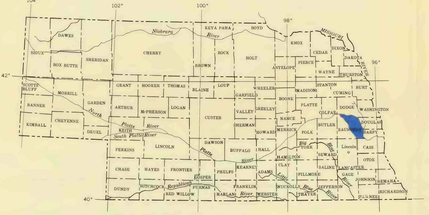
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

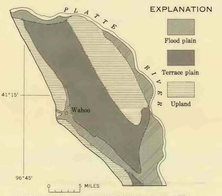
PREPARED IN COOPERATION WITH THE
CONSERVATION AND SURVEY DIVISION
OF THE UNIVERSITY OF NEBRASKA

HYDROLOGIC INVESTIGATIONS
ATLAS HA-266

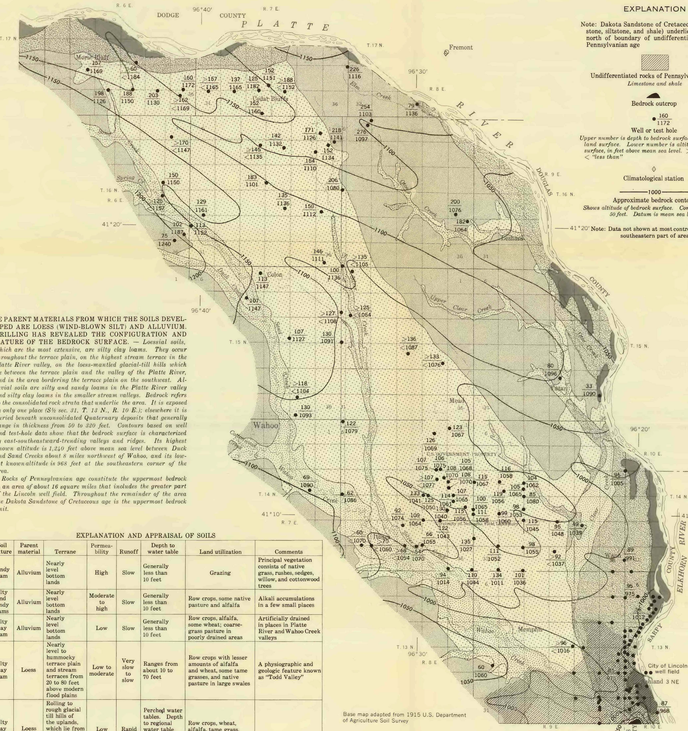
PHYSICAL SETTING AND CLIMATE



THE REPORT AREA IS LOCATED IN EAST-CENTRAL NEBRASKA, SOUTH OF THE PLATTE RIVER



THREE PHYSIOGRAPHIC REGIONS HAVE BEEN IDENTIFIED IN EASTERN SAUNDERS COUNTY



EXPLANATION

Note: Dakota Sandstone of Cretaceous age (sandstone, siltstone, and shale) underlies entire area north of boundary of undifferentiated rocks of Pennsylvanian age

Undifferentiated rocks of Pennsylvanian age
Limestone and shale

Bedrock outcrop

160
1172
Well or test hole
Upper number is depth to bedrock surface, in feet below land surface. Lower number is altitude of bedrock surface, in feet above mean sea level. > "more than"; < "less than"

Climatological station

1000
Approximate bedrock contour
Shows altitude of bedrock surface. Contour interval, 50 feet. Datum is mean sea level

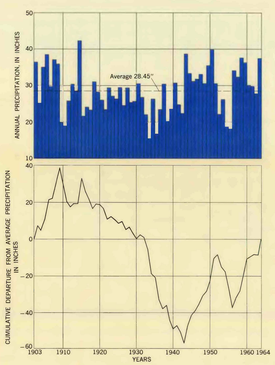
41°20' Note: Data not shown at most control points in southeastern part of area

