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Ground-water Resources of the Republican River Valley

Between Concordia and Clay Center, Kansas

by

Kenneth L. Walters
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KANSAS GEOLOGICAL SURVEY
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GROUND-WATER RESOURCES OF THE REPUBLICAN RIVER VALLEY
BETWEEN CONCORDIA AND CLAY CENTER, KANSAS
By Kenneth L. Walters and C. K. Bayne

This report is a joint product of the program of the Interior Department for development of the Missouri River Basin and the cooperative ground-water program of the United States Geological Survey, the State Geological Survey of Kansas, the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture.

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GROUND-WATER RESOURCES OF THE REPUBLICAN RIVER VALLEY
BETWEEN CONCORDIA AND CLAY CENTER, KANSAS

By Kenneth L. Walters and C. K. Bayne

ABSTRACT

This report describes the ground-water resources of the Republican River valley between Concordia and Clay Center, Kans. Because of a drought in Kansas from 1951 to 1956, interest in irrigation with ground water has increased considerably. By 1955, 43 irrigation wells had been drilled.

The rocks that crop out in this area range in age from Permian to Recent. The oldest outcropping rocks comprise the Nolans limestone or Permian age, which underlies the alluvium downstream from about Clay Center. The Nolans limestone yields only small quantities of water. The Wellington formation forms most of the valley walls between Clay Center and Morganville and underlies the alluvial fill of the valley to the Clay-Cloud County line. The Wellington formation yields only very small quantities of water in this area. The Dakota formation forms the valley walls from about Morganville to above Concordia and underlies the alluvial fill of the valley through Cloud County. The Dakota formation yields moderate quantities of water under artesian pressure in this area. In the area near Concordia the water in the Dakota formation is salty, and enough water moves from the Dakota formation into the alluvial fill to result in salty water at the base of the alluvial fill.

Deposits of Pleistocene age consisting of alluvium, terrace deposits, and Meade formation in the Republican Valley range in thickness from

about 60 to 100 feet. They consist of such coarse gravel, sand, silt, and clay. Four irrigation wells in the alluvium had yields ranging from 540 to 1,000 gpm and averaged 750 gpm. The coefficients of transmissibility of the alluvium determined from four pumping tests range widely in value, but generally are between 100,000 and 250,000 gpd per foot. In the western part of the area some of the water may be highly mineralized by contamination from the underlying Dakota formation. Downstream from Ames, the water is of good quality.

In 1955, the 43 irrigation wells in the Republican Valley pumped about 5,500 acre-feet, and about 3,600 acres of land was being irrigated.

About 731,400 acre-feet of water is in storage in the valley. Water is replenished by recharge from precipitation and by infiltration of the stream flow of Republican River.

INTRODUCTION

In 1955 at a planning conference in Denver the United States Bureau of Reclamation reported the need for a better knowledge of the availability of ground water in the Republican River valley between Concordia and Clay Center, Kans. The records of municipal wells and some irrigation wells indicated that abundant supplies of ground water were available for irrigation use.

In the fall of 1954 there were 6 irrigation wells in this part of the Republican Valley. By October 1955 there were 43 irrigation wells. Because of the great interest shown in irrigation in this area, a study was started in 1955 as a part of the program of the Department of the Interior for development of the Missouri River basin.

In 1954 a study was started of the ground-water resources of Clay and Cloud Counties, which includes most of the Republican Valley area included in this report. The investigation in Clay and Cloud Counties was made as a part of the cooperative ground-water program of the U.S. Geological Survey in cooperation with the State Geological Survey of Kansas, the Division of Water Resources of the State Board of Agriculture, and the Division of Sanitation of the State Board of Health. The cooperative ground-water study of Clay and Cloud Counties has been integrated with the study of the ground-water resources of Republican Valley.

The area covered by this report is in north-central Kansas. The area included is shown in Plate 1.

GEOLOGY IN RELATION TO GROUND WATER

Permian System

Nolans Limestone

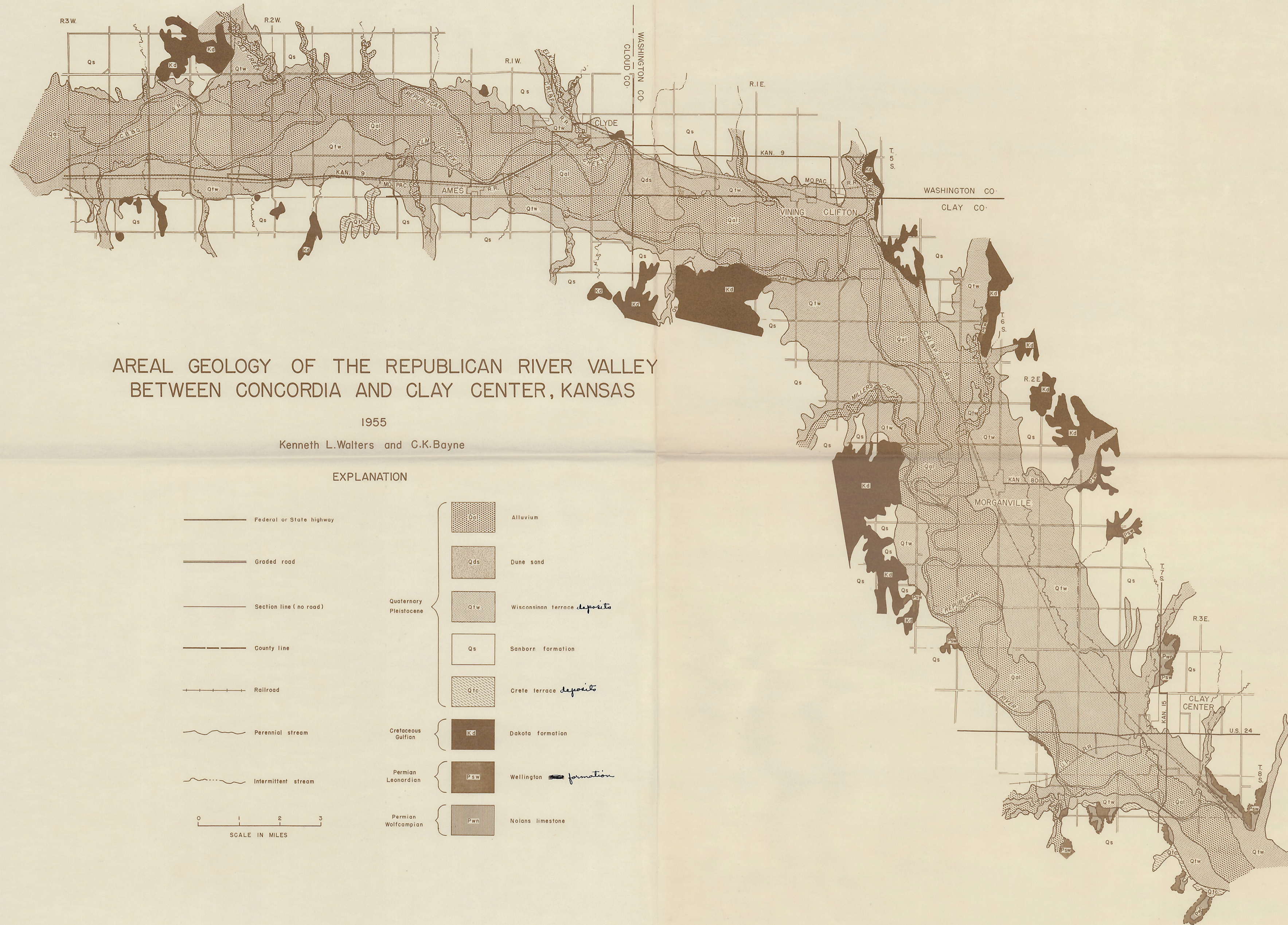
In that part of Republican River valley within two or three miles of Clay Center, the Republican River has cut through the Nolans limestone (Pl. 1). The base of the alluvial fill in the deepest part of the channel rests on the Winfield limestone (Pl. 2), and downward cutting probably has been somewhat retarded by this resistant formation.

The width of the valley decreases very noticeably near Clay Center at the point where the Republican River has cut through the Nolans limestone (Pl. 1), and the valley walls where formed by the Nolans limestone are more bluff-like than in the area upstream. The geologic cross sections (Pl. 3) and the bedrock contour map show that the bedrock surface below the alluvial fill is more deeply cut in the upper part of the area than below Morganvills. The deeper cutting in the bedrock in the northern part of the area is reflected in the saturated thickness map (Pl. 4).

The Nolans limestone is the oldest formation exposed in the area covered by this report. It includes, in ascending order, the Krider limestone, Paddock shale, and Herington limestone members. The thickness of the formation in this area ranges from 15 to 20 feet.

The Krider limestone member consists in some places of one bed of limestone and in other places of two beds separated by a thin shale bed. The thickness of the Krider limestone member rarely exceeds two feet. The limestone part of the member is generally a sandy, yellow, nodular limestone containing many fossil brachiopods and pelecypods. The Paddock

Plate 1.--Areal geology of the Republican River valley between
Concordia and Clay Center, Kans.



AREAL GEOLOGY OF THE REPUBLICAN RIVER VALLEY
BETWEEN CONCORDIA AND CLAY CENTER, KANSAS

1955

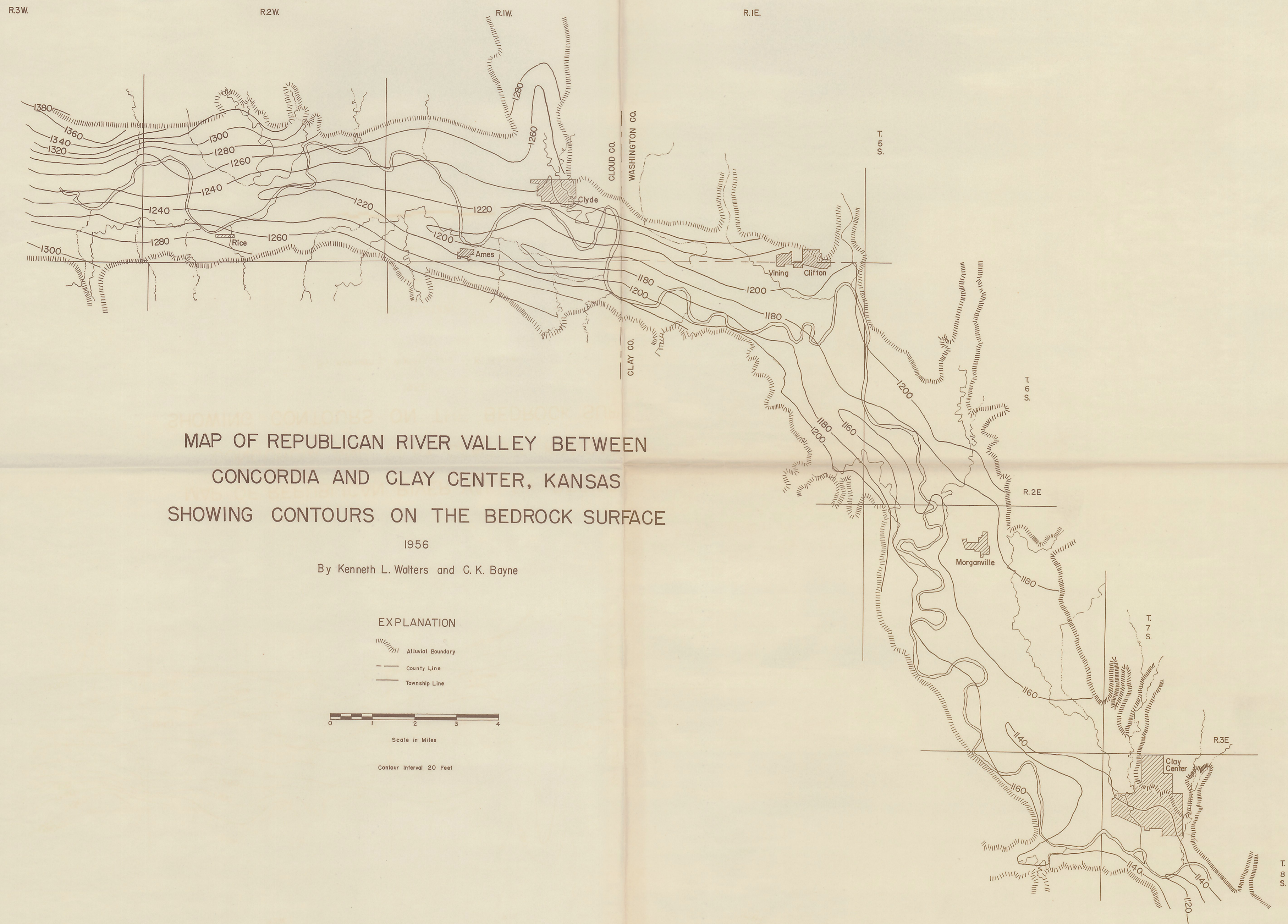
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EXPLANATION

—	Federal or State highway		Alluvium
—	Graded road		Dune sand
—	Section line (no road)		Wisconsinan terrace deposits
—	County line		
—	Railroad		Sanborn formation
—	Perennial stream		Crete terrace deposits
—	Intermittent stream		Dakota formation
			Wellington formation
			Nolans limestone

0 1 2 3
SCALE IN MILES

Plate 2.—Map of Republican River valley between Concordia and Clay
Center, Kans., showing contours on the bedrock surface.






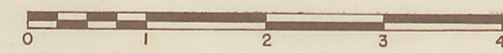
MAP OF REPUBLICAN RIVER VALLEY BETWEEN
CONCORDIA AND CLAY CENTER, KANSAS
SHOWING CONTOURS ON THE BEDROCK SURFACE

1956

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EXPLANATION

-  Alluvial Boundary
-  County Line
-  Township Line



Scale in Miles

Contour Interval 20 Feet

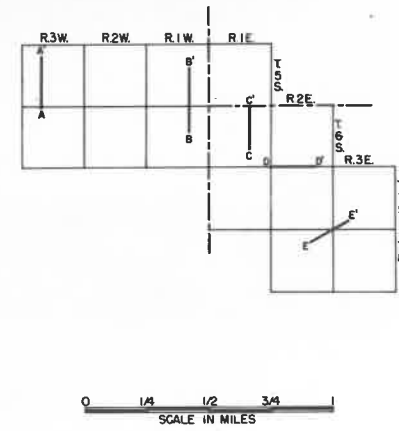
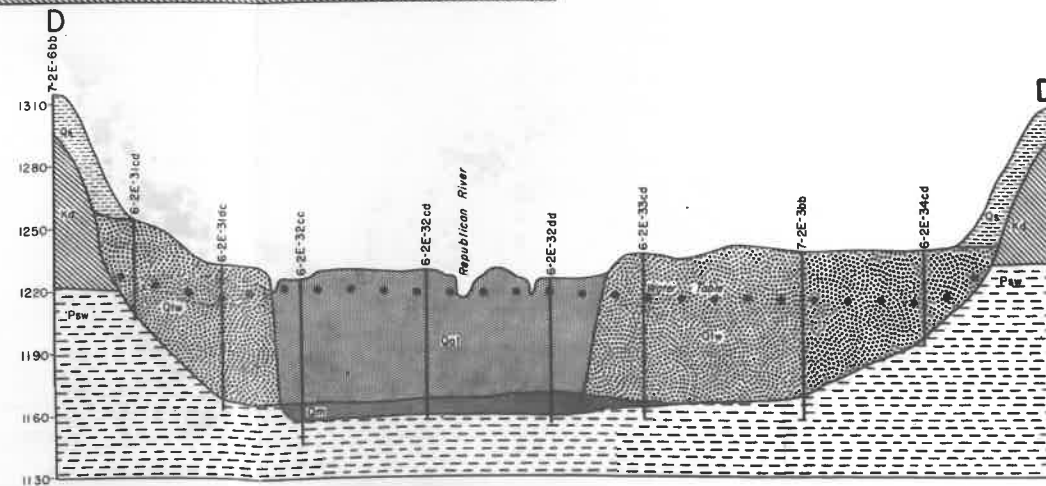
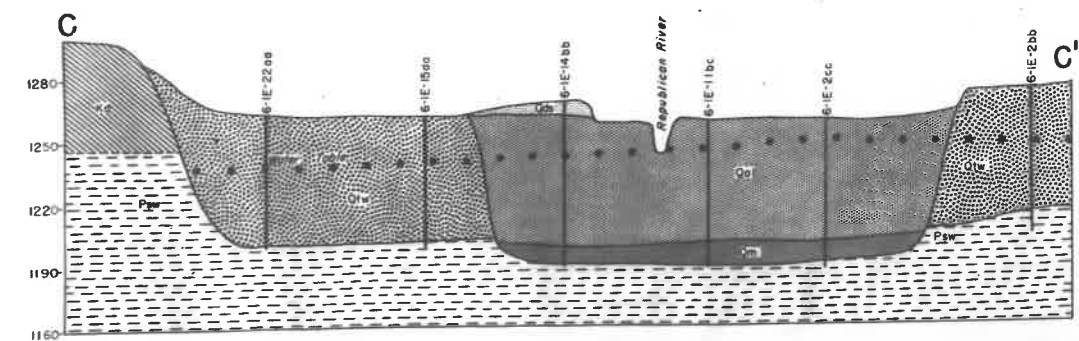
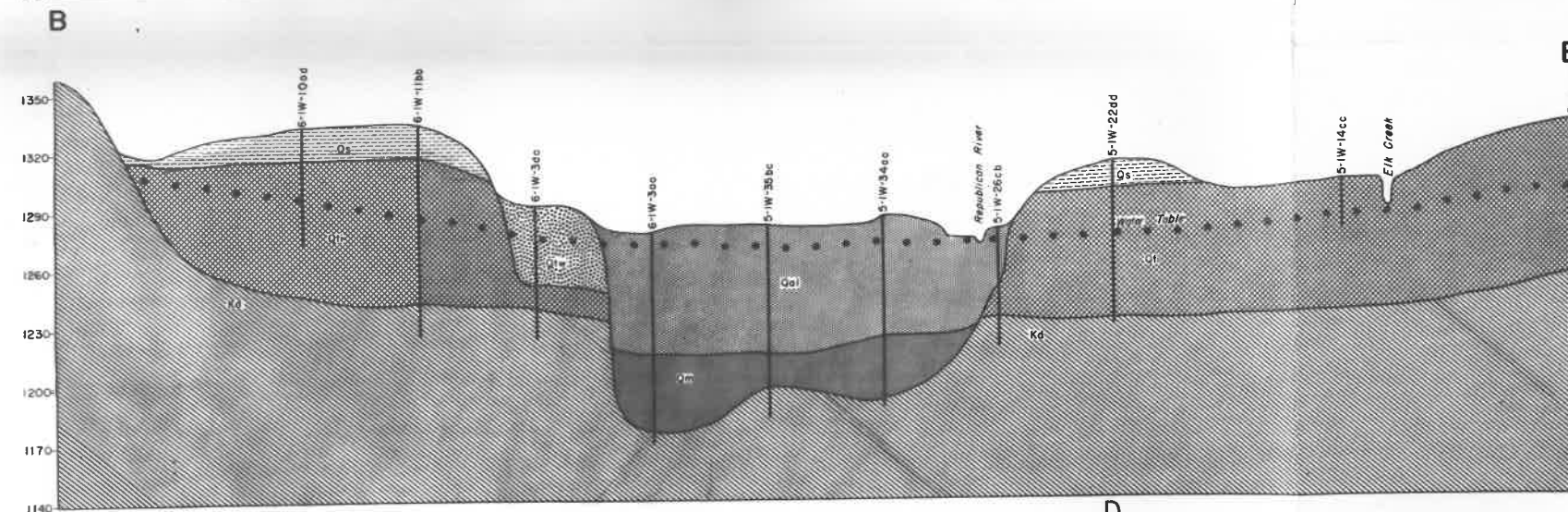
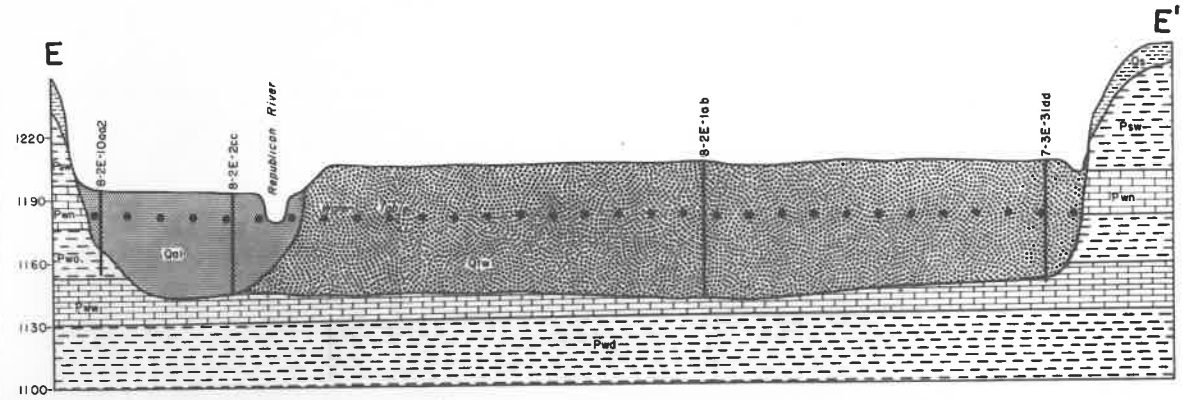
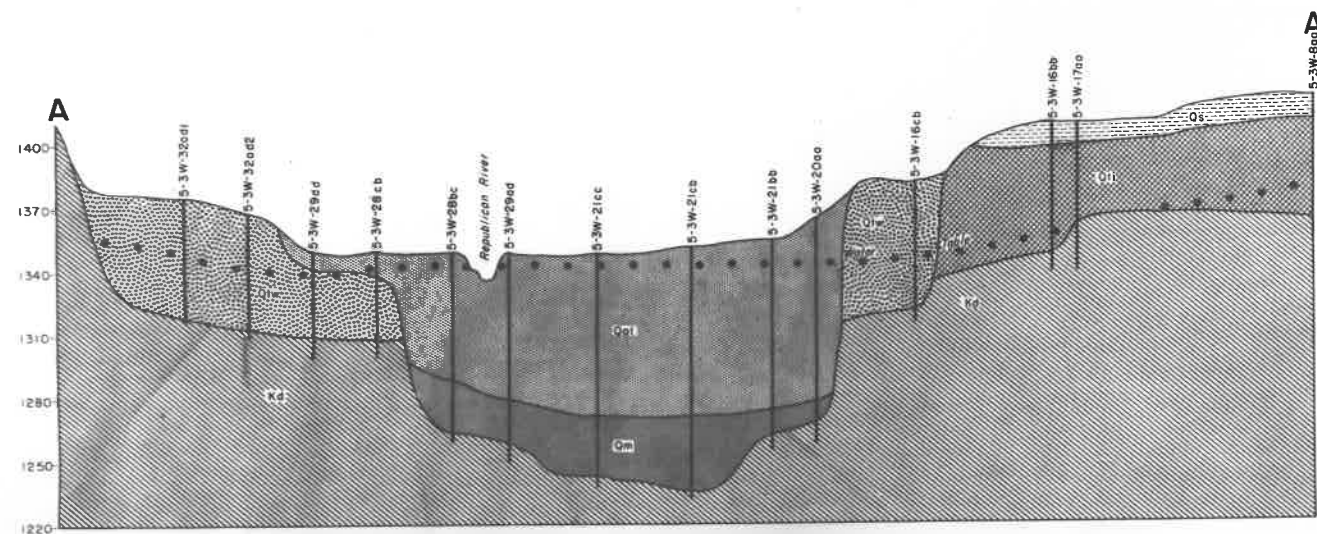
Plate 3.—Geologic cross sections in the Republican River valley
between Concordia and Clay Center, Kans.

