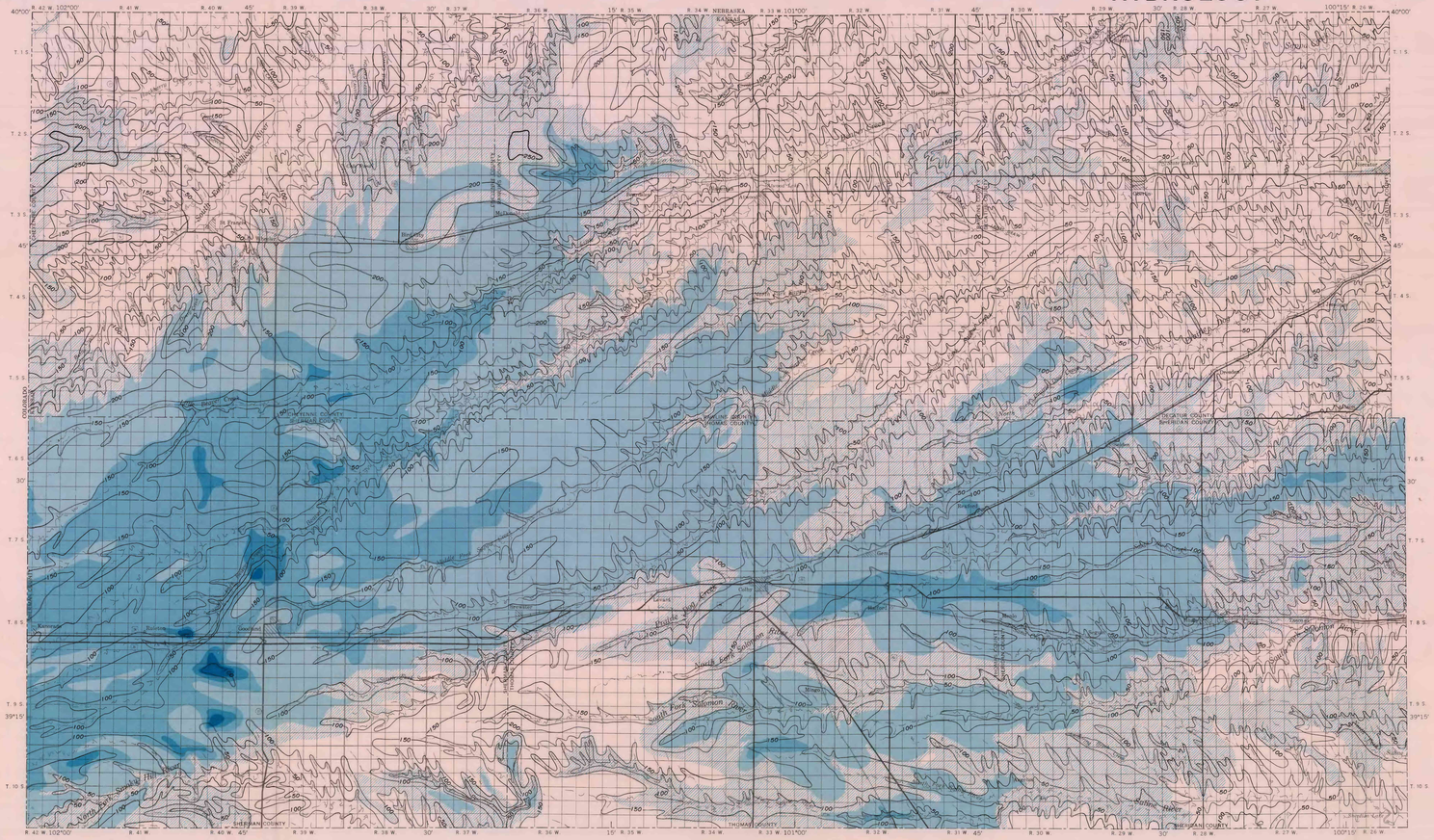
PREPARED IN COOPERATION WITH THE
STATE GEOLOGICAL SURVEY OF KANSAS
KANSAS STATE DEPARTMENT OF HEALTH
KANSAS STATE BOARD OF AGRICULTURE