THE PARENT MATERIALS FROM WHICH THE SOILS DEVELOPED ARE LOESS (WIND-BLOWN SILT) AND ALLUVIUM. DRILLING HAS REVEALED THE CONFIGURATION AND NATURE OF THE BEDROCK SURFACE. — *Loessial soils, which are the most extensive, are silty clay loams. They occur throughout the terrace plain, on the highest stream terrace in the Platte River valley, on the loess-mantled glacial-till hills which lie between the terrace plain and the valley of the Platte River, and in the area bordering the terrace plain on the southwest. Alluvial soils are silty and sandy loams in the Platte River valley and silty clay loams in the smaller stream valleys. Bedrock refers to the consolidated rock strata that underlie the area. It is exposed in only one place (*$S\frac{1}{2}$ *sec. 31, T. 14 N., R. 10 E.); elsewhere it is buried beneath unconsolidated Quaternary deposits that generally range in thickness from 50 to 320 feet. Contours based on well and test-hole data show that the bedrock surface is characterized by east-southeastward-trending valleys and ridges. Its highest known altitude is 1,240 feet above mean sea level between Dodd and Sand Creeks about 8 miles northwest of Wahoo, and its lowest known altitude is 968 feet at the southeastern corner of the area.*

Rocks of Pennsylvanian age constitute the uppermost bedrock in an area of about 16 square miles that includes the greater part of the Lincoln well field. Throughout the remainder of the area the Dakota Sandstone of Cretaceous age is the uppermost bedrock unit.

EXPLANATION AND APPRAISAL OF SOILS

Map key	Soil texture	Parent material	Terrane	Permeability	Runoff	Depth to water table	Land utilization	Comments
	Sandy loam	Alluvium	Nearly level bottom lands	High	Slow	Generally less than 10 feet	Grazing	Principal vegetation consists of native grass, rushes, sedges, willow, and cottonwood trees.
	Silty and sandy loams	Alluvium	Nearly level bottom lands	Moderate to high	Slow	Generally less than 10 feet	Row crops, some native pasture and alfalfa	Alkali accumulations in a few small places
	Silty clay loam	Alluvium	Nearly level bottom lands	Low	Slow	Generally less than 10 feet	Row crops, alfalfa, some wheat; coarse-grass pasture in poorly drained areas	Artificially drained in places in Platte River and Wahoo Creek valleys
	Silty clay loam	Loess	Nearly level to hummocky loess-plain and stream-terraces from 20 to 80 feet above modern flood plains	Low to moderate	Very slow to slow	Ranges from about 10 to 70 feet	Row crops with lesser amounts of alfalfa and wheat, some tame grasses, and native pasture in large swales	A physiographic and geologic feature known as "Todd Valley"
	Silty clay loam	Loess	Rolling to rough glacial till hills of the uplands, which lie from about 100 to 150 ft. above modern flood plains		Rapid	Perched water tables. Depth to regional water table ranges from 70 to about 120 feet.	Row crops, wheat, alfalfa, tame grass, and some native pasture	



WIDE EXTREMES OF BOTH TEMPERATURE AND PRECIPITATION CHARACTERIZE THE WEATHER IN EASTERN SAUNDERS COUNTY.—*The difference between the recorded monthly minimum and maximum temperatures is slightly more than 200° F. for the winter months and averages about 75° F. for the summer months. Freezing temperatures have been recorded in all months except June, July, and August, and temperatures exceeding 100° F. have been recorded in the months from May through September. The mean annual temperature is 50.3° F., and the recorded extremes are —31° F. and 116° F.*

