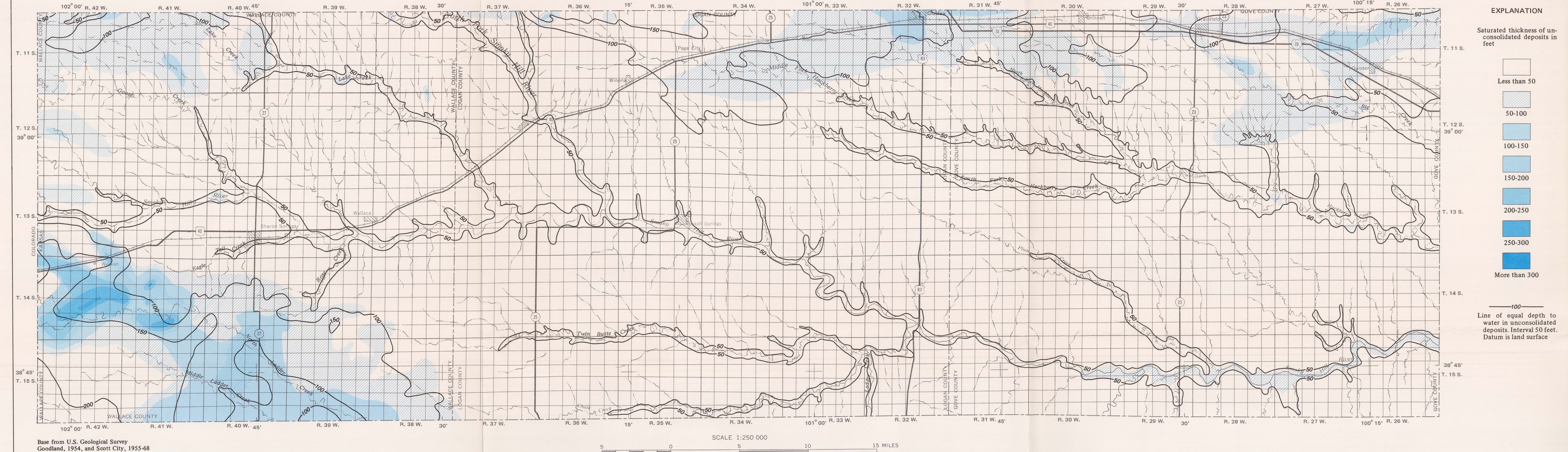
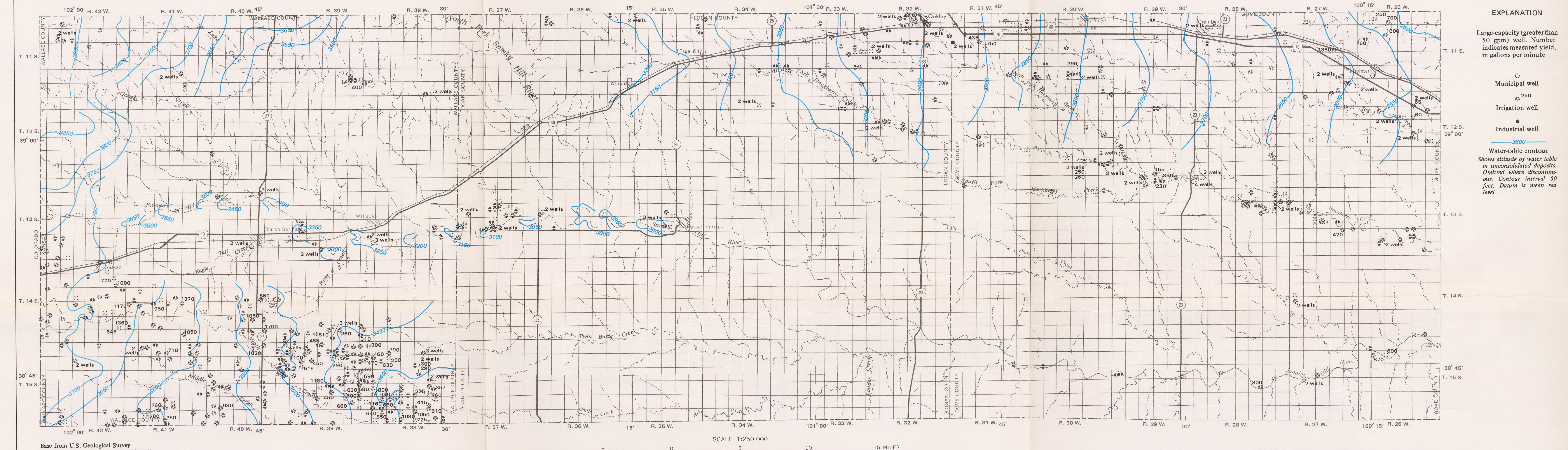
Prepared in cooperation with the
STATE GEOLOGICAL SURVEY OF KANSAS
KANSAS STATE DEPARTMENT OF HEALTH
KANSAS STATE BOARD OF AGRICULTURE

