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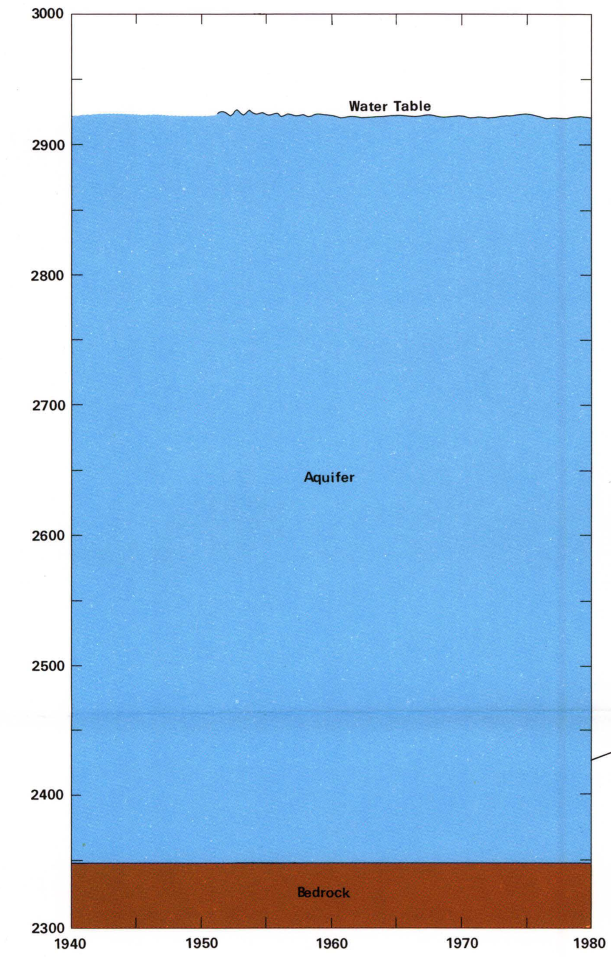
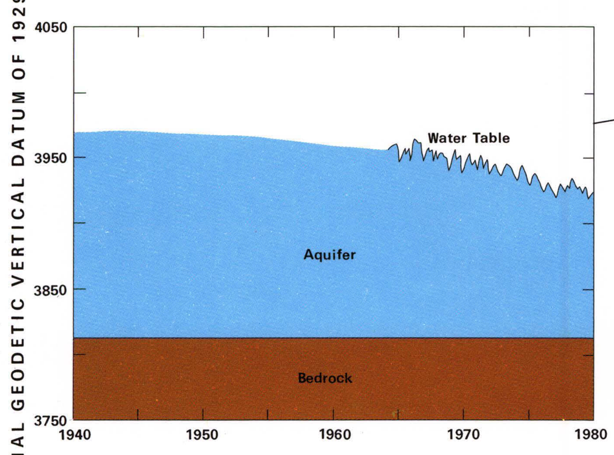