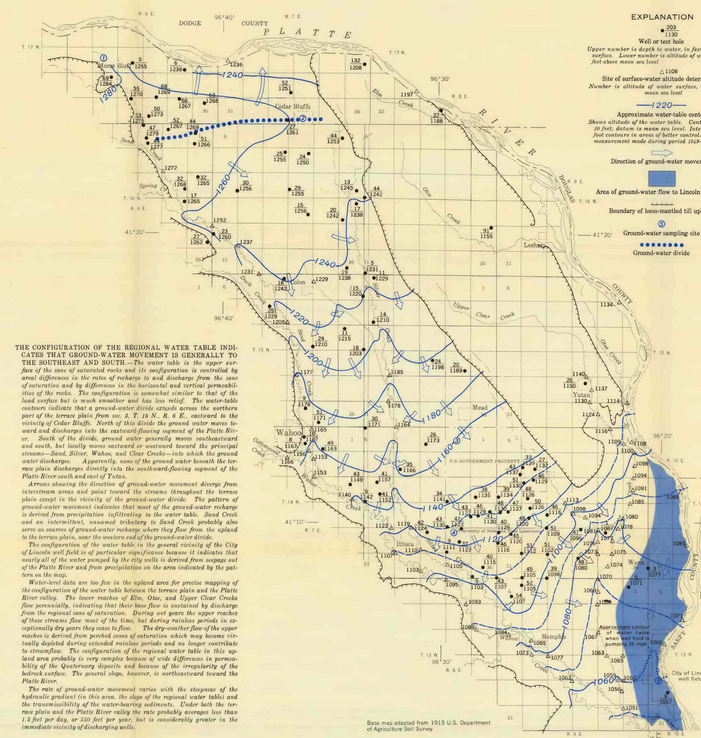
Precipitation generally is greatest during the months from May through September; the average for these months is more than 4 inches and in June exceeds 4 inches. The total precipitation during the driest year (1934) was 15.50 inches, and for the wettest year (1915) was 42.41 inches, or nearly three times greater. Less-than-average precipitation characterized 21 of the 28 years in the period 1916–43 and the 4 years in the period 1952–55. Above-average precipitation was received each year between those two droughts and all but 1 year since the 1931–37 drought.

Crop production is related only partly to total annual precipitation. In years of above-average total precipitation crops may suffer from deficient moisture if rainfall is not advantageously distributed during the growing season. Furthermore, excess moisture can delay planting, can drown crops at any stage of growth, and can hamper harvesting. Conversely, in years of deficient precipitation, crop yields are sometimes better than average if soil moisture is ample for seed germination and rainfall is timely during the growing season.

RANGE OF TEMPERATURE AND PRECIPITATION

	Temperature, in degrees Fahrenheit, at Fremont			Precipitation, in inches. (Average of Wahoo, Fremont, and Ashland 3 NE)		
Month	Mean	Minimum	Maximum	Mean	Totals for driest year (1934)	Totals for wettest year (1915)
Jan.	21.4	−31	69	0.76	0.31	1.83
Feb.	25.5	−31	73	1.03	.90	2.95
Mar.	37.0	−16	89	1.47	.84	1.80
Apr.	51.1	7	96	2.58	.35	1.59
May	61.6	22	106	3.71	.30	6.39
June	71.4	38	108	4.66	2.86	5.50
July	76.7	36	116	3.46	.75	8.99
Aug.	74.8	38	115	4.01	1.97	6.89
Sept.	66.2	24	107	3.01	2.79	3.61
Oct.	54.3	5	96	1.70	1.74	.81
Nov.	38.4	−16	82	1.27	2.24	1.44
Dec.	26.4	−30	72	.79	.45	.61
Year	50.3	−31	116	28.45	15.50	42.41

HYDROLOGY AND GROUND-WATER QUALITY



EXPLANATION

203
1130
Well or test hole
Upper number is depth to water, in feet below land surface. Lower number is altitude of water table, in feet above mean sea level

1108
Site of surface-water altitude determination
Number is altitude of water surface, in feet above mean sea level

1220
Approximate water-table contour
Shows altitude of the water table. Contour interval, 20 feet; datum is mean sea level. Intermediate 10-foot contours in areas of better control. Water-level measurement made during period 1948–1961