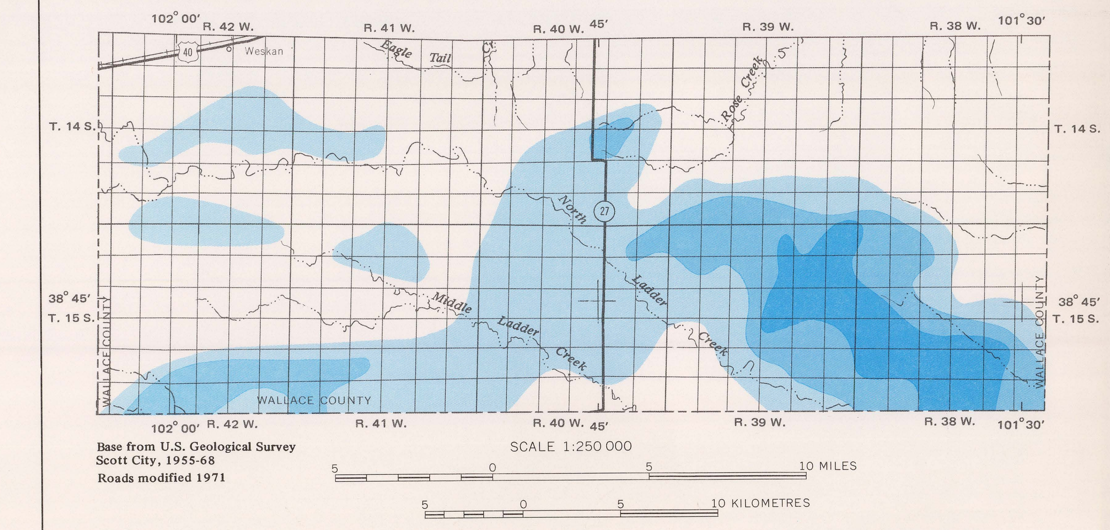
HYDROLOGY



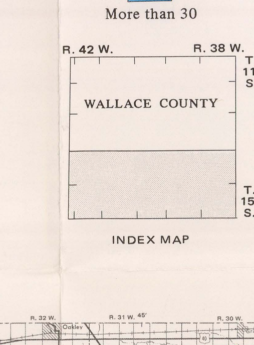
MAP SHOWING GENERALIZED SATURATED THICKNESS AND DEPTH TO WATER (1969-70)



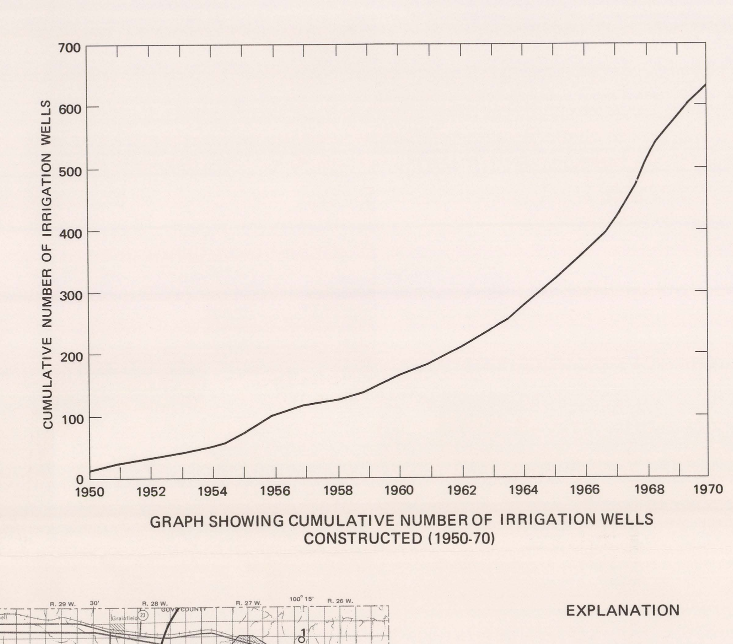
MAP SHOWING MEASURED WELL YIELDS (1969-70), LOCATION OF LARGE-CAPACITY WELLS (JANUARY 1971), AND CONFIGURATION OF WATER TABLE (1969-70)