HYDROLOGY



MAP SHOWING SATURATED THICKNESS AND GENERALIZED DEPTH TO WATER, 1965–68

EXPLANATION

Saturated thickness of water-bearing material 1965–68, in feet

Less than 50

50–100

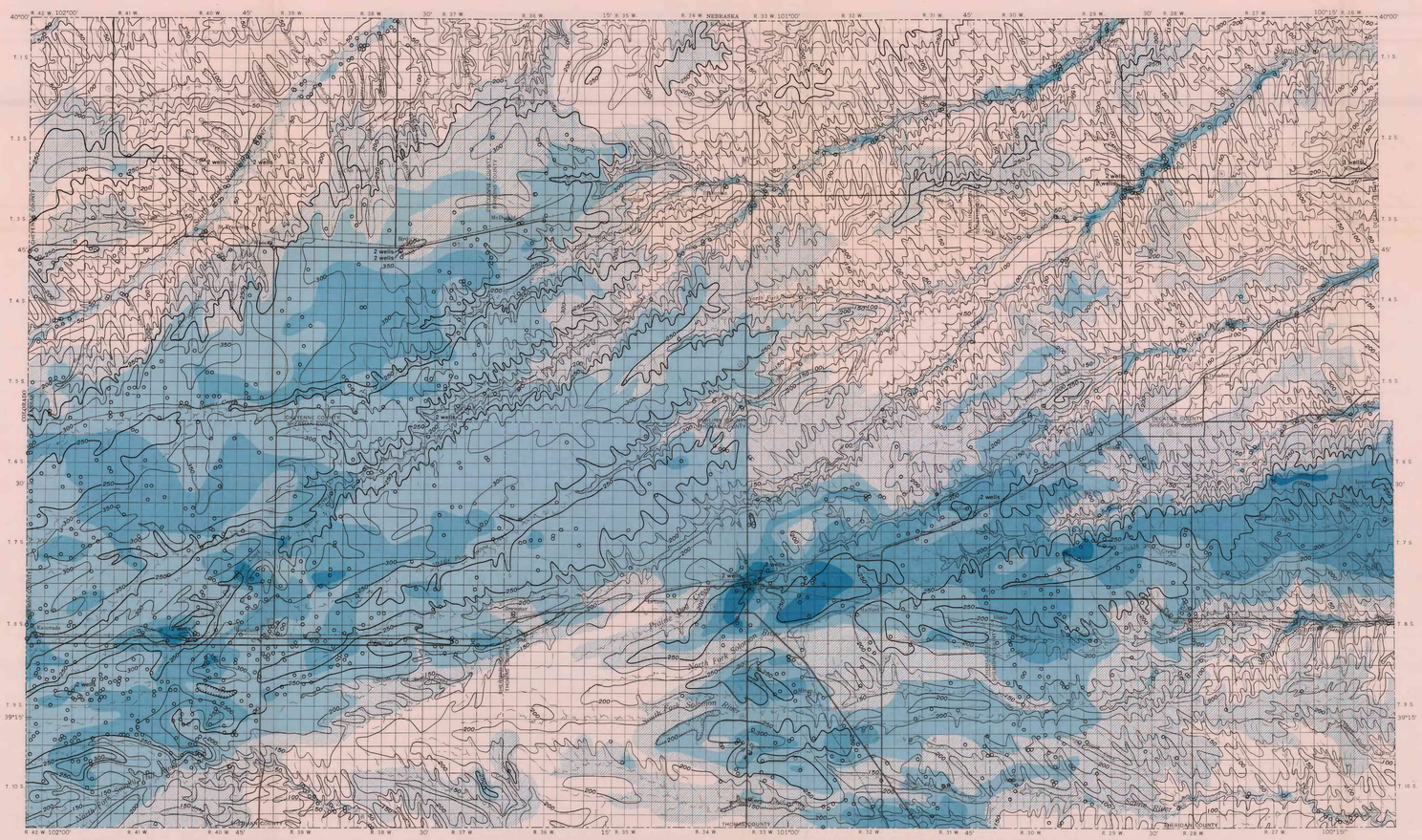
100–150

150–200

200–250

250–300

250 — Line of equal depth to water, 1965–68. Interval 50 feet. Datum is land surface



MAP SHOWING POTENTIAL YIELD OF LARGE-CAPACITY WELLS AND GENERALIZED DEPTH TO BEDROCK

EXPLANATION

Potential yield of large-capacity wells, in gallons per minute

Less than 250

250–500

A potential yield of less than 250 gallons per minute may be considered marginal for irrigation in the valleys where lifts are small, whereas a potential yield of less than 500 gallons per minute may be considered marginal for the upland areas where lifts are more than 150 feet

500–1000

1000–1500

Greater than 1500

The above values are based on measured and reported yields, aquifer tests, and specific capacities, with consideration for length of test, percentage of drawdown, and saturated thickness. Yields may vary locally from those shown because of variations in hydraulic conductivity, well construction, well interference, saturated thickness, and water level

250 — Line of equal depth to bedrock. Interval 50 feet except along parts of Little Beaver, South Beaver, North Fork Sappa, and Middle Fork Sappa Creeks in Rawlins County where intermediate contours are dropped. Datum is land surface

Large-capacity (100–2,000 gallons per minute) irrigation, municipal, or industrial well, January, 1969

SCALE 1:250 000

0 5 10 15 MILES

0 5 10 15 KILOMETERS

KANSAS
MAP LOCATION

GROUND WATER

Ground water of suitable quality and quantity is available for domestic and stock purposes in most of the area, and for irrigation purposes throughout a large part of the area (see maps showing saturated thickness and potential yield).

