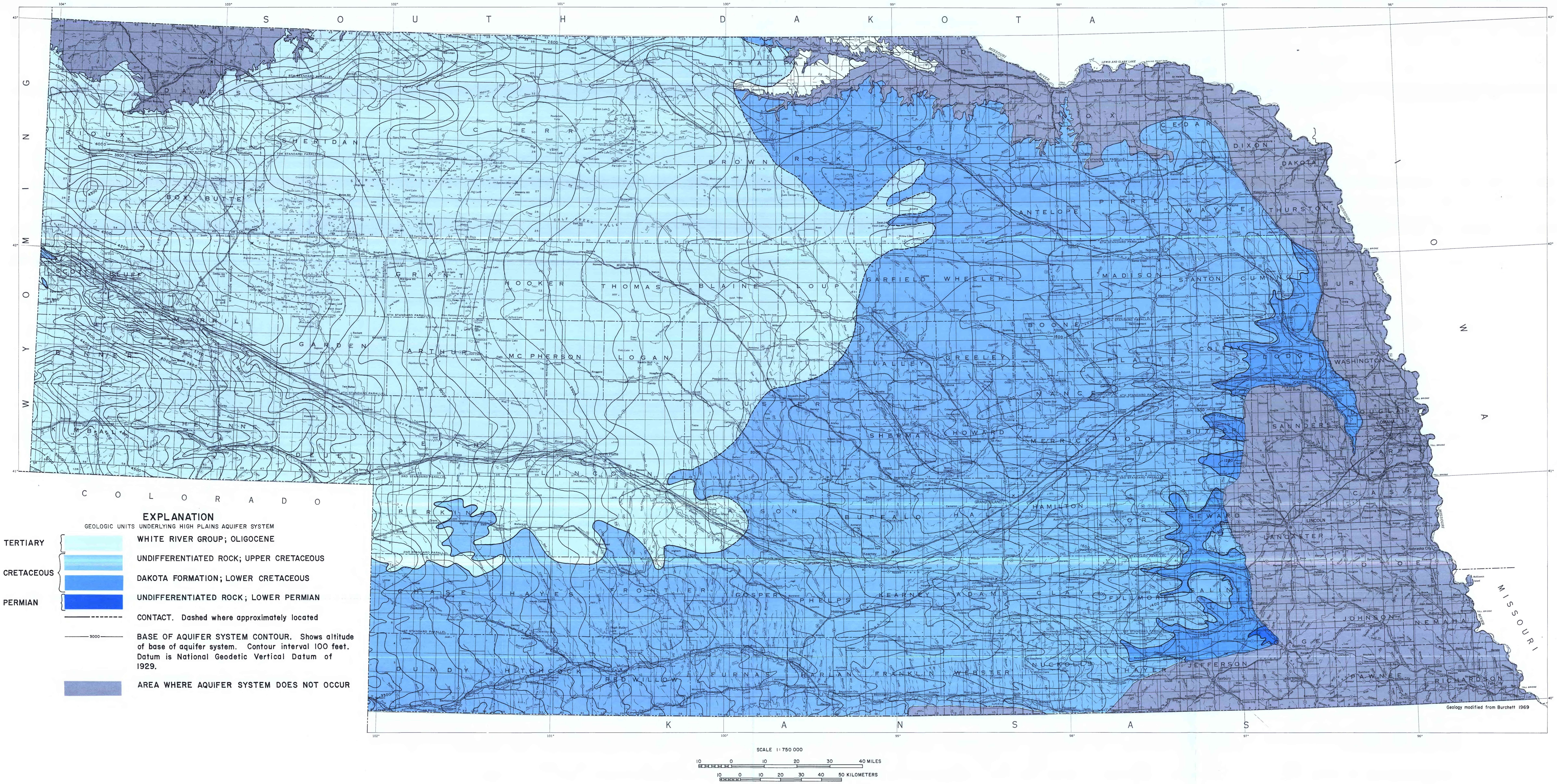


MAP SHOWING ALTITUDE AND CONFIGURATION OF THE BASE OF THE AQUIFER SYSTEM AND GEOLOGY OF UNDERLYING UNITS

INTRODUCTION

The U.S. Geological Survey in 1977 began a 5-year regional study of an aquifer system that underlies 177,000 mi^2 of the High Plains Section of the Great Plains Physiographic Province (Fenneman, 1931). This vast aquifer system, which extends from near the Southern Rocky Mountains on the west to the Central Lowlands on the east and from southern South Dakota to mid-Texas, underlies parts of eight States, including 64,770 mi^2 in Nebraska. The geologic units comprising the aquifer system are the Ogallala Formation of Tertiary age and other Tertiary and Quaternary deposits that are saturated and hydraulically connected to the Ogallala.

The objectives and work plan for the regional study (Weeks, 1978), provided for the collection and interpretation of hydrologic information by Geological Survey personnel in the individual States and for the preparation of interpretive reports of both State and regional scope.

The purpose of this report is to present, in more detail than could be accommodated in the generalized regional reports, interpretive maps of geohydrologic data that can be used to evaluate the ground-water potential of the High Plains aquifer system in Nebraska. All data used in preparing this report have been correlated and integrated with data from adjoining States and stored in the U.S. Geological Survey's regional water-resources data storage and retrieval system. Interpretive maps in this report show geology and configuration of the base of the aquifer system, the potentiometric surface of the aquifer system prior to 1950 (predevelopment) and during 1980, and depth to water and saturated thickness of the aquifer system during 1980.