MAP SHOWING WATER-LEVEL DECLINE IN SOUTHERN WALLACE COUNTY (JANUARY 1958 TO JANUARY 1971)



INDEX MAP



GRAPH SHOWING CUMULATIVE NUMBER OF IRRIGATION WELLS CONSTRUCTED (1950-70)

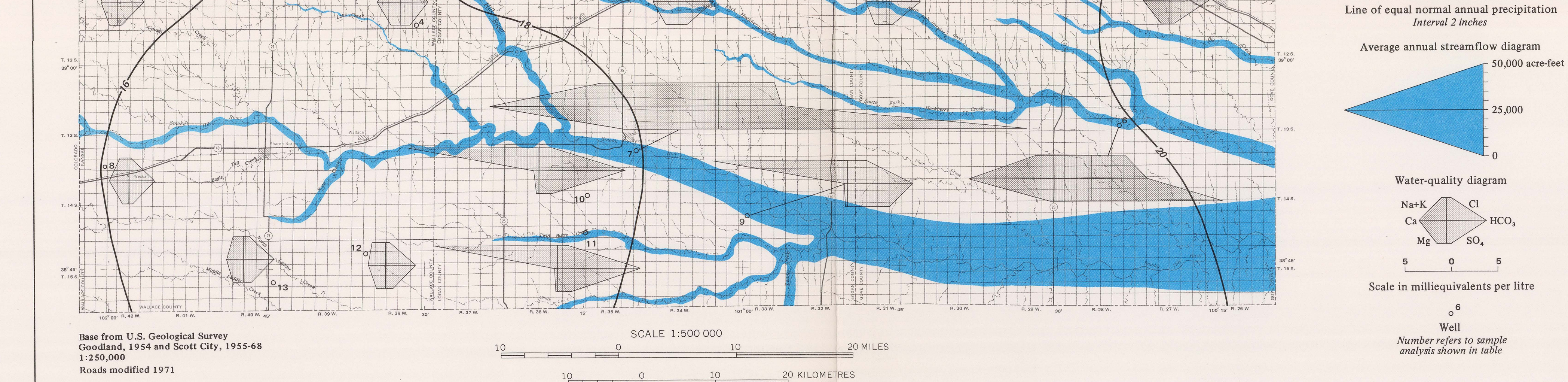
Chemical analyses of ground water from selected wells

Sample number	Well location	Geologic source[1]	Depth of well (ft)	Date of collection	Dissolved solids[2] (mg/l)	Specific conductance (micromhos per centimetre at 25°C)
1	11S–26W–18abb	To	212	5–20–70	290	450
2	11S–31W– 8cba	To	181	5–04–70	295	460
3	11S–34W–13aab	To	214	5–04–70	320	500
4	11S–38W–35ccc	To	189	5–21–71	300	470
5	11S–42W– 7ddd	To	187	5–20–70	204	330
6	13S–28W–14acc	Qal	56	5–20–70	1,510	1,970
7	13S–35W–25bbb	Qal, Qt	[3]26	4–29–69	3,080	3,580
8	13S–42W–32dcc	To	264	5–12–70	224	360
9	14S–33W–22cdd	Kd	895	3–06–70	930	1,380
10	14S–35W–17bca	Kd	1,335	10–19–70	826	1,340
11	15S–35W– 6bac	Kd	1,145	4–02–68	771	1,250
12	15S–38W– 7bbb	To	178	5–20–70	268	430
13	15S–40W–23cac	To	245	5–06–70	274	430

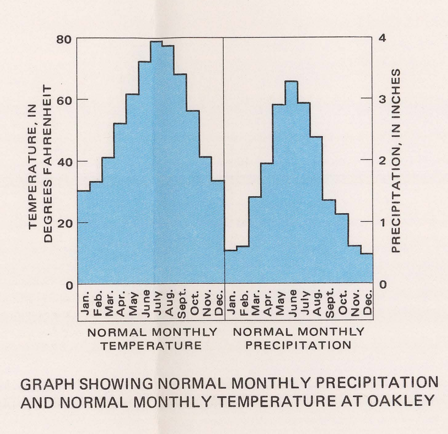
[1] Kd, Dakota Formation; Qal, alluvium; Qt, terrace deposits; To, Ogallala Formation.

