeded 20 feet, although some of these areas recorded rises in 1986 and 1987. Farther north, water-level declines in smaller portions of Carson, Dallam, Hartley, Hutchinson, Moore, and Sherman counties also exceeded 20 feet from 1980 to 1990. The average rate of decline in these areas was approximately two feet per year. The remaining 15 percent of the Panhandle is located within the Canadian River "breaks" and is outside of the aquifer boundary.

Volume of Water in Storage

The recoverable volume of water in storage in the High Plains aquifer system in 1990 was approximately 417 million acre-feet as calculated using saturated thickness, area, and specific yield. This volume of water does not include water contained in the basal 10 feet of the aquifer, which has insufficient thickness for reasonable operation of large-capacity wells. This unrecoverable volume amounts to approximately 36 million acre-feet. Approximately two-thirds of the water in storage occurs in the northern High Plains where land-surface conditions are not generally conducive to irrigated agriculture. The 1990 volume of water in storage is listed by county in Tables 2 and 3.

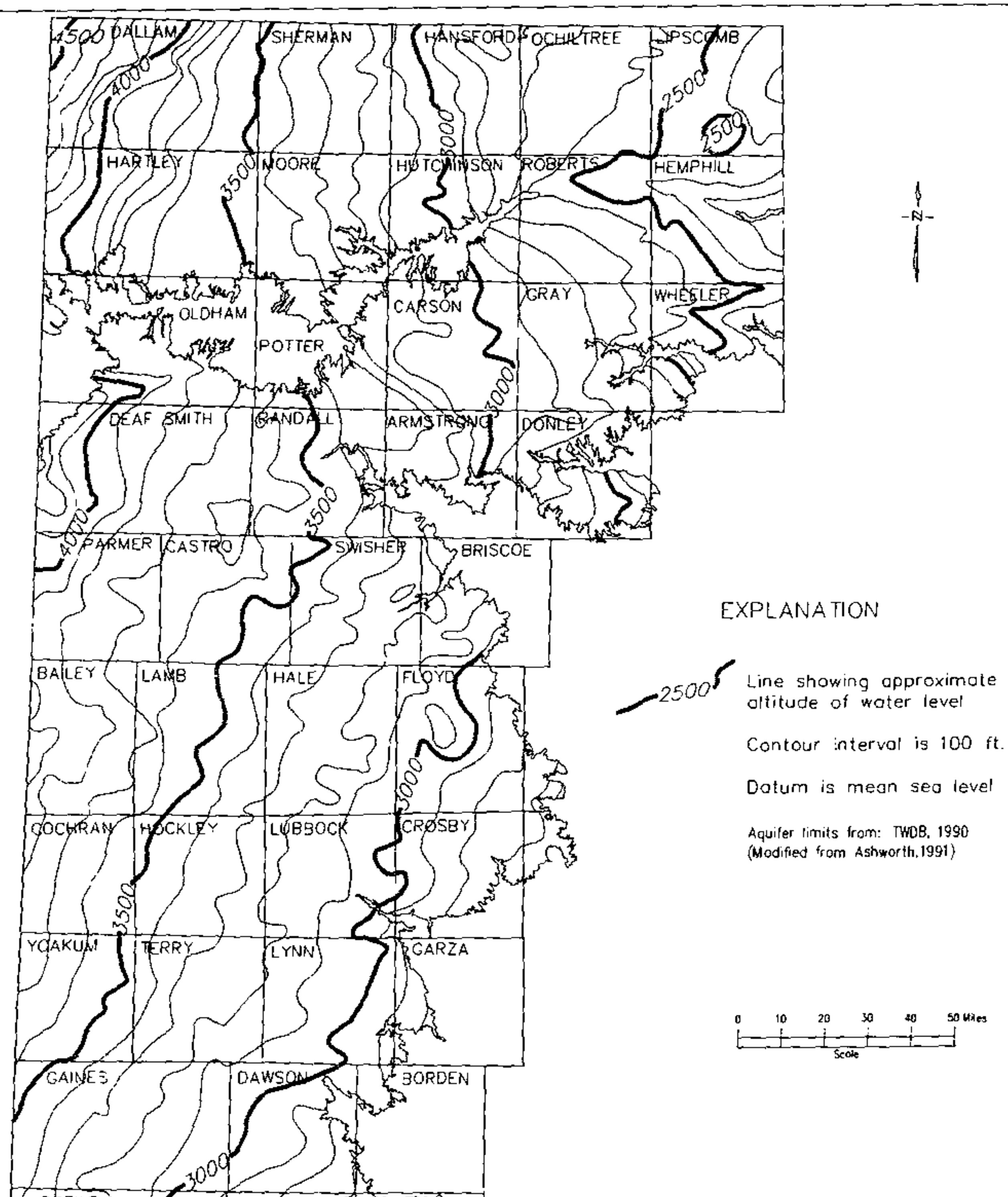


Figure 3

APPROXIMATE ALTITUDE OF WATER LEVELS IN THE HIGH PLAINS AQUIFER, 1990

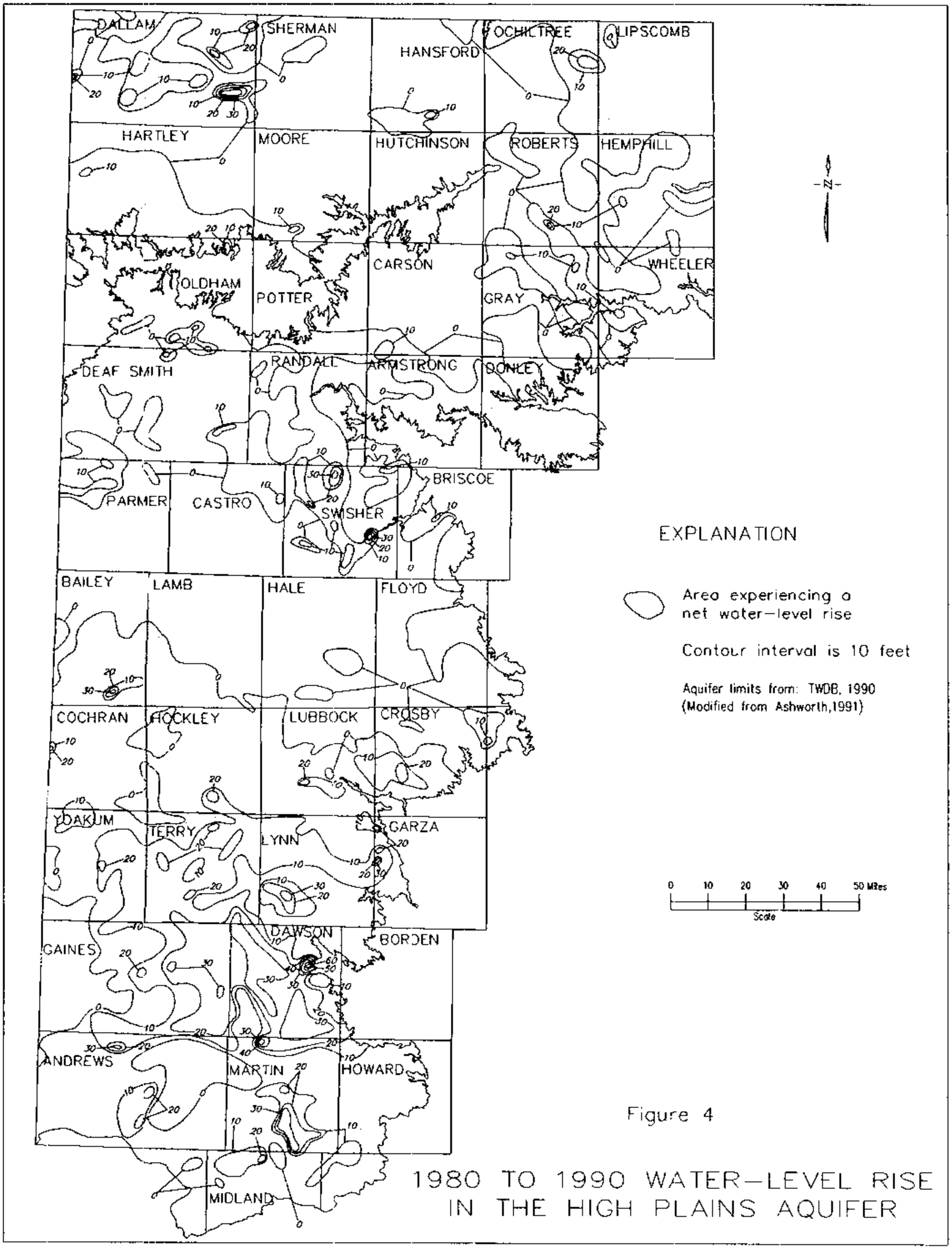


Figure 4

1980 TO 1990 WATER-LEVEL RISE
IN THE HIGH PLAINS AQUIFER

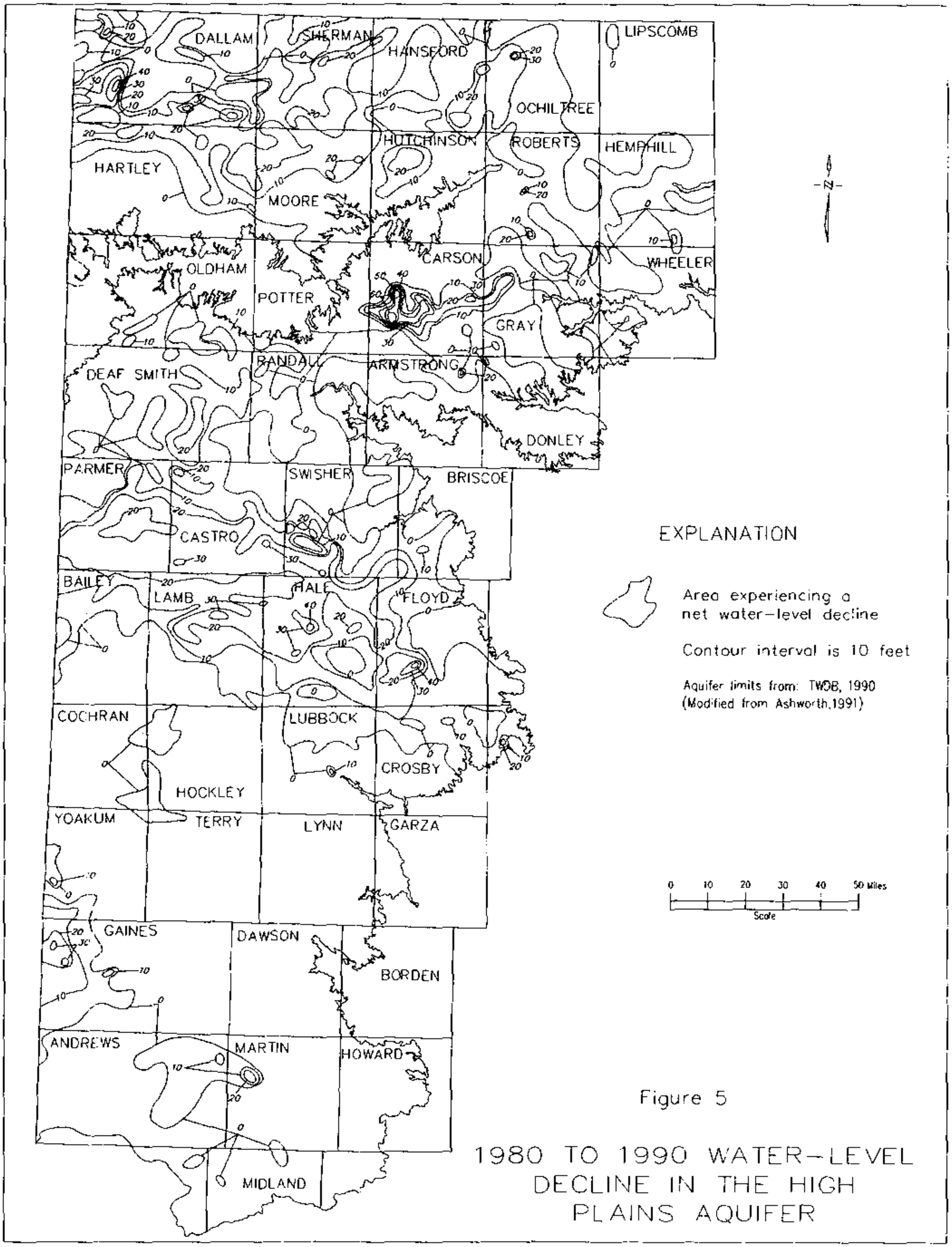


Figure 5

1980 TO 1990 WATER-LEVEL DECLINE IN THE HIGH PLAINS AQUIFER

Table 2. - Volume of Water in Storage for Future Periods, North Model

County	Unrecoverable	1990	2000	2010	2020	2030	2040
Armstrong	.47	3.53	3.40	3.26	3.13	3.02	2.92
Carson	.92	13.19	12.53	11.93	11.37	10.83	10.21
Dallam	1.71	29.97	25.71	23.78	22.20	20.91	19.52
Donley	.64	8.09	8.10	8.11	8.12	8.15	8.16
Gray	1.02	12.96	12.30	12.25	11.89	11.59	11.29
Hansford	1.06	23.27	21.36	19.54	17.95	16.56	15.13
Hartley	1.61	27.82	26.06	24.24	22.56	21.47	20.41
Hemphill	.93	16.57	16.74	16.88	17.00	17.12	17.21
Hutchinson	.69	10.54	9.97	9.39	8.95	8.55	8.12
Lipscomb	.96	20.82	20.74	20.61	20.50	20.39	20.32
Moore	.76	13.20	11.11	9.14	7.46	6.06	4.75