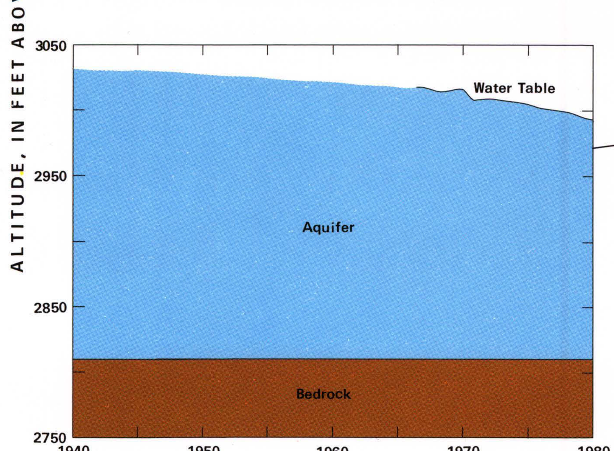
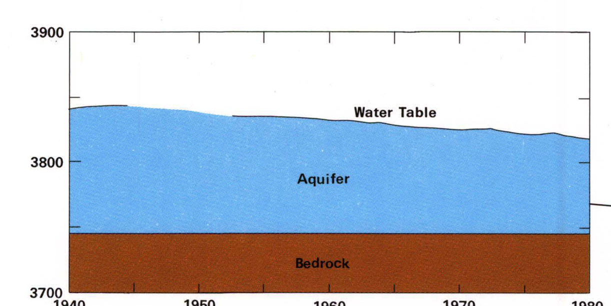
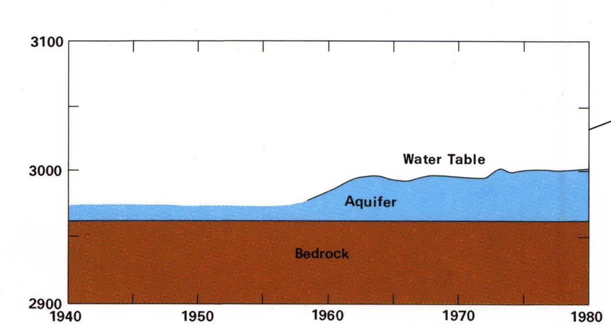
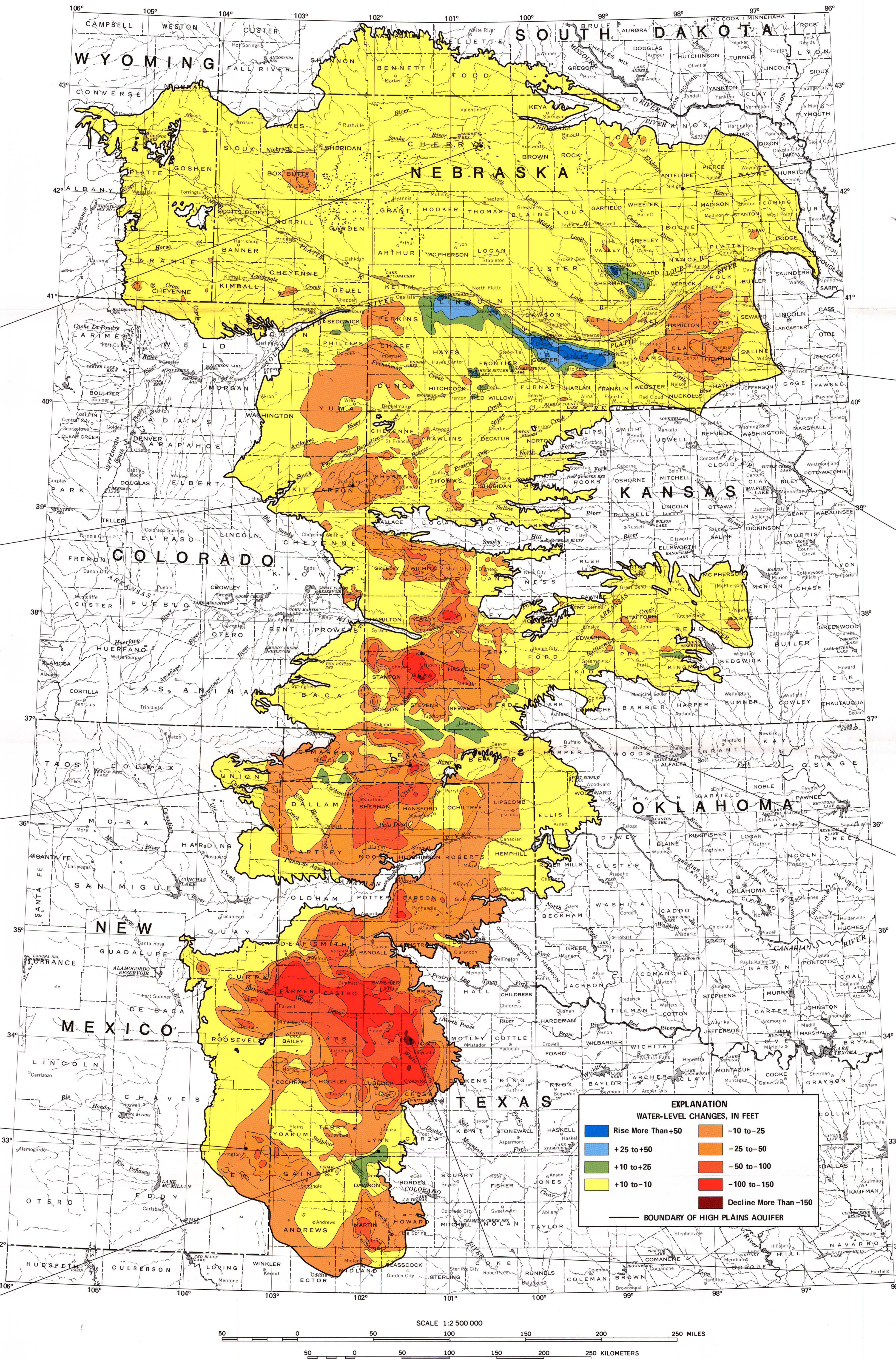