Direction of ground-water movement

Area of ground-water flow to Lincoln well field

Boundary of loess-mantled till uplands

Ground-water sampling site

Ground-water divide

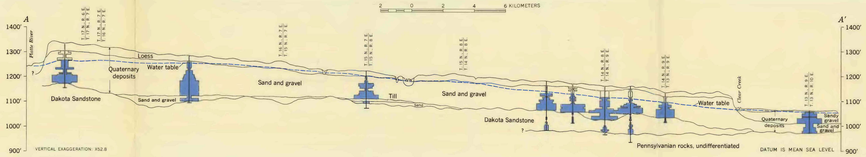
THE CONFIGURATION OF THE REGIONAL WATER TABLE INDICATES THAT GROUND-WATER MOVEMENT IS GENERALLY TO THE SOUTHEAST AND SOUTH.—*The water table is the upper surface of the zone of saturated rocks and its configuration is controlled by areal differences in the rates of recharge to and discharge from the zone of saturation and by differences in the horizontal and vertical permeabilities of the rocks. The configuration is somewhat similar to that of the land surface but is much smoother and has less relief. The water-table contours indicate that a ground-water divide extends across the northern part of the terrace plain from sec. 2, T. 16 N., R. 6 E., eastward to the vicinity of Cedar Bluffs. North of this divide the ground water moves southward and discharges into the eastward-flowing segment of the Platte River. South of the divide, ground water generally moves southeastward and south, but locally moves eastward or westward toward the principal streams—Sand, Silver, Wahoo, and Clear Creeks—into which the ground water discharges. Apparently, none of the ground water beneath the terrace plain discharges directly into the southward-flowing segment of the Platte River south and east of Yutan.*

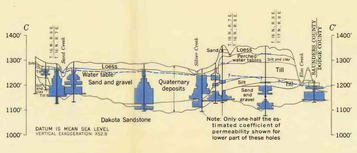
Arrows showing the direction of ground-water movement diverge from intermediate areas and point toward the streams throughout the terrace plain except in the vicinity of the ground-water divide. The pattern of ground-water movement indicates that most of the ground-water recharge is derived from precipitation infiltrating to the water table. Sand Creek and an intermittent, unnamed tributary to Sand Creek probably also serve as sources of ground-water recharge where they flow from the upland to the terrace plain, near the western end of the ground-water divide.

The configuration of the water table in the general vicinity of the City of Lincoln well field is of particular significance because it indicates that nearly all of the water pumped by the city wells is derived from seepage out of the Platte River and from precipitation on the area indicated by the pattern on the map.

Water-level data are too few in the upland area for precise mapping of the configuration of the water table between the terrace plain and the Platte River valley. The lower reaches of Elm, Otoe, and Upper Clear Creeks flow perennially, indicating that their base flow is sustained by discharge from the regional zone of saturation. During wet years the upper reaches of these streams flow most of the time, but during various periods in exceptionally dry years they cease to flow. The groundwater flow of the upper reaches is derived from perched zones of saturation which may become virtually depleted during extended rainless periods and no longer contribute to streamflow. The configuration of the regional water table in this upland area probably is very complex because of wide differences in permeability of the Quaternary deposits and because of the irregularity of the bedrock surface. The general slope, however, is northeastward toward the Platte River.

The rate of ground-water movement varies with the steepness of the hydraulic gradient (in this area, the slope of the regional water table) and the transmissibility of the water-bearing sediments. Under both the terrace plain and the Platte River valley the rate probably averages less than 1.5 feet per day, or 550 feet per year, but is considerably greater in the immediate vicinity of discharging wells.





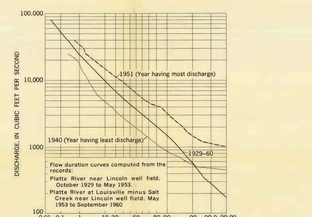
EXPLANATION

Land surface
Unsaturated permeable material
Relatively impermeable material (silt, clay, and till)
Saturated permeable material (sand and gravel)
Test hole or well
Vertical scale
100
80
60
40
20
0
Feet
0 2000 4000
Scale for estimated coefficient of permeability, in gallons per day per square foot (gpd/ft.²)

DRILLING HAS SHOWN THAT A LARGE PART OF THE AREA IS UNDERLAIN BY SATURATED SAND AND GRAVEL DEPOSITS.—*Most of the terrace plain is underlain by about 15 to 30 feet of loess below which is about 70 to 190 feet of sand and gravel. Much of the Platte River valley is underlain by sand and gravel to a depth of about 90 feet. The upland areas are underlain by about 5 to 20 feet of loess below which are unconsolidated deposits ranging about 150 to 250 feet in thickness and consisting of glacial till, silty clay, silt, and some sand and gravel.*

The permeable unconsolidated deposits are saturated below the regional water table. Where the zone of saturation consists largely of moderately to highly permeable sand and gravel, it is capable of transmitting large quantities of water to points of withdrawal. Most large-yield wells are screened in the lower part of the sand and gravel deposits. In some parts of the upland areas deposits of sand and gravel are thin or absent and large supplies of water cannot be obtained from wells. Locally in the upland areas thin zones of saturation are perched above the regional water table. Wells tapping such zones have small yields and are likely to go dry during long periods of drought.