Ochiltree	.90	18.57	17.67	16.73	15.91	15.17	14.43
Oldham	.03	.03	.04	.04	.05	.05	.06
Potter	.27	2.59	2.31	2.05	1.85	1.70	1.56
Randall	.12	.56	.51	.47	.45	.43	.41
Roberts	1.01	27.62	27.70	27.76	27.80	27.82	27.84
Sherman	1.05	21.88	19.79	18.05	16.48	15.07	13.28
Wheeler	.58	8.45	8.36	8.31	8.28	8.26	8.24
Total	**14.73**	**259.66**	**244.40**	**232.54**	**221.95**	**213.15**	**203.86**

- Portions of Armstrong, Oldham, Potter, and Randall counties in South Model
- Approximate representation of counties
- Data measured in 1990
- Volume, in millions of acre-feet

Table 3. - Volume of Water in Storage for Future Periods, South Model

County	Unrecoverable	1990	2000	2010	2020	2030	2040
Andrews	1.23	4.92	4.77	4.68	4.63	4.58	4.53
Armstrong	0.03	0.11	0.10	0.10	0.09	0.09	0.08
Bailey	0.81	6.28	5.50	4.87	4.32	3.87	3.51
Borden	0.01	0.17	0.16	0.15	0.13	0.12	0.11
Briscoe	0.24	1.69	1.35	1.14	1.00	0.90	0.82
Castro	1.05	11.74	9.76	8.10	6.61	5.32	4.21
Cochran	0.83	4.06	3.37	2.87	2.47	2.15	1.90
Crosby	0.53	6.62	5.86	5.15	4.50	3.94	3.47
Dawson	0.70	6.31	5.96	5.65	5.35	5.05	4.77
Deaf Smith	1.54	10.66	9.01	7.74	6.72	5.92	5.28
Dickens	0.04	0.93	0.85	0.81	0.77	0.74	0.71
Ector	0.45	2.31	2.27	2.23	2.19	2.16	2.13
Floyd	0.99	9.37	8.23	7.18	6.21	5.35	4.57
Gaines	1.37	13.63	12.27	11.15	10.23	9.48	8.85
Garza	0.07	0.71	0.67	0.63	0.60	0.56	0.53
Glasscock	0.14	1.73	1.71	1.68	1.65	1.62	1.58
Hale	1.12	12.32	9.99	7.97	6.08	4.43	3.17
Hockley	0.88	4.40	3.68	3.16	2.74	2.38	2.07
Howard	0.39	2.01	1.92	1.87	1.83	1.81	1.78
Lamb	1.05	10.09	8.30	6.78	5.42	4.26	3.29
Lubbock	0.80	5.11	3.97	3.14	2.47	1.96	1.58
Lynn	0.80	3.62	3.24	2.99	2.80	2.63	2.50
Martin	0.86	4.83	4.73	4.64	4.54	4.46	4.37
Midland	0.41	2.00	1.88	1.78	1.69	1.61	1.55
Motley	0.08	0.82	0.78	0.74	0.71	0.68	0.65
Oldham	0.30	1.11	1.03	0.95	0.87	0.81	0.75
Parmer	0.98	9.64	7.98	6.67	5.55	4.62	3.88
Potter	0.09	0.48	0.45	0.43	0.42	0.40	0.39
Randall	0.79	3.95	3.49	3.08	2.74	2.45	2.22
Swisher	0.80	4.75	3.64	2.82	2.22	1.82	1.54
Terry	0.96	5.60	4.70	3.98	3.42	2.98	2.64
Yoakum	0.83	5.71	5.08	4.65	4.32	4.06	3.84
Total	**21.17**	**157.68**	**136.70**	**119.78**	**105.29**	**93.21**	**83.27**