[2] Milligrams per litre. Milligrams per litre is approximately equal to parts per million.

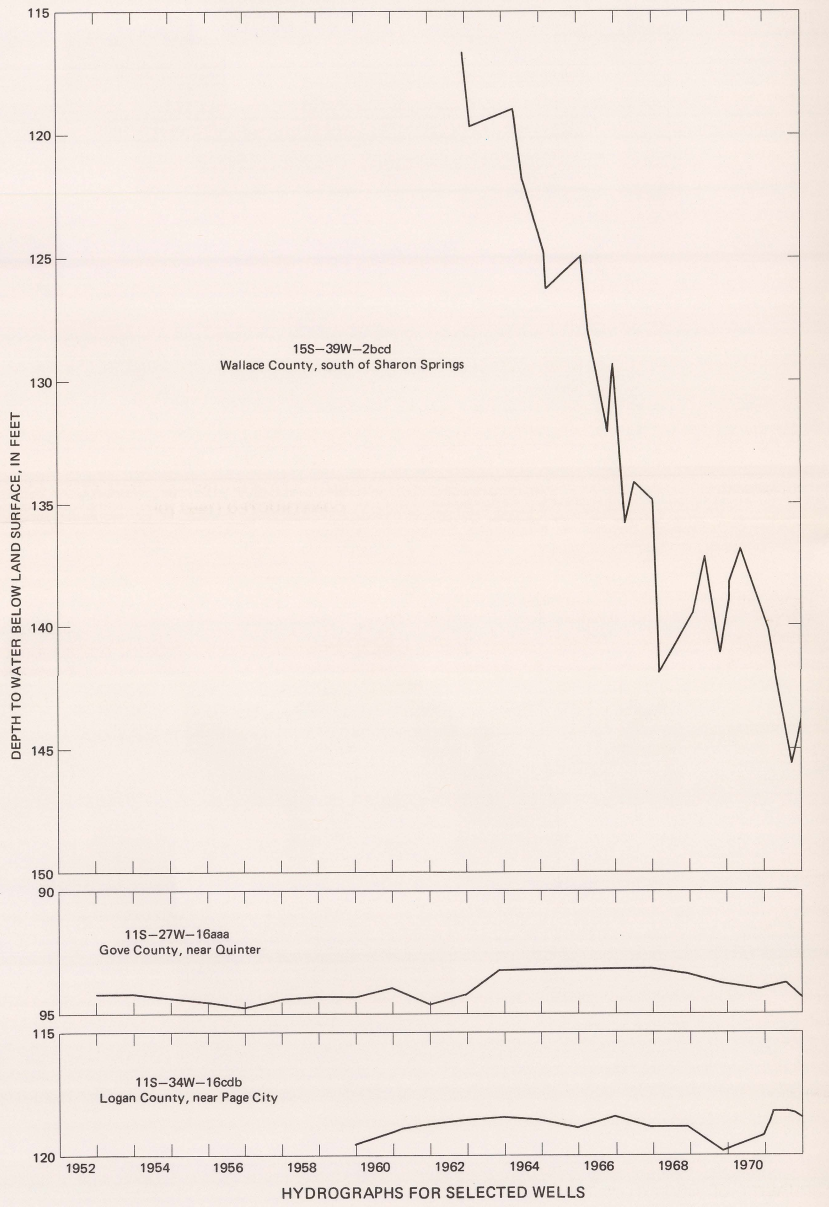
[3] Composite sample from two or more wells.