The principal water-bearing formations (aquifers) are the Ogallala Formation, which underlies most of the area, and the alluvium, which underlies the larger valleys. The Ogallala aquifer has a saturated thickness of as much as 270 feet and yields as much as 2,000 gpm (gallons per minute) to wells, with the largest yields generally occurring in the areas having the greatest saturated thickness. Transmissivities (ability of an aquifer to transmit water) of the Ogallala range from 10,000 to 130,000 gallons per day per foot and specific capacities of wells range from less than 10 to about 60 gallons per minute per foot of drawdown. The alluvial aquifer has a saturated thickness of as much as 65 feet and yields as much as 625 gpm along the South Fork of the Republican River valley, 1,200 gpm along Beaver Creek valley, 1,500 gpm along Sappa Creek valley, 1,000 gpm along Prairie Dog Creek valley, 800 gpm along the North Fork of the Solomon River valley, 950 gpm along the South Fork of the Solomon River valley, and 500 gpm along the Saline River valley. Transmissivities of the alluvium range from 15,000 to 135,000 gallons per day per foot and specific capacities of wells range from less than 10 to about 100 gallons per minute per foot of drawdown.

The water table in the Ogallala Formation slopes generally northeastward about 15 feet per mile, and the water moves in that direction at a rate of about 100 to 500 feet per year. The water table in the alluvium slopes in the direction of the valleys and very nearly parallels the land surface. Water in the alluvium moves at the rate of about 300 to 500 feet per year.

The generalized depth-to-water map shows the approximate distance that must be drilled before the water table is reached; this distance also is the minimum pumping lift. The generalized depth-to-bedrock map shows the approximate depth to which a large-capacity well should be drilled. Although these depths are representative for most of the area, they may vary somewhat where there are abrupt changes in land-surface topography.