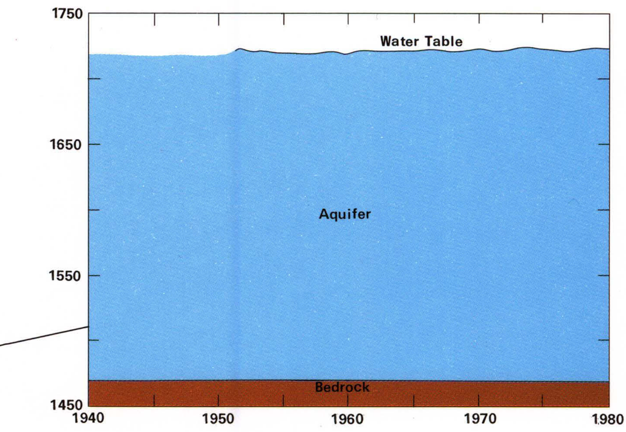


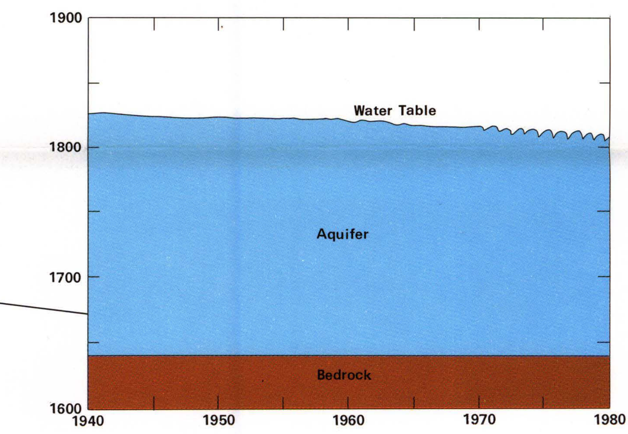






PREDEVELOPMENT TO 1980 WATER-LEVEL CHANGES





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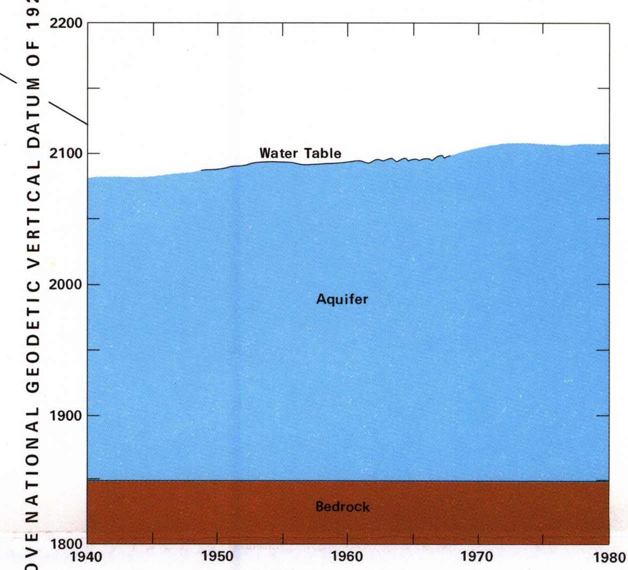