The Dakota Sandstone, which underlies the Quaternary deposits throughout most of the area, is known to contain beds that are generally to moderately permeable. The full ground-water potential of the Dakota is unknown.



THE FLOW DURATION CURVES INDICATE THAT ABOUT 95 PERCENT OF THE TIME FROM 1929 THROUGH 1960 THE FLOW OF THE PLATTE PAST THE LINCOLN WELL FIELD WAS GREATER THAN 1,000 CFS (CUBIC FEET PER SECOND), OR ABOUT 2,000 ACRE-FEET PER DAY, AND ABOUT 50 PERCENT OF THE TIME IT WAS 3,100 CFS, OR 7,400 ACRE-FEET PER DAY.—*From 1950–60, the annual discharge of the Platte River was about 2.7 million acre-feet at North Bend and about 3.9 million acre-feet at the Lincoln well field in the southeastern corner of the area. The increased discharge is due primarily to inflow from the Elkhorn River. Flow past the well field is particularly important because a large part of the water pumped from wells is induced recharge from the river. Wahoo Creek and its principal tributaries drain about 75 percent of the report area; the remainder drains directly to the Platte River. The average annual discharge of Wahoo Creek at Ithaca from 1950–60 was 50 thousand acre-feet and amounted to 0.27 acre-foot per square mile of drainage area. The amount of water pumped from streams and ponds is unknown, but is negligible compared to the total stream discharge.*

Sample number	Location	pH	Hardness as $CaCO_3$, in ppm
1	Sec. 20, T. 17 N., R. 6 E.	7.1	512
2	Sec. 34, T. 17 N., R. 7 E.	7.5	348
3	Sec. 2, T. 14 N., R. 8 E.	7.4	263
4	Sec. 26 T. 14 N., R. 8 E.	6.9	149
5	Sec. 30, T. 13 N., R. 10 E.	7.5	180

THE GROUND WATER BENEATH THE TERRACE PLAIN AND THE PLATTE RIVER VALLEY TYPICALLY CONTAINS A FAIRLY HIGH CONCENTRATION OF BICARBONATE AND GENERALLY IS HARD TO VERY HARD.—*The few available chemical analyses of ground water indicate that it is progressively softer and contains fewer total dissolved solids in a southeastward direction across the terrace plain.*

