WATER-LEVEL CHANGES, 1980 TO 1997, AND SATURATED THICKNESS, 1996–97, IN THE HIGH PLAINS AQUIFER

The High Plains aquifer underlies one of the major agricultural regions in the world, including parts of eight States—Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. In the area underlain by the High Plains aquifer (called the High Plains region in this report), the total number of acres irrigated with ground water expanded rapidly after 1940: 1949—2.1 million acres; 1959—6.1 million acres; 1969—9.0 million acres; and 1980—13.7 million acres (Gutentag and others, 1984; Thelin and Heimes, 1987). In 1990, about 95 percent of the water withdrawn from the High Plains aquifer (about 15.7 million acre-feet) was used for irrigation (Marilee Horn, U.S. Geological Survey, written commun., 1996).

Water-level declines began to occur in the High Plains aquifer soon after extensive ground-water irrigation development began. By 1980, water levels in the High Plains aquifer in parts of Texas, New Mexico, and southwestern Kansas had declined more than 100 feet (Luckey and others, 1981). In response to these declines, the U.S. Geological Survey, in cooperation with numerous Federal, State, and local water-resource agencies, began a ground-water monitoring program in 1988 to assess annual water-level change in the aquifer using water-level measurements from more than 7,000 wells. The purpose of this report is to present (1) water-level changes in the High Plains aquifer from 1980 to 1997 and from 1996 to 1997, (2) the precipitation pattern in the High Plains region during 1996, and (3) estimated saturated thickness of the High Plains aquifer in 1996–97. The water-level measurements used in this report were collected in winter or early spring when irrigation wells were not pumping. Map scale and density of water-level elevation data preclude showing small areas in the maps of water-level change and saturated thickness where the value may be more or less than indicated.

Water-Level Changes, 1980 to 1997

The water-level changes in the High Plains aquifer result from an imbalance between discharge, the largest component of which is ground-water withdrawals for irrigation, and recharge, which is primarily from precipitation. This imbalance began with large-scale development of the aquifer for irrigation. Ground-water withdrawals for irrigation in a given year can be affected by climatic conditions, particularly precipitation, which can cause large variations in the amount of irrigation water needed to satisfy the water requirements for crops.

Water levels declined 2.7 feet from 1980 to 1997

The pattern of water-level changes in the High Plains aquifer from 1980 to 1997 (fig. 1) is based on water-level measurements from 5,233 wells (table 1). A large area in the northern part of the southern High Plains in New Mexico and Texas with greater than 100 feet of water-level declines from predevelopment to 1980 (Luckey and others, 1981) has continued to decline, but at slower rates. The average area-weighted rate of decline in this area from predevelopment to 1980 was 3.7 feet per year; the rate of decline in this area from 1980 to 1997 was 1.6 feet per year. Areas with substantial water-level declines from predevelopment to 1980 in the southern part of the southern High Plains in Texas and in the southeastern part of the northern High Plains in Nebraska (Luckey and others, 1981) had considerably slower rates of decline, or rising water levels, from 1980 to 1997.