GEOLOGIC CROSS SECTIONS IN THE REPUBLICAN RIVER VALLEY BETWEEN CONCORDIA AND CLAY CENTER, KANSAS

Plate 3

1956

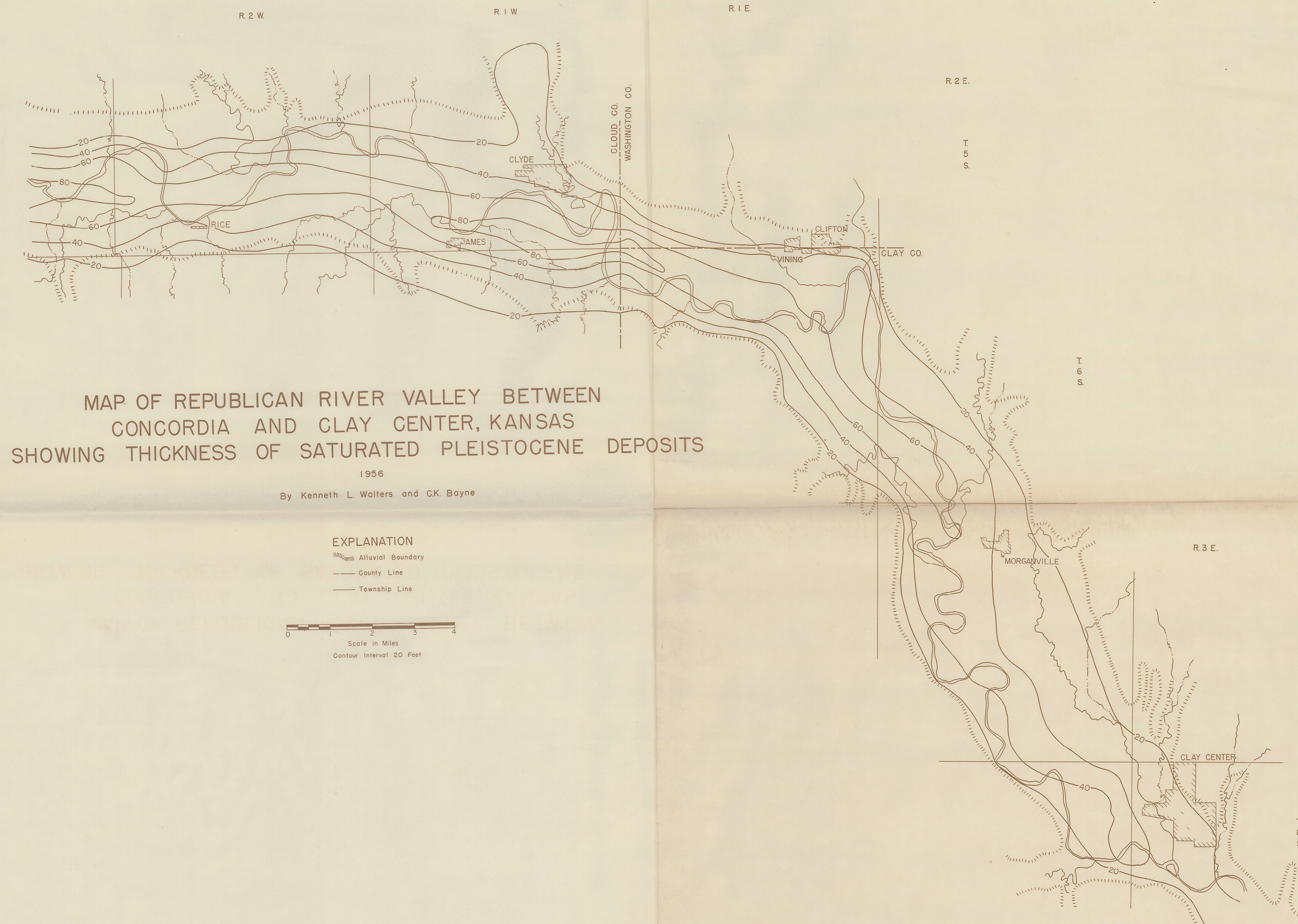
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EXPLANATION

Qd	Dune sand				
Al	Alluvium	PLEISTOCENE QUATERNARY	Pw	Wellington formation	LEONARDIAN PERMIAN
Q1w	Wisconsinan terrace deposits		Pwl	Wolans limestone	
Qs	Sanborn eolian deposits		Pwc	Odell shale	
Q1i	Illinoian terrace deposits		Pwv	Winfield limestone	
Jm	Meade formation		Pw	Dayle shale	
Kd	Dakota formation	GULFIAN CRETACEOUS			

Plate 4.—Map of Republican River valley between Concordia and Clay
Center, Kans., showing thickness of saturated Pleistocene deposits.

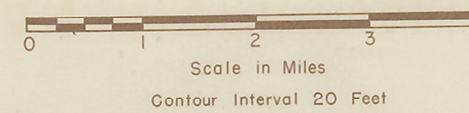


MAP OF REPUBLICAN RIVER VALLEY BETWEEN
CONCORDIA AND CLAY CENTER, KANSAS
SHOWING THICKNESS OF SATURATED PLEISTOCENE DEPOSITS

1956
By Kenneth L. Walters and CK. Bayne

EXPLANATION

- Alluvial Boundary
- County Line
- Township Line



shale member consists of about 11 to 13 feet of gray, fossiliferous shale. The Herington limestone member is the most conspicuous part of the Nolans limestone and forms a rather prominent escarpment along much of its outcrop. The member generally consists of 6 to 8 feet of yellow to brown pelecypod-bearing limestone. The upper part of the member is the most massive.

Only moderate amounts of water can be obtained by wells from the Nolans limestone. The quality of water in the Nolans limestone, and in the underlying Odell shale and Winfield limestone, is good except where the rocks are deeply buried. The small amount of water entering the alluvial fill from these formations has no effect on the quality of the water in the alluvial fill of Republican River valley.

Wellington Formation

The Wellington formation forms most of the walls of Republican River valley between Clay Center and Morganville and underlies the alluvial fill of the valley about to the Clay-Cloud County line.

The Wellington formation consists of greenish-gray and red clay shale. A persistent bed of dolomitic limestone, the Hollenberg limestone, occurs about 40 feet above the base of the formation. Locally, a bed of massive gypsum about 8 feet thick occurs near the base of the formation. A bed of dark-gray to black chert has been observed at several places about 15 feet above the Hollenberg limestone. The Hutchinson salt member of the Wellington formation, which is present in an area to the southwest, is absent in this area. The maximum thickness of the Wellington formation in Republican River valley is probably about 250 feet.

The Wellington formation yields only very small quantities of water in this area, and where it underlies the Republican River valley, does not have any effect on the quality of water in the alluvial fill.

Cretaceous System

Dakota Formation

The Dakota formation forms the walls of the Republican River valley from near Morganville to above Concordia and underlies the alluvial fill of the valley in Cloud County.

The Dakota formation is divided into two members - the lower Terra Cotta clay member and the upper Jansen clay member. The formation consists chiefly of varicolored clay containing discontinuous beds and lenses of sandstone and siltstone. Minor amounts of lignite, pyrite, quartzite, limonite, hematite, and siderite occur as concretions and thin beds throughout the formation. In the subsurface most of the sandstone is light-gray in color, but it becomes yellow, dark-brown, or almost red where weathered. Some of the sandstone beds are very resistant to weathering and form prominent outcrops. The prominence of the sandstone outcrops has led to the common belief that the Dakota formation is composed chiefly of sandstone, but clay is the dominant material. The thickness of the Dakota formation may be as much as 165 feet locally, but is probably somewhat less in the area of this report.

The Dakota formation yields moderate quantities of water under artesian pressure in this area. Near Concordia, water in the Dakota formation is salty and enough water moves from the Dakota formation

into the alluvial fill to contaminate the water in the base of the alluvial fill (Pl. 5). Water samples collected during test drilling in the uplands of Cloud County showed that where the Dakota formation is deeply buried, the water is salty. Salt water from the Dakota formation probably is entering the alluvial fill of Republican River valley from the northwest. A water sample from test hole 5-3W-15ab drilled in the Dakota contained 16,050 ppm of chloride. In areas where beds of sandstone of the Dakota formation are not too deeply buried, the formation yields moderate quantities of good quality water.

Quaternary System

Pleistocene Series

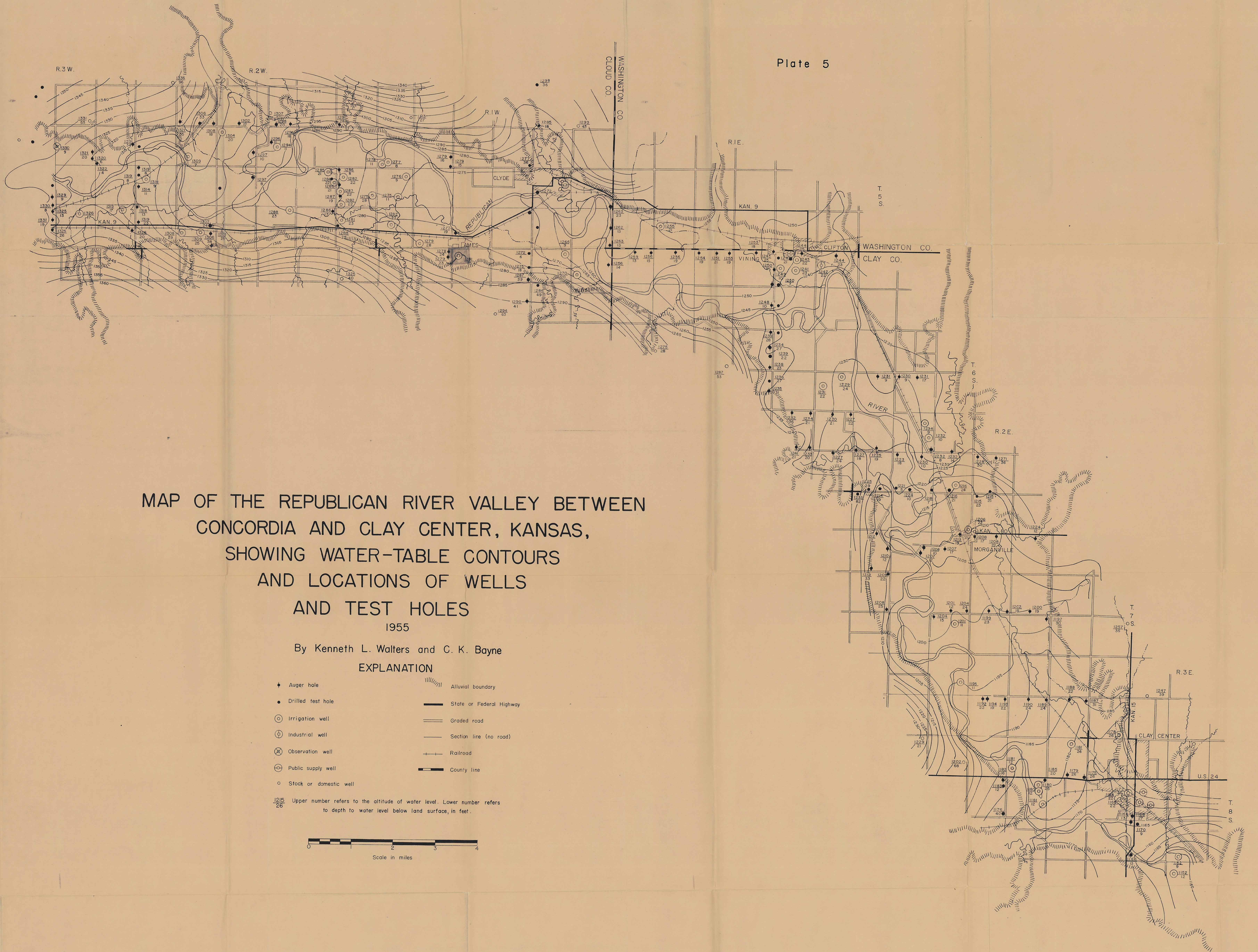
The Quaternary System is represented in the area included in this report by deposits of the Kansan, Illinoian, and Wisconsinan stages of the Pleistocene series. These deposits are present in the valley and as terrace remnants bordering the valley.

Meade Formation - Kansan Stage

The Republican River was not in its present location in this area during most of Kansan time. Until the Kansan ice sheet blocked its course, the Republican River flowed eastward across southern Nebraska (Fishel, 1948). However, a major southeastern-flowing tributary to a southern drainage system had its course along the route of the present Republican River. This ancestral stream carried drainage from an area of several counties and had its headwaters in what is now White Rock Creek in Jewell County.

As the area of this report was in the headwaters of the ancestral

Plate 5.—Map of the Republican River valley between Concordia and Clay Center, Kans., showing water-table contours and locations of wells and test holes.



MAP OF THE REPUBLICAN RIVER VALLEY BETWEEN
CONCORDIA AND CLAY CENTER, KANSAS,
SHOWING WATER-TABLE CONTOURS
AND LOCATIONS OF WELLS
AND TEST HOLES

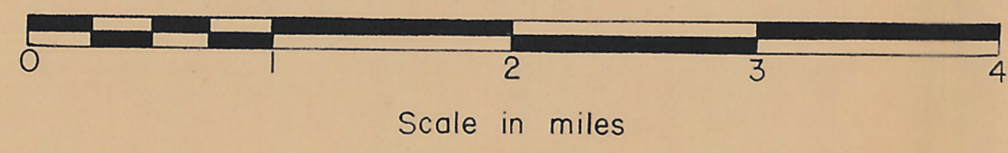
1955

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EXPLANATION

- | | |
|--------------------------|----------------------------|
| ◆ Auger hole | ~~~~~ Alluvial boundary |
| ● Drilled test hole | — State or Federal Highway |
| ○ Irrigation well | — Graded road |
| ⊙ Industrial well | — Section line (no road) |
| ⊗ Observation well | — Railroad |
| ⊕ Public supply well | — County line |
| ○ Stock or domestic well | |

Upper number refers to the altitude of water level. Lower number refers to depth to water level below land surface, in feet.



stream, most of the Kansan deposits are of a local origin. In the area around Concordia and for about 5 miles downstream from Concordia, most of the test holes drilled in the valley area penetrated several feet of principally locally derived gravel resting on bedrock. The locally derived basal gravel and the overlying clay bed, where present, are classified as Kansan in age and probably are equivalent to the Meade formation (Pl. 3). The gravels of the Meade formation are not exposed in the area covered by this report and are not shown on the geologic map (Pl. 1). Although they are outside the area of this report, the geologic cross section a-a' and the logs of the test holes shown in that cross section are included because they show the relative position of the Meade formation to the Dakota formation in the contaminated area.

As previously mentioned, near Concordia salt water is entering the basal part of the alluvial fill of Republican River valley from the Dakota formation. The clay layer that overlies the gravel of the Meade formation in this area acts as a confining bed and prevents the salt water from moving upward into the younger alluvial deposits. The gravel deposits of the Meade formation should yield considerable quantities of water to wells in the Concordia area where they are the thickest, but the water is too salty for most purposes. West of Ames the wells should not be extended through the clay layer overlying the gravels of the Meade formation. Because the water in the Dakota formation downstream from Ames is not high in chlorides, the Kansan deposits yield water of good quality to wells.

Sanborn Formation

Terrace Deposits - Illinoian Stage

Terrace deposits of Illinoian age along the Republican River are represented by the Crete sand and gravel member of the Sanborn formation.

The Crete sand and gravel member consists chiefly of silt and clay and minor amounts of sand and gravel. Nearly all the deposits of the Crete sand and gravel member are blanketed by a thick covering of loess and, therefore, are not shown on Plate 1. The upper surface of the Crete sand and gravel member is generally about 30 to 40 feet above the level of the floodplain.

Generally only a part of the terrace deposits of the Crete sand and gravel member is saturated, but a saturated bed of locally derived gravel at the base of the member is present in some places and yields small to moderate supplies of water of good quality.

Terrace Deposits - Wisconsinan Stage

Deposits of sand, gravel, and clay that are 100 feet thick locally were laid down along Republican River during late Wisconsinan time. The river has subsequently cut to a lower level, and these deposits are now in a low terrace position. The Wisconsinan terrace deposits are classified as an unnamed member of the Sanborn formation, but in order to differentiate them from the silt members of the Sanborn formation they are mapped separately on Plate 1. The Wisconsinan terrace deposits do not have the hummocky topography typical of the Recent alluvium, and the upper surface of the terrace deposits generally lies about 12 feet above the upper surface of the alluvium. The Wisconsinan terrace deposits thin considerably in the southeastern part of the area covered by this report as shown in the cross sections (Pl. 3).

The Wisconsinan terrace deposits along the Republican River in this area are composed almost entirely of arkosic sand and gravel in the uppermost 15 to 20 feet, which is generally silt and clay.

The Wisconsin terrace deposits yield large quantities of water to wells nearly everywhere in the area covered by this report. These deposits thin considerably between Morganville and Clay Center (Pl. 4) because the bedrock is more resistant and yields from wells in this part of the area are not as large.

Water from the Wisconsin terrace deposits is hard, but it is suitable for most uses. In small local areas east of Concordia the water is contaminated by salt water seeping upward through wells or gravel pits that perforate the clay seal separating the underlying Meade formation from the Wisconsin terrace deposits.

Eolian Silt - Illinoian and Wisconsin Stages

The terraces of the Crete sand and gravel member and much of the uplands bordering the Republican Valley are blanketed by wind-deposited silt (loess). The loess in this area is part of the Sanborn formation. The oldest silt member of the Sanborn formation, the Loveland silt member, is Illinoian in age. In fresh exposures the Loveland silt member consists of reddish-yellow silt and clay never more than a few feet thick and in many places entirely contained within the Sangamon soil developed on the Loveland loess. The Loveland loess is overlain by the Peoria silt member of the Sanborn formation. The Peoria silt member is gray-buff in color and is generally thicker than the Loveland loess. The Peoria silt member is Wisconsin in age.

The silt members of the Sanborn formation lie above the water table in the area of this report and do not yield water to wells. The silt

members have low permeability and retard the downward movement of precipitation and, thus, hinder recharge in the uplands bordering the Republican River valley.

Alluvium - Recent Stage

The floodplain of Republican River is underlain by alluvium of Recent age. The alluvium consists principally of sand and gravel having silt and clay at the top and ranges in thickness from about 40 to 90 feet. The upper surface of the alluvium is typically very hummocky and is generally about 12 feet lower than the upper surface of the Wisconsinan terrace deposits. Much of the alluvium is covered by water during major floods and is subject to erosion in some places and deposition in other places.

The composition of the Recent alluvium is much like that of the Wisconsinan terrace deposits, but because the alluvium is generally thicker than the terrace deposits and has a greater percentage of saturation, larger yields of water generally are obtained from wells in the alluvium. The quality of the ground water from the alluvium is the same as that from the Wisconsinan terrace deposits; it is hard, but suitable for most uses.

Dune Sand

In a rather extensive area west of Vining and in several other smaller areas, the wind has piled up sand from the channel and floodplain of the Republican River into dunes. These dunes are partly active and very little soil has developed on them. The dunes are above the water table and do not yield water to wells, but because of their high permeability and lack of surface drainage, they act as important catchment and recharge areas.

Coefficients of Permeability, Transmissibility, and Storage

The permeability, transmissibility, and storage coefficients of the alluvium and terrace deposits in the part of the Republican Valley included in this report were determined by aquifer tests using four wells. The coefficients of permeability, transmissibility, and storage were computed from the test data using formulas developed by Theis, Thiem, and Jacob. In the following paragraphs are given the expressions of these formulas, the definitions of their terms, and a short discussion of their application.

Theis Recovery Method

The Theis recovery method (Theis, 1935, p. 522) of computing the coefficient of transmissibility, T , is a method whereby a value for T may be computed when only the pumped well is available for measuring recovery.

The Theis recovery formula is expressed as follows:

$$T = \frac{264 Q \log_{10} t/t'}{s'}$$

in which T is the coefficient of transmissibility,

Q is the pumping rate in gallons a minute,

t is the time since pumping began in minutes,

t' is the time since pumping stopped in minutes,

s' is the residual drawdown in pumped well at time t' .

The solution is simplified by substituting the drawdown, s , or depth to water, dw , for s' and plotting t/t' on a logarithmic coordinate and

s or dw on an arithmetic coordinate. $\log_{10} t/t'$ taken over one log cycle becomes unity and the formula becomes $T = \frac{264 Q}{\Delta s}$ where Δs is the difference in water level over one log cycle.

Thiem Method

The Thiem method (Wenzel, 1942) of determining the coefficient of transmissibility, T, of an aquifer consists of an analysis of the decline in water level during the pumping period in several observation wells near the pumped well.

The Thiem formula is expressed as follows:

$$T = \frac{527.7 Q \log_{10} r_2/r_1}{(s_1 - s_2)}$$

in which T is the coefficient of transmissibility,

Q is the rate of discharge of well in gallons a minute,

r_1 and r_2 are the distances of observation wells from pumped well,

s_1 and s_2 are the drawdowns of water levels in observation wells

at distance r_1 and r_2 respectively.

When values for s_1 , s_2 , etc. are plotted on the arithmetic coordinate of semi-log paper and the values of r_1 , r_2 , etc. are plotted on the logarithmic coordinate, a straight line relation exists and its value is given by the slope of the line. The formula then becomes

$$T = \frac{527.7 Q}{\Delta s}$$

where Δs is the drawdown over one log cycle.

Theis Nonequilibrium Method

The Theis nonequilibrium formula (Theis, 1935) is:

$$T = \frac{114.6 Q}{s} \int_0^u \frac{e^{-u}}{1.87r^2s} \frac{du}{Tt}$$

Evaluating the integral:

$$T = \frac{114.6 Q}{s} (-0.5772 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \frac{u^4}{4.4!} + \dots)$$

where $r = \frac{1.87r^2s}{Tt}$

and s is the drawdown in feet in an observation well at time t ,

r is the distance in feet from pumped well to observation well,

Q is the rate of discharge of pumped well in gallons per minute,

t is the time in days since pumping began or stopped,

T is the coefficient of transmissibility in gallons per day per foot,

S is the coefficient of storage.