- Portions of Armstrong, Oldham, Potter, and Randall counties in North Model
- Approximate representation of counties
- Data measured in 1990
- Volume, in millions of acre-feet

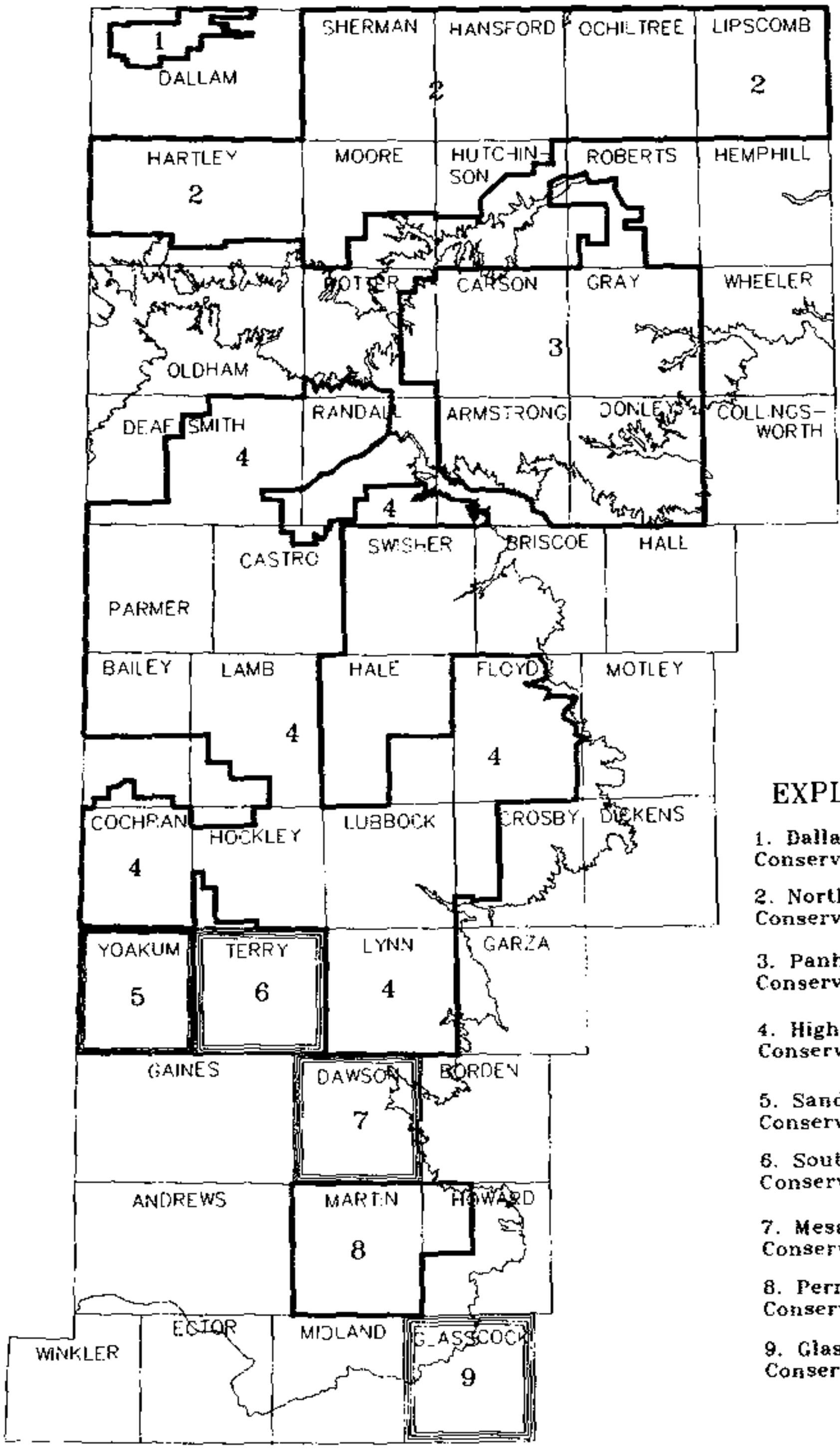
UNDERGROUND WATER CONSERVATION DISTRICTS

Underground water conservation districts have played a significant role in the management of the High Plains aquifer system. The Texas Groundwater Districts Act established by the Texas Legislature in 1949 provided for the creation of local underground water conservation districts. Chapter 52 of the Texas Water Code authorizes these districts to "provide for the conservation, preservation, protection, recharging, and prevention of waste of the underground water . . ." within their boundaries.

By 1955, five districts had been established on the High Plains ranging in size from small parts of single counties to multi-county districts. As of 1992, nine districts were in operation and some original districts had expanded to include additional territory (Figure 6).

Underground water conservation districts have led the way in encouraging conservation management practices. As a result of their efforts, many 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. The High Plains Underground Water Conservation District No. 1 reports that water levels within their 15-county area stabilized in 1985 for the first time in the 40-year history of the District. A net water-level rise was recorded in 1986 and 1987. This marks a vast improvement over times such as the 1960s when water-level declines of three to four feet per year were common.

Texas High Plains districts have also established programs such as monitoring the water level and quality, public education, research, closing abandoned wells, assisting municipalities, and other programs that provide for the most effective conservation management.



EXPLANATION

1. Dallam County Underground Water Conservation District No.1
2. North Plains Ground Water Conservation District No.2
3. Panhandle Ground Water Conservation District No.3
4. High Plains Underground Water Conservation District No.1
5. Sandy Land Underground Water Conservation District
6. South Plains Underground Water Conservation District
7. Mesa Underground Water Conservation District
8. Permian Basin Underground Water Conservation District
9. Glasscock County Underground Water Conservation District

Figure 6

UNDERGROUND WATER CONSERVATION DISTRICTS

Graphics by Steve Gifford

DIGITAL COMPUTER MODEL

Application

The High Plains aquifer system study conducted by the Texas Department of Water Resources (TDWR) (Knowles and others, 1984) included the construction of a two-part, north and south, digital model designed with the capability of predicting future water levels and saturated thicknesses. The model was calibrated for the period January 1960 through December 1979. Transmissivity and storage coefficient values were adjusted accordingly to simulate known aquifer conditions. Then, the model was applied to predict future conditions of the aquifer, with several runs made while varying the degree to which management practices reduce net withdrawal rates. The computer program written to do the simulation is ***GWSIM-III, Ground-Water Simulation Program*** and is documented in TDWR User's Manual UM-36 (Knowles, 1981). The basic simulation was a procedure developed by T. A. Prickett and C. G. Lonnquist (1971).

Contemporaneously, the U. S. Geological Survey (USGS) constructed a digital model of the High Plains aquifer system that incorporated the entire eight-state extent of the aquifer for a regional aquifer-system analysis. The review of published reports from that analysis provided additional information and data for the current evaluation.

The evaluation started during the winter of 1989-1990 with measuring water levels from selected wells in the High Plains. In the spring, work began on updating data files to be used in a new 50-year projection of water in storage. The project design was to use recharge rates developed by the USGS (Tables 4 and 5), initiate projection from the year 1990, and incorporate current projections for pumpage. The work was completed under the guidance of Dr. Tommy Knowles, Director of Planning. Table 6 indicates data retained from the 1980 runs and data sets updated for the current model. A detailed explanation of how the data were determined and applied to the model is documented in TDWR Report 288, Volume 1 (Knowles and others, 1984). A thorough investigation of the recharge values is described by Luckey and others (1986).

As an evaluation of accuracy, the model simulated the 1980 to 1990 period. The evaluation used withdrawal rates determined by the Texas Water Development Board (TWDB, 1989). Aquifer physical data developed for the 1980 run and the new recharge values generated by Luckey and others (1986) were incorporated. This produced a good correlation of simulated water levels with observed levels (Figure 7).