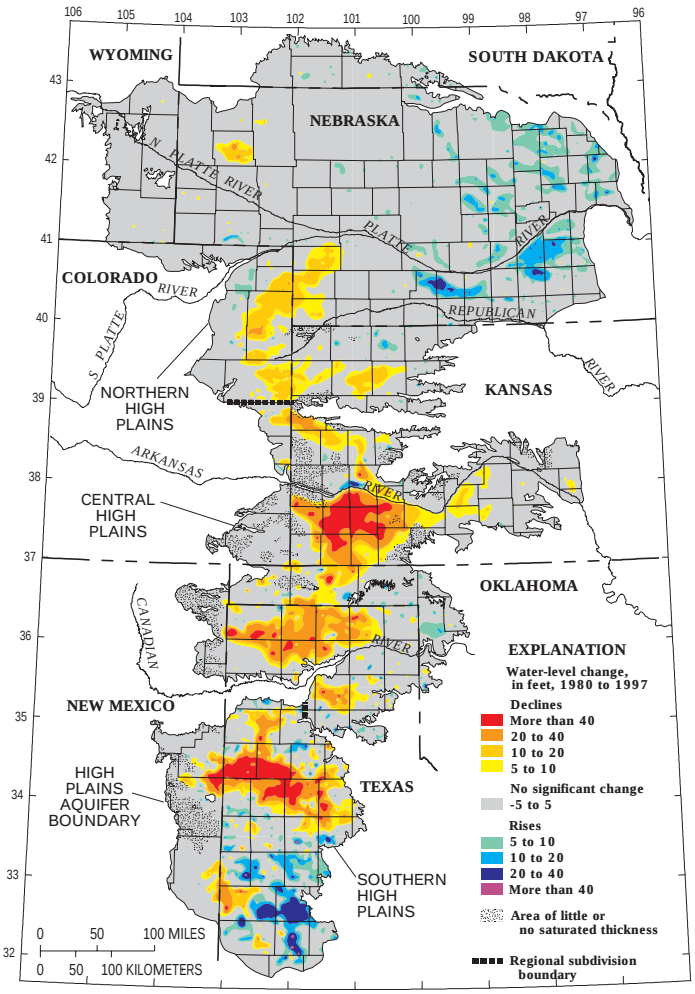

Figure 1. *Water-level changes in the High Plains aquifer, 1980 to 1997.*

Table 1. Number of High Plains aquifer wells measured for 1996 and 1997 and used for the water-level comparison periods—1980 to 1997 and 1996 to 1997

State	Wells measured for:		Wells used for water-level comparison periods	
	1996	1997	1980 to 1997	1996 to 1997
Colorado	604	604	502	579
Kansas	1,174	1,298	755	889
Nebraska	3,490	3,617	1,937	3,401
New Mexico	751	547	168	104
Oklahoma	298	268	171	256
South Dakota	114	105	70	100
Texas	2,903	2,581	1,617	2,364
Wyoming	83	63	13	62
High Plains	**9,417**	**9,083**	**5,233**	**7,755**

Ninety-nine percent of all water-level changes from 1980 to 1997 are within a rise of 32 feet and a decline of 60 feet. The average area-weighted water level in the High Plains aquifer declined 2.7 feet from 1980 to 1997 compared to a decline of 9.9 feet from predevelopment to 1980 (table 2). Assuming 1950 as the beginning of irrigation development in the High Plains region, the rate of water-level decline decreased from 0.33 foot per year (1950 to 1980) to 0.16 foot per year (1980 to 1997).

Factors that contributed to the smaller rate of water-level decline from 1980 to 1997 as compared to predevelopment to 1980 are: (1) a decrease in ground-water withdrawals from the High Plains aquifer for irrigation, and (2) greater than normal precipitation from 1980 to 1996. Ground-water withdrawals for irrigation were 18.0 million acre-feet in 1980 and 15.7 million acre-feet in 1990 (Thelin and Heimes, 1987; Marilee Horn, U.S. Geological Survey, written commun., 1996). Precipitation from 1981 to 1996 in the High Plains region averaged 21.2 inches per year, 1.4 inches per year more than normal (table 3).

Factors that may have caused a decrease in ground-water withdrawals, in addition to increased precipitation, include: (1) a decrease in irrigated acreage in areas with water-level declines and in areas with large potential rates of aquifer depletion; (2) use of more efficient irrigation technology, such as low-pressure nozzles and drop tubes on center pivots; (3) improved farm-management practices, including irrigation scheduling, reuse of irrigation return flow, the conversion to alternative crops or crop varieties with smaller consumptive irrigation requirements, and methods to retain soil moisture; (4) local regulation of ground-water withdrawals for irrigation and development of irrigated land; and (5) economic considerations, including declining or stable commodity prices, increased production costs (including energy and fertilizer costs), and various agricultural programs of the Federal government that encourage the transfer of marginal land out of irrigated production.