The aquifer system extends beyond Nebraska's border in most of the report area. The aquifer system thins to nonexistence in the northwestern and northeastern corners of the State. However, in the east and southeast, deposits that constitute the aquifer system interfinger with glacial deposits and extend eastward along buried bedrock valleys. Consequently, the boundary in this area was designated to follow streams that form a practicable hydrologic boundary or to follow the western limits of glacial till, identifiable by a marked change in the density of irrigation wells.

Sediments that comprise the High Plains aquifer system were deposited during the Quaternary or Tertiary Periods. Those deposited during the Quaternary Period are mostly alluvium, eolian sand, and valley-fill deposits and consist chiefly of unconsolidated gravel, sand, loess, and silty clay. Those deposited during the Tertiary Period are mostly silt, clay, and smaller amounts of sand and gravel and are represented in descending order by the Ogallala Formation, the Arikaree Group, and the upper 100 ft of the Brule Formation of the White River Group, where overlain by Quaternary deposits. The extent of the predominant geologic units comprising the aquifer system in different areas across the State is indicated on the map to the right. For example, the numbers "3, 4" indicate that the predominant geologic units are valley-fill deposits of Quaternary Period and the Ogallala Formation of Tertiary Period.

GEOLOGY AND ALTITUDE AND CONFIGURATION OF BASE OF AQUIFER SYSTEM

The geology and altitude and configuration of the base of the aquifer system in the High Plains area of Nebraska are shown on the above map. The geology of the units comprising the base of the aquifer system was determined from published information on the sequence of geologic units beneath the High Plains in Nebraska, on the hydrologic properties of those units, and on data indicating the ability of those units to yield water to wells. Also shown on the map is the areal extent of each of the geologic units designated as the base of the aquifer system in their respective areas. A description of these units follows.