All recharge is derived, either directly or indirectly, from precipitation on the area of study or on contiguous areas of Colorado to the west and Wallace County, Kans., to the south. Recharge from nearby areas occurs as ground-water inflow and as seepage to the alluvium from streams that enter and flow across the area from west to east. Ground-water inflow was computed to be about 35,000 acre-feet per year. The amount of seepage from streams is not known. Annual recharge has been estimated to range from 0.05 to 0.5 inch for the southern High Plains of New Mexico and Texas, and 0.9 inch for the Frenchman Creek basin of the northern High Plains of northeastern Colorado and southwestern Nebraska. Recharge to the study area cannot be expected to be as great as to the Frenchman Creek basin because of differences in surficial material. The High Plains area of northwestern Kansas is mantled by loess (windblown silt and clay), which is only moderately permeable, whereas about a third of the Frenchman Creek basin is mantled by dune sand, which promotes infiltration and inhibits runoff. The rate of recharge within the area also varies with vertical hydraulic conductivity; topography; vegetation; agricultural practices; condition, type, and thickness of deposits overlying the aquifer; and intensity, duration, and seasonal distribution of precipitation. Annual recharge from precipitation is assumed to be 0.25 inch but may be as much as 0.5 inch. A recharge of 0.25 inch per year would be about 50,000 acre-feet for the area underlain by a saturated thickness of 50 feet or more (the area developed by large-capacity wells), or about 80,000 acre-feet for the entire study area.

The idea that a quantity of water equivalent to the amount of recharge can be pumped without upsetting the hydraulic continuity of the aquifer often is misinterpreted. Natural recharge to and natural discharge from the aquifer probably will not change appreciably for many years after pumping begins. A significant amount of recharge cannot be salvaged by pumping until the natural discharge has been greatly reduced or stopped. Thus, in northwestern Kansas pumpage must come primarily from storage at the present time. The amount of ground water in storage, based on a storage coefficient of 0.15, is of the magnitude of 60 million acre-feet.

Ground water is discharged by evapotranspiration, by seepage to streams, by outflow to the east, and by wells. Most of the evapotranspiration occurs along the bottom lands of the more than 250 miles of gaining streams, where a luxuriant growth of trees exists and where the depth to water is less than 10 feet. Although this area of shallow water table occupies only a small part of the total study area, the amount of evapotranspiration could be 20,000 to 50,000 acre-feet per year. Ground-water seepage to streams as determined in March 1968, a period of little evapotranspiration or precipitation, was about 30,000 acre-feet per year. Ground-water outflow was computed to be about 25,000 acre-feet per year. It is not known how much ground water, if any, may be lost to the underlying bedrock. The greatest discharge of ground water is by large-capacity irrigation, industrial, and municipal wells. The amount of water pumped is increasing at an accelerating rate as more wells are drilled and more land is put under irrigation. The number of large-capacity wells has increased from less than 100 during the 1940's and 1950's to about 1,200 in 1969. During the period 1966–69 the number of wells increased 33 percent, while the amount of water pumped increased 50 percent. The map showing potential yield also shows the density of large-capacity wells.

A sampling of wells powered by natural-gas engines indicates that the amount of gas required to pump 1 acre-foot of water ranges from 3,500 to 10,000 cubic feet, depending on the efficiency of the pumping plant, the pumping lift, and the pressure head at the pump. An average of 4,200 cubic feet of natural gas is required to lift 1 acre-foot of water to the land surface in the valleys, whereas 7,000 cubic feet is required in the upland areas. Computations, based on power records and acres irrigated, show that annual pumpage for 1966 was about 200,000 acre-feet and for 1968 was about 300,000 acre-feet. Although most of the water pumped for irrigation is consumed by vegetation, enough no doubt percolates to the water table to constitute an important, though small, amount of return flow.

