POTENTIOMETRIC-SURFACE MAP OF WATER IN THE FOX HILLS-LOWER HELL CREEK AQUIFER IN THE NORTHERN GREAT PLAINS AREA OF MONTANA

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INTRODUCTION

In 1978 the U.S. Geological Survey began a 4-year study of aquifers of Cenozoic and Mesozoic age in the northern Great Plains to define the hydrologic system, to determine the availability and chemical quality of ground water, and to predict the effects of various water-use management plans on the system. The purpose of this map is to show the generalized potentiometric surface of water in the Fox Hills-lower Hell Creek aquifer.

Data used in compiling the map were collected from water wells and two oil test wells (Levings, 1981a, 1981b). The altitude of the potentiometric surface in the water wells was determined from measured or reported depths to water level or was calculated from pressure-gage readings on flowing wells. The water-well data range in age from 1940 to 1980. The altitude of the potentiometric surface of two oil test wells was determined by drill-stem tests (1971 and 1979).

GEOLOGIC SETTING

The Fox Hills Sandstone (Upper Cretaceous) is composed of sandstone beds deposited during receding marine seas. The overlying Hell Creek Formation is composed of sandstone beds separated by shales and siltstones. The lower part of the Hell Creek, which is predominantly sandstone, is hydraulically connected to the Fox Hills Sandstone and, together, they are referred to as the Fox Hills-lower Hell Creek aquifer. The thickness of the aquifer ranges from 0 to about 1,000 feet (R. D. Feltis, U.S. Geological Survey, written commun., 1982). In general the aquifer thins from south to north, with the thickness in the northern one-fourth of the area being less than 200 feet. In the Powder River basin, the thickness is 400 to 1,000 feet, in the Bull Mountains basin it is 200 to 400 feet, and in the Crazy Mountains basin it is 200 to about 1,000 feet.

The regional dip of the Fox Hills-lower Hell Creek aquifer is northeast and southwest from the Miles City arch. However, the structural complexity accounts for many localized exceptions.

Rocks underlying the Fox Hills-lower Hell Creek aquifer crop out in areas of structural highs such as the Pryor and Bighorn Mountains, Cedar Creek anticline, Porcupine dome, and Black Hills uplift. Underlying the Fox Hills-lower Hell Creek aquifer is the Upper Cretaceous Bearpaw Shale, a dark-gray marine shale that may be as much as 700 feet thick. Overlying the aquifer is the Paleocene Fort Union Formation. In the Crazy Mountains basin, the Fox Hills-lower Hell Creek aquifer interfingers with continental sediments of the Upper Cretaceous Livingston Group (Roberts, 1972).

POTENTIOMETRIC SURFACE

Although the Fox Hills-lower Hell Creek aquifer does not produce oil or gas, drill-stem tests have been conducted on oil and gas test wells. Two of these tests were used to calculate an altitude of the potentiometric surface at the test well using the following equation:

$$h = (FSIP \times C) - PRD + LSD \qquad (1)$$

where

- h is hydraulic head, in feet above NGVD of 1929;
- $FSIP$ is final shut-in pressure, in pounds per square inch, measured by a pressure-recording device;
- C is a factor to convert $FSIP$ to equivalent feet of water;
- PRD is depth of the pressure-recording device, in feet below the measuring point; and
- LSD is altitude of the measuring point, in feet above NGVD of 1929.

The factor C equals 2.307 feet of water per pressure increment of 1 pound per square inch. It assumes pure water at a temperature of 4°C having a density of 1.00 gram per cubic centimeter. Thus, the hydraulic-head values calculated from drill-stem tests reflect the potentiometric surface of water in the Fox Hills-lower Hell Creek aquifer if it contained a homogeneous fluid having a density of 1.00 gram per cubic centimeter. The density of water in the aquifer at the test wells is unknown.

At some data sites the altitude of the potentiometric surface may be anomalously high or low. These altitudes may represent reported water levels or may reflect problems in compilation of the drill-stem-test data and application of the data to the hydrology of the aquifer system. The anomalous data are retained to show the location of the data site and to indicate that a different interpretation is possible. In some instances the differences in altitude may indicate a decline in potentiometric surface during a number of years as a result of water production. Isolated data points were not contoured.