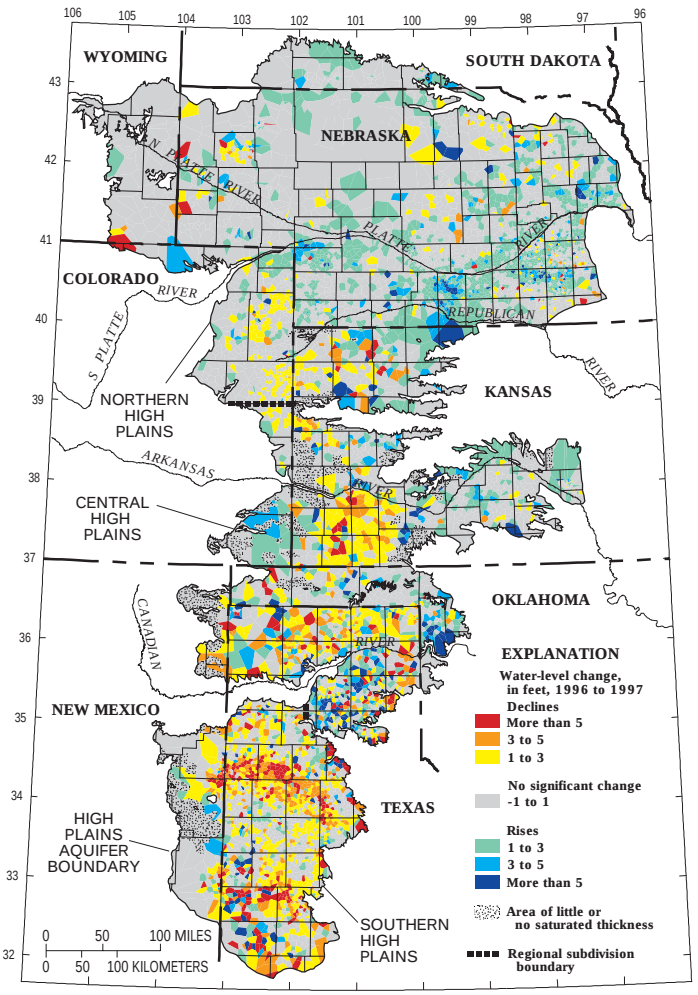

Figure 2. *Generalized water-level changes in the High Plains aquifer, 1996 to 1997.*

Table 2. Characteristics of the High Plains aquifer in 1980 and water-level changes in the High Plains aquifer, predevelopment to 1980, 1980 to 1997, and 1996 to 1997

[ft, foot; ft/yr, foot per year]

State	Percentage of total aquifer area[1]	Percentage of total volume of drainable water in storage in 1980[2]	Average area-weighted water-level change				
			Predevelopment (1950 to 1980)		1980 to 1997		1996 to 1997
			Water-level change[3] (ft)	Rate of change (ft/yr)	Water-level change (ft)	Rate of change (ft/yr)	Water-level change (ft)
Colorado	8.2	3.7	–4.2	–0.14	–5.9	–0.35	+0.15
Kansas	16.2	9.9	–9.9	–0.33	–8.0	–0.47	+0.23
Nebraska	38.6	65.5	0	0	+2.3	+0.13	+0.58
New Mexico	3.6	1.5	–9.8	–0.33	–4.0	–0.23	–0.65
Oklahoma	4.2	3.4	–11.3	–0.38	–2.7	–0.16	+0.70
South Dakota	2.9	1.8	0	0	+3.1	+0.18	+0.82
Texas	21.5	12.0	–33.7	–1.12	–7.4	–0.43	–0.98
Wyoming	4.8	2.2	0	0	–1.5	–0.09	–0.24
High Plains	**100**	**100**	**–9.9**	**–0.33**	**–2.7**	**–0.16**	**+0.08**

[1]Does not include areas of little or no saturated thickness.
[2]Modified from Gutentag and others (1984).
[3]Luckey and others (1981).

Table 3. Average area-weighted precipitation and comparison to 30-year normal precipitation (1961–90) in the High Plains region, 1981 to 1996, and 1996

[Data from National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina; data values are in inches per year]

State	1981 to 1996		1996	
	Average precipitation	Departure from 30-year normal	Average precipitation	Departure from 30-year normal
Colorado	17.5	+1.3	19.0	+2.8
Kansas	22.6	+1.3	26.7	+5.4
Nebraska	23.3	+1.5	24.1	+2.3
New Mexico	17.6	+1.3	15.4	–1.0
Oklahoma	21.3	+1.3	25.3	+5.3
South Dakota	20.3	+2.0	22.4	+4.0
Texas	20.1	+1.2	18.6	–0.3
Wyoming	15.6	+1.1	13.6	–0.9
High Plains	**21.2**	**+1.4**	**22.0**	**+2.2**

Water-Level Changes, 1996 to 1997, and Precipitation, 1996

Ninety-nine percent of all water-level changes from 1996 to 1997 (fig. 2) are within a rise of 11.1 feet and a decline of 11.1 feet. The average area-weighted water level in the High Plains aquifer rose 0.08 foot from 1996 to 1997 (table 2) based on measurements from 7,755 wells (table 1). The average area-weighted water-level change in the High Plains aquifer from 1996 to 1997 by State ranged from a rise of 0.82 foot in South Dakota to a decline of 0.98 foot in Texas (table 2).