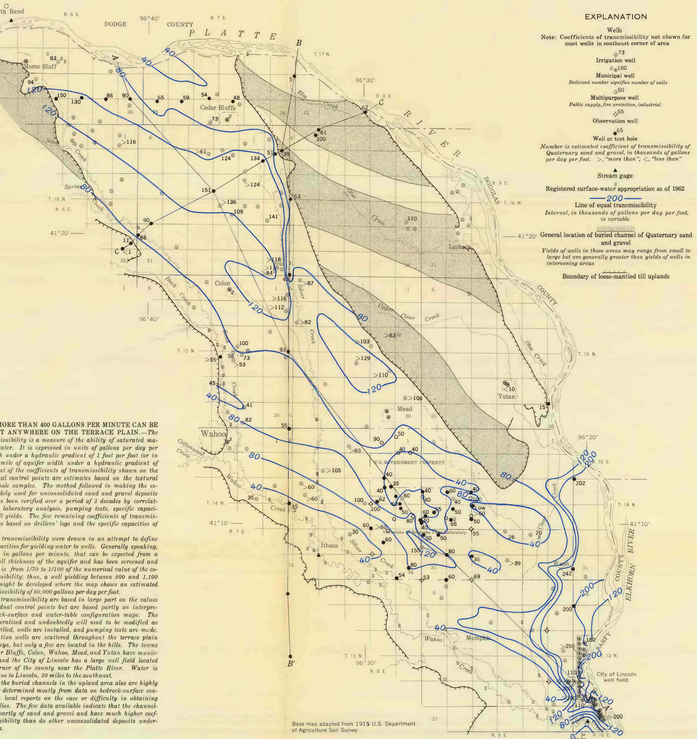
WELLS YIELDING MORE THAN 400 GALLONS PER MINUTE CAN BE LOCATED ALMOST ANYWHERE ON THE TERRACE PLAIN.—*The coefficient of transmissibility is a measure of the ability of saturated material to transmit water. It is expressed in units of gallons per day per foot of aquifer width under a hydraulic gradient of 1 foot per foot (or in gallons per day per mile of aquifer width under a hydraulic gradient of 1 foot per mile). Most of the coefficients of transmissibility shown on the map at the individual control points are estimates based on the saturated composition of test-hole samples. The method followed in making the estimates has been widely used for unconsolidated sand and gravel deposits in Nebraska and has been verified over a period of 3 decades by correlating the results with laboratory analyses, pumping tests, specific capacities of wells, and well yields. The few remaining coefficients of transmissibility are estimates based on drillers' logs and the specific capacities of large-yield wells.*

The lines of equal transmissibility were drawn in an attempt to define areas of different capacities for yielding water to wells. Generally speaking, the maximum yield, in gallons per minute, that can be expected from a well that taps the full thickness of the aquifer and has been screened and developed properly is from 1/70 to 1/100 of the numerical value of the coefficient of transmissibility, thus, a well yielding between 300 and 1,200 gallons per minute might be developed where the map shows an estimated coefficient of transmissibility of 90,000 gallons per day per foot.

The lines of equal transmissibility are based in large part on the values shown at the individual control points but are based partly on interpretations of the bedrock-surface and water-table configuration maps. The lines are highly generalized and undoubtedly will need to be modified as new test holes are drilled, wells are installed, and pumping tests are made.

Large-yield irrigation wells are scattered throughout the terrace plain and the alluvial valleys, but only a few are located in the hills. The towns of Morse Bluff, Cedar Bluffs, Colon, Wahoo, Mead, and Yutan have municipal-supply wells, and the City of Lincoln has a large well field located in the southeast corner of the county near the Platte River. Water is transported by pipeline to Lincoln, 10 miles to the southeast.

The boundaries of the buried channels in the upland area also are highly generalized and were determined mostly from data on bedrock-surface configuration and from local reports on the ease or difficulty in obtaining domestic water supplies. The few data available indicate that the channel-fill deposits consist partly of sand and gravel and have much higher coefficients of transmissibility than do other unconsolidated deposits underlying the upland area.



EXPLANATION

Wells
Note: Coefficients of transmissibility not shown for most wells in southeast corner of area
73
Irrigation well
2,180
Municipal well
Italicized number specifies number of wells
90
Multipurpose well
Public supply, fire protection, industrial
95
Observation well
65
Well or test hole
Number is estimated coefficient of transmissibility of Quaternary sand and gravel, in thousands of gallons per day per foot. >, "more than"; <, "less than"

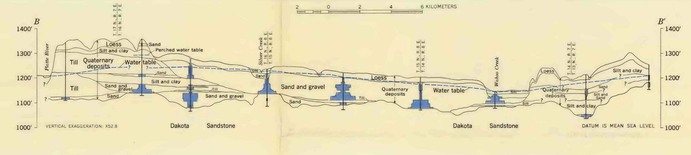
Stream gage

2
Registered surface-water appropriation as of 1962

200
Line of equal transmissibility
Interval, in thousands of gallons per day per foot, is variable

General location of buried channel of Quaternary sand and gravel
Yields of wells in these areas may range from small to large but are generally greater than yields of wells in intervening areas

Boundary of loess-mantled till uplands



SUMMARY

The sand and gravel deposits of Quaternary age constitute the most important ground-water reservoir and are the source of nearly all the water pumped from wells in the area. An estimated 3.5 million acre-feet of good quality water is stored in those deposits and an additional 1.5 million acre-feet is stored in the underlying Dakota Sandstone. Even larger quantities are stored at greater depths in the Paleozoic dolomites and sandstones, but the water is of poorer quality.