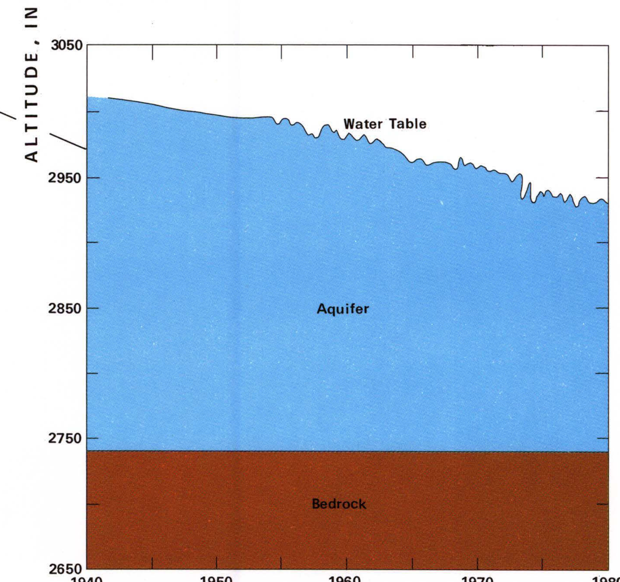

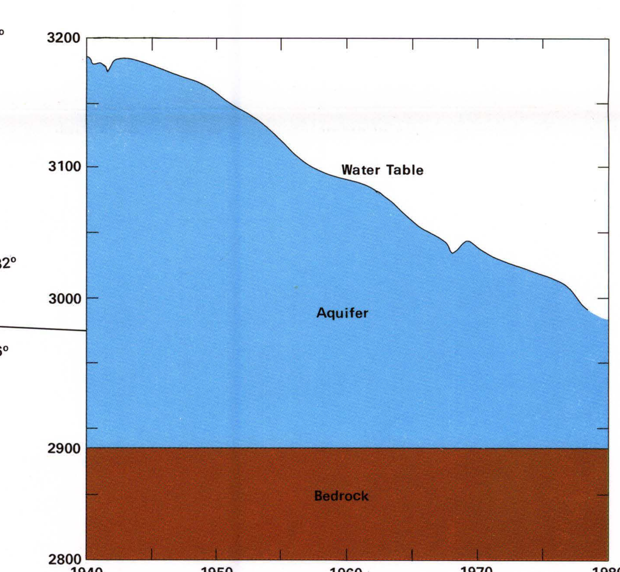

INTRODUCTION

The U.S. Geological Survey initiated a 5-year study of the High Plains regional aquifer in 1978 to provide: (1) Hydrologic information needed to evaluate the effects of continued ground-water development; and (2) computer models to predict aquifer response to changes in ground-water development. The plan of study for the High Plains Regional Aquifer-System Analysis was described by Weeks (1978). A map of the 1978 water table in the High Plains aquifer was presented by Gutentag and Weeks (1980), and maps describing bedrock geology, altitude of base, and 1980 saturated thickness of the aquifer were presented by Weeks and Gutentag (1981). This report describes the water-level and saturated-thickness changes from predevelopment to 1980. The change maps presented herein were compiled from maps prepared by U.S. Geological Survey personnel in each of the eight States in the High Plains. Their work is an integral part of this study.

The High Plains aquifer consists of the surficial geologic units underlying 174,000 square miles in eight States--Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Within this area, the aquifer is the principal source of water for irrigation as well as industrial, municipal, and domestic use. About 170,000 wells pump water from the aquifer to irrigate about 25,000 square miles (16 million acres) in the High Plains. In parts of the High Plains, declining water levels in the aquifer and increasing energy costs have caused the economics of irrigated agriculture to become marginal, and, in some places, unprofitable. A thorough understanding of the effects of pumping and various land-use practices on the High Plains aquifer will be necessary to manage the remaining water resources in the most beneficial manner.