The exponential integral generally is written symbolically as $W(u)$, and substituting, the formula becomes $T = \frac{114.6 Q W(u)}{s}$. The presence of two unknowns and the nature of the exponential integral make exact analytical solution impossible, but solution can be obtained by a graphical method of superposition of a field curve over a type curve. The field curve is obtained by plotting s on the vertical coordinate of log log paper and t on the horizontal coordinate. The type curve is obtained by plotting values of $W(u)$ on the vertical coordinate of the same scale log log paper and values of u on the horizontal coordinate. Superposing one curve on top of the other, a point on the type curve is selected and marked on the field curve. The coordinates of this common point for s , $W(u)$, t , and $\frac{r^2}{t}$ are then used in the non-equilibrium formula to solve for T and S as follows:

$$T = \frac{114.6 Q W(u)}{s}$$

$$S = \frac{T r^2}{1.87 T t}$$

Modified Nonequilibrium Formula

Jacob (1946) recognized that in the Theis nonequilibrium formula when u becomes small, the sum of the terms in $W(u)$ beyond $\log_e u$ become insignificant. As t increases and as r decreases, u will become small. Therefore, for large values of t , and reasonably small values of r , the terms beyond $\log_e u$ may be neglected and the equation becomes :

$$T = \frac{114.6 Q}{s} (0.5772 - \log_e u)$$

This equation can be solved graphically (Ferris, 1951). Values for s are plotted on the vertical axis of semilog paper and values for t are plotted on the horizontal scale. This plot will yield a straight line plot and the slope of the line is used to calculate the value of T and the zero intercept is used to calculate S . Expressions for these computations are:

$$T = \frac{264 Q}{\Delta s} \quad \text{and} \quad S = \frac{0.3T t_0}{r^2}$$

where T is the coefficient of transmissibility,

S is the coefficient of storage,

Q is the discharge in gallons a minute,

Δs is the drawdown difference in feet per log cycle,

r is the distance from pumped well to observation well in feet,

t_0 is the intercept of straight line with zero drawdown axis in days.

Pumping Tests

Four pumping tests were made using wells in the area covered by this report. The test using well 5-2W-25cb was made in 1942. The tests using wells 5-2W-25cc, 6-1W-4bb, and 6-1E-2ac were made in October 1955.

Pumping Test Using Well 5-2W-25cb

For the test using well 5-2W-25cb, observation wells were not available and the Theis recovery formula for solving transmissibility, T , of the aquifer was applied.

The well was pumped at a rate of 730 gpm from 8:28 a.m. to 2:40 p.m. on August 27, 1942. Water-level measurements made during the pumping and recovery periods are given in Table 1. From Table 1 the ratio t/t' (time since pumping started in minutes divided by time since pumping stopped in minutes) is obtained and is plotted in Figure 1 against depth-to-water measurements on semilog paper.

From Figure 1 it is determined that $\Delta s = 0.36$ and applying the Theis recovery formula:

$$T = \frac{264 Q}{\Delta s} \text{ where } Q = 730 \text{ gpm and } \Delta s = 0.36 \text{ feet}$$
$$T = 535,000$$

The thickness of the water-bearing material (m) at well 5-2W-25cb is 47 feet and from the relation $P = \frac{T}{m}$ the coefficient of permeability, P , is $\frac{535,000}{47}$ or 11,400 gpd per ft². Drawdown at the end of the pumping period was 12.27 feet at a pumping rate of 730 gpm giving a specific capacity of 59 gpm per foot.

Pumping Test Using Well 5-2W-25cc

A pumping test was made using well 5-2W-25cc on October 11, 1955. For this test, four observation wells, a, b, c, and d, were drilled at distances of 20.4, 51, 100, and 150 feet respectively from the pumped well. The well was pumped from 8:45 a.m. until 2:05 p.m. (320 minutes)

Table 1.--Water-level measurements made during pumping and recovery of well
5-24-25cb and values for t, t', and t/t'.

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
8:20 a.m.	static water level			18.43
8:28	pumping started			
8:40	12			30.32
9:10	42			30.55
9:40	72			30.59
10:45	137			30.62
11:40	192			30.55
1:00 p.m.	272			30.78
2:30	362			30.70
2:40	372	pumping stopped		
2:40:15	372.25	0.25	1,489	24.13
2:41	373	1	373	20.51
2:42	374	2	137	19.64
2:42:30	374.5	2.5	150	19.48
2:43	375	3	125	19.38
2:43:30	375.5	3.5	107	19.32
2:44	376	4	94	19.25
2:44:30	376.5	4.5	84	19.20
2:45	377	5	75	19.16
2:45:30	377.5	5.5	69	19.13
2:46	378	6	63	19.10
2:46:30	378.5	6.5	58	19.08
2:47	379	7	54	19.06
2:48	380	8	48	19.02
2:49	381	9	42.3	18.99
2:50	382	10	38.2	18.97
2:52	384	12	32.0	18.92
2:54	386	14	27.6	18.89
2:56	388	16	24.3	18.86
2:58	390	18	21.7	18.84
3:00	392	20	19.6	18.82
3:05	397	25	15.9	18.80
3:10	402	30	13.4	18.77
3:15	407	35	11.6	18.76
3:20	412	40	10.3	18.75
3:30	422	50	8.4	18.72

Table 1.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
3:40	432	60	7.2	18.68
4:00	452	80	5.7	18.64
4:20	472	100	4.7	18.62
4:40	492	120	4.1	18.59
5:00	512	140	3.7	18.59
5:30	542	170	3.2	18.57

Fig. 1.--Depth-to-water level in well 5-2#-25cb plotted against t/t'
(time since pumping started divided by the time since pumping
stopped).

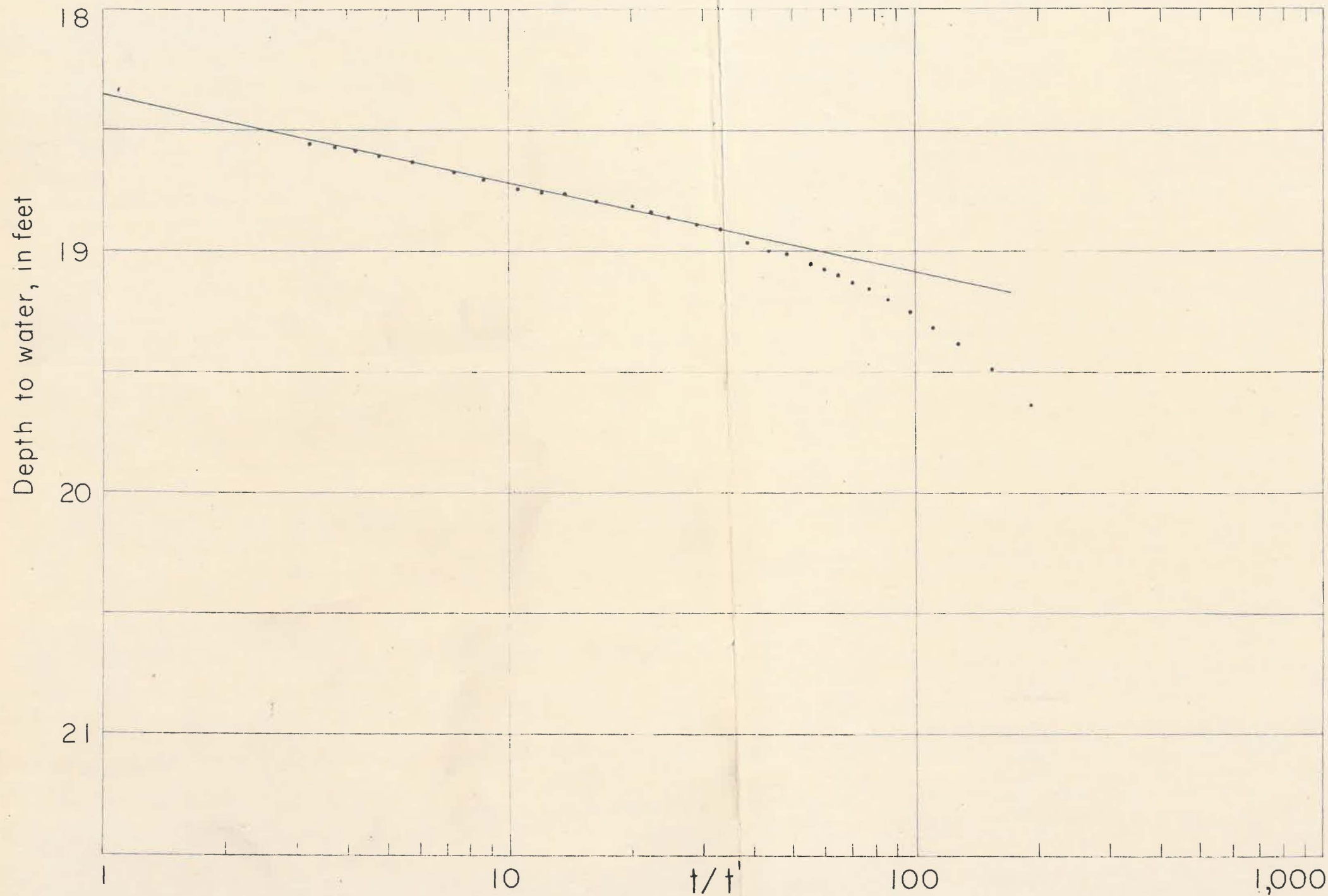


Fig. 1-- Depth to water level in well 5-2W-25cb plotted against t/t' (time since pumping started divided by the time since pumping stopped)

at a rate of 1,000 gpm. The water-level measurements made in the pumped well during the pumping and recovery periods and the values for t , t' , and t/t' are given in Table 2.

Depth-to-water measurements are plotted against the ratio t/t' on semilog. paper in Figure 2. The points on this plot do not fall in a straight line. Therefore, an arbitrary line has been drawn using points where the value of t/t' was between 2 and 5 and Δs was determined as 1.15 feet. Applying the Theis recovery formula:

$$T = \frac{(264)(1,000)}{1.15} = 230,000 \text{ gpd per ft.}$$

The thickness of the saturated materials at the well is 47 feet and from the relation $P = \frac{T}{m}$, $P = 4,900 \text{ gpd per ft}^2$.

Water-level measurements made in observation well a, 20.4 feet from the pumped well, during the pumping of well 5-2W-25cc are given in Table 3. The drawdown is plotted against time in minutes since pumping started, t , on semilog. paper in Figure 3. The slope of the line drawn through these points over one log cycle gives a value of 1.13 feet for Δs and applying the modified nonequilibrium formula:

$$T = \frac{(264)(1,000)}{1.13} = 233,600 \text{ gpd per ft.}$$

$$S = \frac{(3)(2.33)(10^5)(.6)}{(416.16)(1.44)(10^3)} = 0.07$$

Drawdown and recovery measurements of the water levels made in observation well b, 51 feet from pumped well 5-2W-25cc are given in Table 4. The drawdown and recovery data are plotted in Figure 4 where the depth to water is plotted against time since pumping started, t , or

Table 2.—Water-level measurements made during pumping and recovery of well 5-2W-25cc. and values for t, t', and t/t'.

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
8:44 a.m.	static water level			22.42
8:45	pumping started			
8:45:20	.33			31.20
8:46	1			31.72
8:46:30	1.5			31.90
8:47	2			31.94
8:47:30	2.5			31.97
8:48	3			32.01
8:49	4			32.03
8:50	5			32.10
8:51	6			32.17
8:52	7			32.22
8:53	8			32.26
8:54	9			32.30
8:55	10			32.31
8:58	13			32.31
9:00	15			32.31
9:05	20			32.32
9:10	25			32.34
9:15	30			32.38
9:20	35			32.39
9:30	45			32.47
9:40	55			32.50
9:45	60			32.57
10:00	75			32.62
10:10	85			32.66
10:30	105			32.71
10:45	120			32.78
11:04	139			32.86
11:20	155			32.90
11:35	170			32.90
11:50	185			32.91

Table 2.—(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
12:05 p.m.	200			32.92
12:25	220			32.92
12:50	245			32.98
1:05	260			33.01
1:25	280			33.02
1:50	305			33.06
2:00	315			33.12
2:05	320	pumping stopped		
2:05:30	320.5	.5	641	23.75
2:05:45	320.75	.75	427	24.18
2:06	321	1	321	24.17
2:06:15	321.25	1.25	257	24.17
2:06:30	321.5	1.5	214	24.11
2:06:45	321.75	1.75	183	24.10
2:07	322	2	161	24.09
2:07:30	322.5	2.5	129	24.08
2:08	323	3	107	24.07
2:08:30	323.5	3.5	92	24.05
2:09	324	4	81	24.04
2:10	325	5	65	24.01
2:11	326	6	54	23.99
2:12	327	7	46	23.97
2:13	328	8	41	23.95
2:14	329	9	36	23.92
2:15	330	10	33	23.90
2:17	332	12	27	23.87
2:19	334	14	24	23.85
2:22	337	17	20	23.82
2:25	340	20	17	23.78
2:28	343	23	15	23.75
2:31	346	26	13	23.73
2:34	349	29	12	23.69

Table 2.—(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped in minutes, t'	t/t'	Depth to water, feet
2:39	354	34	10	23.65
2:44	359	39	9.21	23.61
2:49	364	44	8.27	23.59
3:00	375	55	6.82	23.51
3:05	380	60	6.33	23.49
3:10	385	65	5.92	23.47
3:15	390	70	5.57	23.44
3:25	400	80	5.00	23.41
3:35	410	90	4.56	23.36
3:45	420	100	4.20	23.33
3:55	430	110	3.91	23.32
4:10	445	125	3.56	23.26
4:25	460	140	3.29	23.21
4:40	475	155	3.06	23.16
4:55	490	170	2.88	23.12
5:10	505	185	2.73	23.09
5:25	520	200	2.60	23.08
5:30	525	205	2.56	23.06
7:10	625	305	2.05	22.95
7:40	655	335	1.96	22.89
8:10	685	365	1.88	22.87
8:40	715	395	1.81	22.84
9:25	760	440	1.73	22.81

Fig. 2.--Depth-to-water level in well 5-2W-25cc plotted against t/t'
(time since pumping started divided by the time since pumping
stopped).

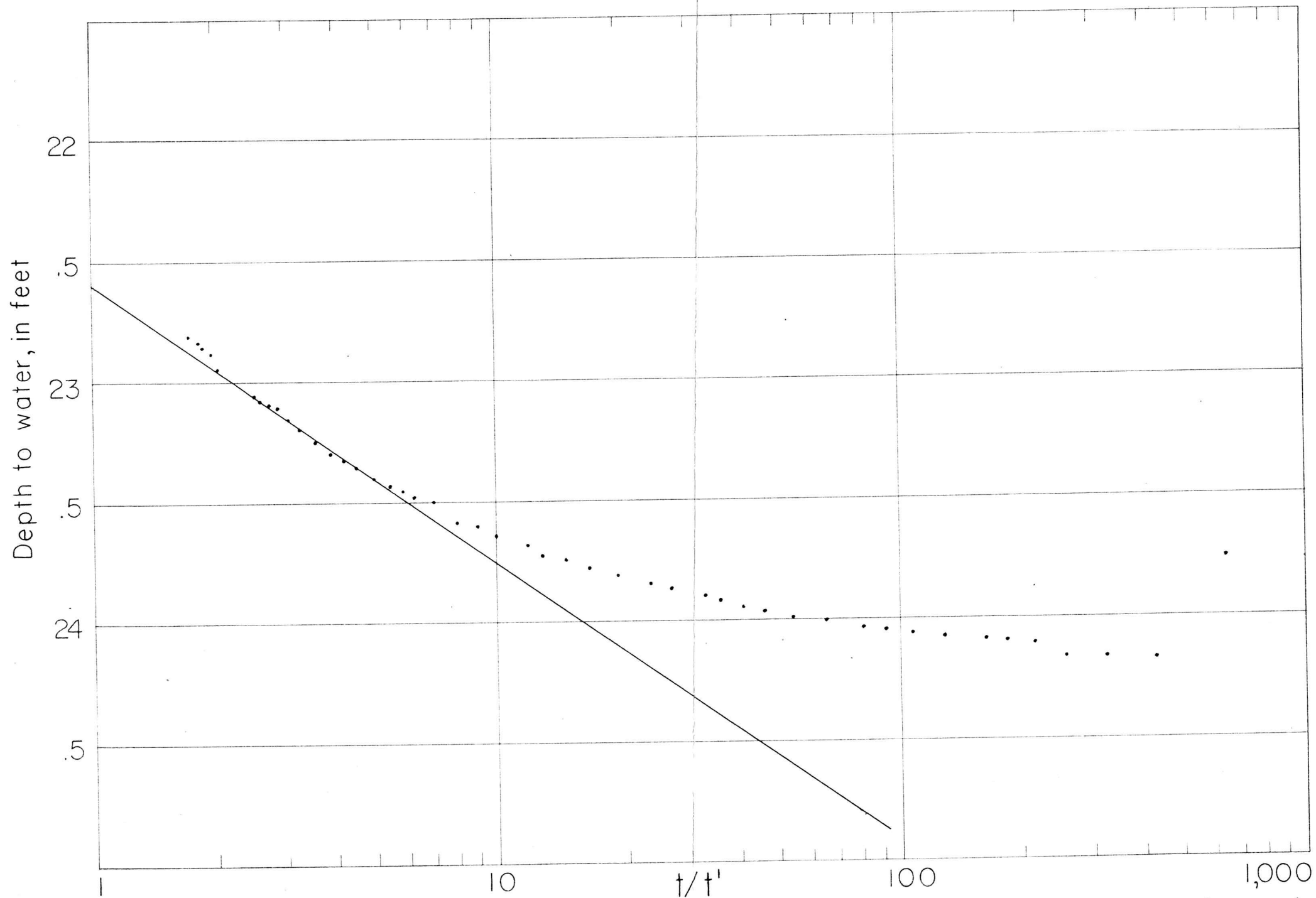


Fig. 2- - Depth to water level in well 5-2W-25cc plotted against t/t' (time since pumping started divided by the time since pumping stopped)

Table 3.--Water-level measurements in observation well a, 20.4 feet from pumped well, made during pumping test using well 5-2#-25cc.

<u>Time</u>	<u>Time since pumping started, in minutes</u>	<u>Depth to water, feet</u>
8:44 a.m.	static water level	24.87
8:45	pumping started	
8:45:30	.5	25.79
8:47	2	26.20
8:49	4	26.35
8:50	5	26.45
8:52	7	26.53
8:56	11	26.59
8:58	13	26.66
9:00	15	26.74
9:02	17	26.78
9:05	20	26.80
9:10	25	26.86
9:20	35	26.97
9:30	45	27.03
9:40	55	27.13
9:55	70	27.26
10:05	80	27.31
10:25	100	27.42
10:45	120	27.51
11:05	140	27.60
11:20	155	27.64
11:35	170	27.69
11:50	185	27.71
12:05 p.m.	200	27.77
12:25	220	27.80
12:45	240	27.86
1:05	260	27.91
1:25	280	28.00
1:50	305	28.02

Fig. 3.—Drawdown of water level in observation well a plotted against time for the pumping period of well 5-2%-25cc.

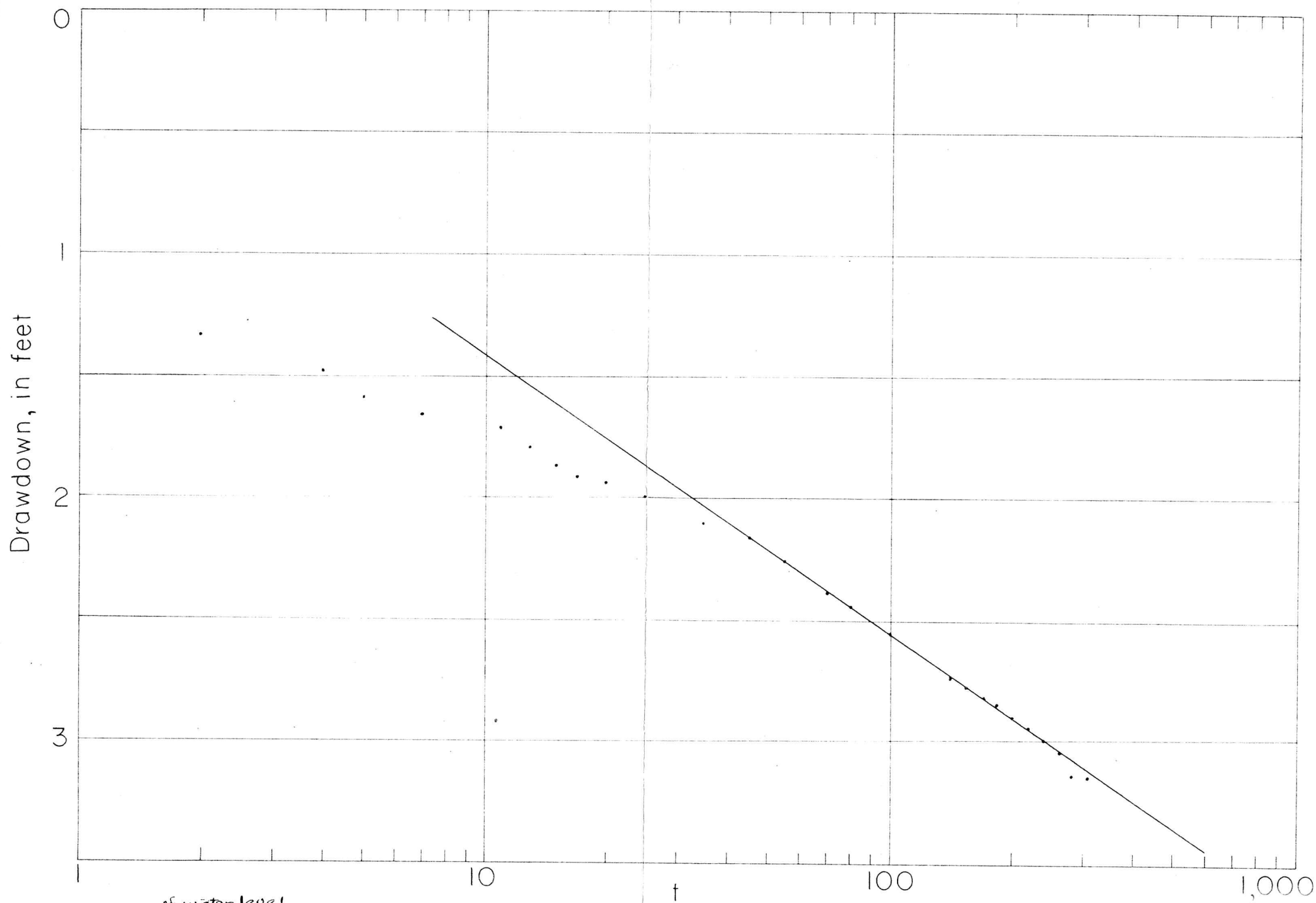


Fig. 3--Drawdown in observation well a plotted against time for the pumping period of well 5-2W-25cc.

Table 4.--Water-level measurements in observation well b, 51 feet from pumped well, made during pumping and recovery periods of well 5-24-25cc.