Simulation of Future Conditions

The 1990 model application simulated in ten-year increments the aquifer response to projected pumpage to the year 2040. Pumpage projections used for municipal, industrial, domestic, livestock, and irrigation were developed by the Texas Water Development Board (TWDB, 1989). All projections represent estimated maximum needs under less than normal precipitation conditions with conservation practices in place. Municipal and industrial pumpage is assigned to current locations of well fields, while domestic and livestock pumpage is apportioned evenly by county. Projected irrigation withdrawals are assigned to areas of each county based on the 1989 TWDB survey of irrigation in Texas (TWDB, 1991), and the rates determined from TWDB projected demands.

Table 4. Recharge, in Acre-Feet per Year, North Model

County^	Rate 1980-2029 Report 288	Rate 1990-2039 Based on USGS
Armstrong^^	4,420	2,950
Carson	6,120	4,819
Dallam	16,190	4,681
Donley	10,350	2,767
Gray	8,040	4,512
Hansford	4,270	2,954
Hartley	13,610	8,659
Hemphill	9,460	7,409
Hutchinson	4,820	2,216
Lipscomb	8,910	15,295
Moore	3,730	2,378
Ochiltree	4,930	2,754
Oldham^^	450	125
Potter^^	2,640	1,577
Randall^^	980	885
Roberts	9,580	2,778
Sherman	5,530	2,829
Wheeler	9,220	1,602
Total	**123,250**	**71,190**

^ - Approximate representation of counties
^^ - Part of county in south models

Table 5. Recharge, in Acre-Feet per Year, South Model

County^	Rate 1980-2029 Report 288	Rate 1990-2039 Based on USGS
Andrews	25,720	6,535
Armstrong^^	100	308
Bailey	14,110	3,921
Borden	300	269
Briscoe	780	1,615
Castro	3,310	11,300
Cochran	23,240	3,460
Crosby	2,860	8,496
Dawson	24,600	3,921
Deaf Smith	4,550	6,727
Dickens	180	807
Ector	4,850	1,999
Floyd	2,730	10,879
Gaines	50,750	6,458
Garza	1,730	846
Glasscock	940	769
Hale	5,930	14,600
Hockley	7,620	3,960
Howard	2,610	2,076
Lamb	14,600	7,842
Lubbock	6,830	4,036
Lynn	18,590	4,113
Martin	7,760	3,883
Midland	3,270	2,037
Motley	210	500
Oldham^^	1,700	1,538
Parmer	3,260	16,503
Potter^^	380	384
Randall^^	2,440	3,767
Swisher	2,600	3,844
Terry	44,040	4,651
Yoakum	33,070	3,806
Total	**315,660**	**145,858**

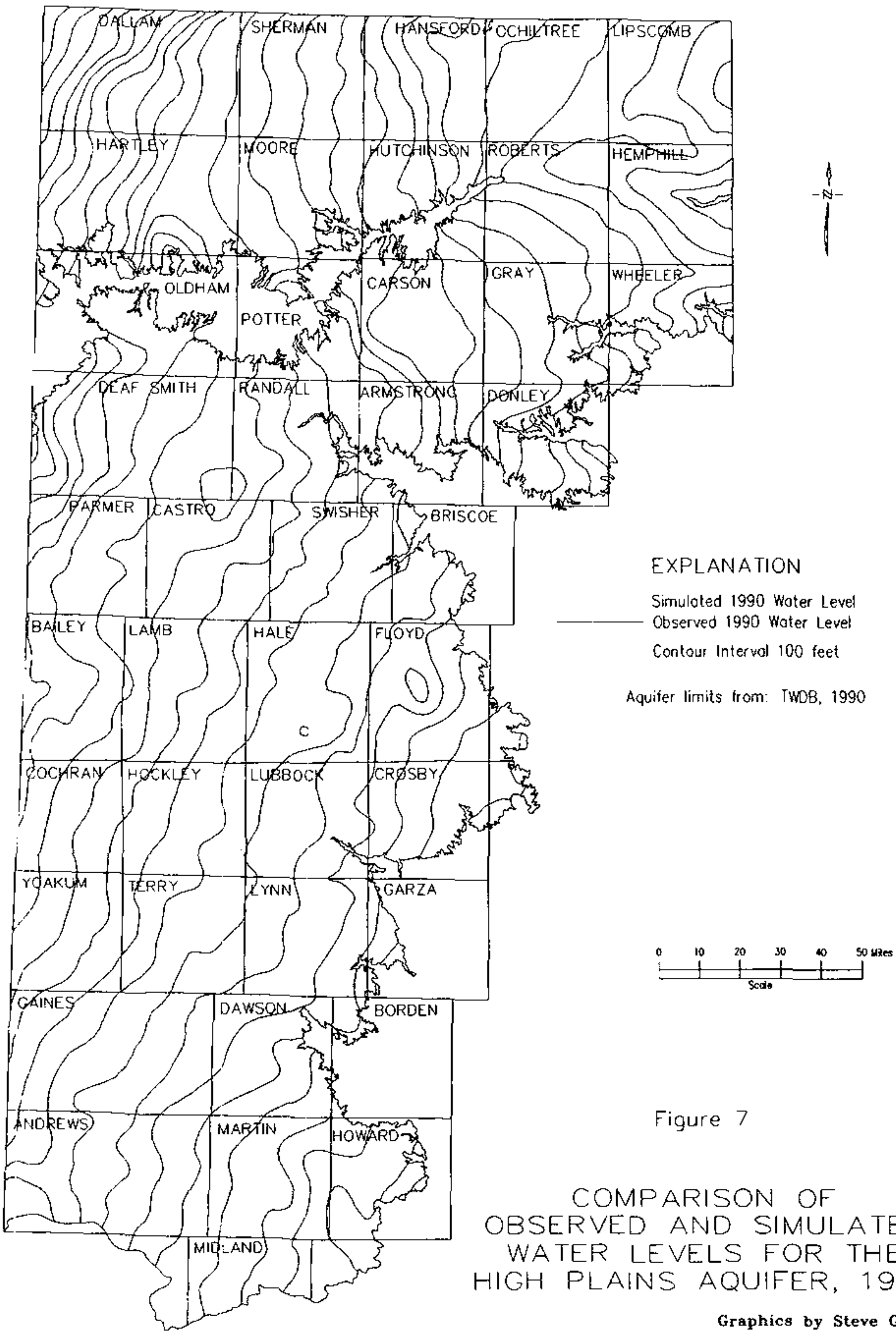
^ - Approximate representation of counties
^^ - Part of county in north model

Table 6. - Origin of Model Data

Used from 1980 Model	Updated for New Projections
Finite Grid Spacing	1990 Water Level Elevation
Nodal Designation	Irrigated Area
Base of Aquifer Elevation	Irrigation Rates
Hydraulic Conductivity	Municipal Pumpage
Storage Coefficient	Domestic and Livestock Pumpage
Land Surface Elevation	USGS Recharge Rates
Cell County Code Assignment	
Transmissivity and Pumping Lift Constraints	

Simulated water levels are the aquifer response to assigned pumpage. The difference between the water level and the aquifer base provides a saturated thickness for each model cell. The saturated thickness values are mapped to allow visual display of projected regional relationships (Figures 8 through 13) and graphed to show the distribution of saturated thickness (Figure 14). Finally, the projected volumes of water in storage are calculated for every county (Tables 2 and 3). These various forms of output can then be evaluated for planning purposes.

The 1980 model operated using an application rate adjustment to simulate various changes in irrigation practices. Subsequent runs were made using one-half and no adjustment to illustrate the impact of the full adjustment. The idea of the adjustment was that increased conservation efficiency practices would result in less water returning to the aquifer as irrigation return flow. Since no accurate return flow data is currently available and projected pumpage now better incorporates increased efficiency, the 1990 model incorporates no adjustment factor. Figure 15 provides a comparison of the three runs from 1980 with the 1990 run. The result of not using an adjustment results in a conservative projection for volumes in storage as compared with the same projections made in the 1980 model (Tables 24 and 25 of TDWR Report 288).