During the 3-year period 1966–69, water levels declined an average of 2 feet. In areas of heavy development, water levels declined as much as 16 feet. The hydrographs for the observation wells show the effects of ground-water development on water levels in several areas. Records for the well at Goodland reflect the decline in an area of heavy development; records at Colby and Hoxie reflect the decline in an area of lighter development. The general decline shown on the hydrographs indicates that water is being "mined" and the reservoir is being slowly depleted.

SURFACE WATER

The South Fork of the Republican River, which is affected by irrigation diversions and by storage in Bonny Reservoir, and the Arikaree River are the only perennial streams in the western part of the area. Several streams in the eastern part have a small continuous flow and act as drains where they intersect the water table and where flows are maintained by effluence from springs and seeps that issue from the Ogallala Formation and the alluvium. Most of the streamflow leaving the area is derived from storm runoff during periods of heavy precipitation. The combined annual streamflow from the area is about 170,000 acre-feet (see map showing annual streamflow). Annual diversions from streams for irrigation average 3,000 acre-feet.

CLIMATE

The climate is semiarid with light to moderate precipitation, moderately high average wind velocity, and high evaporation rate. Summers are hot with frequent dry winds and low relative humidity, and winters are characterized by moderate weather with occasional blizzards and cold periods of short duration. The average length of the growing season is 159 days.

The normal annual precipitation at Colby as determined by the U.S. Weather Bureau is 18.34 inches, with most of the rainfall occurring during the growing season. The annual precipitation graph for Colby shows the cyclic nature of the wet and dry periods and the lines of equal precipitation on the map show the variation over the area. Because the precipitation during the growing season is insufficient in most years to supply the moisture required for high yields of beans, corn, grain sorghums, and sugar beets, irrigation plays a major role in the agricultural economy of northwestern Kansas.

WATER QUALITY

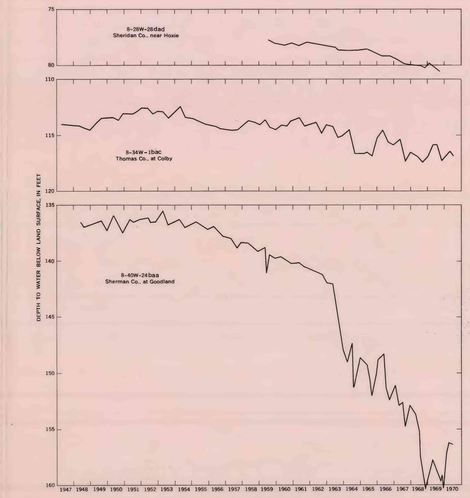
The chemical analyses of water from the Ogallala Formation and alluvium throughout the area indicate that the water generally is hard and is a calcium bicarbonate type. The water-quality diagrams (see map showing chemical quality of ground water) show the general chemical character of ground water, based on analyses of water from wells at indicated points. The ionic concentrations are plotted for calcium (Ca), magnesium (Mg), sodium and potassium (Na+K), sulfate (SO_4), bicarbonate (HCO_3), and chloride (Cl). Anions (negatively charged ions) are plotted to the right of the center line and cations (positively charged ions) to the left. The area of a diagram indicates dissolved-solids content—the larger the area, the greater the dissolved-solids content. Changes in the configuration of the diagram reflect differences in the chemical character of the water.

Concentrations of dissolved solids in the ground-water samples from the Ogallala Formation range from 206 to 591 mg/l (milligrams per liter) and average 290 mg/l, and from the alluvium commonly range from 270 to 1,200 mg/l. Water from the Ogallala Formation is suitable for domestic, stock, and irrigation purposes and meets all standards of chemical characteristics, except hardness, recommended by the U.S. Public Health Service. Water from the alluvium has a higher mineral content than water from the Ogallala, but is suitable for domestic, stock, and irrigation uses in most localities.