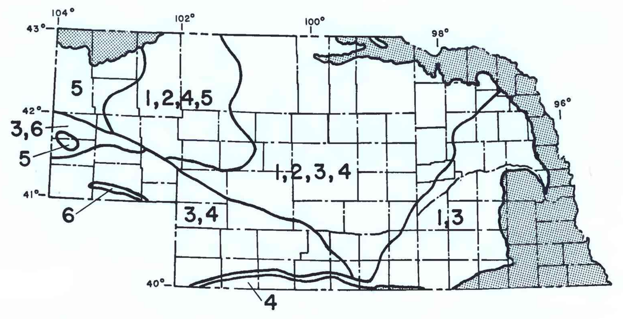
The top of the White River Group of Oligocene age is the base of the aquifer system in most of western and north-central Nebraska. This Group is recognized in the logged profile by a marked decrease in the sand as one moves down the profile from the Ogallala or Arikaree Group to the White River Group. The White River Group, which consists mostly of clays, silts, and channel sandstones (Lugn, 1939), has minimal hydraulic conductivity. However, fractures exist in the upper layers of the Brule Formation of the White River Group where it is in contact with overlying Quaternary deposits. These fractures contain sufficient water for irrigation both north and south of the North Platte River in Scotts Bluff and Morrill Counties, along either side of Lodgepole Creek in Cheyenne and Deuel Counties, and along Pumpkin Creek in Banner County. Consequently, where such fractures exist, the base of the aquifer system is designated as being 100 ft below the top of the White River Group. The tops of the undifferentiated Cretaceous rocks, Dakota Formation, and Permian rocks, which also have minimal hydraulic conductivity, are the base of the aquifer system in south-central and eastern Nebraska. The uppermost of these deposits consist mostly of shale and smaller amounts of sandstone, limestone, and chalk (Condra and Reed, 1943).

The altitude and configuration of the base of the aquifer system portray the buried erosional surface and its associated features upon which the material that constitutes the High Plains aquifer system was deposited. The altitude and configuration were constructed by evaluating and interpreting data from 2,700 published and unpublished test-hole logs from State and Federal test-drilling programs, including 67 logs from test holes drilled as part of the regional study. The availability of the new logs and reinterpretation of some of the older ones led, in some places, to substantial adjustments of previously constructed base-of-aquifer maps.

The base of the aquifer system ranges in altitude from 5,200 ft (National Geodetic Vertical Datum of 1929) in southwest Kimball County to 1,100 ft (NGVD) in Dodge County. The configuration can be used to locate ancestral drainage patterns and associated ridges, valleys, knobs, and depressions that underlie the aquifer system, and to compute the thickness of the aquifer system.

Some of the more prominent ancestral stream valleys underlie the present North Platte, Republican, and Niobrara Rivers, and Lodgepole Creek valleys. Some prominent ancestral stream valleys that do not underlie present stream valleys are those on a line from Thayer County to Adams County, from Cuming County through Valley County, and from Wayne County to Blaine County. Closed contours show the location of knobs and depressions.

Maps of the base of aquifer for the Republican River basin in Nebraska showing more detail than above have been prepared by Lappala (1978) and Ellis (1981).