EXPLANATION

Simulated 1990 Water Level
Observed 1990 Water Level
Contour Interval 100 feet

Aquifer limits from: TWDB, 1990

Figure 7

COMPARISON OF OBSERVED AND SIMULATED WATER LEVELS FOR THE HIGH PLAINS AQUIFER, 1990

Graphics by Steve Gifford

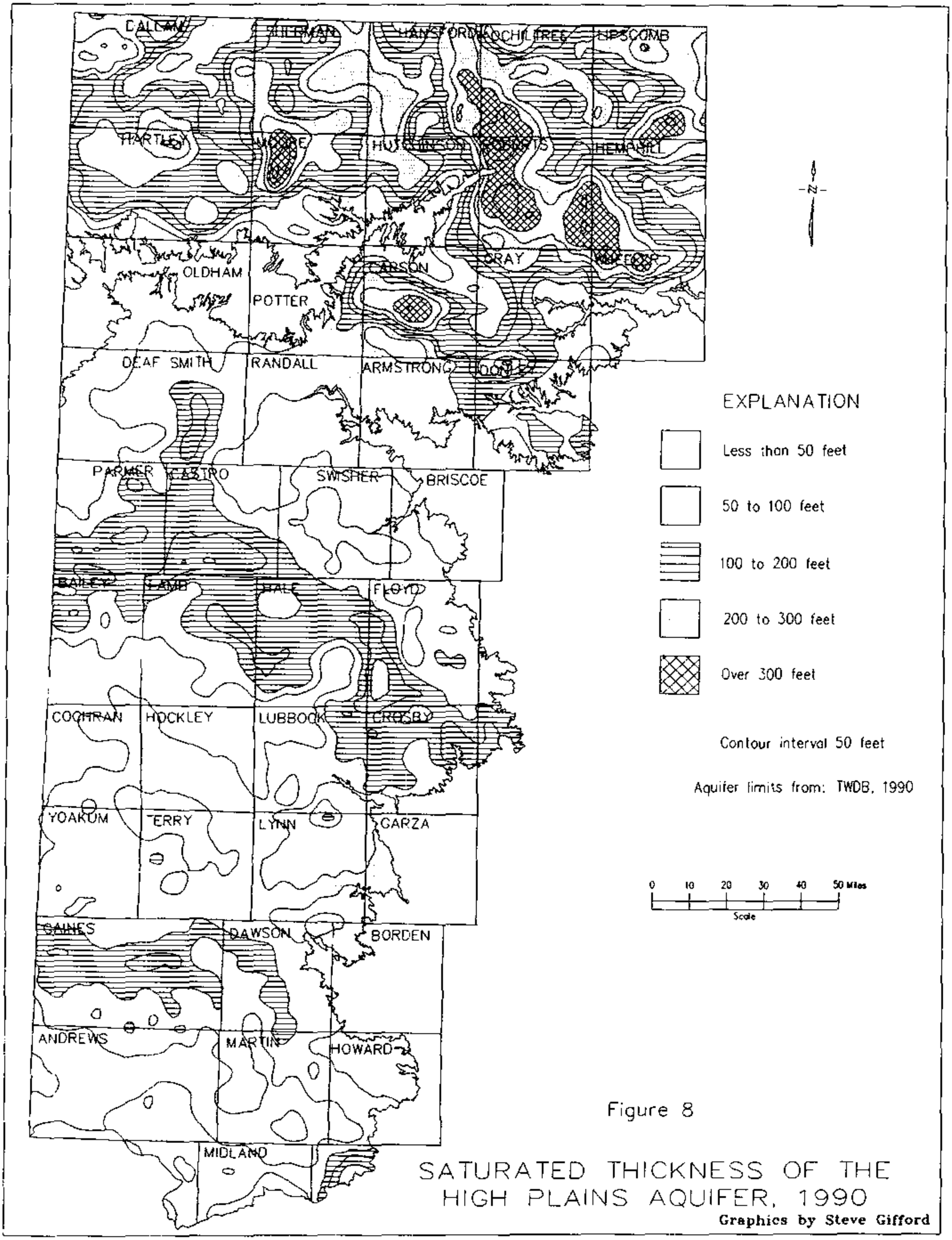


Figure 8

SATURATED THICKNESS OF THE
HIGH PLAINS AQUIFER, 1990

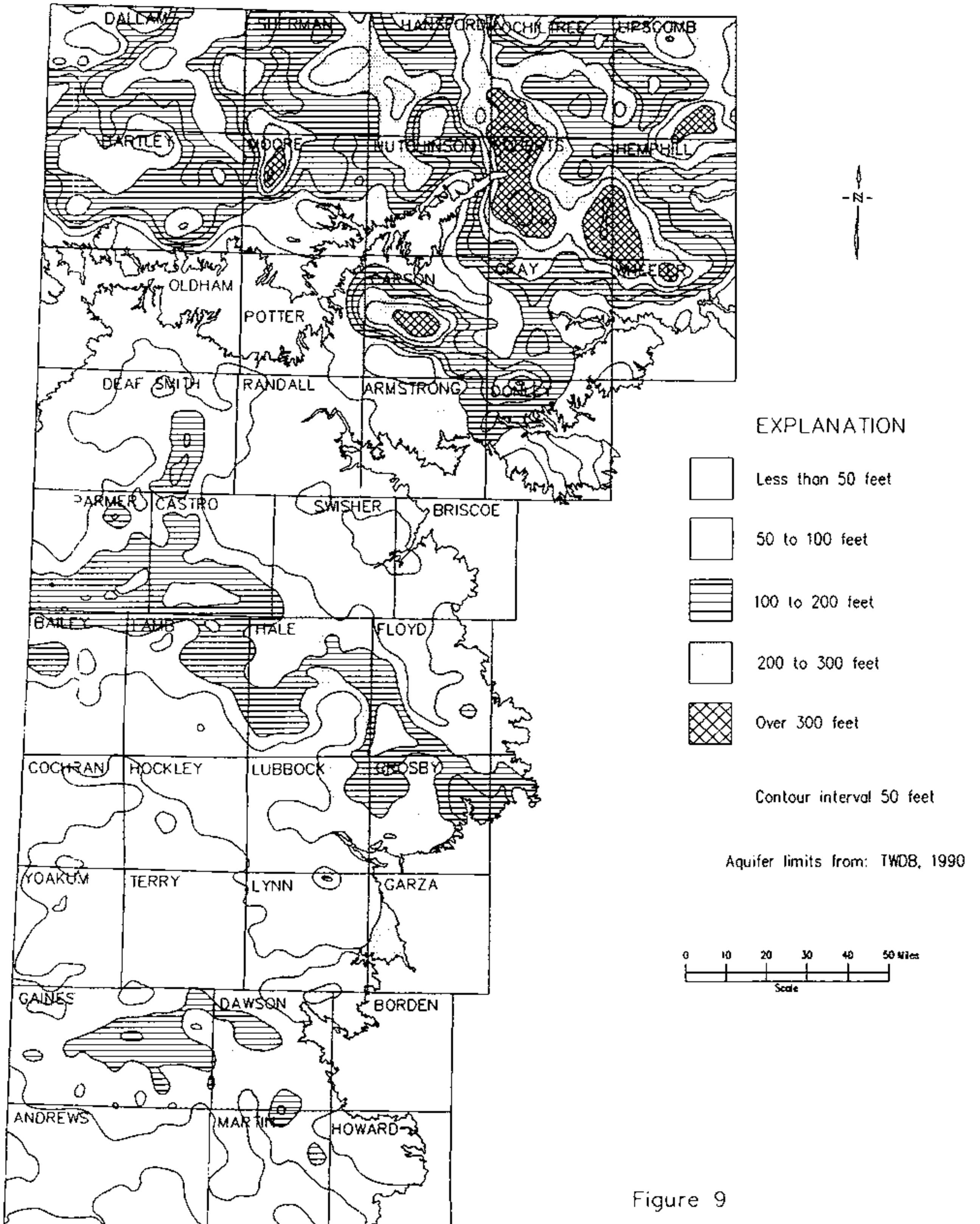


Figure 9

PROJECTED SATURATED THICKNESS OF THE HIGH PLAINS AQUIFER, 2000

Graphics by Steve Gifford

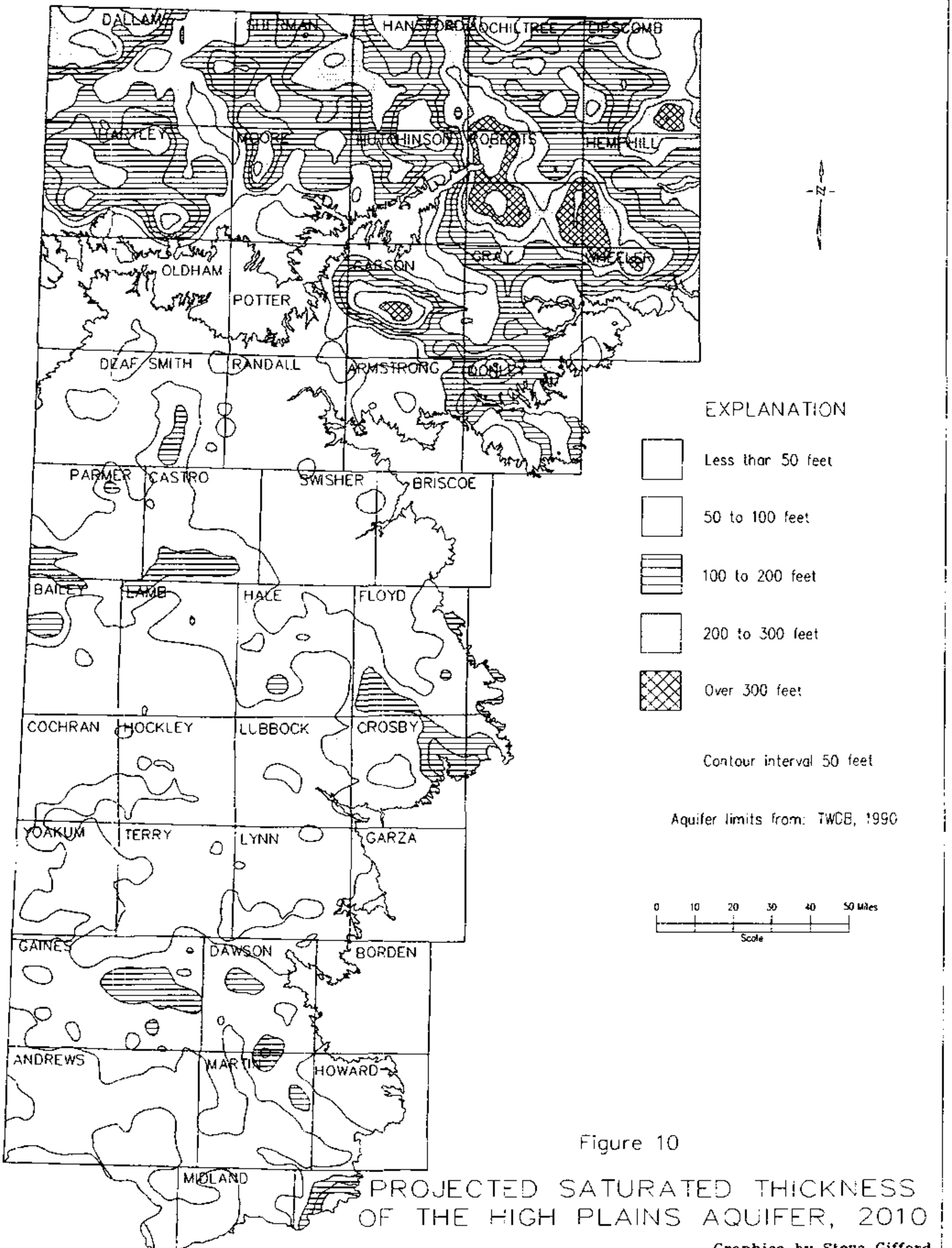


Figure 10
PROJECTED SATURATED THICKNESS
OF THE HIGH PLAINS AQUIFER, 2010

Graphics by Steve Gifford

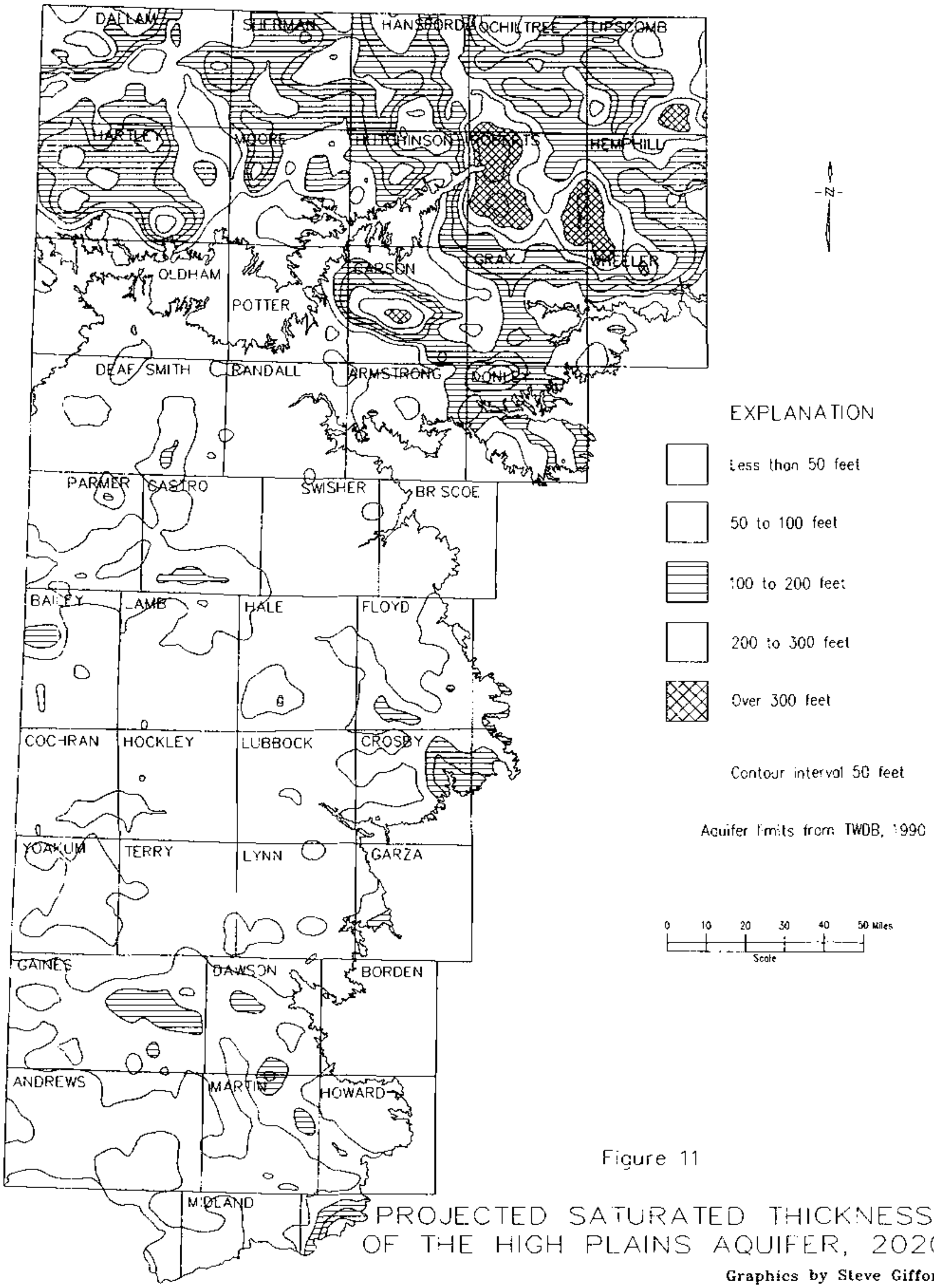


Figure 11

PROJECTED SATURATED THICKNESS OF THE HIGH PLAINS AQUIFER, 2020

Graphics by Steve Gifford

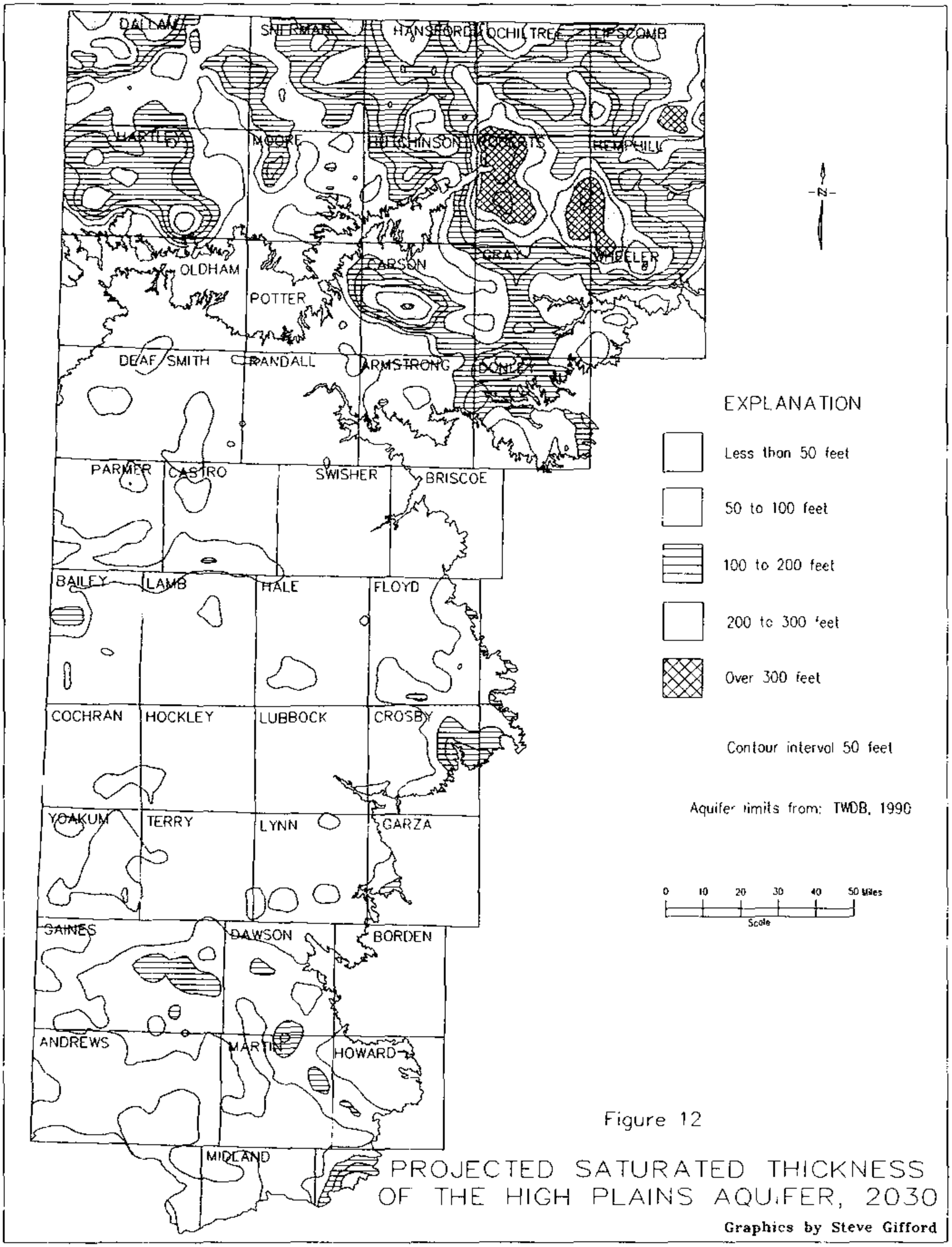


Figure 12

PROJECTED SATURATED THICKNESS OF THE HIGH PLAINS AQUIFER, 2030

Graphics by Steve Gifford

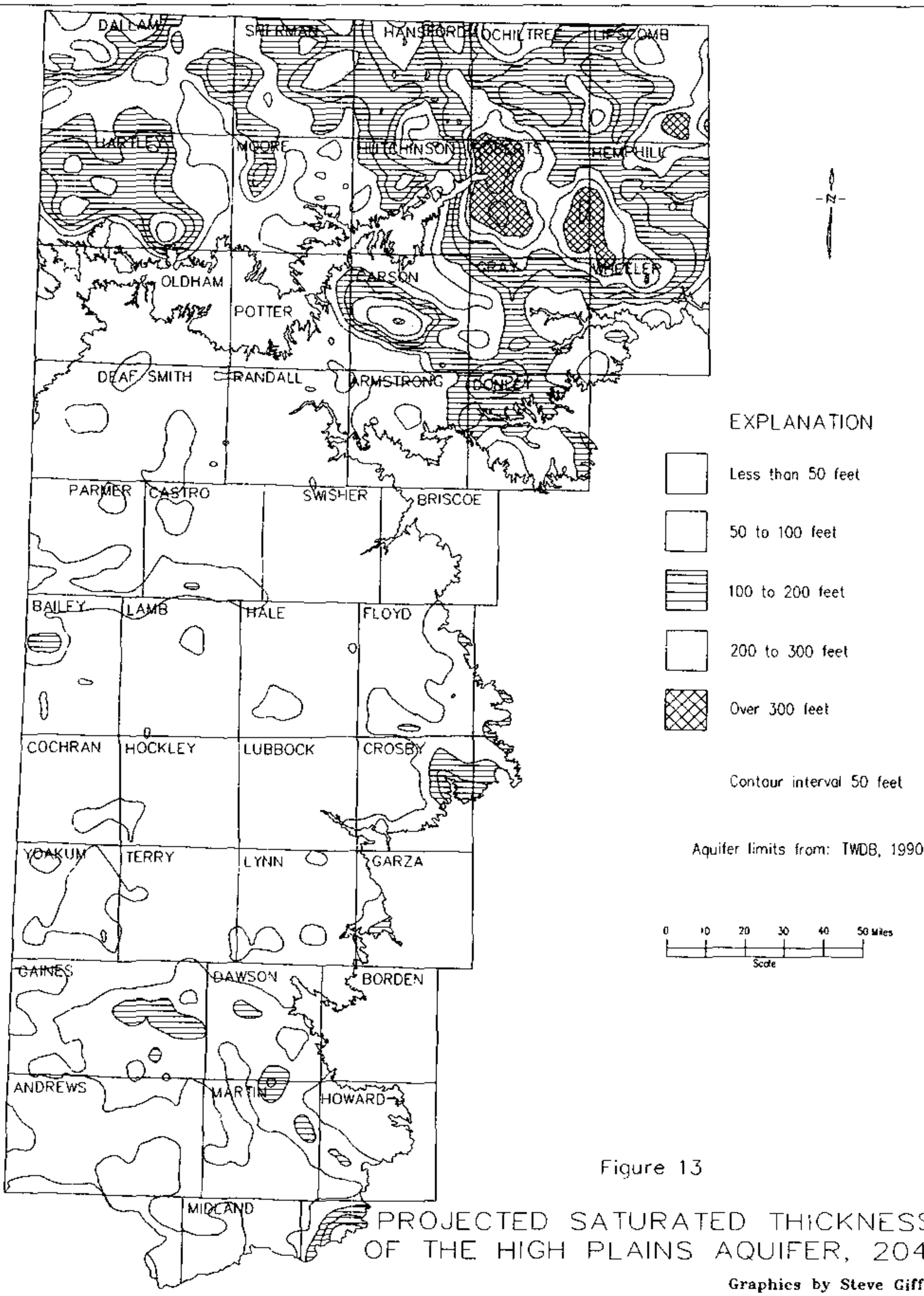


Figure 13

PROJECTED SATURATED THICKNESS
OF THE HIGH PLAINS AQUIFER, 2040

Graphics by Steve Gifford

Figure 14
Distribution of Saturated Thickness

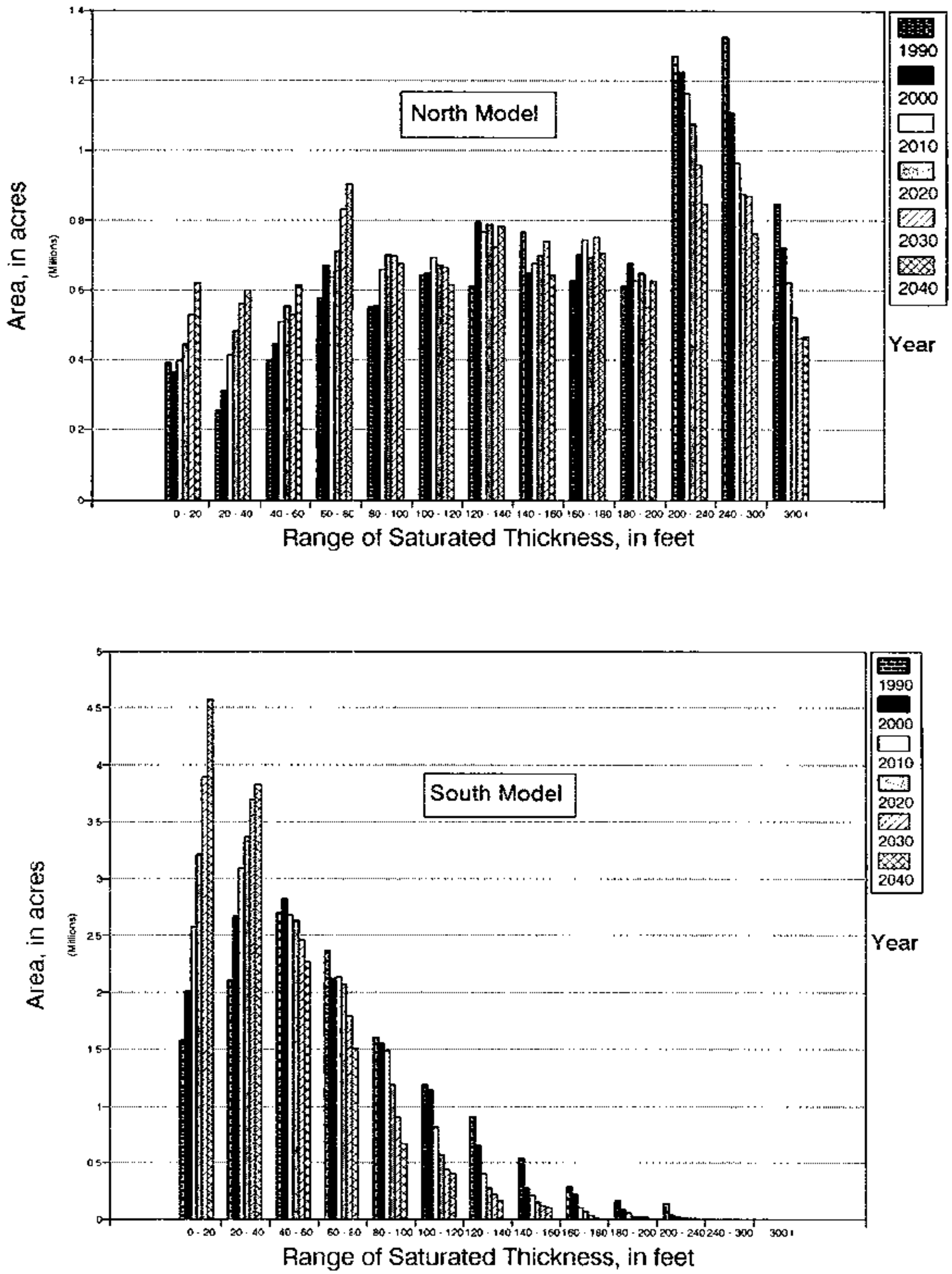
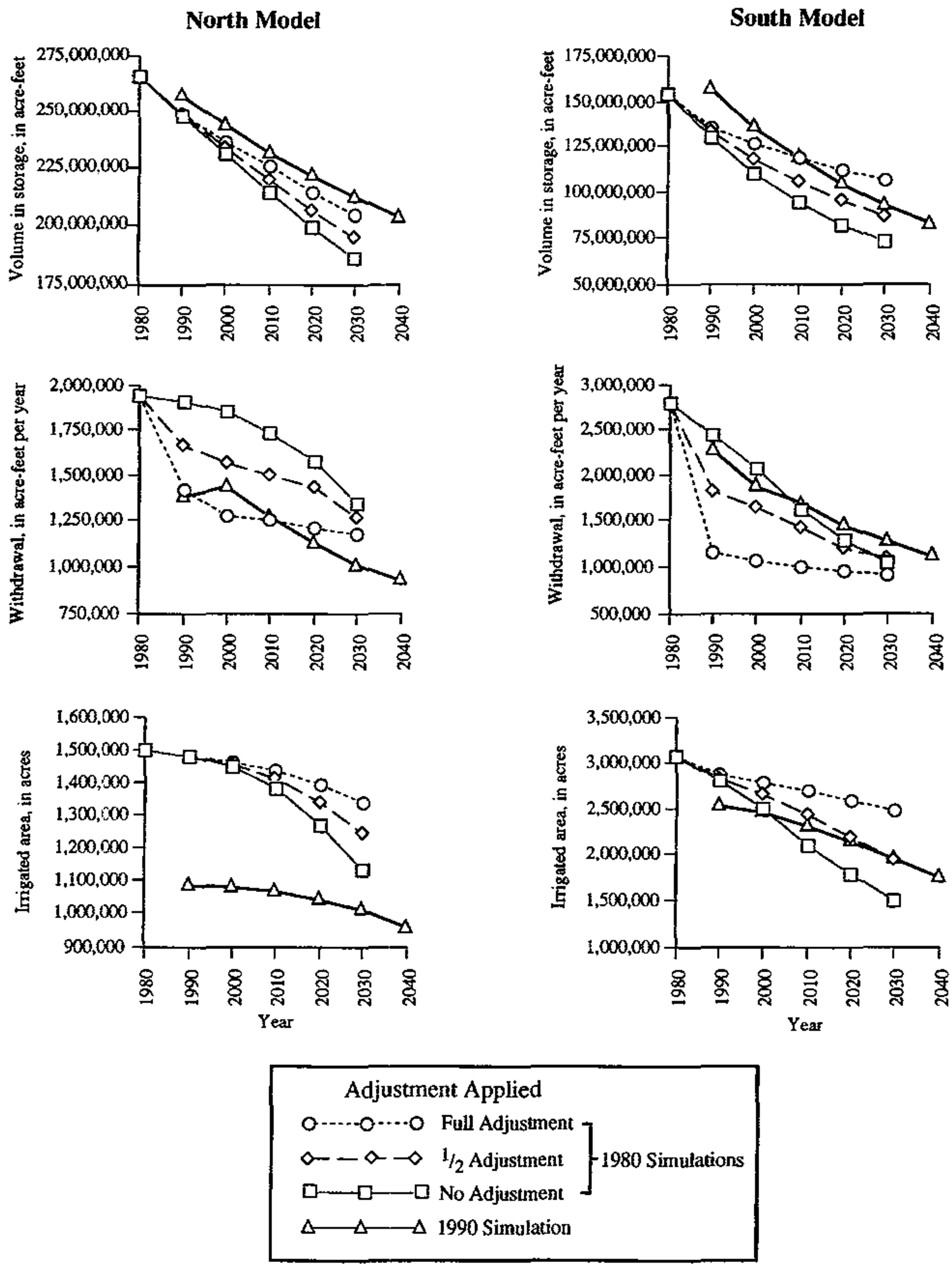


Figure 15

Selected Results for Future Periods



CONCLUSIONS AND RECOMMENDATIONS