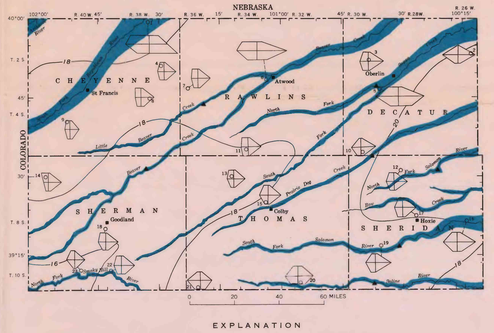
Chemical analyses of ground water from selected wells

Sample number	Well number	Depth of well (feet)	Geologic source[1]	Date of collection	Dissolved solids (mg/l)[2]	Specific conductance (micromhos per centimeter at 25° C)
1	1–38W– 2dbb	41	Qal	5–16–66	1,010	1,460
2	2–26W–11cda	125	To	5–13–53	307	----
3	2–30W–13ddd	169	To	5–13–53	306	----
4	2–37W–20ddd	220	To	12–05–50	298	----
5	3–29W–21bad	62	Qal	9–18–62	712	1,090
6	3–33W– 8dbd	[3]53	Qal	2–12–53	710	----
7	3–36W–17ccc	300	To	7–22–64	319	440
8	3–38W–36bad	[3]260	To	2–03–50	298	----
9	4–41W–25bcb	167	To	6–01–67	206	330
10	5–30W–35bcc	200	To	8–14–62	281	480
11	5–34W–28adc	250	To	7–24–64	326	470
12	6–29W–24abb	211	To	5–09–67	297	440
13	6–35W–26acd	260	To	7–04–65	273	400
14	6–42W–26caa	338	To	7–20–64	283	380
15	7–34W–25aaa	240	To	10–30–64	301	450
16	8–26W–16cdd	72	Qal	5–24–66	413	650
17	8–28W– 9abc	206	To	10–17–52	298	----
18	8–39W–30bcc	166	To	10–31–49	259	----
19	9–29W–17bab	196	To	9–01–64	283	450
20	10–32W–29aaa	180	To	6–05–64	414	650
21	10–36W–32aaa	224	To	5–09–67	342	540
22	10–39W– 8bcc	24	Qal	10–31–49	272	----
23	10–40W– 7abb	204	To	5–23–67	202	310

[1]To, Ogallala Formation; Qal, alluvium.
[2]Milligrams per liter. Milligrams per liter equals parts per million.
[3]Composite sample from two or more wells tapping the same aquifer.



HYDROGRAPHS FOR SELECTED WELLS



EXPLANATION

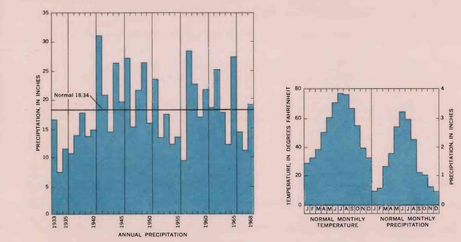
Line of equal normal annual precipitation. Interval 2 inches

ACRE-FEET 50,000 25,000 0
Point of effluence, April 1968
Average annual streamflow diagram

Na+K, Cl, Ca, HCO_3, Mg, SO_4
0 5 10
Water-quality diagram
Scale in milliequivalents per liter

Well
Number refers to sample analysis shown in table

MAP SHOWING DISTRIBUTION OF PRECIPITATION, ANNUAL STREAMFLOW AND CHEMICAL QUALITY OF GROUND WATER



GRAPHS SHOWING ANNUAL PRECIPITATION, NORMAL MONTHLY TEMPERATURE AND NORMAL MONTHLY PRECIPITATION AT COLBY

Base from U.S. Geological Survey
Goodland, 1954 and Limon, 1954–64
Roads modified 1969

WATER RESOURCES OF NORTHWESTERN KANSAS

By
Richard Howard Pearl, Robert S. Roberts, Katherine M. Keene
and Thomas J. McClain

1972