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	Depth to water, feet
8:44 a.m.	static water level		25.04
8:45	pumping started		
8:45:30	.5		25.44
8:46:30	1.5		25.68
8:47:15	2.25		25.77
8:48	3		25.86
8:49	4		25.95
8:50	5		26.02
8:51	6		26.04
8:52	7		26.07
8:53	8		26.11
8:54	9		26.13
8:55	10		26.15
8:56	11		26.18
8:57	12		26.20
8:58	13		26.22
8:59	14		26.23
9:00	15		26.25
9:02	17		26.26
9:05	20		26.32
9:08	23		26.35
9:10	25		26.36
9:15	30		26.40
9:20	35		26.47
9:25	40		26.50
9:30	45		26.54
9:38	53		26.61
9:45	60		26.64
9:55	70		26.72
10:00	75		26.74
10:10	85		26.78
10:15	90		26.81

Table 4.--(Continued)

Time	Time since pumping started, in minutes, t.	Time since pumping stopped, in minutes, t'	Depth to water, feet
10:25	100		26.85
10:45	120		26.94
11:05	140		27.03
11:20	155		27.07
11:35	170		27.12
11:50	185		27.16
12:05 p.m.	200		27.20
12:25	220		27.24
12:45	240		27.29
1:05	260		27.33
1:25	280		27.38
1:50	305		27.43
2:05		pumping stopped	
2:05:30	320.5	.5	26.86
2:07:30	322.5	2.5	26.81
2:08:30	323.5	3.5	26.78
2:09:30	324.5	4.5	26.75
2:11	326	6	26.70
2:12	327	7	26.69
2:13	328	8	26.68
2:14	329	9	26.66
2:15	330	10	26.63
2:16	331	11	26.61
2:17	332	12	26.60
2:18	333	13	26.59
2:20	335	15	26.58
2:22	337	17	26.56
2:24	339	19	26.55
2:30	345	25	26.46
2:40	355	35	26.36
2:52	367	47	26.28
3:00	375	55	26.22

Table 4.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	Depth to water, feet
3:30	405	85	26.09
4:00	435	115	25.96
4:30	465	145	25.87
5:00	495	175	25.80
5:13	508	188	25.77

Fig. 4.--Depth-to-water level in observation well b plotted against time for the pumping and recovery of well 5-2W-25cc.

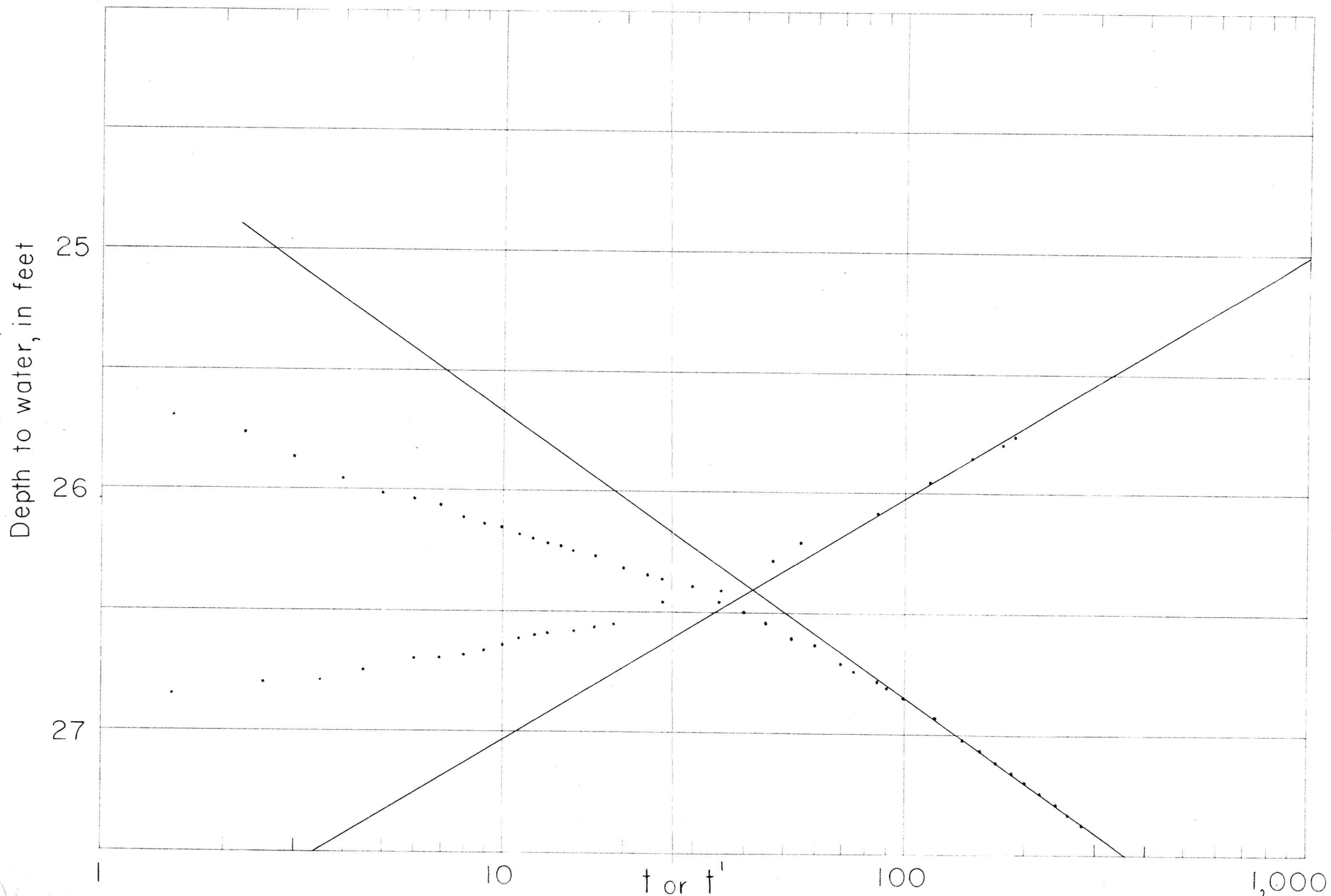


Fig. 4--Depth-to-water level in observation well b plotted against time for the pumping and recovery of well 5-2W-25cc.

stopped, t' . Lines through the points where t and t' become large give values of 1.17 feet for Δs on the drawdown plot and 1.0 foot on the recovery plot. Applying the modified nonequilibrium formula for the drawdown curve:

$$T = \frac{(264)(1,000)}{1.17} = 226,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(2.26)(10^5)(2.9)}{(2,601)(1,440)} = 0.05$$

and for the recovery curve:

$$T = \frac{(264)(1,000)}{1.0} = 264,000 \text{ gpd per ft.}$$

Water-level measurements made in observation well c, 100 feet from the pumped well, during the pumping period on well 5-2W-25cc are given in Table 5. Drawdown, s , is plotted against time, t , in Figure 5.

A line through the points where t becomes large gives a value of 1.02 feet for Δs and applying the modified nonequilibrium formula:

$$T = \frac{(264)(1,000)}{1.02} = 259,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(2.59)(10^5)(6.5)}{(1)(10^4)(1,440)} = 0.04$$

Water-level measurements made in observation well d, 150 feet from the pumped well, during the pumping period on well 5-2W-25cc are given in Table 6. Depth to water is plotted against time since pumping started, t , in Figure 6. A line through the points where t is large gives a value of 0.96 feet for Δs and applying the modified nonequilibrium formula:

$$T = \frac{(264)(1,000)}{.96} = 275,000 \text{ gpd per ft.}$$

Table 5.--Water-level measurements in observation well c, 100 feet from pumped well 5-27-25cc.

<u>Time</u>	<u>Time since pumping started, in minutes, t</u>	<u>Depth to water, feet</u>
8:44	static water level	22.45
8:45	pumping started	
8:45:30	.5	22.55
8:46:30	1.5	22.63
8:47:30	2.5	22.73
8:48:30	3.5	22.85
8:49:30	4.5	22.88
8:50:30	5.5	22.97
8:52	7	23.02
8:53	8	23.06
8:54	9	23.09
8:56	11	23.13
8:58	13	23.17
9:00	15	23.20
9:03	18	23.24
9:05	20	23.27
9:10	25	23.31
9:15	30	23.35
9:25	40	23.42
9:35	50	23.48
9:45	60	23.50
9:55	70	23.59
10:05	80	23.63
10:15	90	23.63
10:25	100	23.68
10:45	120	23.77
11:05	140	23.82
11:20	155	23.85
11:35	170	23.90
11:50	185	23.93
12:05 p.m.	200	23.97
12:25	220	24.02
12:45	240	24.05
1:05	260	24.09
1:25	280	24.11
1:50	305	24.12
2:05	pumpin g stopped	

Fig. 5.—Drawdown of water level in observation well c plotted against time for the pumping period of well 5-2W-25cc.

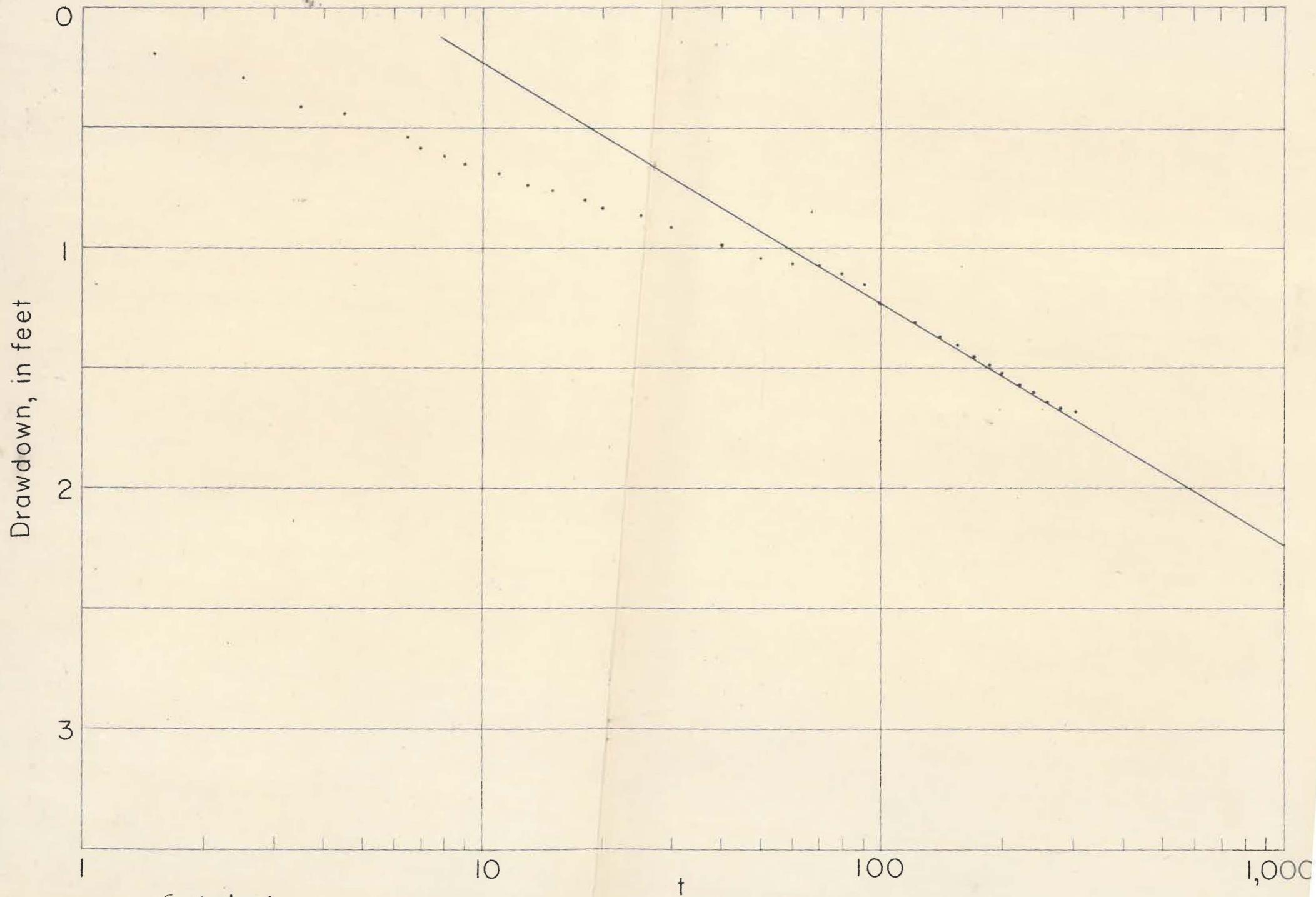


Fig. 5--Drawdown_A in observation well c plotted against time for the pumping period of well 5-2W-25cc.

Table 6.--Water-level measurements in observation well d, 150 feet from pumped well 5-24-25cc.

<u>Time</u>	<u>Time since pumping started, in minutes, t</u>	<u>Depth to water, feet</u>
8:44 a.m.	static water level	23.95
8:45	pumping started	
8:48	3	24.13
8:50	5	24.29
8:52	7	24.36
8:54	9	24.43
8:56	11	24.50
8:58	13	24.50
9:00	15	24.57
9:03	18	24.59
9:05	20	24.57
9:10	25	24.60
9:15	30	24.60
9:25	40	24.73
9:35	50	24.80
9:45	60	24.81
9:55	70	24.85
10:05	80	24.88
10:15	90	24.90
10:25	100	24.95
10:45	120	24.98
11:05	140	25.04
11:20	155	25.06
11:35	170	25.09
11:50	185	25.13
12:05 p.m.	200	25.15
12:25	220	25.18
12:45	240	25.23
1:05	260	25.25
1:25	280	25.28
1:50	305	25.32
2:05	pumping stopped	

Fig. 6.--Depth-to-water level in observation well d plotted against time for the pumping period of well 5-2W-25cc.

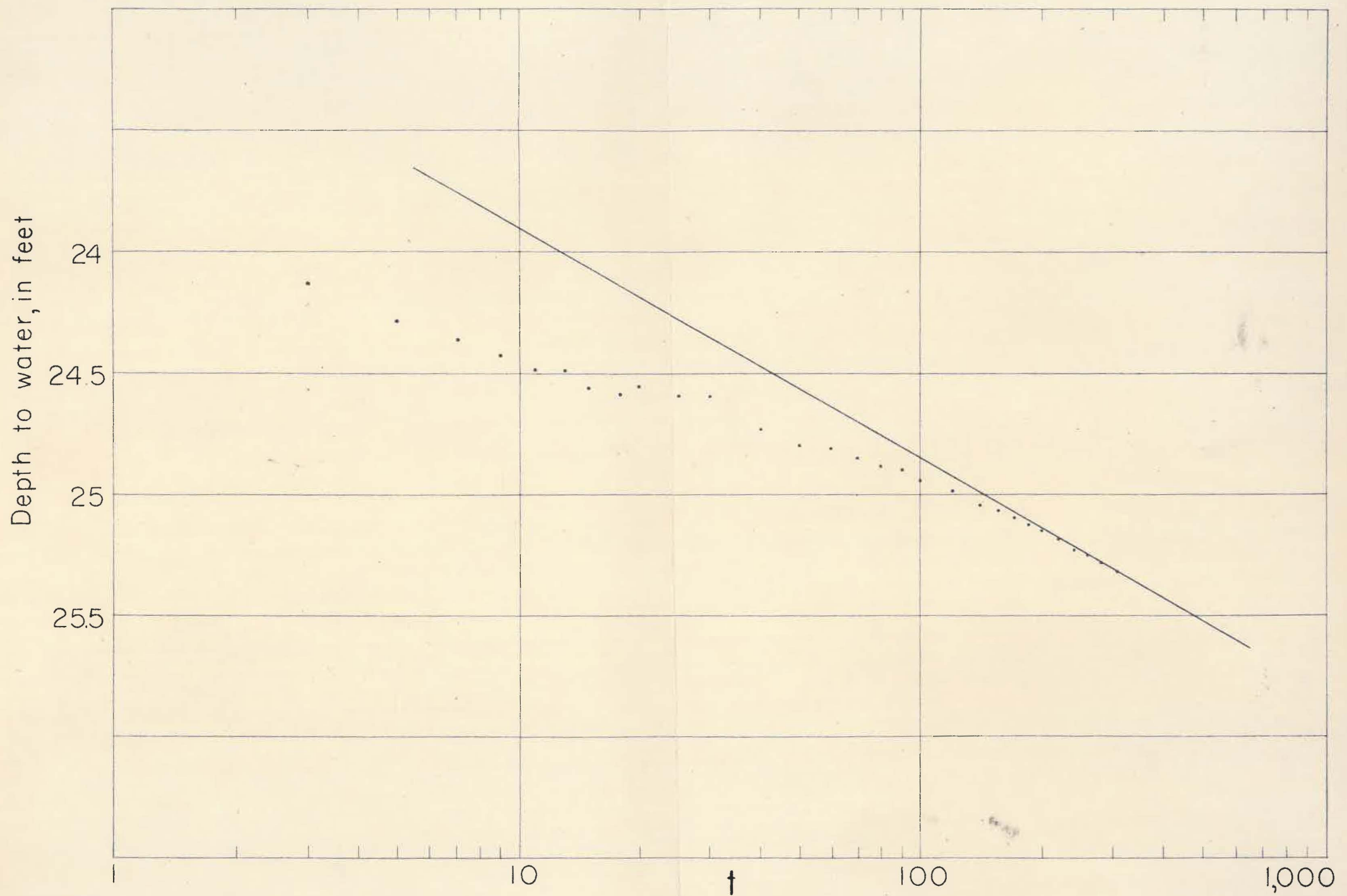


Fig. 6--Depth-to-water level in observation well d plotted against time for the pumping period of well 5-2W-25cc.

$$S = \frac{(.3)(2.75)(10^5)(11.5)}{(2.25)(10^4)(1.44)(10^3)} = 0.03$$

Drawdown of water levels in observation wells a, b, c, and d 305 minutes after pumping started is plotted against the distance of the observation wells from the pumped well in Figure 7. A line through these points gives a value of 2.12 feet for Δs and applying the Thiem formula:

$$T = \frac{(528)(1,000)}{2.12} = 249,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(2.49)(10^5)(305)}{(409.6)(10^3)(1.44)(10^3)} = 0.04$$

Pumping Test Using Well 6-1W-4bb

For the pumping test using well 6-1W-4bb three observation wells, a, b, and c, were drilled at distances of 48, 100, and 147 feet respectively from the pumped well. The well was pumped from 12:25 p.m. until 4:35 p.m. (245 minutes) October 12, 1955, at an average rate of 540 gpm. Water-level measurements were made in the pumped well and the observation wells during the pumping period, and recovery measurements of the water level were made in the pumped well for a period of 295 minutes after pumping stopped. Water-level measurements made in well 6-1W-4bb during the pumping and recovery period and values for t , t' , and t/t' are given in Table 7.

Small changes in the pumping rate caused the points on a modified nonequilibrium plot of the drawdown period to be too erratic for a solution by this method. The Theis recovery method was used for solving for T using the data from the pumped well. The ratio t/t' is plotted against depth to water on semilog paper in Figure 8. The latest points on the

Fig. 7.--Drawdown of water levels in observation wells a, b, c, and d plotted against the distance of the observation wells from pumped well 5-27-25cc, 305 minutes after pumping started .

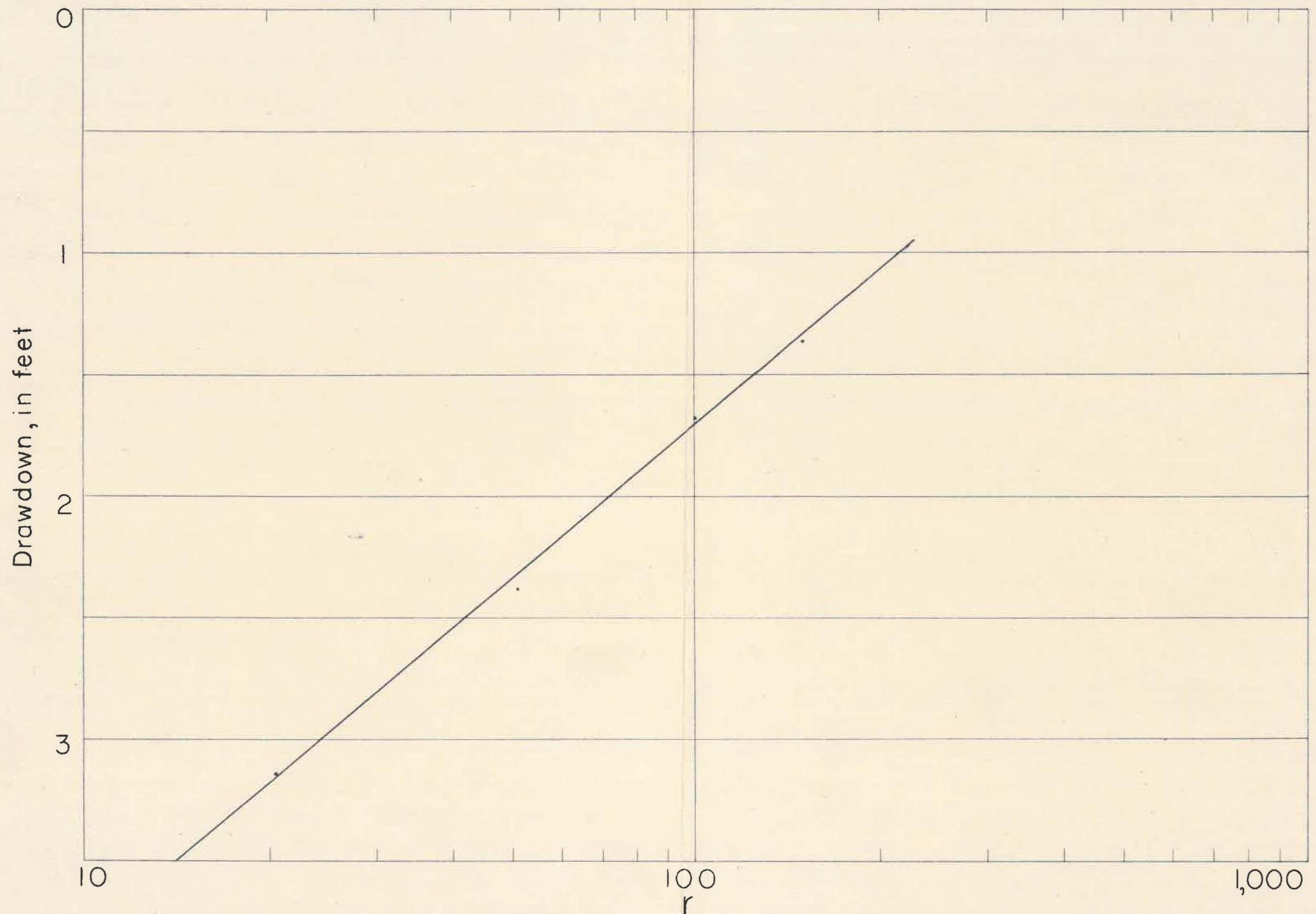


Fig. 7--Drawdown of water levels in observation wells a, b, c, and d plotted against the distance of the observation wells from pumped well 5-2W-25cc, 305 minutes after pumping started.

Table 7.—Water-level measurements made during pumping and recovery periods
in well 6-1W-4bb. and values for t, t', and t/t'.