Conclusions reached in the 1990 evaluation of the High Plains aquifer system differ little from those reached in 1980. Current model projections suggest a slight increase in future water availability over 1980 projections; however, withdrawal of water will continue to exceed recharge and water levels will continue to decline. Continued efforts toward developing conservation practices and prevention of quality deterioration are essential to extending the useful life of the aquifer. Because of the large volume of water in storage, the aquifer can continue to support the various water needs of the High Plains region for many years.

The High Plains aquifer system model is a regional ground-water simulation that attempts to describe the aquifer as a whole. As such, there are inherent limitations on its development and use that are the same now as they were in 1980. One such limitation is that the model simulates water levels on a regional scale. Thus, it does not represent the exact measured level in a well at any specific location. Also, the size of the cells used in the model is large, approximately nine square miles, and it is possible that physical features of the aquifer that have small areal extent are not recognized in the model. These limitations, however, in no way restrict the use of the model in evaluating the long-term effects of pumpage and recharge on the aquifer. This model is similar to other simulation models in that it is a tool to aid in the understanding of how the aquifer responds to various stresses.

The 1990 evaluation of the hydraulic conditions in the High Plains aquifer system and the update of the aquifer simulation model demonstrate the dynamic and sensitive nature of the aquifer system. During 1980 to 1990, portions of the High Plains received above-average precipitation and experienced less than projected pumpage withdrawals that resulted in higher water levels than predicted by the 1980 model for the year 1990. Though very high annual precipitation occurred only during two or three years, it had a profound effect on the model analysis of the aquifer for the entire ten-year period.

In the current evaluation of the model, as expected, 1990 simulated water levels matched observed levels in areas that experienced recharge and withdrawals similar to the amounts projected. Generally, the southern areas did not model as accurately as the northern areas and attempts to refine the model verified that the problems were not the values used to represent water movement and storage (hydraulic conductivity and specific yield). Thus, the inexactness is with the values representing the amount of water entering and exiting the system (recharge and discharge). This implies that the effects from recharge may have been greater than expected by the 1980 evaluation.

Limitations and recommendations developed during the construction of the 1980 model still hold true today. Recharge to and discharge from the system are still the two most crucial parameters necessary for improving model accuracy and should continue to be studied. A quantitative and qualitative study is needed to characterize the hydrologic interaction between the Ogallala and underlying Cretaceous formations in the Southern High Plains. Results of this study then need to be incorporated into the southern model to increase its accuracy.

The High Plains model can best be employed as an effective tool used in managing the aquifer as a regional resource. Cooperative efforts should be made with the local underground water conservation districts to refine the base data from the model into smaller regional models. These models could be used to refine ground-water availability, evaluate efficient water-use management techniques, and demonstrate the effects of local pumpage scenarios on the aquifer. The information from such efforts would then be available to those responsible for managing this precious resource.

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