Water-level changes in the High Plains aquifer from predevelopment to 1980 are shown on the accompanying map and hydrographs and summarized in the table on this sheet. The distribution of changes in saturated thickness from predevelopment to 1980 are described on the second sheet of this report.

WATER-LEVEL CHANGES

The water-level-change map on this sheet illustrates the areal extent of water-level changes that occurred from predevelopment to 1980 in the High Plains aquifer. This map was constructed by superimposing maps of predevelopment and 1980 water levels and connecting points of equal water-level change. Where available, published water-level-change maps (see Selected References) were used as guides in contouring. Each water-level-change interval on the map shows the range of change that predominates in that area. Because of map scale, it is not possible to show small areas within each interval where water-level change may be more or less than that indicated.

Predevelopment water-level data were collected prior to significant development of irrigation wells in the High Plains. Development generally progressed northward from New Mexico and Texas during the 1930's, to Oklahoma and Kansas during the 1940's, and Colorado, Nebraska and Wyoming during the 1950's and 1960's. Significant development has not yet occurred in South Dakota.

Before irrigation development, the High Plains ground-water system was in a state of dynamic equilibrium, with long-term recharge equal to long-term discharge. In many parts of the High Plains, natural equilibrium was significantly modified by one or more of the following activities: (1) Development of irrigation wells that increased discharge and removed large quantities of water from the aquifer; (2) surface-water diversions for irrigation that increased recharge from deep percolation of surface water applied to irrigated crops; and (3) changes in land management that affected the amount of recharge the aquifer received from precipitation. These activities cause water levels to either rise or decline as the system seeks to re-establish equilibrium between recharge and discharge. In much of the High Plains aquifer, equilibrium is not possible because the current discharge by wells is much larger than natural recharge.

In most of the areas irrigated in the High Plains, ground water is being mined; that is, more water is removed annually from storage in the ground-water reservoir than is replaced by recharge. As a result, water levels in these areas are declining. Declines are most apparent in areas of extensive withdrawals for irrigation, industrial, and municipal uses. Areas of decline caused by irrigation pumpage are found in all States except South Dakota, where irrigation development, relative to other High Plains States, is sparse. The largest area of water-level declines exceeding 100 feet occurs south of the Canadian River extending from Curry County, New Mexico, to Crosby County, Texas. Large scale water-level declines were noted in this area as early as 1951 by Bonnen and others (1952). The areal extent of these declines has increased considerably during the last 30 years and the maximum decline has increased from about 45 feet to more than 150 feet. A small area of decline greater than 100 feet occurs in Carson County, Texas.

North of the Canadian River, water-level declines exceeding 100 feet caused by pumping are found in Hansford County, Texas, Texas County, Oklahoma, and Grant and Finney Counties, Kansas. Irrigation development in both areas began during the 1930's. Extensive declines also occur in eastern Colorado, northwestern Kansas, and southern Nebraska. Declines in these areas are less severe, primarily because irrigation development started later.

Water-level declines greater than 25 feet in Laramie County, Wyoming, result directly from the stress imposed upon the aquifer by pumpage from the Cheyenne municipal well field. Similarly, the area of decline in Harvey County, Kansas, is the result of pumpage from the Wichita municipal well field.

Most of the water-level rises in Nebraska are due to deep percolation of applied surface-water irrigation. Water-level rises in Dawson, Gosper, Kearney, and Phelps Counties result from deep percolation of applied surface water that is released from Lake McConaughy and diverted from the Platte River to be distributed by canals to irrigation projects. In Lincoln County, water levels have risen because of recharge from irrigation projects associated with Sutherland and Jeffrey Reservoirs. In Howard and Sherman Counties, water levels have risen because of recharge from surface water delivered from Sherman Reservoir. Water-level rises in Frontier and Red Willow Counties, Nebraska, are caused by surface-water irrigation. Small water-level rises in Colorado may be due to land use changes.