Water levels rose 0.08 foot from 1996 to 1997

The average area-weighted precipitation during 1996 in the High Plains region was 22.0 inches, or 2.2 inches greater than the 30-year normal (table 3). The precipitation pattern ranged from more than 10 inches greater than normal to more than 5 inches less than normal (fig. 3).

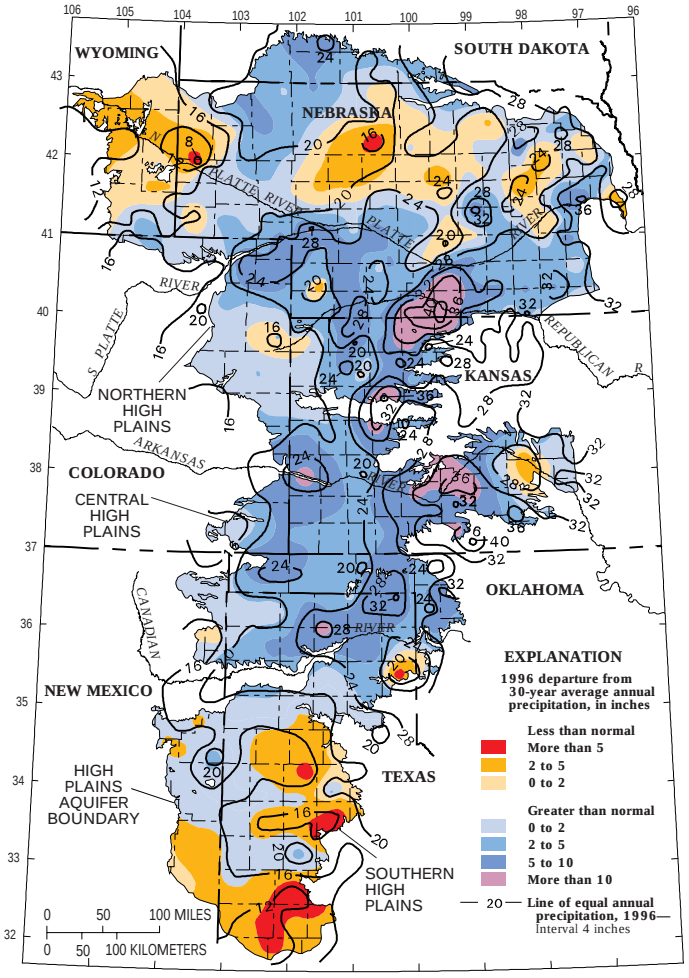

Figure 3. *Annual precipitation, 1996, and departure from 30-year normal precipitation (1961–90) (precipitation data from the National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina).*

Saturated Thickness, 1996–97

A saturated-thickness map of the High Plains aquifer (fig. 4) was prepared by superimposing a 1996–97 water-table map over a map of the elevation of the base of the aquifer and contouring the elevation difference. The 1996–97 water-table map was based on 10,085 measurements—49 stream elevations (March 1997) and 10,036 water-level elevations in wells (1,370 from 1996 and 8,666 from 1997). A water level was used only if the land-surface elevation of the well had been determined; a 1996 water level was used only if the 1997 water level was not available for a given well. Within aquifer areas where there were no 1996 or 1997 measurements, such as in the northern High Plains in northeastern Wyoming, parts of western Nebraska, and north of the South Platte River in northeastern Colorado, the 1980 saturated-thickness contours were used (Weeks and Gutentag, 1981). Around the boundary of the aquifer, the contours were approximated.

Saturated thickness in 1996–97 ranged from generally 0 at the boundary of the aquifer to more than 1,000 feet in west-central Nebraska. The percentage of the area of the High Plains aquifer within each saturated thickness interval in 1980 (Gutentag and others, 1984) and in 1996–97 is summarized by State in table 4. The tabulated results show that the area of the High Plains aquifer with less than 100 feet of saturated thickness increased from 46 percent in 1980 to 49 percent in 1996–97.