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



GRAPH SHOWING NORMAL MONTHLY PRECIPITATION AND NORMAL MONTHLY TEMPERATURE AT OAKLEY



HYDROGRAPHS FOR SELECTED WELLS

GROUND WATER

Ground water is available from the unconsolidated deposits for domestic, stock, industrial, public supply, and irrigation purposes in much of the area along the northern boundary of the study area, in southern Wallace County, and in the alluvium of valleys (maps showing saturated thickness and measured yields). However, in some localities in central Wallace County and in central and southern Gove and Logan Counties, the unconsolidated deposits have little or no saturated thickness. Wells in southern Gove and Logan Counties have been drilled to the Codell Sandstone Member of the Carlile Shale or to the Dakota Formation to obtain water for domestic or stock use. The wells that tap the Codell are few, and none were inventoried.

The Ogallala Formation is the principal water-bearing unit (aquifer) along the northern part of the area and in southern Wallace County. Much of the Ogallala has been removed by erosion along the Smoky Hill River valley, and it is thin and discontinuous along tributary divides in the central and southeastern part of the counties. The Ogallala aquifer has a saturated thickness of as much as 300 feet, and commonly yields 500 to 1,500 gpm (gallons per minute) of water to wells. The largest yields generally occur in areas having the greatest saturated thickness.

Irrigation supplies also are obtained from the alluvium and terrace deposits in the larger stream valleys and from terrace deposits in the "Missouri Flats" area (Tps. 14 and 15 S., Rs. 27 and 28 W.), a loess-mantled segment of the Smoky Hill River valley abandoned in middle Pleistocene time. The alluvium has a saturated thickness of as much as 80 feet and commonly yields 300 to 800 gpm to wells. The terrace deposits have a saturated thickness of as much as 40 feet and commonly yield 100 to 400 gpm to wells, although some wells tapping these deposits also penetrate the Ogallala.

The water table in the Ogallala Formation slopes generally eastward at about 12 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 downvalley at about 15 feet per mile and very nearly parallels the land surface. The slope of the water table varies inversely with the transmissivity (ability of the aquifer to transmit water); thus, where the aquifer has a high transmissivity, the water-table contours are spaced farther apart, as shown on the water-table map.

The generalized depth-to-water map shows the approximate depth that must be drilled before the water table in the unconsolidated deposits is reached; this distance also is the minimum pumping lift. Although these depths are representative for most of the area, they may vary somewhat where the land-surface topography changes abruptly.

The Dakota Formation reportedly yields as much as 20 gpm to domestic and stock wells, but locally the water may be chemically unsuitable for some purposes. Depths to the top of the Dakota generally range from less than 500 feet below land surface in the southeastern part of the area to more than 2,200 feet in the northwestern part. (See map showing depth to top of Dakota Formation, sheet 1.)

All recharge to the ground-water reservoir is derived, either directly or indirectly, from precipitation on the area of study or on contiguous areas in Colorado. Recharge derived from precipitation on nearby areas occurs as ground-water inflow and as seepage from streams that flow across the area from west to east. Ground-water inflow was computed to be about 25,000 acre-feet per year. The amount of seepage from streams is not known.

The rate of recharge from precipitation on the area 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 has been estimated to range from 0.05 to 0.5 inch for the southern High Plains of New Mexico and Texas, to be less than 0.5 inch for southwestern Kansas, and to be 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 west-central Kansas is mantled by loess (windblown silt and some fine sand), 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. Annual recharge from precipitation in the study area is assumed to be 0.25 inch but it may be as much as 0.5 inch. A recharge of 0.25 inch per year to the Ogallala aquifer would be about 15,000 acre-feet of water. Some of the water from wells that is applied annually for irrigation returns to the ground-water reservoir as recharge. The amount of this return flow is unknown but probably is small because most of the water is consumed by crops, or is evaporated from the land surface.

The alluvium and terrace deposits along the valleys can be discharged and recharged more rapidly than the Ogallala. The alluvial aquifers are limited in width and thickness and, therefore, in amount of storage. Pumping for irrigation in the valleys causes rapid depletion of ground-water storage; periodic streamflow causes rapid recharge of the alluvial aquifers.

The concept that a quantity of water equivalent to the annual amount of recharge to the Ogallala Formation can be pumped annually without upsetting the hydrologic balance of the aquifer often is misinterpreted. Natural discharge from the Ogallala 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, ground-water withdrawals in the area studied are primarily from storage in the Ogallala Formation at the present time. The amount of ground water in storage, based on a storage coefficient of 0.15 to 0.20, is of the magnitude of 8 to 10 million acre-feet.