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
12:25 p.m.	static water level			26.05
12:30	pumping started			
12:30:20	.33			37.80
12:30:45	.75			40.80
12:31	1			42.55
12:32	2			45.00
12:32:30	2.5			46.50
12:33	3			47.60
12:34	4			48.30
12:35	5			51.30
12:36	6			52.40
12:37	7			53.48
12:38	8			54.80
12:39	9			55.52
12:40	10			56.09
12:45	15			58.44
12:50	20			60.51
12:55	25			62.75
1:00	30			64.45
1:10	40			65.14
1:21	51			66.05
1:30	60			66.06
4:35	245	pumping stopped		
4:37	247	2	123	42.71
4:38	248	3	83	41.72
4:39	249	4	62	41.18
4:40	250	5	50	40.81
4:41	251	6	42	40.50
4:42	252	7	36	40.22
4:43	253	8	32	39.98
4:44	254	9	28	39.74
4:45	255	10	26	39.55

Table 7.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped in minutes, t'	t/t'	Depth to water, feet
4:46	256	11	23	39.41
4:47	257	12	21	39.26
4:48	258	13	20	39.11
4:49	259	14	18.5	38.97
4:50	260	15	17.3	38.83
4:51	261	16	16.3	38.70
4:52	262	17	25.1	38.56
4:53	263	18	14.6	38.44
4:54	264	19	13.9	38.33
4:55	265	20	13.2	38.22
4:56	266	21	12.7	38.10
4:57	267	22	12.1	37.99
4:58	268	23	11.7	37.86
4:59	269	24	11.2	37.77
5:00	270	25	10.8	37.66
5:01	271	26	10.4	37.55
5:02	272	27	10.1	37.45
5:03	273	28	9.7	37.34
5:04	274	29	9.4	37.23
5:05	275	30	9.2	37.13
5:07	277	32	8.2	36.93
5:10	280	35	8.0	36.67
5:13	285	40	7.1	36.25
5:20	290	45	6.5	35.86
5:25	295	50	5.9	35.53
5:30	300	55	5.5	35.22
5:35	305	60	5.1	34.93
5:40	310	65	4.8	34.66
5:45	315	70	4.5	34.40
5:50	320	75	4.3	34.14
5:56	326	81	4.0	33.88
6:00	330	85	3.9	33.68

Table 7.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
6:06	336	91	3.7	33.45
6:15	345	100	3.5	33.11
6:25	355	110	3.2	32.80
6:35	365	120	3.0	32.50
7:53	443	198	2.2	30.83
8:25	475	230	2.1	30.35
9:30 p.m.	540	295	1.8	29.65
8:50 a.m.	1,220	975	1.3	27.26

Fig. 8.—Depth-to-water level in well 6-1W-4bb plotted against t/t'
(time since pumping started divided by the time since pumping stopped).

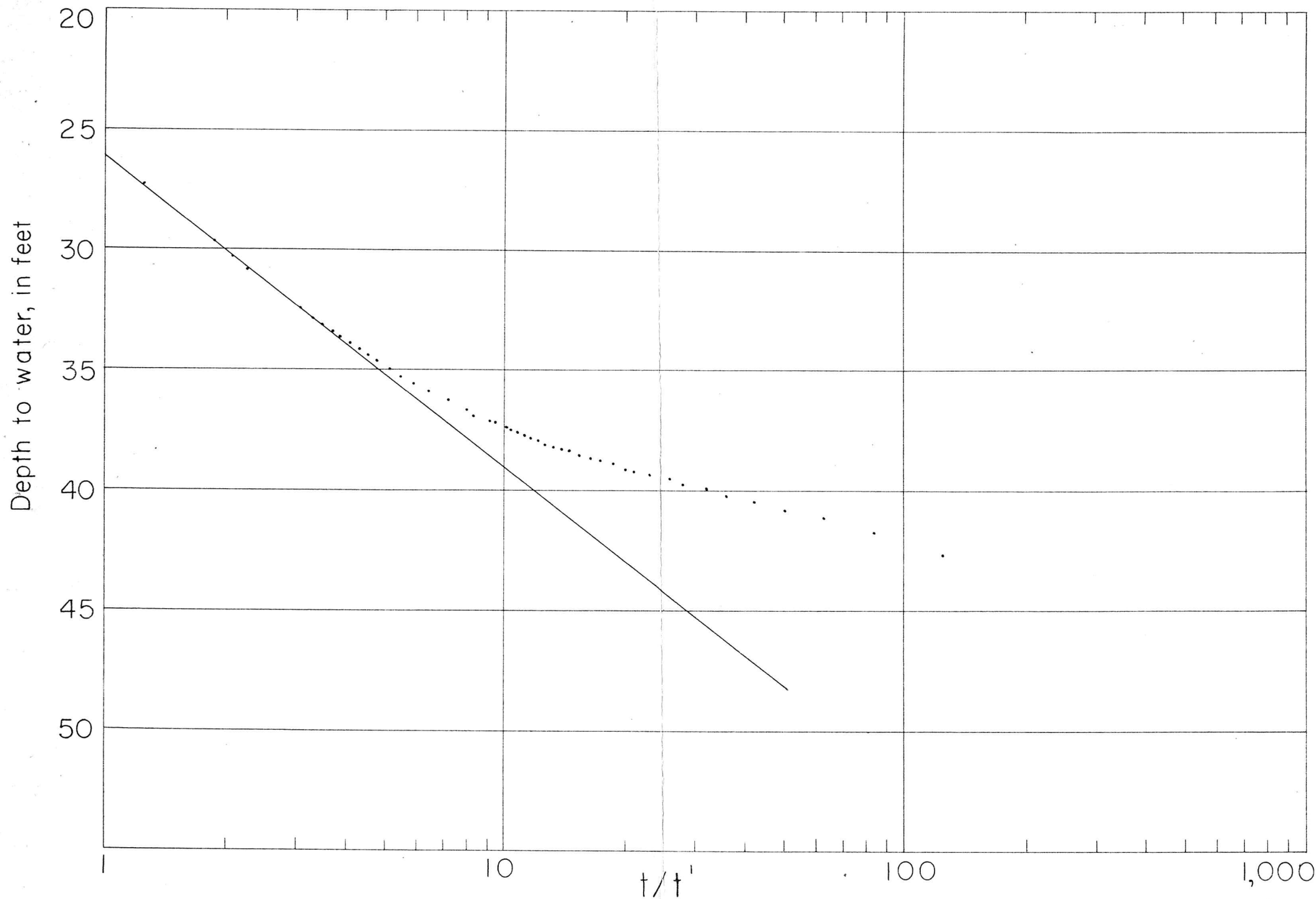


Fig. 8--Depth-to-water level in well 6-1W-4bb plotted against t/t' (time since pumping started divided by the time since pumping stopped)

curve where t/t' approaches unity seem to fall in a straight line. The slope of this line gives a value of 13.0 feet for Δs and applying the Theis recovery formula:

$$T = \frac{(264)(540)}{13.0} = 11,000 \text{ gpd per ft.}$$

The saturated thickness of materials at the well is 43 feet and from the relation $P = \frac{T}{M}$, $P = 300 \text{ gpd per ft.}^2$. Drawdown at the end of the pumping period was 40 feet and the specific capacity of the well was 13.5 gpm per ft.

Depth-to-water measurements made in observation well a during the pumping period of well 6-1W-4bb are given in Table 8. The drawdown, s , is plotted on the vertical axis of log log paper and time since pumping started, t , is plotted on the horizontal axis in Figure 9. Using the type curve, the match point gives the following values:

$$s = 8.3 \text{ feet}$$

$$t = 17.8 \text{ minutes}$$

$$\frac{l}{u} = 10$$

$$W(u) = 1.823$$

Then, using the Theis nonequilibrium formula:

$$T = 208.5 \frac{Q}{S}$$

$$S = (3.71)(10^{-5}) \frac{T t(\text{min})}{r^2}$$

Hence:

$$T = 13,560 \text{ gpd per ft.}$$

$$S = 0.003$$

Table 8.—Water-level measurements in observation well a, 48 feet from pumped well, made during pumping test using well 6-1W-4bb.

<u>Time</u>	<u>Time since pumping started, in minutes, t</u>	<u>Depth to water, feet</u>
12:26 p.m.	static water level	26.66
12:30	pumping started	
12:31	1	27.05
12:32	2	27.52
12:33	3	28.69
12:34	4	28.69
12:35	5	30.22
12:36	6	30.82
12:37	7	31.66
12:38	8	31.95
12:39	9	32.34
12:40	10	32.70
12:42	12	33.31
12:44	14	33.89
12:46	16	34.44
12:48	18	34.86
12:50	20	35.27
12:54	24	36.00
12:57	27	36.43
1:00	30	36.86
1:05	35	37.49
1:11	41	38.11
1:16	46	38.69
1:21	51	39.13
1:25	55	39.40
1:30	60	39.70
1:35	65	39.96
1:40	70	40.19
1:45	75	40.44
1:50	80	40.72
1:55	85	40.90
2:00	90	41.10

Table 8.--(Continued)

Time	Time since pumping started, in minutes, t	Depth to water, feet
2:11	101	41.38
2:20	110	41.63
2:30	120	41.84
2:40	130	42.05
2:52	142	42.25
3:00	150	42.42
3:15	165	42.61
3:30	180	42.79
3:45	195	42.94
4:00	210	43.04
4:15	225	43.15
4:30	240	43.20
4:35	pumping stopped	

Fig. 9.--Drawdown of water level in observation well a plotted against time since pumping started in well 6-18-4bb.

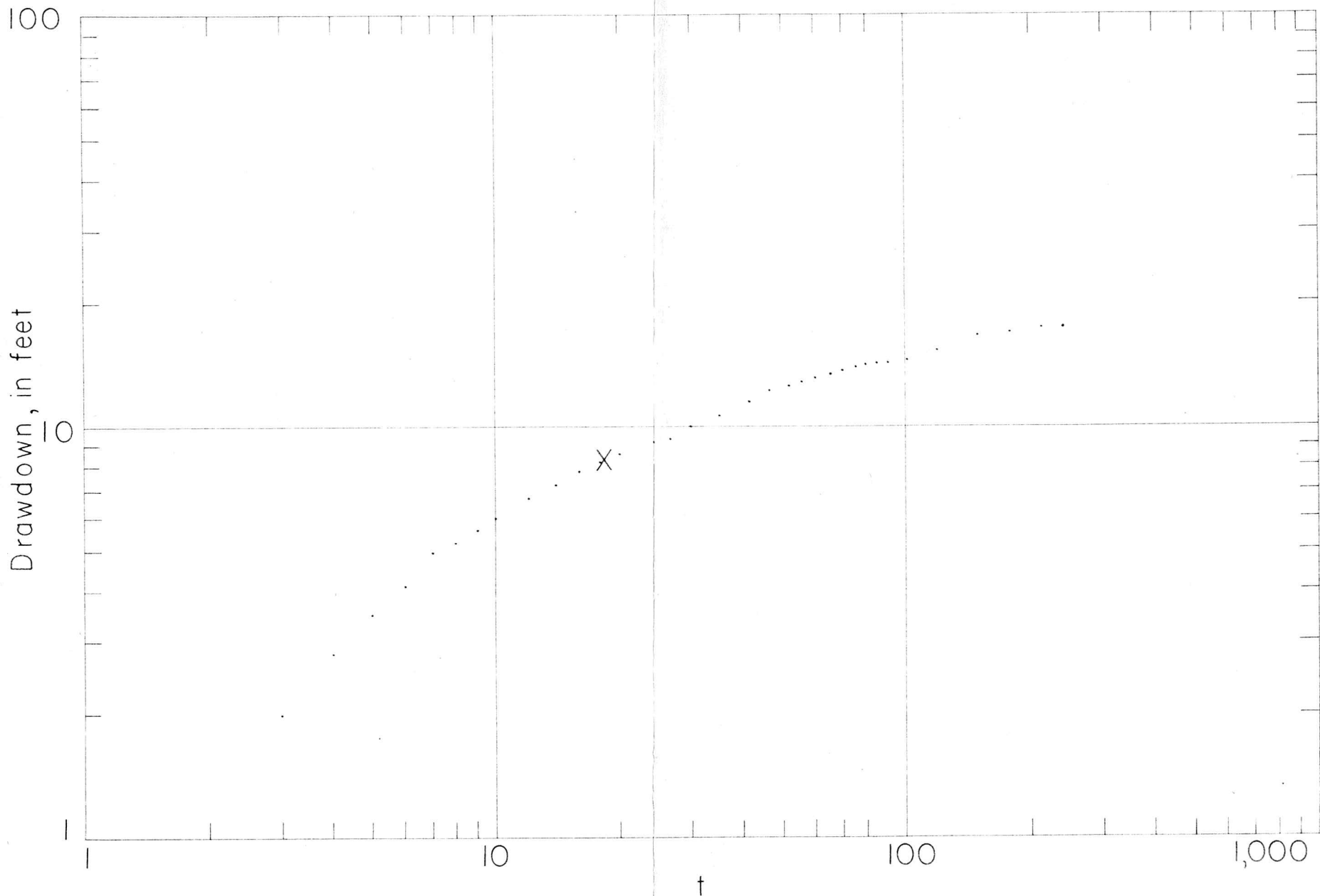


Fig. 9--Drawdown of water level in observation well a plotted against time since pumping started in well 6-1W-4bh.

Water-level measurements made in observation well b during the pumping period of well 6-1W-4bb are given in Table 9. The drawdown, s, in observation well b is plotted on the vertical axis and the time since pumping started, t, is plotted on the horizontal axis in Figure 10. For a match point on the type curve of 9.0 feet for s and 43 minutes for t, the Theis nonequilibrium formula gives:

$$T = \frac{(208.5)(540)}{9.0} = 12,500 \text{ gpd per ft.}$$

$$S = (3.71)(10^{-5}) \frac{(1.25)(10^4)(43)}{48^2} = 0.001$$

Water-level measurements made in observation well c during the pumping period of well 6-1W-4bb are given in Table 10. The drawdown, s, is plotted on the vertical axis of log log paper and the time since pumping stopped, t, is plotted on the horizontal axis in Figure 11. For a match point on the type curve of 8.6 feet for s and 28 minutes for t the Theis nonequilibrium formula gives:

$$T = \frac{(208.5)(540)}{8.6} = 13,100 \text{ gpd per ft.}$$

$$S = (3.71)(10^{-5}) \frac{(1.3)(10^4)(28)}{100^2} = 0.001$$

Pumping Test Using Well 6-1E-2ac

A pumping test was made using well 6-1E-2ac on October 13, 1955. The well is a gravel-walled well, 18 inches in diameter, and 70 feet deep. Three observation wells, a, b, and c, were drilled at distances of 25, 50, and 100 feet respectively from the pumped well. The well was pumped at a rate of 800 gpm from 9:25 a.m. until 9:55 a.m. when

Table 9.--Water-level measurements in observation well b, 100 feet from pumped well, made during pumping test using well 6-1W-4bb.

Time	Time since pumping started, in minutes, t	Depth to water, feet
12:26 p.m.	static water level	25.88
12:30	pumping started	
12:31	1	25.89
12:32	2	25.92
12:33	3	26.20
12:34	4	26.49
12:35	5	26.86
12:36	6	27.23
12:37	7	27.76
12:38	8	28.23
12:40	10	28.87
12:41	11	29.24
12:42	12	29.93
12:44	14	30.36
12:48	18	31.41
12:50	20	31.82
12:52	22	32.39
12:54	24	32.71
12:56	26	33.18
12:58	28	33.47
1:02	32	33.98
1:04	34	34.22
1:06	36	34.53
1:10	40	34.93
1:15	45	35.45
1:21	51	35.75
1:26	56	36.45
1:31	61	36.78
1:36	66	37.10
1:41	71	37.35
1:46	76	37.62
1:52	82	37.87

Table 9.--(Continued)

Time	Time since pumping started, in minutes, t	Depth to water, feet
1:57	87	38.08
2:01	91	38.24
2:11	101	38.58
2:21	111	38.85
2:30	120	39.11
2:40	130	39.40
2:50	140	39.60
3:00	150	39.82
3:15	165	40.05
3:30	180	40.27
3:45	195	40.45
4:00	210	40.60
4:15	225	40.74
4:30	240	40.82
4:35	245	pumping stopped

Fig. 10.—Drawdown of water level in observation well b plotted against time since pumping started in well 6-1W-4bb.

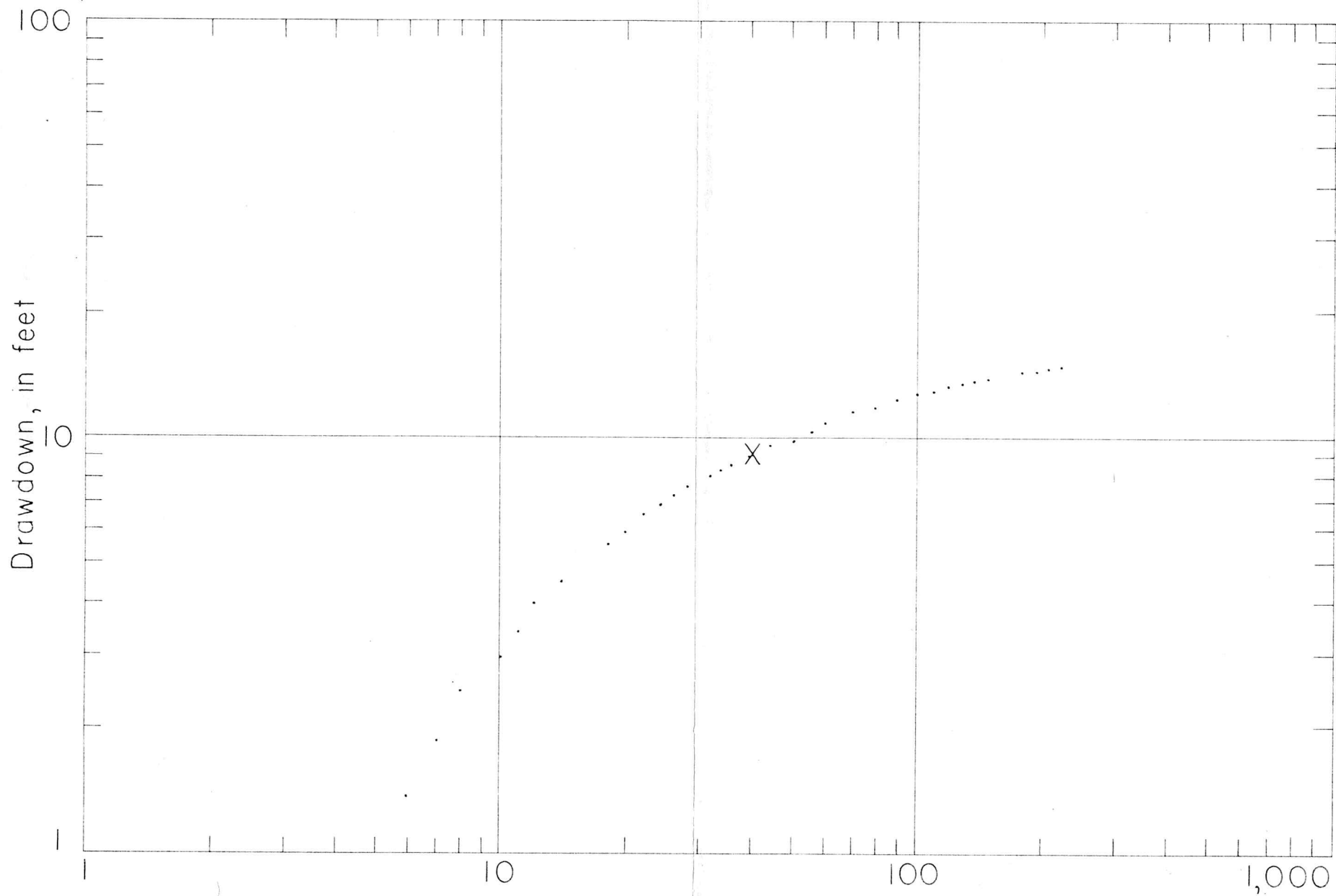


Fig. 10--Drawdown of water level in observation well b plotted against time since pumping started in well 6-1W-4bb.

Table 10.--Water-level measurements in observation well c, 147 feet from pumped well, made during pumping test using well 6-1W-4bb.

Time	Time since pumping started, in minutes, t	Depth to water, feet
12:23 p.m.	static water level	26.82
12:30	pumping started	
12:31	1	26.82
12:40	10	26.89
12:45	15	27.16
12:50	20	27.38
12:55	25	27.60
1:00	30	27.86
1:05	35	28.13
1:10	40	28.40
1:15	45	28.90
1:21	51	28.97
1:25	55	29.18
1:30	60	29.40
1:35	65	29.64
1:40	70	29.70
1:45	75	30.08
1:50	80	30.33
1:55	85	30.52
2:00	90	30.69
2:10	100	31.06
2:20	110	31.42
2:30	120	31.69
2:40	130	32.00
2:50	140	32.32
3:00	150	32.58
3:15	165	32.93
3:30	180	33.29
3:45	195	33.63
4:00	210	33.89
4:15	225	34.16
4:30	240	34.85
4:35	pumping stopped	

Fig. 11.--Drawdown of water level in observation well c plotted against time since pumping started in well 6-1#-4bb.

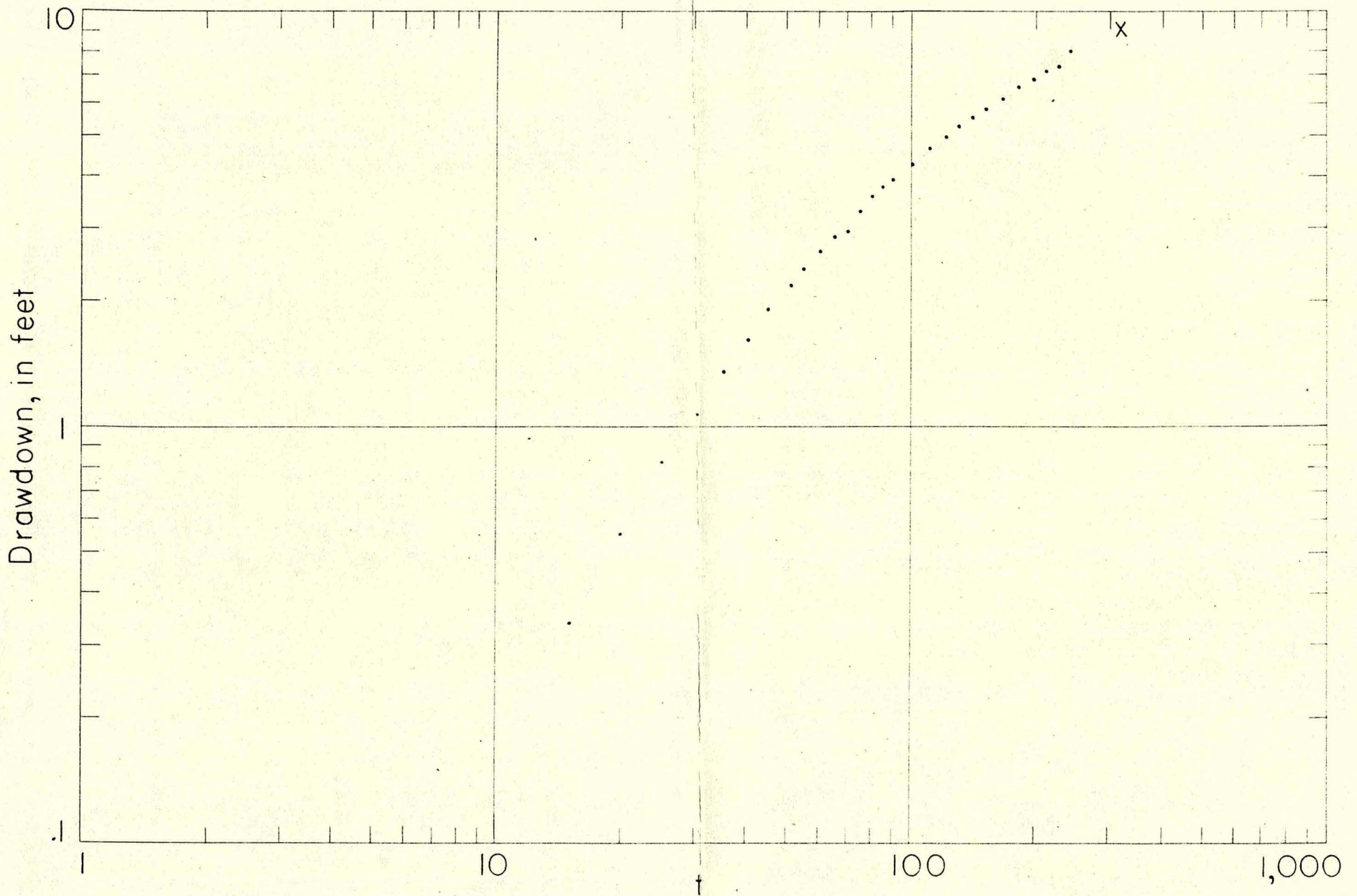


Fig. 11--Drawdown of water level in observation well c plotted against time since pumping started in well 6-1W-4bb.

pumping stopped for 45 minutes owing to a power failure. Pumping was resumed at 10:40 a.m. and continued until 1:10 p.m.