MAP SHOWING PREDOMINANT GEOLOGIC UNITS COMPRISING AQUIFER SYSTEM

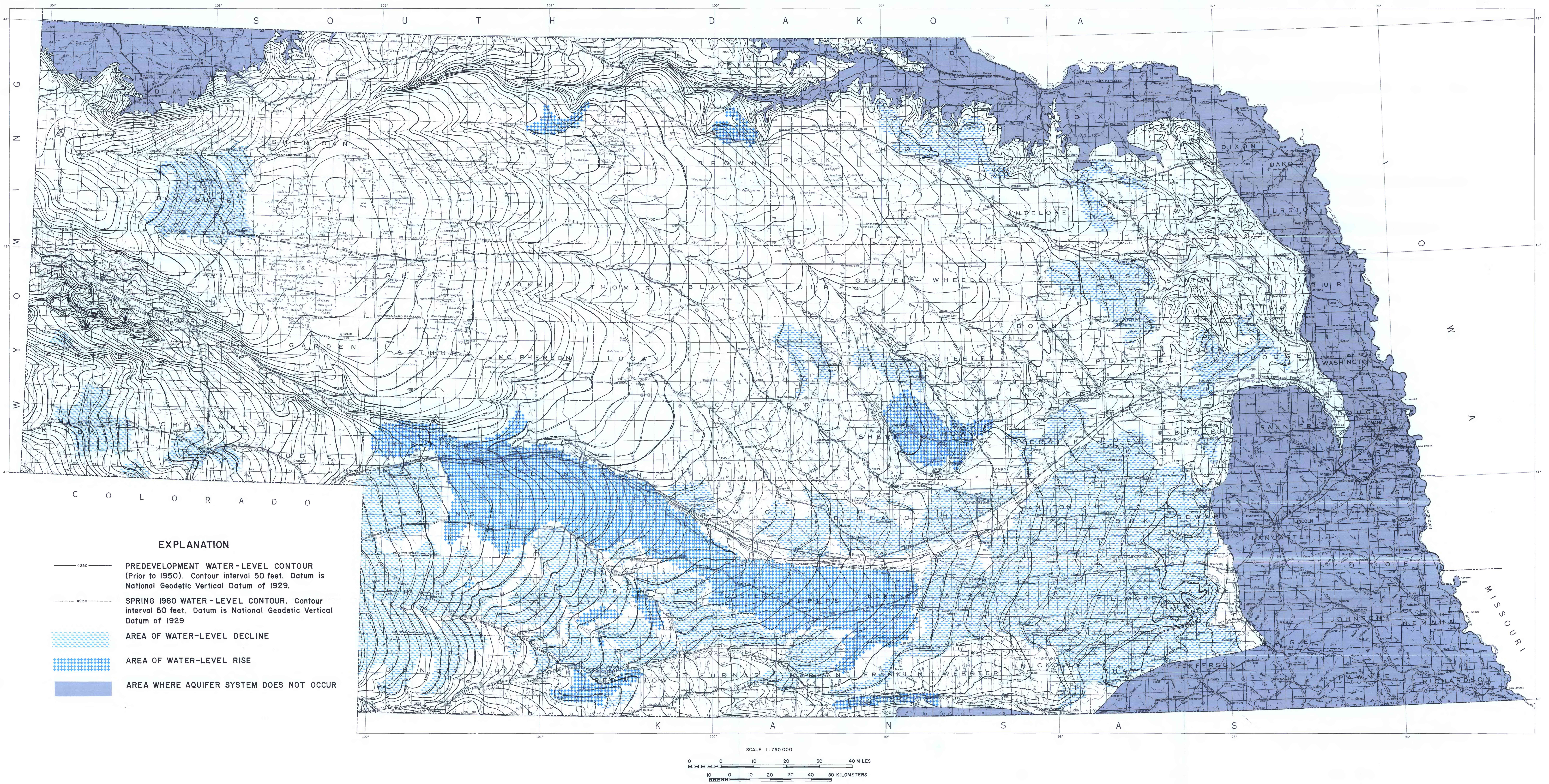
Base from U.S. Geological Survey State base map, 1962

GEOHYDROLOGY OF THE HIGH PLAINS AQUIFER SYSTEM IN NEBRASKA

By

Robert A. Pettijohn and Hsiu-Hsiung Chen

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



MAP SHOWING ALTITUDE AND CONFIGURATION OF POTENTIOMETRIC SURFACES OF AQUIFER SYSTEM, PREDEVELOPMENT AND SPRING 1980, AND AREA OF WATER LEVEL CHANGE

ALTITUDE AND CONFIGURATION OF POTENTIOMETRIC SURFACE OF AQUIFER SYSTEM

The altitude and configuration of the predevelopment potentiometric surface in the High Plains aquifer system and of the potentiometric surface during the spring of 1980 are shown on the above map. The potentiometric surface is the approximate upper boundary of the saturated aquifer system and fluctuates in response to both natural and man-induced recharge and discharge. Water-level data used to construct the above map were obtained from records of water-level measurements made between 1930 and 1980. Where major ground- and surface-water resource developments have occurred, only data obtained prior to 1950 were used to construct predevelopment water-level contours.

The potentiometric surface of the aquifer system declined as much as 50 ft in some localized areas and rose as much as 89 ft in others between 1950 and 1980 (Johnson and Pederson, 1981). The major cause of the declines and rises was the development of ground-water and surface-water resources for irrigation.