Ground water is discharged by evapotranspiration, by seepage to streams, by subsurface outflow to the east and southeast, and by wells. Most of the evapotranspiration occurs along the bottom lands of valleys, where a luxuriant growth of trees exists and the depth to water is less than 10 feet. Although the area of shallow water table is only a small part of the total study area, the amount of evapotranspiration probably is considerable, but unknown.

Several streams have eroded below the water table in the Ogallala Formation and, hence, act as drains from the ground-water reservoir. Tributaries of the Smoky Hill River have eroded headward into the Ogallala Formation, from which they derive water. These streams flow mainly in winter when transpiration by plants and evaporation are reduced. The most prominent tributaries draining water from the Ogallala Formation are Rose Creek south of Sharon Springs, Ladder Creek in southeastern Logan County, Lake Creek and the North Fork Smoky Hill River in Logan and Wallace Counties, and Hackberry Creek in Gove County. During the summer of 1970 no flow was observed in Hackberry or Plum Creeks; however, the Ogallala Formation and the terrace deposits were, no doubt, discharging water to the alluvium of the valleys through springs at their contacts with the underlying bedrock. This water either was being consumed by transpiration and evaporation along the valleys or was being withdrawn by wells in the alluvium. No excess ground water remained to discharge as streamflow. The amount of water discharged by springs and seeps is not known.

The contact of the Ogallala Formation and the underlying bedrock represents a hydrologic boundary beneath upland plain areas. As shown on the configuration-of-bedrock-surface map (sheet 1), the surface of the underlying bedrock slopes generally eastward, but locally the slopes are toward points of outcrop and the Smoky Hill River. Ground-water outflow beneath stream valleys is relatively small owing to the narrow cross section of the valleys of Smoky Hill River, Hackberry Creek, and other drainage. How much ground water, if any, may be lost to the underlying bedrock is not known.

Water-table contours show that ground water in the Ogallala Formation moves southeastward out of southeastern Wallace County and moves eastward out of northern Gove County. The amount of water in the Ogallala that leaves the study area as underflow is estimated to be 10,000 acre-feet per year.

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 irrigated. The number of irrigation wells (graph) has increased from less than 50 during the early 1950's to about 630 in 1970. The well-location map shows the location and 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 3,700 to 18,500 cubic feet, depending on the efficiency of the pumping plant, the pumping lift, and the pressure head at the pump. An average of 4,000 cubic feet of natural gas is required to lift 1 acre-foot of water to the land surface in the valleys, whereas 8,400 cubic feet is required in the upland areas. Computations, based on power records and acres irrigated, indicate that annual pumpage from the Ogallala, alluvium, and terrace deposits for 1970 was about 100,000 acre-feet, of which 55,000 acre-feet was pumped from the Ogallala in southern Wallace County.

During the 13-year period 1958–71, water levels generally declined 5 feet or less in Gove, Logan, and northern Wallace Counties but declined more than 30 feet in southern Wallace County. The hydrographs for observation wells show the effect of ground-water development on water levels in three areas. Records for well 15S-39W-2bcd reflect the decline in an area of heavy development. Records for wells 11S-27W-16aaa and 11S-34W-16cdb reflect the decline in an area of lighter development. The general decline shown by the hydrograph for well 15S-39W-2bcd and by the water-level-decline map of southern Wallace County indicates that water is being "mined," and the reservoir is being slowly depleted.

Water is mined because the amount of water pumped from the ground-water reservoir exceeds the amount of salvageable recharge. For example, 1 square mile (640 acres) of the Ogallala aquifer having a saturated thickness of 100 feet would contain from 10,000 and 13,000 acre-feet of water, assuming that the total volume of saturated material would yield 15 to 20 percent water. However, all the water in the aquifer cannot be withdrawn; therefore, a possible 6,000 to 8,000 acre-feet is available for development. If one well on each 160 acres is assumed to pump 200 acre-feet per year, an amount of water equal to the original amount available would be withdrawn in a period of 7 to 10 years. Actually wells mine water not only from beneath their own boundaries but also from a radius of influence that may extend beneath several square miles; therefore, the useful life of an aquifer, such as the Ogallala, will depend on the rate that water is mined. Annual recharge per square mile from precipitation, being in the magnitude of 15 to 30 acre-feet, is negligible when compared to the annual pumpage potential of 800 acre-feet. As in development of other resources, management can play an important role in deriving the greatest benefits of mining ground water for irrigation.