Measurements of water levels made in the pumped well during the pumping and recovery periods and values for t , t' , and t/t' are given in Table II. The depth to water in the pumped well is plotted against time since pumping started on semilog paper in Figure 12. A line through these points gives a value of 2.18 feet for Δs and applying the modified nonequilibrium formula:

$$T = \frac{(264)(800)}{2.18} = 97,000 \text{ gpd per ft.}$$

Depth-to-water measurements in the pumped well made during the recovery period are plotted against the ratio t/t' in Figure 13. The points do not fall in a straight line, but form a gentle curve. The earliest points in the recovery curve give a value for T much higher than that indicated by methods using the observation wells. The latest points on the curve give a value for T that is much lower than that indicated by the methods using the observation wells. An arbitrary line was drawn through points where the value of t/t' ranges from 4 to 8 and the slope of this line gives a value of 2.18 feet for Δs . Applying the Theis recovery formula:

$$T = \frac{(264)(800)}{2.18} = 97,000 \text{ gpd per ft.}$$

This plot is not a valid plot and the value of T obtained could not be considered reliable without substantiating evidence from the drawdown plot or the results obtained by using the observation wells.

Table 11.--Water-level measurements made during pumping and recovery periods
in well 6-1E-2ac. and values for t, t', and t/t'.

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
9:20 a.m.	static water level			22.21
9:25	pumping started			
9:25:20	.33			31.35
9:25:45	.75			32.87
9:26:15	1.25			33.55
9:26:45	1.75			33.99
9:27:15	2.25			34.17
9:28	3			34.44
9:29	4			34.77
9:29:30	4.5			34.86
9:30	5			34.95
9:30:30	5.5			35.04
9:31	6			35.11
9:31:30	6.5			35.19
9:32	7			35.26
9:32:30	7.5			35.32
9:33	8			35.36
9:33:30	8.5			35.42
9:34	9			35.48
9:34:30	9.5			35.52
9:35	10			35.57
9:36	11			35.67
9:37	12			35.78
9:38	13			35.83
9:39	14			35.89
9:40	15			35.95
9:45	20			36.15
9:50	25			36.47
9:54	pumping stopped			
10:39				22.98
10:40	pumping started			
10:40:30	75.5			33.87

Table 11.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
10:41	76			34.77
10:41:30	76.5			35.16
10:42	77			35.42
10:42:30	77.5			35.67
10:43	78			35.81
10:44	79			36.00
10:44:30	79.5			36.10
10:45	80			36.20
10:45:30	80.5			36.29
10:46	81			36.38
10:46:30	81.5			36.44
10:47	82			36.52
10:47:30	82.5			36.57
10:48	83			36.66
10:48:30	83.5			36.70
10:49	84			36.74
10:49:30	84.5			36.78
10:50	85			36.83
10:50:30	85.5			36.87
10:51	86			36.90
10:51:30	86.5			36.93
10:52	87			36.95
10:52:30	87.5			36.97
10:53	88			37.00
10:53:30	88.5			37.01
10:54	89			37.03
10:54:30	89.5			37.06
10:55	90			37.09
10:57	92			37.16
10:59	94			37.23
11:02	97			37.35
11:05	100			37.48
11:10	105			37.61
11:15	110			37.78
11:20	115			37.90
11:25	120			38.00

Table 11.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
11:30	125			38.13
11:35	130			38.22
11:40	135			38.30
11:50	145			38.48
12:00 noon	155			38.55
12:10	165			38.60
12:20	175			38.67
12:30	185			38.81
12:40	195			38.86
12:50	205			38.90
1:00	215			38.94
1:10	225			38.96
1:13	228	pumping stopped		
1:14	229	1	229	26.83
1:15	230	2	115	26.38
1:16	231	3	77	26.17
1:17	232	4	58	26.01
1:18	233	5	46	25.90
1:19	234	6	39	25.80
1:20	235	7	33	25.71
1:21	236	8	29	25.63
1:22	237	9	26	25.57
1:23	238	10	23.8	25.49
1:24	239	11	21.7	25.44
1:25	240	12	20.0	25.39
1:26	241	13	18.5	25.35
1:28	243	15	16.2	25.26
1:30	245	17	14.4	25.16
1:32	247	19	13.0	25.09
1:34	249	21	11.8	25.02
1:36	251	23	10.9	24.95
1:38	253	25	10.1	24.90
1:41	256	28	9.1	24.80
1:44	259	31	8.3	24.74
1:47	262	34	7.7	24.66
1:50	265	37	7.1	24.58

Table 11.--(Continued)

Time	Time since pumping started, in minutes, t	Time since pumping stopped, in minutes, t'	t/t'	Depth to water, feet
1:54	269	41	6.5	24.52
1:58	273	45	6.0	24.45
2:02	277	49	5.6	24.38
2:06	281	53	5.3	24.32
2:10	285	57	5.0	24.24
2:15	290	62	4.6	24.15
2:21	296	68	4.3	24.09
2:28	303	75	4.0	24.01
2:35	310	82	3.7	23.98
2:45	320	92	3.4	23.91
2:55	330	102	3.2	23.81
3:05	340	112	3.0	23.74
3:15	350	122	2.9	23.66
3:25	360	132	2.7	23.60
3:35	370	142	2.6	23.54
3:50	385	157	2.5	23.46
4:05	400	172	2.3	23.40
4:20	415	187	2.2	23.32

Fig. 12.--Depth-to-water level in well 6-1E-2ac plotted against time since pumping started.

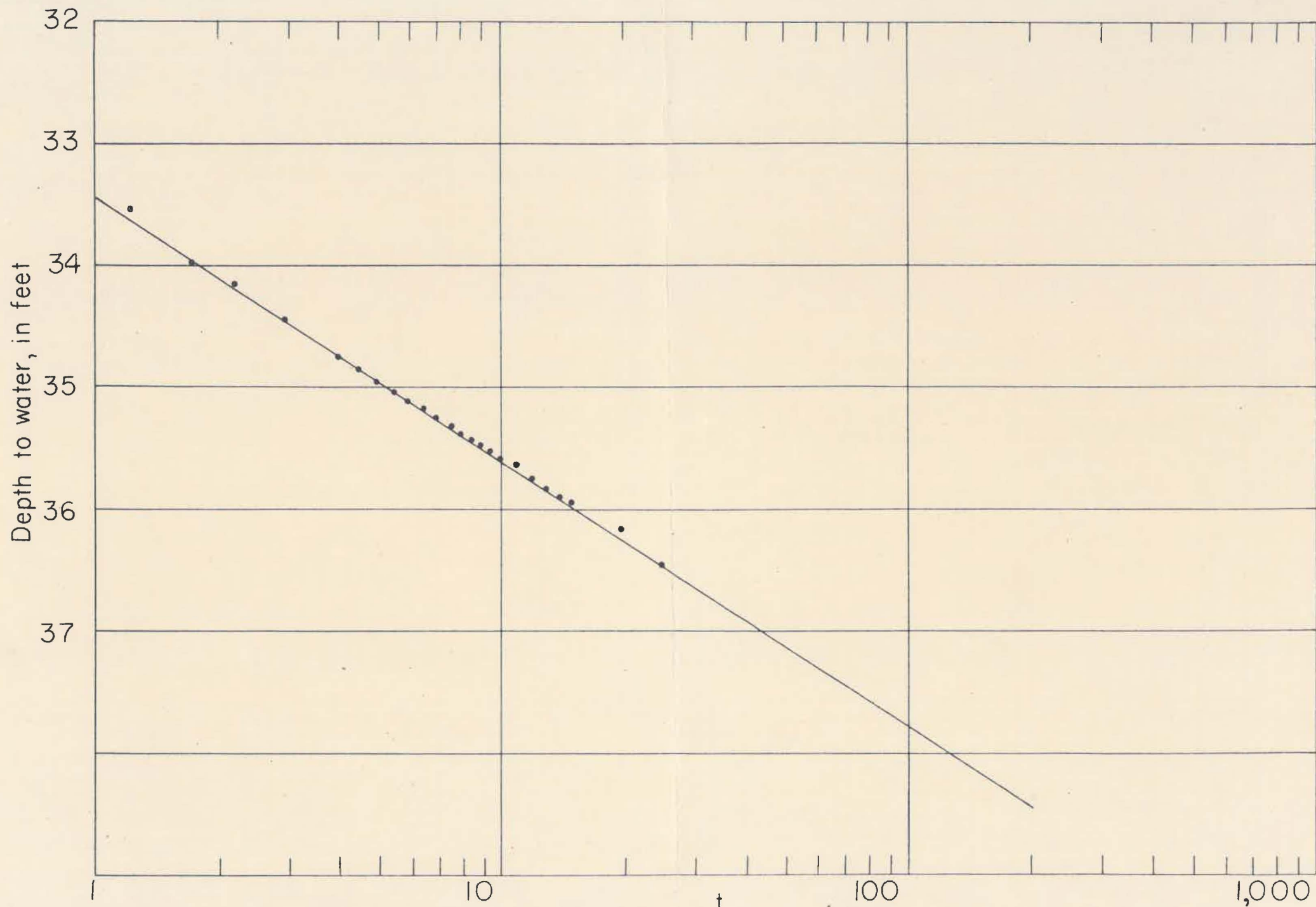


Fig. 12--Depth-to-water level in well 6-1E-2ac plotted against time since pumping started.

Fig. 13.--Depth-to-water level in well 6-1E-2ac plotted against the ratio t/t' (time since pumping started divided by the time since pumping stopped).

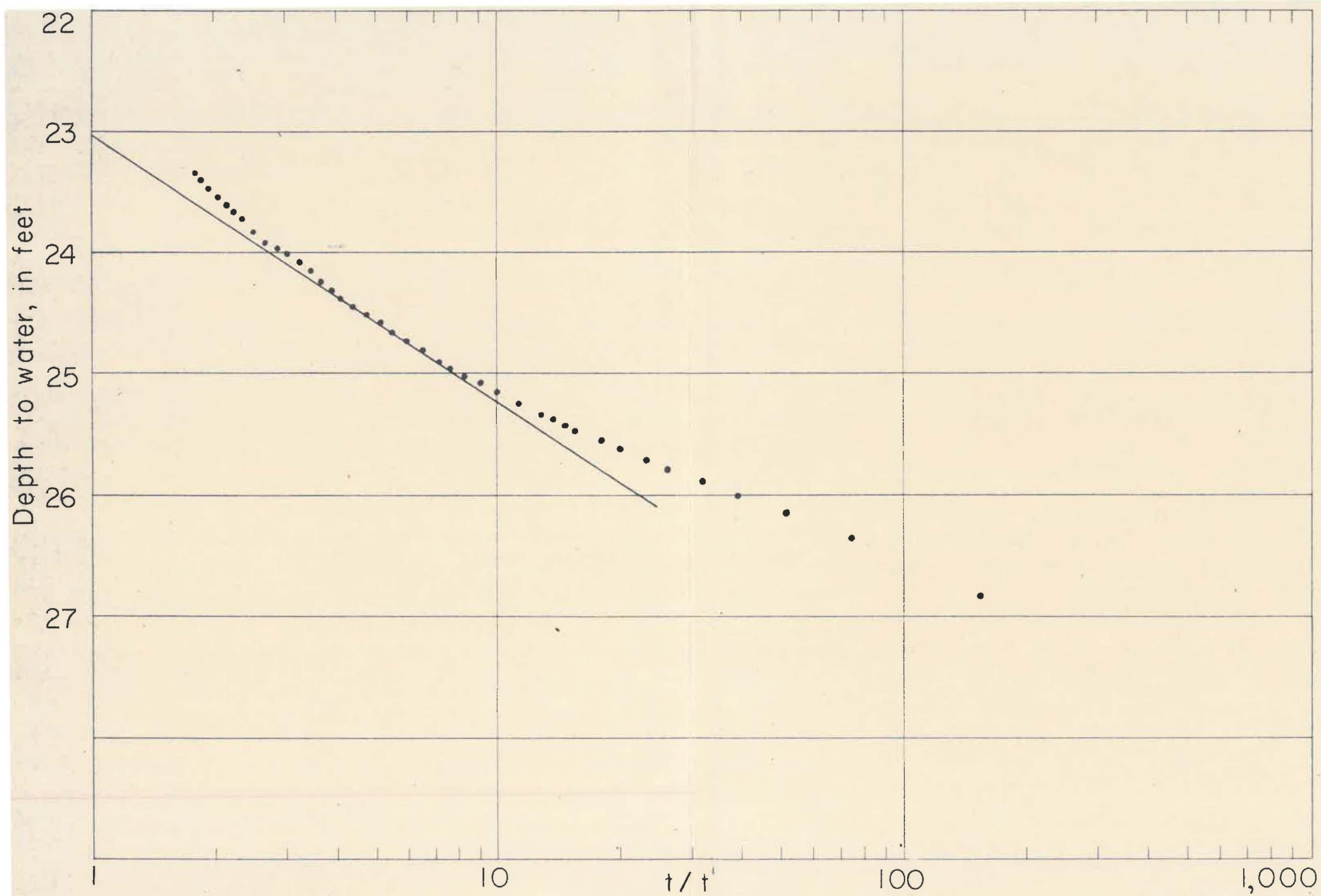


Fig. 13--Depth-to-water level in well 6-1E-2ac plotted against the ratio t/t' (time since pumping started divided by the time since pumping stopped)

The saturated thickness at well 6-1E-2ac is 43 feet and from the relation $P = \frac{T}{H}$, $P = 2,250$ gpd per ft.².

Depth-to-water measurements made in observation well a during the pumping period of well 6-1E-2ac are given in Table 12. Depth to water is plotted on the vertical axis of semilog paper and time since pumping began is plotted on the horizontal axis in Figure 14. A line extended through the points between 10 minutes and 28 minutes when the power failure occurred passes through the latest points on the curve. The slope of this line gives a value of 2.55 feet for Δs . Applying the modified nonequilibrium formula:

$$T = \frac{(264)(800)}{2.55} = 83,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(83,000)(.92)}{(25^2)(1,440)} = 0.02$$

Depth-to-water measurements made in observation well b during the pumping period of well 6-1E-2ac are given in Table 13. The depth to water is plotted against time since pumping started on semilog paper in Figure 15. A line extended through the points early in the test just before the power failure passes through the latest points in the test and gives a value of 2.15 feet for Δs . Applying the modified nonequilibrium formula:

$$T = \frac{(264)(800)}{2.15} = 98,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(98,000)(.16)}{(50^2)(1,440)} = 0.001$$

Depth-to-water measurements made in observation well c during the pumping and recovery periods of well 6-1E-2ac are given in Table

Table 12.--Water-level measurements in observation well a, 25 feet from pumped well 6-1E-2ac.

Time	Time since pumping started, in minutes, t	Depth to water, feet
9:20 a.m.	static water level	23.40
9:25	pumping started	
9:26	1	24.31
9:27	2	24.69
9:29	4	25.05
9:30	5	25.23
9:32	7	25.56
9:34	9	25.72
9:36	11	25.93
9:38	13	26.08
9:40	15	26.23
9:42	17	26.35
9:44	19	26.47
9:46	21	26.60
9:48	23	26.69
9:50	25	26.78
9:53	28	26.98
9:54	pumping stopped	
10:38		24.24
10:40	pumping started	
10:41	1	25.12
10:42	2	25.37
10:43	3	25.75
10:44	4	25.84
10:47	7	26.05
10:49	9	26.30
10:51	11	26.50
10:53	13	26.67
10:55	15	26.84
10:57	17	26.98
11:00	20	27.10
11:05	25	27.26

Table 12.--(Continued)

Time	Time since pumping started, in minutes, t	Depth to water, feet
11:10	30	26.48
11:15	35	26.68
11:20	40	26.86
11:25	45	26.99
11:30	50	28.13
11:35	55	28.24
11:40	60	28.32
11:45	65	28.42
11:50	70	28.50
11:55	75	28.58
12:00 noon	80	28.64
12:10	90	28.69
12:20	100	28.80
12:30	110	28.89
12:40	120	28.98
12:50	130	29.03
1:00	140	29.09
1:10	150	29.15

Fig. 14.--Depth-to-water level in observation well a plotted against time since pumping started in well 6-1E-2ac.

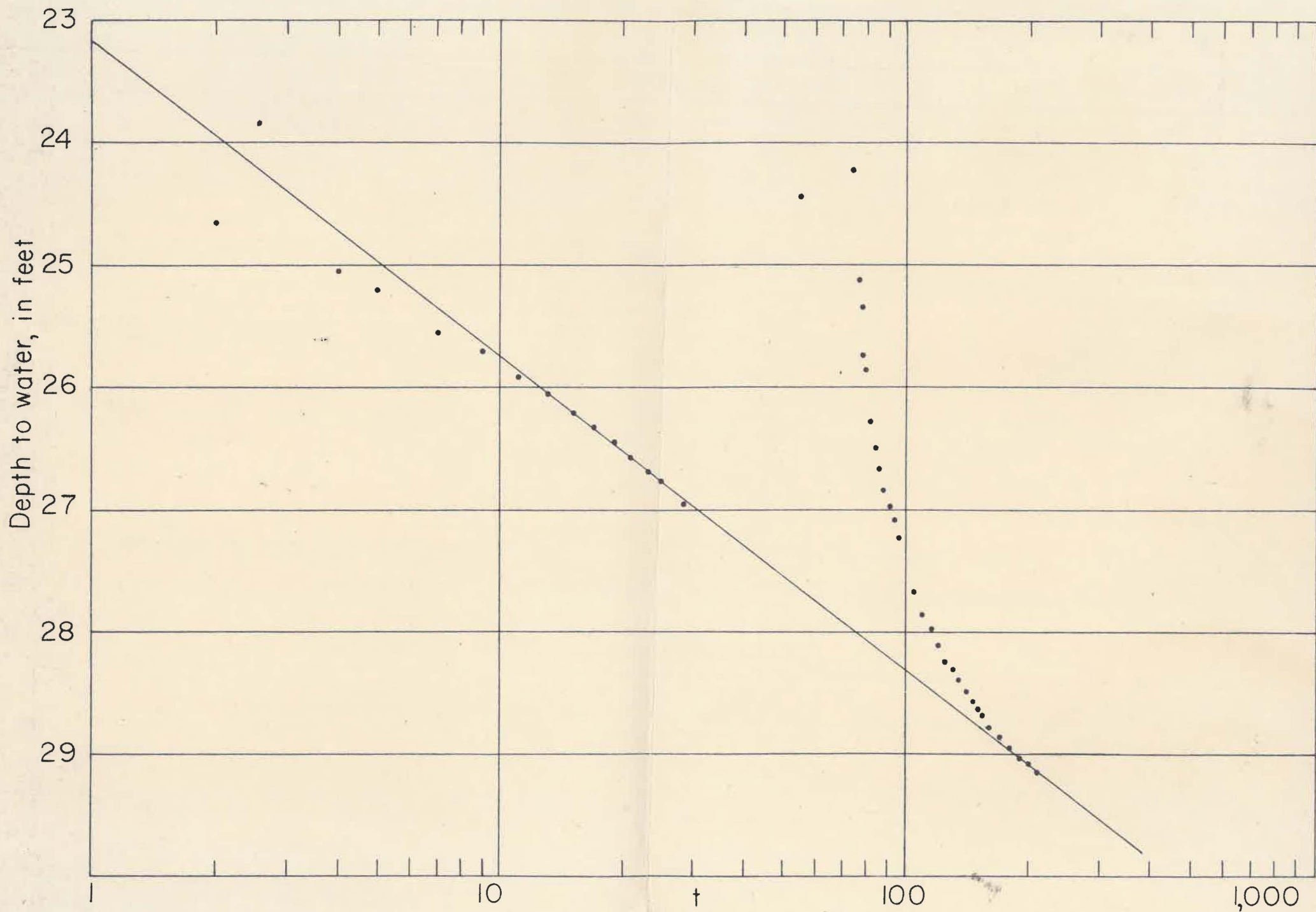


Fig. 14--Depth-to-water level in observation well a plotted against time since pumping started in well 6-1E-2ac.

Table 13.--Water-level measurements in observation well b, 50 feet from pumped well 6-1E-2ac.

<u>Time</u>	<u>Time since pumping started, in minutes, t</u>	<u>Depth to water, feet</u>
9:20 a.m.	static water level	23.34
9:25	pumping started	
9:26:30	1.5	26.63
9:27:30	2.5	27.12
9:28:15	3.25	27.32
9:29	4	27.48
9:30	5	27.61
9:31	6	27.71
9:32	7	27.82
9:33	8	27.90
9:34	9	27.98
9:35	10	28.04
9:36	11	28.11
9:38	13	28.19
9:40	15	28.34
9:42	17	28.43
9:44	19	28.51
9:46	21	28.59
9:48	23	28.67
9:50	25	28.75
9:53	28	28.84
9:54	pumping stopped	
10:38		24.00
10:40	pumping started	
10:41:30	1.5 76.5	27.48
10:43	3 78	27.98
10:44	4 79	28.22
10:45	5 80	28.36
10:46	6 81	28.47
10:48	8 83	28.64
10:50	10 85	28.79
10:52	12 87	28.90

Table 13.—(Continued)

Time	Time since pumping started, in minutes,		Depth to water, feet
	t	t	
10:55	15	90	29.04
10:58	18	93	29.15
11:00	20	95	29.23
11:05	25	100	29.38
11:10	30	105	29.51
11:15	35	110	29.66
11:20	40	115	29.77
11:25	45	120	29.85
11:30	50	125	29.95
11:40	60	135	30.11
11:50	70	145	30.23
12:00 noon	80	155	30.33
12:10	90	165	30.45
12:20	100	175	30.54
12:30	110	185	30.63
12:40	120	195	30.69
12:50	130	205	30.73
1:00	140	215	30.79

Fig. 15.--Depth-to-water level in observation well plotted against time since pumping started in well 6-1E-2ac.