Table 4. Saturated-thickness distribution in the High Plains aquifer, 1980 and 1996–97

[ft, feet; <, less than]

State	Area of High Plains aquifer within State[1] (square miles)	Year[2]	Percentage of area within each saturated thickness interval						
			0 to 100 ft		100 to 200 ft	200 to 400 ft	400 to 600 ft	600 to 800 ft	800 to 1,200 ft
			0 to 50 ft	50 to 100 ft					
Colorado	14,900	1980		76	18	6	--	--	--
		1996–97	58	23	15	4	--	--	--
Kansas	30,500	1980		66	21	12	1	--	--
		1996–97	51	19	18	11	1	--	--
Nebraska	63,650	1980		14	21	29	22	10	4
		1996–97	9	8	20	28	22	9	4
New Mexico	9,450	1980		85	15	--	--	--	--
		1996–97	72	17	11	--	--	--	--
Oklahoma	7,350	1980		58	25	11	6	--	--
		1996–97	35	21	28	12	4	--	--
South Dakota	4,750	1980		44	13	25	18	--	--
		1996–97	26	12	15	32	15	--	--
Texas	35,450	1980		61	25	14	--	--	--
		1996–97	33	32	<23	12	<1	--	--
Wyoming	8,000	1980		46	26	18	4	4	2
		1996–97	41	7	28	16	<5	<4	<1
High Plains	**174,050**	**1980**		**46**	**22**	**18**	**9**	**4**	**1**
		1996–97	**32**	**17**	**20**	**17**	**9**	**4**	**1**

[1]Luckey and others (1981), includes areas of little or no saturated thickness.
[2]All 1980 values are from Gutentag and others (1984).

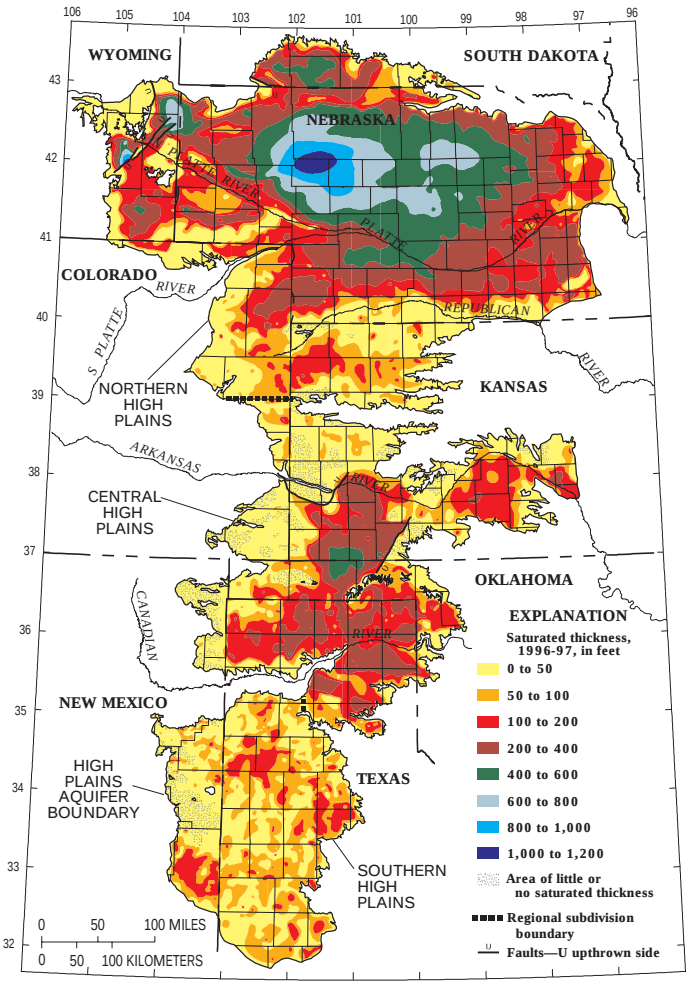

Figure 4. *Saturated thickness of the High Plains aquifer, 1996–97 (modified from Weeks and Gutentag, 1981).*

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