On the above map, areas designated as declines or rises are ones having continual water-level declines or rises for 5 years or longer regardless of magnitude. The area of decline, as delimited on the above map, is about 9,740 mi^2, or 15 percent of the aquifer area; the area of rise is about 2,900 mi^2, or 4 percent of the aquifer area. Johnson and Pederson (1981) designated as areas of decline or rise only those areas having water-level changes of 5 ft or more. Consequently, their areas of decline or rise are smaller than those just mentioned. Information from their report indicates that the total area of decline exceeds 6,500 mi^2, or 10 percent of the aquifer area, and occurs in the Blue River basin, the Central Platte River basin, southwestern Nebraska, Valley County, the panhandle, and northeastern Nebraska. Furthermore, information from their report indicates that the total area of rise exceeds 2,100 mi^2, or 3 percent of the aquifer area, and occurs in Lincoln, Gosper, Phelps, Kearney, Sherman, and Howard Counties. On the map above, in areas of water-level decline, the 1980 contour (dashed) is upgradient from the 1950 contour (solid). In areas of water-level rise, the opposite is true. The distance between the two contours (dashed and solid) is directly proportional to the amount of decline or rise in water levels, provided that the local gradient in the potentiometric surface is the same in the areas being compared.

The map showing the altitude and configuration of the potentiometric surface is a graphic representation of hydraulic gradient or slope. Because hydraulic gradient is dependent on recharge, discharge, hydraulic conductivity, and saturated thickness, changes in spacing of contours may reflect differences in one or any combination of these four parameters. However, if three of these parameters are known, changes in spacing of contours may be used to infer differences in the fourth parameter. For example, if recharge, discharge, and saturated thickness are known, changes in spacing of the contours on the potentiometric-surface map can be used to infer areas of change in hydraulic conductivity. Applying this reasoning to the Wildcat Ridge area, one can infer that the close spacing of contours is due primarily to decreasing hydraulic conductivity; data indicate that the saturated thickness of the aquifer is not decreased, nor are there differences in recharge or discharge to account for the close spacing. In applying this reasoning to the area between the uplands and the valleys of the upper North Platte River and Niobrara River in Cherry County, one can infer that the close spacing of contours is due to decreasing aquifer thickness, because data indicate that hydraulic conductivity and the recharge-discharge relationship are uniform between the uplands and the valleys.

Reasoning such as used in the previous paragraph also applies in interpreting widely-spaced contours. The wide spacing in the lower Platte River valley in Dodge County and in the Blue River basin is due to increased hydraulic conductivity, because data indicate that the aquifer thickness is decreased and that many of the streams are either intermittent or ephemeral and therefore have little effect on discharge or recharge to the aquifer, or on the slope of the potentiometric surface. Because hydraulic conductivity does not change appreciably across the sandhills of Sheridan and Garden Counties, one can infer that the wide spacing of contours in this area is probably due to discharge and recharge from the large number of lakes in the area.

Contours that bend sharply near a stream or are closed, such as on divides or between streams, indicate areas of recharge or discharge. For example, along the Platte, Niobrara, and Republican Rivers and Lodgepole Creek, the contours that bend in an upstream direction indicate that water is being discharged from the aquifer to the stream. On the other hand, the contours that bend in a downstream direction indicate that water from the stream is recharging the aquifer. Contours that bend neither upgradient nor downgradient near a stream indicate either that the potentiometric surface lies below the streambed and there is no effective hydraulic connection between the aquifer and the stream, or that the stream and the aquifer are in equilibrium.

The altitude of the potentiometric surface ranges from a high of 5,250 ft in Kimball County near the intersection of the Colorado, Nebraska, and Wyoming borders, to a low of 1,100 ft at the eastern extent of the High Plains aquifer system along the Platte River valley in Douglas County. The gradient of the potentiometric surface ranges from a maximum of 85 ft/mi on Wildcat Ridge in Scotts Bluff County to less than 2 ft/mi in the lakes area of the sandhills of Sheridan and Garden Counties. The general direction of ground-water movement in the aquifer system is eastward.