In Kingman, Kiowa, Meade, Seward, and Stevens Counties, Kansas, and Beaver, Cimarron, and Texas Counties, Oklahoma, the water-level rises probably represent recovery from abnormally low water levels during the great drought of 1933-40. In Dawson and Lynn Counties, Texas, water-level rises are attributed to clearing sandy soils of native vegetation for cultivation, which increased the rate of recharge from precipitation on dryland crop areas.

The changes shown on the map are summarized by State in the accompanying table, which shows that significant declines in water levels (more than 10 feet) have occurred in 29 percent of the area of the High Plains aquifer and that significant rises in water level (more than 10 feet) have occurred only in 1 percent of the area. A total of 50,000 square miles (32 million acres) of the aquifer has had water-level declines in excess of 10 feet, and more than 12,000 square miles (7.7 million acres) has had water-level declines in excess of 50 feet. The data in the table also indicate that more than 1 billion acre-feet of aquifer material has been dewatered, which, assuming a specific yield of 0.15, represents about 150 million acre-feet of water. This estimate assumes that 70 percent of the High Plains averages zero water-level change (the interval +10 to -10 feet in the table and on the map). If the average water-level change for that interval is a decline of 4 feet, another 50 million acre-feet of water may have been removed from storage in the aquifer.

DISTRIBUTION OF WATER-LEVEL CHANGES AND VOLUME OF AQUIFER DEWATERED, HIGH PLAINS AQUIFER, PREDEVELOPMENT TO 1980

State	Area of High Plains aquifer within State[1] (square miles)	Percentage of area within each water-level change interval									Volume of aquifer material dewatered[2] (millions of acre-feet)
		More than 50 feet rise	+50 to +25	+25 to +10	+10 to -10	-10 to -25	-25 to -50	-50 to -100	-100 to -150	More than 150 feet decline	
Colorado------	14,900	-	-	-	78	19	3	--	-	-	39
Kansas--------	30,500	-	-	1	72	11	11	4	1	-	180
Nebraska------	63,650	1	1	2	90	5	1	--	-	-	1
New Mexico----	9,450	-	-	-	62	23	11	4	-	-	63
Oklahoma------	7,350	-	-	3	56	29	10	2	-	-	45
South Dakota--	4,750	-	-	-	100	--	--	--	-	-	---
Texas---------	35,450	-	-	1	23	34	17	18	7	-	730
Wyoming-------	8,000	-	-	-	99	1	--	--	-	-	---
TOTAL----	174,050	-	-	1	70	15	7	5	2	-	1,058

[1]Areas revised from those previously published (Gutentag and Weeks, 1980, and Weeks and Gutentag, 1981); 1.6 percent change in total area.

[2]Volumes cannot be calculated directly from data in this table because supplemental intervals were used in determining areas of change.

HYDROGRAPHS

Hydrographs are graphical representations of water-level changes with time. The water-level-change map shows the extent of changes, and the hydrographs adjacent to the map show the rate of water-level change in selected wells. The hydrographs are colored to show the saturated thickness of the aquifer and top of bedrock at the well site. These hydrographs can be divided into three classes: (1) Those showing virtually equilibrium conditions; (2) those showing water-level rises; (3) and those showing water-level declines.

Hydrographs showing virtually equilibrium conditions are from Antelope and Cherry Counties, Nebraska, where irrigation development is sparse. The well in Antelope County, in the valley of the Elkhorn River, shows the moderating effects of the nearby perennial stream; thus only long-term climatic fluctuations affect the hydrograph. The well in Cherry County is located in the vast Nebraska Sand Hills, where saturated thickness is large and irrigation wells are sparsely spaced (about 1 well per 10 square miles, Johnson and Pederson, 1980). The water level in this well is affected mainly by fluctuations in precipitation; the overall effect is one of equilibrium, as shown by the virtually uniform hydrograph.