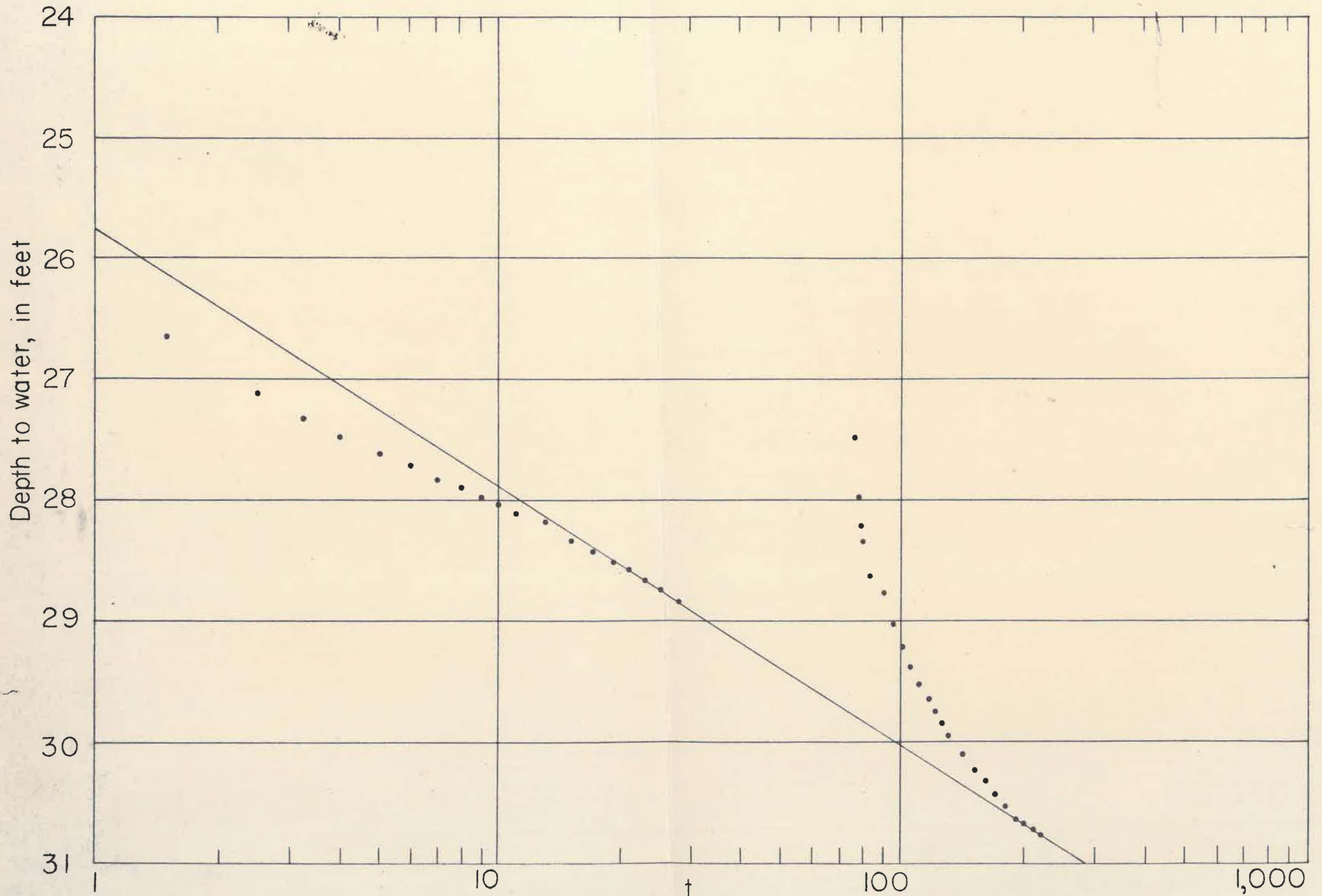


Fig. 15--Depth-to-water level in observation well b plotted against time since pumping started in well 6-1E-2ac.

14. The water-level measurements made in observation well c during pumping and recovery of well 6-1E-2ac are plotted on semilog paper, depth to water being plotted against time since pumping started, t, or stopped, t', in Figure 16. A line extended through the early data in the pumping period passes through the latest points and gives a value of 2.67 feet for Δs . Applying the modified nonequilibrium formula:

$$T = \frac{(264)(800)}{2.67} = 80,000 \text{ gpd per ft.}$$

$$S = \frac{(.3)(80,000)(1.8)}{(100^2)(1,440)} = 0.003$$

A line through the latest points on the recovery curve gives a value of 2.17 feet for Δs . Applying the Theis recovery formula:

$$T = \frac{(264)(800)}{2.17} = 97,000 \text{ gpd per ft.}$$

Summary of Information From Pumping Tests

Wells 5-2W-25cb and 5-2W-25cc are about a half mile apart and obtain water from Wisconsinan terrace deposits. The transmissibility from the test using well 5-2W-25cb was 535,000 gpd per foot. The value of T obtained from the test using well 5-2W-25cc ranged from 226,000 to 275,000 and averaged 245,000 gpd per foot. The results of the pumping tests using wells 5-2W-25cb and 5-2W-25cc are given in Table 15. The value of T for well 5-2W-25cb may be too high. The value was obtained from the recovery method only, whereas the values of T for well 5-2W-25cc were obtained by several methods using observation wells and the pumped well. Generally, the values obtained using the recovery method were not satisfactory because either the points did not plot in a straight line

Table 14.—Water-level measurements in observation well c, 100 feet from pumped well 6-1E-2ac

<u>Time</u>	<u>Time since pumping started, t, or stopped, t', in minutes</u>	<u>Depth to water, feet</u>
9:20 a.m.	static water level	23.53
9:25	pumping started	
9:26	1	23.57
9:27	2	23.64
9:28	3	23.73
9:29	4	23.81
9:30	5	23.88
9:31	6	23.97
9:32	7	24.04
9:33	8	24.12
9:34	9	24.18
9:35	10	24.24
9:36	11	24.31
9:37	12	24.38
9:38	13	24.44
9:39	14	24.50
9:40	15	24.56
9:42	17	24.66
9:44	19	24.78
9:46	21	24.90
9:48	23	25.00
9:50	25	25.09
9:53	28	25.21
9:54	pumping stopped	
10:38		24.37
10:40	pumping started	
10:41	1	24.39
10:42	2	24.45
10:43	3	24.52
10:44	4	24.58
10:45	5	24.66
10:46	6	24.73
10:47	7	24.79
10:48	8	24.86
10:49	9	24.93
10:50	10	24.99

Table 14.--(Continued)

Time	Time since pumping started, t, or stopped, t', in minutes	Depth to water, feet
10:52	12	25.10
10:54	14	25.21
10:56	16	25.23
10:58	18	25.42
11:00	20	25.51
11:03	23	25.63
11:06	26	25.76
11:09	29	25.86
11:12	32	26.00
11:15	35	26.09
11:20	40	26.25
11:25	45	26.38
11:30	50	26.52
11:35	55	26.62
11:40	60	26.71
11:45	65	26.94
11:50	70	26.95
11:55	75	27.02
12:00 noon	80	27.07
12:10	90	27.20
12:20	100	27.30
12:30	110	27.43
12:40	120	27.49
12:50	130	27.57
1:00	140	27.59
1:10	150	27.67
1:13	pumping stopped	
1:14	1	27.62
1:15	2	27.58
1:16	3	27.53
1:17	4	27.45
1:18	5	27.42
1:19	6	27.39
1:20	7	27.29
1:21	8	27.28
1:22	9	27.22

Table 14.--(Continued)

Time	Time since pumping started, t, or stopped, t', in minutes	Depth to water, feet
1:23	10	27.17
1:24	11	27.13
1:25	12	27.09
1:26	13	27.05
1:27	14	27.01
1:28	15	26.97
1:29	16	26.93
1:30	17	26.88
1:31	18	26.86
1:32	19	26.83
1:33	20	26.78
1:34	21	26.76
1:35	22	26.73
1:36	23	26.69
1:37	24	26.67
1:38	25	26.64
1:40	27	26.58
1:45	32	26.45
1:50	37	26.34
1:55	42	26.23
2:00	47	26.14
2:05	52	26.05
2:10	57	25.97
2:15	62	25.89
2:20	67	25.82
2:25	72	25.75
2:30	77	25.69
2:40	87	25.58
2:50	97	25.49
3:00	107	25.39
3:10	117	25.31
3:20	127	25.23
3:31	138	25.14
3:45	152	25.05
4:00	167	25.00
4:15	182	24.88

Fig. 16.--Depth-to-water level in observation well c during pumping and recovery of water level in well 6-1E-2ac plotted against t or t' (time since pumping started or stopped).

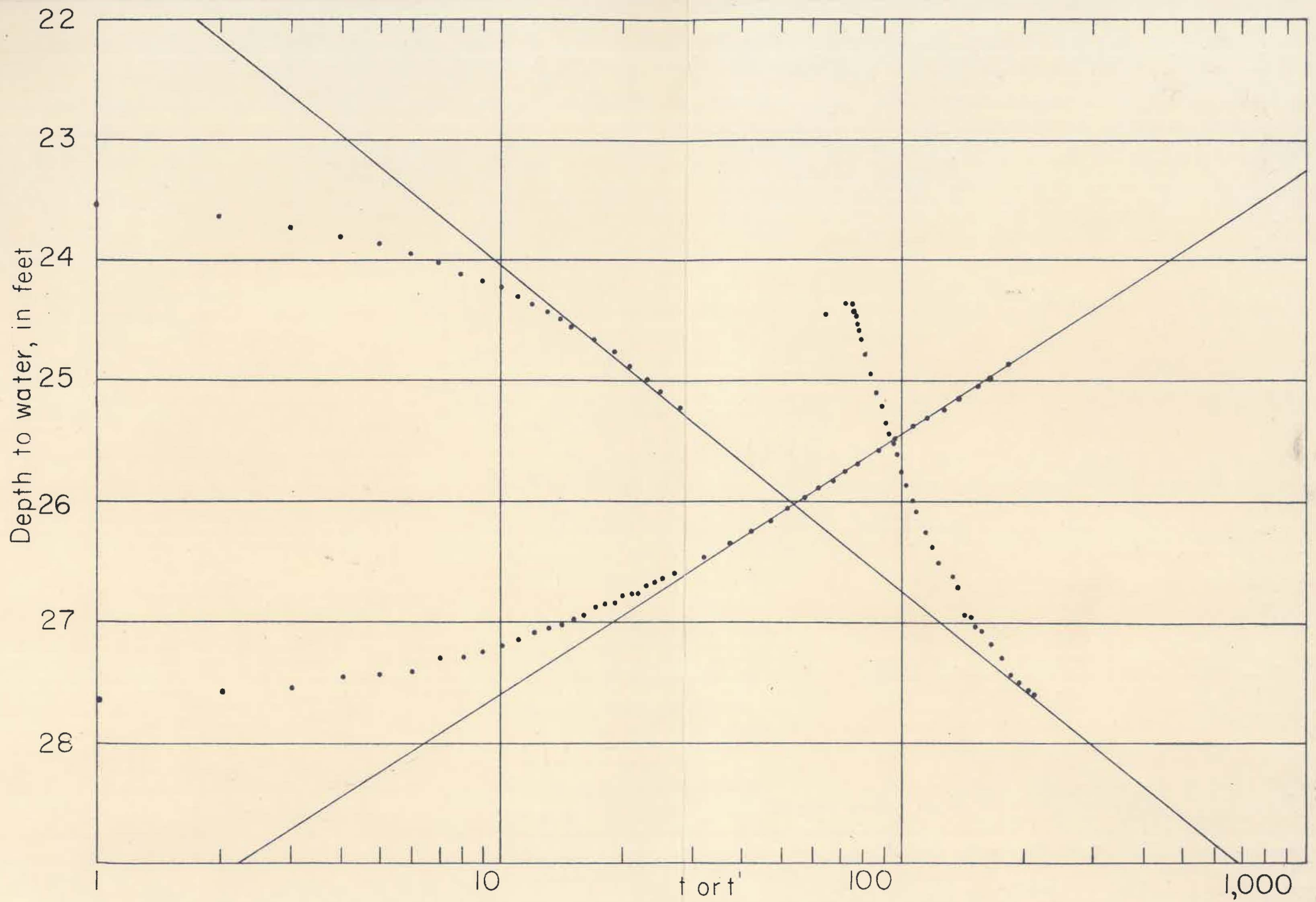


Fig. 16--Depth-to-water level in observation well c during pumping and recovery of water level in well 6-1E-2ac plotted against t or t' (time since pumping started or stopped)

Table 15.—Summary of pumping tests using wells 5-2W-25cb and 5-2W-25cc.

	5-2W-25cb	5-2W-25cc	(unit)
Transmissibility	535,000	226,000	gpd per ft.
Permeability	11,400	4,900	gpd per ft. ²
Saturated thickness	47	47	ft.
Maximum drawdown	12.27	10.75	ft.
Specific capacity	59	93	gpm per ft.
Discharge rate	730	1,000	gpm
Storage coefficient	—	0.03 to 0.07	

TABLE 16.—Analyses of water from typical wells and test holes in Republican Valley between Concordia and Clay Center
 Analyzed by H. A. Stoltenberg Dissolved constituents given in parts per million^a

Well No.	Location	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Hardness as CaCO ₃		
																	Total	Carbonate	Non-carbonate
5-1W-26ad2		158	Dakota formation	8-4-54	56	342	23	0.42	73	11	37	300	31	19	0.3	0.4	227	227	0
5-2W-30bc1		38-40	Alluvium	6-12-54	57	1,107	31	----	38	11	365	354	118	368	0.9	0.9	140	140	0
5-2W-30bc1		76-78	do	6-12-54	57	13,000	32	1.9	229	141	4,470	703	1,690	6,040	0.9	5.3	1,150	576	575
5-3W-15ab		120-122	Dakota formation	10-18-55	56	464	20	----	84	9.4	72	304	71	55	0.4	2.2	248	248	0
5-3W-15ab		340-342	do	10-18-55	56	32,000	----	----	412	353	11,300	870	3,510	16,050	----	----	2,750	714	1,700
5-3W-22bc		78	Alluvium	4-15-43	----	4,590	----	----	107	59	1,650	415	468	2,150	0.4	16	510	340	170
6-1W-3aa		36-41	do	6-15-54	57	392	25	0.93	85	11	43	344	37	21	0.3	0.9	257	257	0
6-1W-3aa		72-77	do	6-15-54	57	424	14	2.0	93	11	49	351	64	19	0.3	0.4	277	277	0
6-1W-10cc		87	Dakota formation	3-4-54	54	293	11	0.94	66	9.6	29	251	39	13	0.2	1.7	204	204	0
6-1E-2ba1		65	Terrace deposits	7-20-45	58	345	24	0.61	70	12	37	290	40	16	0.3	1.5	224	224	0
6-1E-2cc		56-61	Alluvium	6-17-54	58	373	28	3.8	88	13	29	345	26	18	0.3	0.9	273	273	0
6-1E-15da		56-61	Terrace deposits	6-18-54	57	367	28	0.88	75	11	42	303	33	28	0.3	0.8	232	232	0
6-2E-32cc		60-65	Alluvium	6-123-54	56	1,320	18	4.1	315	32	57	300	721	30	0.6	2.3	918	246	672
6-2E-33cd		56-61	Terrace deposits	6-24-54	----	525	23	1.2	122	19	30	317	160	13	0.4	1.7	382	260	122
7-2E-4dd		57	do	11-24-53	----	514	----	0.18	122	24	28	354	140	16	0.3	6.6	403	290	113
7-3E-29cd		76.6	Nolans limestone	10-26-54	55	574	18	0.10	107	44	34	407	121	34	0.4	16	448	334	114
8-3E-8db		58	Terrace deposits	1-31-48	----	655	30	3.5	144	24	29	445	125	15	0.4	5.3	458	365	93

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

or the values for T were too high. The results obtained from the observation-well data seem to be more nearly correct.

Well 6-1W-4bb is near the edge of the terrace deposits in the Republican Valley. The terrace deposits at this location are in part derived from Illinoian terrace deposits bordering the valley. The value of T obtained by the recovery method was 11,000 and values of T obtained by using observation wells ranged from 12,500 to 13,500. The storage coefficient ranged from 0.001 to 0.003, which indicates semiartesian conditions. The saturated thickness at the well is 43 feet, and hence, the permeability is 300 gpd per ft.². The drawdown was 40 feet while pumping at a rate of 540 gpm, and hence, the specific capacity was 13.5 gallons per foot.

Well 6-1E-2ac is near the edge of the Wisconsinan terrace deposits in the Republican Valley. The terrace deposits at this location contain more sand and gravel than in the area near well 6-1W-4bb, and logs of four test holes and wells in the area indicate that better wells should be developed in this area.

The value of T in the test using well 6-1E-2ac ranged from 80,000 to 98,000 gpd per ft. The recovery data on the pumped well did not plot in a straight line. Observation wells a and c responded to pumping much slower than well b and the values for T obtained on these wells were the lowest values obtained. The storage coefficient using well a was 0.02 and using wells b and c was 0.001 and 0.003 respectively. Although T obtained by the many tests has a wide range in value, the results are probably within the right order of magnitude. Using the value $T = 90,000$ and a saturated thickness of 48 feet, $P = 1,875$ gpd per ft.². The drawdown while pumping at a rate of 800 gpm was 16.75 feet

and the specific capacity was 47 gallons per foot.

The values for S calculated from the foregoing tests are not accurate values, but merely indicate hydrologic conditions near the wells during the pumping periods. Over long periods of pumping these values probably would change from semiartesian to water-table conditions.

Chemical Character of Ground Water

The chemical analyses of 17 water samples collected from test holes and representative wells (Table 21) in or near the Republican River valley between Concordia and Clay Center are given in Table 16. The chemical character of some of these samples also is shown graphically in Figure 17, and their suitability for use for irrigation is shown in Figure 18. Symbols used for well numbers in Figure 18 are given in Table 17. Several test holes were sampled at more than one depth, in which case the depth from which the sample was taken is indicated.

The salinity of the ground water in the Republican River valley to the northwest of the area covered by this report was discussed by Fishel (1948) as follows:

...Information obtained during the spring of 1943, however, showed that for certain areas in the Republican River valley the ground water was too salty for most purposes. Two wells which were constructed near the Cen. sec. 22, T. 5 S., R. 3 W. by the Layne-Western Company for the Prisoner of War Camp near Concordia yielded water having a chloride content of 6,835 parts per million. Subsequent test drilling by the Layne-Western Company for the prison camp and by the

Fig. 17.--Analyses of water from aquifers in the Republican River valley
between Concordia and Clay Center shown graphically.

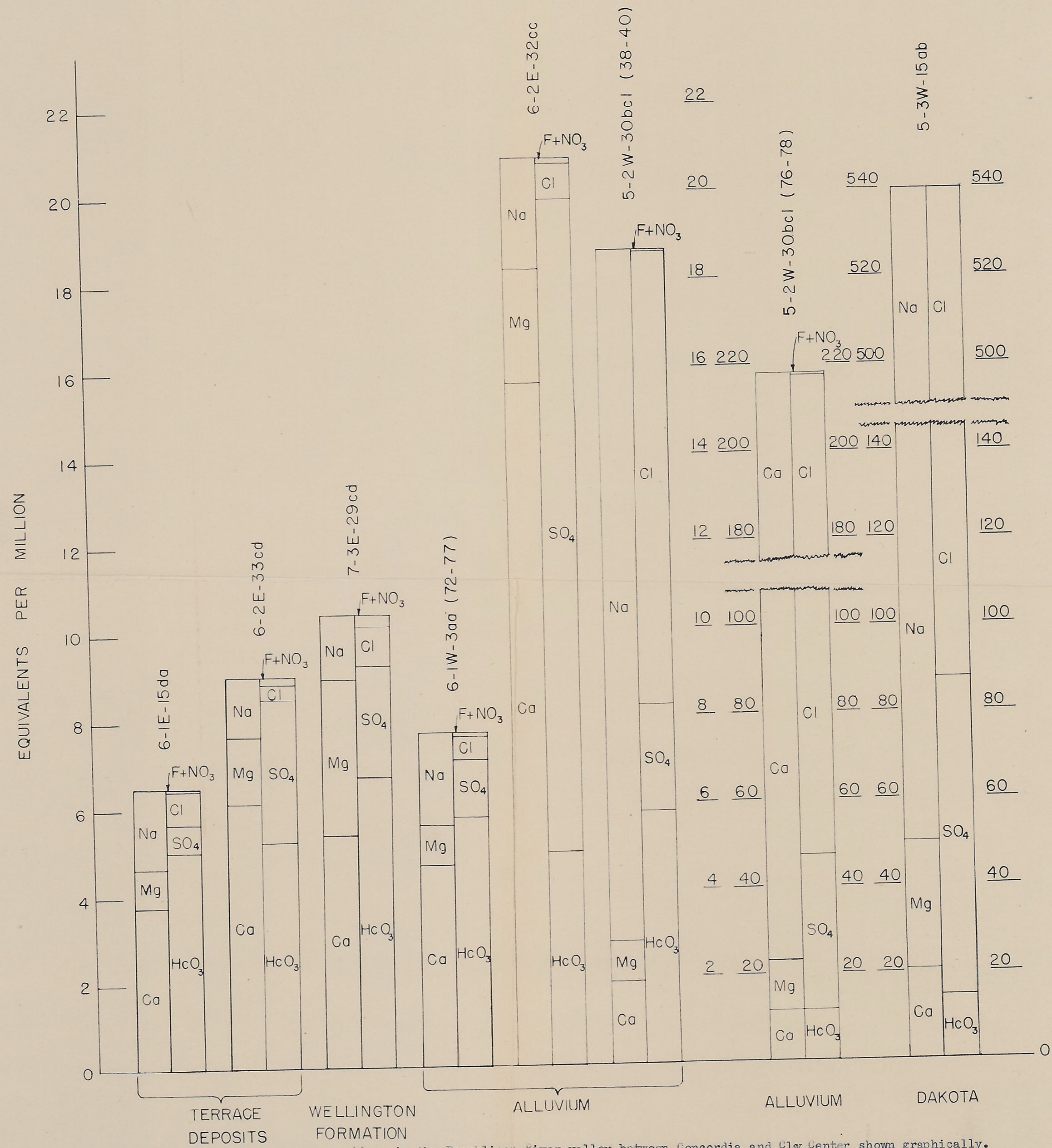


Fig. 17--Analyses of water from aquifers in the Republican River valley between Concordia and Uly Center shown graphically.

Fig. 18.--Classification of water for irrigation use in the Republican
River valley between Concordia and Clay Center.