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) METRIC UNITS

Multiply inch-pound units	By	To obtain SI units
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)

Base from U.S. Geological Survey
State base map, 1962

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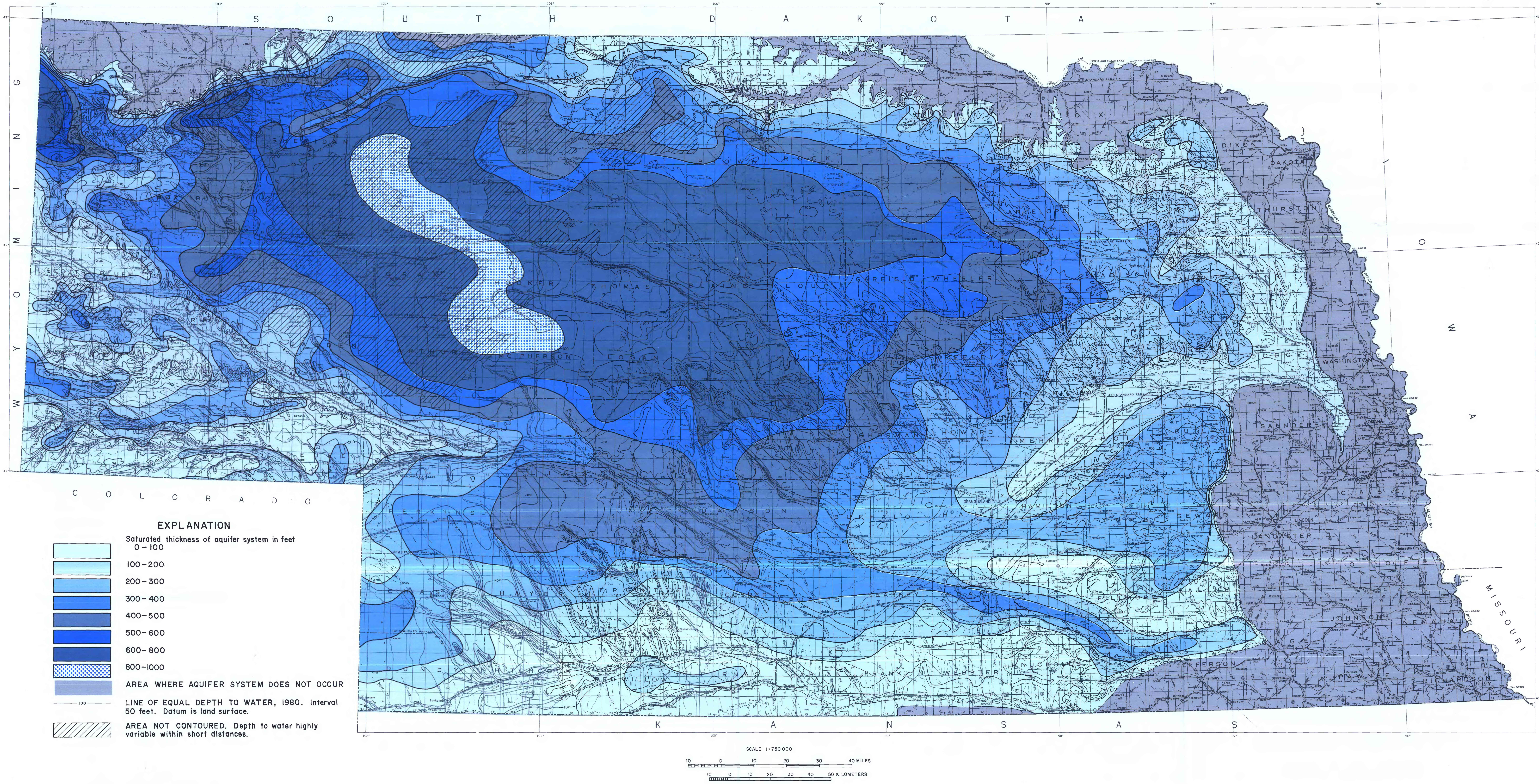