Pumpage for irrigation since 1956 is estimated to have ranged from about 2,500 acre-feet (1962) to about 6,000 acre-feet (1957). The town of Wahoo annually pumps about 460 acre-feet, and other towns pump an estimated total of 180 acre-feet. In 1963 the City of Lincoln pumped 27,000 acre-feet from its well field alongside the Platte River in the southeast corner of the area; since then pumpage has increased and probably is likely to continue to do so. Pumping at Lincoln city well field induces recharge from Platte River.

The quantity of ground water pumped to date is very small compared to the amount of water stored in the rocks. Furthermore, most of the ground water withdrawn has been replaced by infiltrating precipitation and by influent seepage from the Platte River. The large quantity of ground water in storage in addition to the flow of the Platte River indicates that the water resources of the area, if managed properly, can be developed much more extensively without appreciably depleting the supply.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Unit	Approximate depth to top of unit (feet below land surface)	Approximate thickness (feet)	Physical description and areal distribution	Water availability and quality
Quaternary deposits	At the surface	0–320	Widespread soils; floodplain deposits of clay, silt, sand, and gravel; wind-deposited clay and silt; stream-laid sand and gravel; glacial drift, mostly clay and silt. Underlies entire area except for one place in southeast corner.	Surficial deposits influence runoff and recharge to ground water and largely determine use of land. Sands and gravels are principal source of water to wells in area; yields range from small to 1,500 gpm. Water generally contains less than 500 ppm total dissolved solids and is hard to very hard; locally may contain up to 700 ppm total dissolved solids.
Dakota Sandstone	0–320	0–490	Sandstone, siltstone, claystone, and shale; about half of unit is poorly to well cemented sandstone. Underlies all but southeastern part of area and crops out in one place in southeast corner of area.	Important secondary source of ground water and can be utilized in conjunction with the overlying unit to increase yields of wells; is source of water for town of Yutan and part of the source for two irrigation wells. Quality of water inadequately determined but probably similar to that in Quaternary deposits except in northwestern part of area.
Pennsylvanian rocks, undifferentiated	0–600	260–600	Interbedded marine limestones and shales. Underlie entire area and crop out in one place in southeast corner of area.	Not used as a source of water supply in the area; important as a barrier to the movement of ground water.
Paleozoic upper dolomites	390–950	750–950	Thick dolomites having differing porosities, some limestones and shales. Underlie entire area.	Not used as a source of water supply in the area, but large amounts of water are available. Quality of water unknown.
St. Peter Sandstone	1,100–1,900	25–60	Well sorted, poorly cemented, quartz sandstone. Underlies entire area.	Not used as a source of water supply in the area, but small to large amounts of water are available. One analysis and electric logs of oil tests indicate total dissolved solids probably range from about 1,400 ppm to more than 5,000 ppm.
Paleozoic lower dolomites	1,300–1,950	0–250	Dolomites having differing porosities, some limestones and shales. Underlie all but southeastern part of area.	Not used as a source of water supply in the area, but small to large amounts of water are probably available. Quality of water probably similar to that of water in overlying and underlying units.
Paleozoic basal sand	1,300–2,180	0–50	Well sorted, poorly cemented, quartz sandstone. Underlies all but southeastern part of the area.	Not used as a source of water supply in the area, but small to moderate amounts of water are available. One analysis and electric logs of oil tests indicate that total dissolved solids may range from about 1,500 ppm to more than 5,000 ppm.
Precambrian rocks	1,150–2,200	Basement rocks	Diabase and metasediments. Underlie entire area.	Not a source of water supply in the area.

AVAILABILITY OF WATER IN EASTERN SAUNDERS COUNTY, NEBRASKA

By
V. L. Souders
Hydrologist, Conservation and Survey Division, University of Nebraska

1967

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