Hydrographs showing water-level rises are from wells in Kearney County, Nebraska, and Lynn County, Texas. The well in Kearney County is in an area irrigated by surface water diverted from the Platte River. Surface water has been used for irrigation in this area since about 1940. Water-level records for this well began in 1947 and were discontinued in 1967. During that time, recharge from surface-water irrigation caused the water level to rise 16 feet. Ground-water pumpage from nearby wells began to affect the hydrograph in 1961 causing a small decline and recovery each year. If the record had not been discontinued, the hydrograph would undoubtedly show that the effects of pumpage continue to the present time. The well in Lynn County, Texas, is in an area where the saturated thickness of the High Plains aquifer is less than 50 feet and well yields generally are less than 300 gallons per minute. Consequently most farms are not irrigated in this area. The hydrograph shows that between 1958 and 1980 the water level rose 20 feet and saturated thickness increased from about 20 to 40 feet. The water level rise in this area is caused by increased recharge resulting from water conservation practices to increase infiltration of precipitation and conserve soil moisture.

The remaining six hydrographs show various rates of water-level decline. All are from active irrigation well fields and show steadily declining water levels resulting from pumpage. High rates of decline occur during dry years when pumpage increases; conversely, moderate rates of decline occur during wet years when pumpage decreases.

The well in Kit Carson County, Colorado, had a water level of about 210 feet below land surface and 110 feet of saturated thickness during 1980. Water levels in this area developed for irrigation have declined 2 feet per year and saturated thickness has decreased about 20 percent since 1964. There are about two irrigation wells per square mile in the vicinity of this well.

The well in Texas County, Oklahoma, is in an area where irrigation developed rapidly during the mid-1960's. From 1966 to 1970, the water level nearly recovered each year to the pre-pumping water level. After 1970, the water level was unable to fully recover after each irrigation season; and, the water level declined about 2.5 feet per year during 1970-80. The 1980 water level was about 155 feet below land surface, and saturated thickness was 180 feet. Average well density in this area is three wells per square mile.

The hydrograph for the well in Adams County, Nebraska, shows an overall water-level decline since 1951 of about 0.5 foot per year. In 1980, the water level in this well was 120 feet below land surface, and the saturated thickness was 170 feet. Since 1970, nearby pumping during the irrigation season has caused sharp summer declines, followed by recovery. Johnson and Pederson (1980) indicate that the average density of irrigation wells in Adams County is about three wells per square mile.

The well in Lea County, New Mexico, is in an area that is about 30 percent irrigated cropland. The major irrigation development in the area occurred between 1945 and 1950. The hydrograph shows a steady water-level decline of about 0.6 foot per year since 1952. Since 1945, the water level has declined about 25 feet and saturated thickness of the aquifer has decreased nearly 25 percent.

The hydrograph for the well in Grant County, Kansas, indicates a water level of about 200 feet below land surface and saturated thickness of 190 feet in 1980. The average rate of decline since 1954 is nearly 2.5 feet per year, and saturated thickness has decreased 25 percent. This well is in a developed area with about three irrigation wells per square mile.

The hydrograph for the well in Floyd County, Texas, illustrates a long period of declining water levels. After 40 years of withdrawing water for irrigation, the well casing and screen deteriorated and the well was abandoned in 1978; the last part of the hydrograph is inferred. Although the rate of decline changed as the pumping rate changed, the average rate of water-level decline in this well was 5 feet per year during 1940-78. The water level in this well has declined nearly 200 feet and saturated thickness has decreased about 67 percent. In the vicinity of this well, irrigation well density is about four wells per square mile.

Base from U. S. Geological Survey
United States base map, 1972

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1981—W81513

WATER-LEVEL AND SATURATED-THICKNESS CHANGES, PREDEVELOPMENT TO 1980, IN THE HIGH PLAINS AQUIFER IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING

By
Richard R. Luckey, Edwin D. Gutentag, and John B. Weeks

1981

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