MAP SHOWING DEPTH TO WATER AND SATURATED THICKNESS OF AQUIFER SYSTEM, SPRING 1980

DEPTHS TO WATER AND SATURATED THICKNESS OF AQUIFER SYSTEM, SPRING 1980

The depths to water and saturated thickness of the High Plains aquifer system in Nebraska are shown on the above map. Depth-to-water data were computed by subtracting the altitude of the 1980 potentiometric surface from the altitude of the land surface. The generalized depth-to-water contours show the approximate distance that must be drilled to reach water and the approximate lift that would be required to pump it. The patterns indicating saturated thickness provide data that are necessary to compute the transmissivity of the aquifer and the volume of water the aquifer will yield -- two factors necessary for estimating ground-water availability.

The depth to water in the High Plains aquifer system in Nebraska ranges from near land surface in stream valleys and lake areas to about 400 ft in sandhills and upland areas. It is less than 50 ft below land surface in most of the perennial stream valleys. These stream valleys range in width from tens of feet for the smallest stream to 30 mi for the Platte River northeast of Grand Island. It is less than 10 ft below land surface in flat valleys around and between lakes in the sandhills and locally along the Platte River in Buffalo, Hall, Merrick, and Dawson Counties. Depth to water is more than 300 ft below land surface in parts of the uplands in Cheyenne, Kimball, Custer, and Perkins Counties. However, in most upland areas, it ranges from 100 to 250 ft below land surface.

In parts of western and north-central Nebraska, there is a succession of sandhills ranging in height from 20 to 300 ft and interspersed with subirrigated valleys. Because of these topographic variations, the depth to water ranges from zero to more than 200 ft within horizontal distances of less than 1 mi and, therefore, could not be contoured with available data. The largest area for which no contours are shown is in the western part of the Sand Hills region. Other areas are Pine Ridge and Wildcat Ridge.

The saturated thickness of the High Plains aquifer system in Nebraska ranges from almost zero to 1,000 ft. Although preliminary data, such as logs from oil and gas exploration, indicated that the aquifer saturated thickness may be 1,200 ft or greater, recent test-drilling data show maximum saturated thickness to be about 1,000 ft. Saturated thickness was computed by subtracting the altitude of the base of the aquifer from the altitude of the 1980 potentiometric surface. The saturated thickness is least in localized areas where the rocks of the White River Group or undifferentiated Cretaceous rocks crop out. It is greatest in the Sand Hills region of central Nebraska.

Saturated thickness in most of the Sand Hills region, which occupies an area of about 19,300 mi^2 (Keech and Bentall, 1971), exceeds 400 ft. Similar thickness occurs in northeast Sioux County where the Arikaree Group is thick. Saturated thickness in an area circling the Sand Hills region and in buried valleys of eastern Nebraska is between 200 and 400 ft. It is less than 200 ft along the southern border of the State, along the north and east perimeter of the aquifer system in Nebraska, and in the southwestern part of the Panhandle.

An estimate of the volume of water in storage in the High Plains aquifer system in Nebraska is presented in the table below, together with data used to derive the estimate. An assumed average porosity of 35 percent was used.

Saturated thickness interval (feet)	Area (square miles)	Percent of total area	Volume of saturated deposits (millions of acre feet)	Percent of volume of saturated deposit	Volume of water in storage (millions of acre feet)
801-1000	1,438	2	793	6	278
601- 800	9,895	16	4,288	31	1,500
501- 600	6,025	9	2,121	15	742
401- 500	7,271	11	2,094	15	733
301- 400	7,252	11	1,624	12	568
201- 300	10,999	17	1,760	12	616
101- 200	9,426	15	905	6	317
0- 100	12,464	19	399	3	140
Totals	64,770	100	13,984	100	4,894

The data in this report can be used along with data on hydraulic conductivity, recharge, and discharge to calibrate small-scale digital-computer models or large-scale local preliminary digital models of the High Plains aquifer system.

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Base from U.S. Geological Survey
State base map, 1962

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