SURFACE WATER

Most streams in the area are intermittent and losing. That is, they flow during and shortly after heavy rains and, because they have not eroded their channels below the water table in the unconsolidated deposits, they lose water to the unsaturated deposits. Rose Creek, Lake Creek, North Fork Smoky Hill River, and some other tributaries of the Smoky Hill River have eroded below the water table and are gaining streams. The flow from these tributaries sustains flow in the Smoky Hill River for a few miles downstream from the mouth of each tributary, but the water eventually seeps underground, is evaporated, or is consumed by vegetation.

The Smoky Hill River is the principal stream that crosses the area from west to east; it is a gaining stream in the eastern third of the area most of the time. The river and its tributaries drain most of the area. The average annual streamflow of the Smoky Hill River measured in southeastern Logan County at the intersection with U.S. Highway 83, which is 0.1 mile downstream from the confluence with Ladder Creek, is 30,000 acre-feet; of this amount, 8,000 acre-feet is contributed by Ladder Creek. The average annual streamflow of the Smoky Hill River at the east boundary of Gove County is estimated to be 50,000 acre-feet (map showing annual streamflow). An additional annual streamflow of 15,000 acre-feet is estimated to leave the east boundary by Big Creek, Hackberry Creek, and other small drainages.

Heavy rains on August 22 and 23, 1969, principally in the Ladder Creek drainage basin, caused the maximum discharges for the 30-year period 1939–69. On August 23 the discharge was 28,000 cfs (cubic feet per second) on Ladder Creek and 22,300 cfs on the Smoky Hill River 0.1 mile downstream from Ladder Creek.

CLIMATE

The climate is semiarid with a moderately high average wind velocity and a 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 growing season is 162 days.

The normal annual precipitation at Oakley as determined by the National Weather Service (formerly U.S. Weather Bureau) is 19.79 inches, with most of the rainfall occurring during the growing season. The lines of equal precipitation on the map show the variation in rainfall for the area. The monthly precipitation graph for Oakley shows the range in precipitation by months. 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 the three-county area.

WATER QUALITY

Chemical analyses in this report (table) were determined for water samples from the alluvium, terrace deposits, Ogallala Formation, and Dakota Formation. Water from the alluvium and terrace deposits is very hard and of the calcium sulfate type, water from the Ogallala Formation is generally hard and of the calcium bicarbonate type, and water from the Dakota Formation is soft and of the sodium bicarbonate type.

The quality of water in the alluvium and terrace deposits is affected by contact with underlying formations. Where the deposits overlie the Pierre Shale or Niobrara Formation, the water will be much more highly mineralized and of poorer quality than water in areas where the deposits are adjacent to or downstream from outcrops of the Ogallala Formation. Evapotranspiration in areas of shallow water table may cause a concentration of salts in the soil zone from where they may be leached to the water table. However, this concentration and leaching apparently have not significantly affected the water quality in the study area.

The water-quality diagrams (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 in milliequivalents per liter are plotted for magnesium (Mg), calcium (Ca), sodium and potassium (Na+K), sulfate (SO_4), bicarbonate (HCO_3), and chloride (C1). Anions (negatively charged ions) are plotted to the right of the center lines 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 ground-water samples collected from the Ogallala Formation during this study range from 204 to 350 mg/1, from the Dakota Formation range from 771 to 1,290 mg/1, and from the Quaternary alluvium and related terrace deposits range from 368 to 3,080 mg/1.

Water from the Ogallala Formation is suitable for domestic, stock, and irrigation purposes, and meets all standards of chemical characteristics recommended by the U.S. Public Health Service (1962). Water from the alluvium and terrace deposits is suitable for domestic, stock, and irrigation uses in most localities. Analyses of water samples from 11 wells tapping the Dakota Formation indicate that the water is generally high in concentrations of chloride, sodium, fluoride, and sulfate. Further study is needed to determine the chemical quality of water available from the Dakota for irrigation.

Interior—Geological Survey, Reston, Va.—1975

WATER RESOURCES OF GOVE, LOGAN, AND WALLACE COUNTIES, WEST-CENTRAL KANSAS

By
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1975