GROUND-WATER MOVEMENT AND DISCHARGE

Water in the Fox Hills-lower Hell Creek aquifer occurs under water-table and artesian conditions. The areal distribution of wells is shown on the map. Recharge to the aquifer is mainly from infiltration of precipitation on the outcrops. Smaller amounts of recharge may occur from infiltration of streamflow across the outcrops and from leakage across confining beds. As indicated on the map, the general direction of regional water movement in the aquifer is toward the northeast, coinciding with the regional dip. Recharge areas are the flanks of the Black Hills uplift, the Cedar Creek anticline, the southwest part of the Bull Mountains basin, and the outcrop area.

During the project, clusters of test wells were drilled at five sites (see map) to determine the differential in water level between the Fox Hills-lower Hell Creek aquifer and the upper Hell Creek Formation. At site C, the difference between water levels was less than 1 foot and at sites A, B, and D the water level in the upper Hell Creek ranged from 4 to 25 feet higher. The data indicate that the Fox Hills-lower Hell Creek aquifer may receive recharge from the overlying unit. At site E, the water level in the upper Hell Creek was 335 feet higher. This represents a considerable hydraulic-head differential that may be partly explained by comparing tested intervals. At site E, the water level is from the uppermost part of the Hell Creek, some 700 feet above the Fox Hills-lower Hell Creek aquifer. At the other sites, the difference in tested intervals ranged from 54 to 253 feet.

The aquifer probably discharges water to the Yellowstone River along the southeastern edge of the Bull Mountains basin. Although the contours along the lower Yellowstone, Powder, and Little Powder Rivers indicate that the aquifer is discharging to these rivers, the aquifer is several hundred feet below land surface. Also, the hydraulic-head data from sites A, B, and C do not indicate an upward movement of water through the overlying units. The contours probably reflect the concentration of flowing and pumped wells along the rivers that have lowered the hydraulic head near the rivers.

The Fox Hills-lower Hell Creek aquifer yields water to wells in a large part of the study area. The average reported or measured discharge from 335 wells is about 16 gal/min. The discharge ranges from 0.05 to 300 gal/min, with 38 wells having discharges greater than 20 gal/min. The specific capacity of 185 wells ranges from 0.007 to 5.4 (gal/min)/ft and averages 0.49 (gal/min)/ft.

REFERENCES CITED

Levings, G. W., 1981a, Selected drill-stem-test data from the northern Great Plains area of Montana: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-326, 20 p.

______1981b, Selected hydrogeologic data from the northern Great Plains area of Montana: U.S. Geological Survey Open-File Report 81-534, 241 p.

Roberts, A. E., 1972, Cretaceous and early Tertiary depositional and tectonic history of the Livingston area, southwestern Montana: U.S. Geological Survey Professional Paper 526-C, 120 p.

Ross, C. P., Andrews, D. A., and Witkind, I. J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.

METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units:

Multiply inch-pound unit	By	To obtain SI unit
foot	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
mile	1.609	kilometer
pound per square inch	6.895	kilopascal

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the following formula:

$$°F = 1.8°C + 32$$

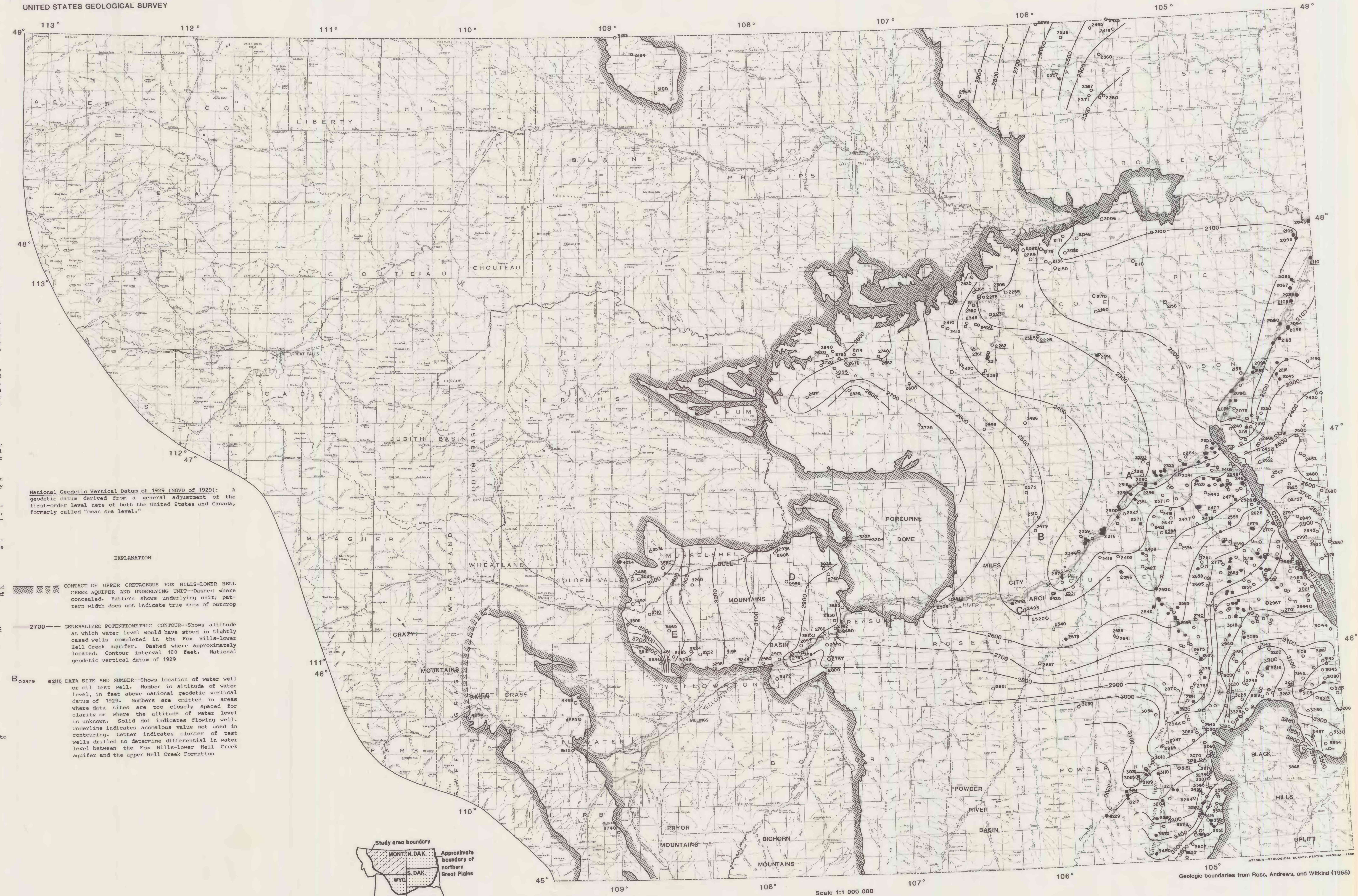
National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level."

EXPLANATION

CONTACT OF UPPER CRETACEOUS FOX HILLS-LOWER HELL CREEK AQUIFER AND UNDERLYING UNIT--Dashed where concealed. Pattern shows underlying unit; pattern width does not indicate true area of outcrop

——2700 — — GENERALIZED POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells completed in the Fox Hills-lower Hell Creek aquifer. Dashed where approximately located. Contour interval 100 feet. National geodetic vertical datum of 1929

B ○2479 ●2110 DATA SITE AND NUMBER--Shows location of water well or oil test well. Number is altitude of water level, in feet above national geodetic vertical datum of 1929. Numbers are omitted in areas where data sites are too closely spaced for clarity or where the altitude of water level is unknown. Solid dot indicates flowing well. Underline indicates anomalous value not used in contouring. Letter indicates cluster of test wells drilled to determine differential in water level between the Fox Hills-lower Hell Creek aquifer and the upper Hell Creek Formation



Base from U.S. Geological Survey State base map, 1968

Scale 1:1 000 000

0 10 20 30 40 MILES

0 10 20 30 40 50 KILOMETERS

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