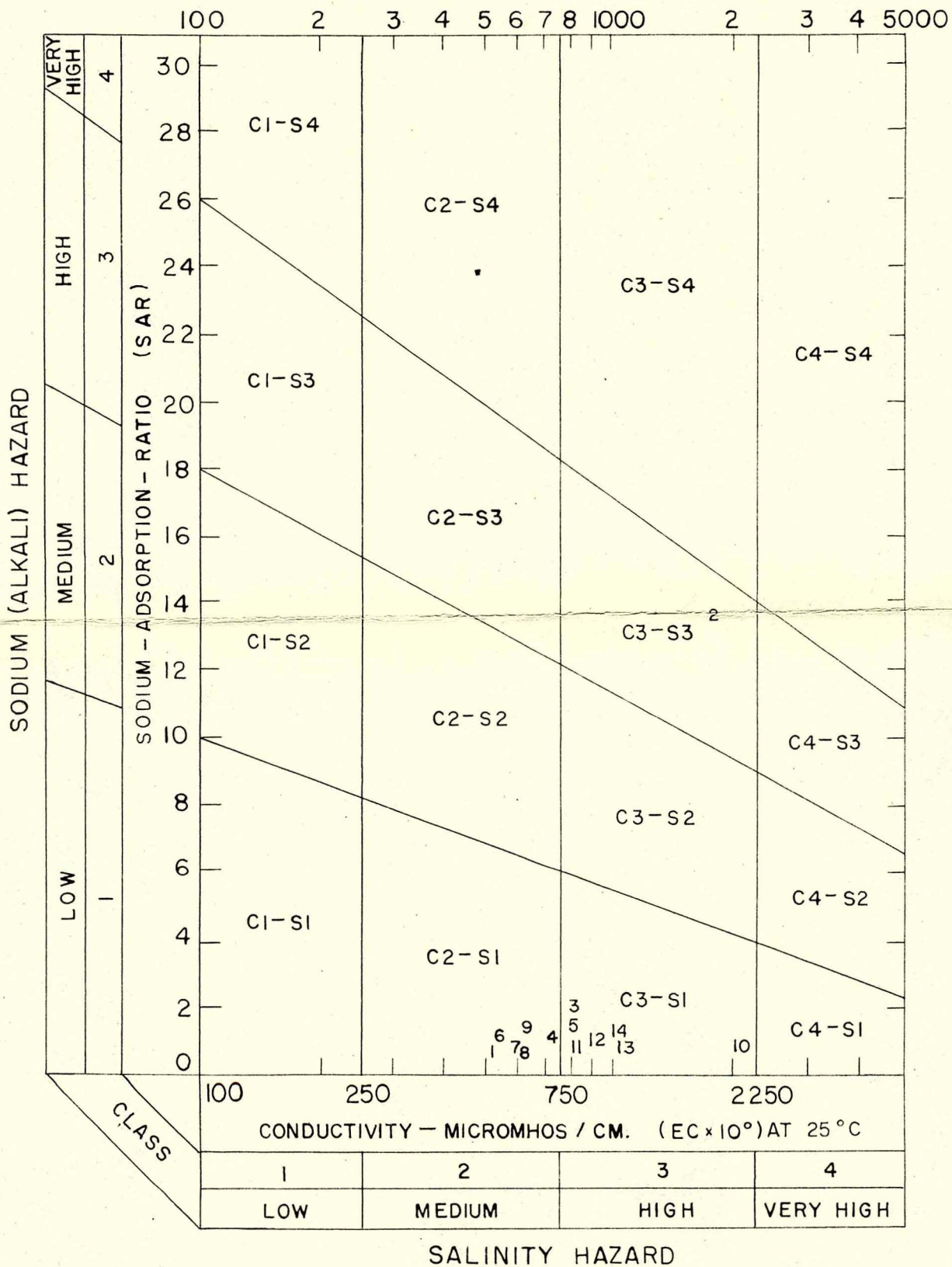


Fig. 18--Classification of water for irrigation use in the Republican River valley between Concordia and Clay Center.

Table 17.—Symbols used for well numbers in Figure 18.

Well Number	Number used on Fig. 18
5-1W-26ad2	1
5-2W-30bel (38-40)	2
5-3W-15ab (120-122)	3
6-1W-3aa (36-41)	4
6-1W-3aa (72-77)	5
6-1W-10cc	6
6-1E-2bal	7
6-1E-2cc	8
6-1E-15da	9
6-2E-32cc	10
6-2E-33cd	11
7-2E-4dd	12
7-3E-29cd	13
8-3E-8db	14

Geological Survey showed that there is quite an extensive area where the water in the alluvium is contaminated by salt water.

In the outcrop area of the Dakota formation in northern Cloud County and southeastern Republic County the water is fresh. However, to the northwest in Republic and Jewell Counties, where the Dakota formation is overlain by several hundred feet of other Cretaceous rocks, the water in the Dakota formation is too salty for domestic use. The alluvium in the valley near Concordia has a known maximum thickness of about 120 feet, and the deepest part of the channel seemingly has been cut into a salty lens of the Dakota formation and as the water in the Dakota is under a greater head than the water in the overlying alluvium the salty water is moving upward into the alluvium. At the same time the alluvium is also receiving fresh water along its edges from shallower beds of the Dakota formation and from rainfall infiltration. The resultant salinity of the water varies with depth and its position in the alluvium. It depends on the presence and extent of clay lenses in the alluvium and on the relative amounts of water derived from the various sources. ...The area of the

greatest contamination as determined by the test holes is in secs. 21 and 22, T. 5 S., R. 3 W. A sample of water from depths of 77 to 87 feet in a test hole near the center of the west boundary of sec. 22 had 13,750 parts per million of chloride. The chloride content of the water from 35 to 45 feet was 167 parts per million. The highest chloride concentration occurs at the base of the alluvium and in the deepest part of the bedrock channel and it decreases with height above the base of the alluvium unless altered by impervious clay lenses.

The chloride concentration of the water in the alluvium decreases both upstream and downstream from secs. 21 and 22. The upstream boundary of the unpotable water is about at the Cloud-Republic County line. The chloride content of the water decreases from 3,760 parts per million in test hole 94 (NW $\frac{1}{4}$ sec. 20, T. 5 S., R. 3 W.) to 1,900 in test hole 93 (NW $\frac{1}{4}$ sec. 19, T. 5 S., R. 3 W.) and 1,240 in test hole 112 (SE $\frac{1}{4}$ sec. 15, T. 5 S., R. 4 W.). The Dakota formation dips below the impervious Graneros shale near the County line and from there to the Nebraska line there have been no reports of salty well water from the alluvium.

The logs of the wells and test holes in sec. 22, T. 5 S., R. 3 W. indicate no impervious clay lenses between the water table and the top of the Dakota formation. All other test holes penetrated at least one clay lens and it was below the bottom clay lens that the waters of the greatest salinity occurred. A well at the Prisoner of War Camp (SE NW NW sec. 28, T. 5 S., R. 3 W.) was drilled down to a clay lens which apparently extends over a large area. The well yields water having a chloride content of less than 100 parts per million. Test hole 101, which is about 400 feet from the above well, yielded water from below the clay lens that contained 5,040 parts per million of chloride...The chloride content in parts per million of water from test holes is given in Table 19 (Table 18 in this report). ...The salinity of water from a well in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 5 S., R. 3 W. at different depths is given in Table 20 (Table 19 in this report).

The evaluation of water with regard to its suitability for irrigation is based on methods outlined in Agriculture Handbook Number 60, U. S. Department of Agriculture (L. A. Richards, and others 1954). When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined by graphically plotting these values on the diagram shown in Figure 18. Low-sodium water

Table 18.—Locations of test holes in the Republican River valley in Cloud County, Kansas, and the chloride content of the water in parts per million. (Table 19 of Fishel, 1948)

Location	Depth, feet	Chloride content, ppm
SW cor. NW sec. 22, T. 5 S., R. 3 W.	35-45	167
	40-50	388
	50-60	1,160
	77-87	13,750
Near cen. SE sec. 21, T. 5 S., R. 3 W.	37-47	48
	53-63	89
	74-84	2,880
SE NE NW sec. 28, T. 5 S., R. 3 W.	35-45	26
	56-66	74
	76-86	630
SW NW NW sec. 28, T. 5 S., R. 3 W.	40-50	27
	61-71	880
NW SW SE sec. 22, T. 5 S., R. 3 W.	25-35	331
	55-65	6,350
SW cor. NW NW sec. 29, T. 5 S., R. 3 W.	51-61	45
SE NW NW sec. 28, T. 5 S., R. 3 W.	41-51	33
SW cor. sec. 21, T. 5 S., R. 3 W.	50-60	34
NW cor. SW sec. 21, T. 5 S., R. 3 W.	35-45	25
	68-78	168
SE SW SW sec. 15, T. 5 S., R. 3 W.	57-67	55
NE cor. sec. 34, T. 5 S., R. 1 W.	55-60	212
	95-100	450
SE SE NE sec. 34, T. 5 S., R. 1 W.	78-80.5	(a)
NW cor. SE sec. 19, T. 5 S., R. 2 W.	66-71	2,450
SE cor. NE sec. 26, T. 5 S., R. 2 W.	75-80	210
	94-99	3,450

Table 18.--(Continued)

Location	Depth, feet	Chloride content, ppm
NE cor. SE sec. 29, T. 5 S., R. 2 W.	37-42	23
	60-65	1,300
	67-72	1,340
	75-80	2,650
NW cor. sec. 19, T. 5 S., R. 3 W.	65-70	58
	75-80	413
	102-107	3,760
SE cor. sec. 19, T. 5 S., R. 3 W.	49-52	21
	62-67	26
	110-115	10,680
SW NE NW sec. 28, T. 5 S., R. 3 W. (680 feet east of Concordia Prison Camp Well 3)	31-36	21
	65-70	86
	98-103	4,360
SE NW NW sec. 28, T. 5 S., R. 3 W. (380 feet east of Concordia Prison Camp Well 3)	35-42	20
	47-52	30
	69-74	228
	102-107	5,040
SE NW NW sec. 28, T. 5 S., R. 3 W. (100 feet south of Concordia Prison Camp Well 3)	15-20	14
	35-40	22
	46-51	227
	74-76	1,400
NW NW NW sec. 28, T. 5 S., R. 3 W.	45-50	22
SW NE NE sec. 29, T. 5 S., R. 3 W.	89-94	3,500
SW SE sec. 33, T. 4 S., R. 4 W.	119-124	(a)
NW cor. NE sec. 14, T. 5 S., R. 4 W.	51-56	47
NW cor. sec. 13, T. 5 S., R. 4 W.	34-39	25
	39-44	43
SE cor. sec. 15, T. 5 S., R. 4 W.	60-65	450
	112-117	1,240

(a) Water not salty to taste

Table 19.--Relation of the salinity of the water to depth in well 253 in the SE¹ NW¹ sec. 22, T. 2 S., R. 3 W., at the Prisoner of War Camp. (Table 20 of Fishel, 1948)

Depth, feet	Chloride content, ppm
19-29	128
35-45	370
45-55	470
55-65	1,525
65-75	4,970
68-78	6,835

(S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils, especially under low-leaching conditions. This water may be safely used on coarse-textured or organic soils with good permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management, such as good drainage, high leaching, and additions of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops with moderate salt tolerances, such as potatoes, corn, wheat, oats, and alfalfa, can be irrigated with C2 water without special practices. High-salinity water (C3) cannot be used on soils with restricted drainage. Very high salinity water (C4) can be used only on certain crops and then only when special practices are followed.

Water samples from several wells were of such poor quality that the sodium-adsorption-ratio (SAR) and the electrical conductivity could not be plotted on the diagram in Figure 18. The sample from another well (5-2-30bc1, 38-40 feet) was of doubtful suitability for irrigation use (Table 17 and Fig. 18). Water from seven wells is in the C3-S1 part of the diagram and should be used only on soils having good drainage. Water from six wells is in the C2-S1 part of the diagram

and its use would require very few special practices.

Chemical Character in Relation to Water-bearing Formations

Wellington Formation and Nolans Limestone

Although only one analysis of water from the Wellington formation and Nolans limestone is given in this report, it is known that these formations and the underlying older rocks yield water that is hard, but suitable for most uses. Water from the Permian formations in the area of this report generally is much higher in sulfate than water from the Dakota formation or alluvial deposits. The Permian formations do not yield enough water to be important as aquifers, nor do they have any noticeable effect upon the quality of the water in the alluvial deposits that may overlies them.

Dakota Formation

In most of the area included in this report, water in the Dakota formation is of good quality. In the extreme western part of the area, and west of the area included in this report the water in the lower part of the Dakota formation is salty. The increase in chloride content of water in the Dakota formation at increased depth is illustrated by the analyses of two samples from test hole 5-3W-15ab. A sample taken from a depth of 120 to 122 feet contained only 55 parts per million of chloride, whereas a sample from 340 to 342 feet contained 16,050 parts per million of chloride. Water in the lower part of the Dakota formation near Concordia is under some artesian head and has contaminated the water in the lower part of the alluvial fill of the Republican River valley.

Meade Formation

In the western part of the area covered by this report, the

water in the Meade formation is highly mineralized by contamination from the underlying Dakota formation. In the area downstream from Ames, the Meade formation is not separated from the overlying gravel beds by a clay layer, and the salty water is diluted by fresh water to such an extent that all the water in the alluvial fill of the valley is of good quality.

Wisconsinan Terraces and Recent Alluvium

The quality of the water in the Wisconsinan terraces and the Recent alluvium is the same and water from these deposits generally is of good quality. In the western part of the area covered by this report, there is considerable mixing of high chloride water from the Kansan gravel (Meade formation) with the water in the younger deposits so that the water in the Wisconsinan and Recent deposits is not as good quality as it is further east.

Availability of Water for Irrigation

In the fall of 1954, only 6 irrigation wells were in operation in the area of the Republican River valley considered in this report. These wells had a total capacity of 4,300 gpm or 19 acre-feet per day. The annual use of water for irrigation was about 570 acre-feet. The drought, which continued through 1955, caused considerable interest in irrigation, and by October 1955, 43 irrigation wells having capacities ranging from 300 to 2,000 gpm and a total capacity of 41,380 gpm (183 acre-feet per day or about 5,500 acre-feet per year) were in operation in the area. Most operators in the area apply about 18 inches of water per year to about 80 acres per well. A total of about 3,600 acres are being irrigated.

During the preparation of this report a water-table map (Pl. 5)

and a map of the bedrock surface (Pl. 2) of the valley area were made, and from these maps a saturated thickness map (Pl. 4) was made. From the saturated thickness map the total volume of saturated material was calculated for each township in the area, and applying a specific yield of 20 per cent, the volume of water in storage was calculated. The volume of saturated material and the volume of water in storage (Table 20) are equal to the quantity that would be pumped in 133 years at the present rate of pumping if the water-bearing materials received no recharge. The water-table contour map (Pl. 5) indicates that water moves into the valley area from the upland areas bordering the valley, and although the amount was not estimated, the quantity thus contributed is considerable. Water also moves into the area as surface flow in the Republican River, and should the water level in the valley be lowered, much of the low-water stream flow would become recharge to the aquifer. Stream-flow records since 1946 at Concordia indicate that the lowest flow in that period was 40 second-feet. Completion of reservoirs upstream in recent years has made it possible to maintain a minimum flow of the stream. There is no immediate danger of depletion in the valley area at the present rate of withdrawal. However, if future development continues at an accelerated rate as it has in the last year, the water table will be lowered considerably and the flow of the stream will be greatly diminished during the growing season, but the water levels should recover after the growing season ends. Probably the greatest danger in heavy development of irrigation is in the western part of the area

Table 20.—Volume of saturated material in the Republican River valley area and the volume of water in storage available for pumping based on a specific yield of 20 per cent.

<u>Township</u>	<u>Volume of water-bearing materials (acre-ft.)</u>	<u>Volume of water in storage (acre-ft.)</u>
T. 5 S., R. 1 W.	637,000	127,400
T. 6 S., R. 1 W.	202,000	40,400
T. 5 S., R. 2 W.	517,000	103,400
T. 5 S., R. 3 W.	760,000	152,000
T. 6 S., R. 1 E.	560,000	112,000
T. 6 S., R. 2 E.	243,000	48,600
T. 7 S., R. 2 E.	505,000	101,000
T. 7 S., R. 3 E.	7,000	1,000
T. 8 S., R. 2 E.	99,000	19,000
T. 8 S., R. 3 E.	127,000	25,400
<u>TOTAL</u>	<u>3,657,000</u>	<u>731,400</u>

where the highly saline waters are confined in the lower part of the valley deposits. Any appreciable lowering of the water table may upset the hydrologic balance between the saline and fresh waters and cause the saline waters to contaminate the fresh water zone.

Records of Wells and Augered and Drilled Test Holes

Information pertaining to 235 wells and augered and drilled test holes in the Republican River valley is given in Table 21. Wells and test holes are numbered in accordance with the United States Bureau of Land Management's system of land subdivision. The first numeral of a well number indicates the township, the second the range, and the third the section in which the well is located. Lowercase letters after the section number indicate the well location within the section: The first letter denotes the 160-acre tract and the second the 40-acre tract. The letters a, b, c, and d are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. To distinguish between two or more wells within the same 40-acre tract, consecutive numbers beginning with 1 are added as a suffix to each well number. For the wells east of the principal meridian the range number is followed by E and for the ones west of the meridian the range number is followed by W. Well 5-1W-19cc2 is the second well described in the SW $\frac{1}{4}$ SW $\frac{1}{4}$, sec. 19, T. 5 S., R. 1 W.

All information classed as reported was obtained from the owner, tenant, or driller. Reported depths of wells are given in feet; measured depths are in feet and tenths. Reported depths-to-water level are given in feet; measured depths-to-water level are given in feet, tenths, and hundredths.

Logs of Test Holes

On the pages that follow are the logs of 48 test holes in the area covered by this report. Forty-five of the logs are sample logs; three are driller's logs furnished by water-well drillers in the area.

5-17-11ec. Sample log of test hole in the SW cor. sec. 11, T. 5 S., R. 1 W.,
on north edge of road about 50 feet east of road intersection.
Drilled June 17, 1954. Surface altitude 1334.0 feet; depth-to-water
level June 25, 1954, 35.60 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Illinoian Stage		
Sanborn formation - Crete sand and gravel and Loveland silt members		
Silt, black	2	2
Clay, sandy, tan to gray	3	5
Clay, sandy, red-brown	10	15
Clay, sandy and silty, tan to brown	15	30
Gravel, fine to medium, chiefly limestone and sandstone, contains some clay	4	34
Clay, sandy, tan to brown	6	40
Clay, very sandy, red-brown; interbedded with fine to medium sand and some ironstone gravel	16	56
Clay, sandy, light-gray to white; contains a few thin sand stringers	24	80
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, tan and blue-gray	6	86

5-1W-14cc. Sample log of test hole in the SW cor. sec. 14, T. 2 S., R. 1 W.,
on east road shoulder in line with north shoulder of road to west.
Augered June 17, 1954. Surface altitude 1,301.7 feet; depth-to-water
level 18.30 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, light-brown	3	4
Silt, dark-brown	7	11
Silt, clayey, brown	5	16
Silt, light-brown; contains fine sand	9	25

5-1W-22dd. Sample log of test hole in the SE¹ SE¹ sec. 22, T. 5 S., R. 1 W.,
on north edge of road, 375 feet west of road intersection. Drilled
June 16, 1954. Surface altitude 1,334.0 feet; depth-to-water level
35.80 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Peoria silt member		
Clay and silt, black	2	2
Clay and silt, greenish-tan	3.5	5.5
Clay and silt, greenish-tan; mottled with brown	7.5	13
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Silt, blocky, dark-brown to black, (Sangamon soil)	2	15
Silt, clayey, sandy, red-tan	7	22
Sand, fine; contains some clay	1	23
Silt and clay, sandy, red-tan	15	38
Sand, fine, sand red-tan clay	3	41
Clay, blue-gray; contains many shell fragments	20	61
Sand, fine; contains many shell fragments	16	77
Sand, fine to medium, tan	3	80
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, tan to gray	3	83

5-1W-26cb. Sample log of test hole in the NW cor. SW¹ sec. 26, T. 5 S., R. 1 W.,
100 feet east of state highway No. 2, on the south side of the first street
north of the Republican River bridge in Clyde. Drilled June 16, 1954.
Surface altitude 1,279.4 feet; depth to water 7.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	2	2
Sand, fine	9	11
Sand, medium to coarse, and fine to medium arkosic gravel	9	20
Gravel, fine to medium, and coarse arkosic sand	8	28
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Clay, tan and gray	17	45
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, sandy, blue-gray; contains some lignite and brown sandstone	15	60

5-17-34aa. Sample log of test hole in NE¹NE¹ sec. 34, T. 5 S., R. 1 W.,

2 feet south of center of road and 12 feet west of stop sign.

Surface altitude 1,286.0 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, soft, gray; contains much sand and many caliche nodules	4	7
Gravel, fine; and coarse to fine sand	3	10
Gravel, medium to fine, and coarse to fine sand	13	23
Clay, blue gray; contains fine sand	.5	23.5
Gravel and sand, coarse to fine, green	6.5	30
Gravel, medium to fine, and coarse to fine sand	10	40
Gravel, coarse to fine, and coarse to medium sand	10	50
Gravel, fine, arkosic, and coarse sand	13	63
Kansan Stage		
Meade formation		
Silt, soft, buff; grades downward to gray, sandy, silt	7	70
Silt, soft, buff; contains coarse lime- stone and sandstone gravel	20	90
Silt, clayey, dark gray	5	95

5-1W-34aa (Continued)

	Thickness, feet	Depth, feet
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, soft, white; contains some pyrite	5	100

5-1W-35bc. Sample log of test hole in SE¹ NW¹ sec. 35, T. 2 S., R. 1 W.,
.45 mile south of section line and 9 feet east of center of road.
Surface altitude 1,281.0 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, soft, light yellow-gray; contains sand	6	8
Gravel and sand, coarse to fine, green	22	30
Gravel, medium to fine, and coarse to fine sand	10	40
Gravel, fine, and coarse to fine sand	10	50
Gravel and sand, coarse to fine, brown and green	10	60
Gravel, fine, and coarse to fine sand, arkosic, brown	6	66
Kansan Stage		
Meads formation		
Silt, soft, buff; contains some sand	2	68
Silt, clayey, gray; contains some sand	10	78
Gravel, medium to fine, limestone and sandstone	2.5	80.5
Silt, clayey, gray	2.5	83
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, soft, white; contains pyrite	17	100

5-2#-19cb. Sample log of test hole in NW¹ SW¹ sec. 19, T. 5 S., R. 2 W.,
 0.6 mile south of section line and 30 feet south of curve in road
 to gravel pit. Drilled 1944.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, dark and light gray; contains fine sand	6	7
Gravel, medium to fine, and coarse to medium sand	3	10
Gravel, medium to fine, and coarse to fine sand, silty	20	30
Gravel, fine, and coarse to fine sand, brown	10	40
Gravel, medium to fine, and coarse to fine sand, brown	31	71
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, gray, yellow and pink, sandy	4	75

5-2W-26aa2. Sample log of test hole in NE¹ NE¹ sec. 26, T. 5 S., R. 2 W.,
0.25 mile south of section line and 33 feet west of center of road.
Drilled 1944. Surface altitude 1,306.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Soil, gray black; contains fine sand	3	3
Silt, yellow gray, contains fine sand	3.5	6.5
Silt, gray black, sandy	.5	7
Silt, soft, yellow gray, and fine to medium sand	9.5	16.5
Gravel, fine, and coarse to fine sand	8.5	25
Gravel, medium to fine, coarse to fine sand and soft gray silt	15	40
Gravel and sand, coarse to fine	10	50
Gravel, medium to fine, and coarse to fine sand	10	60
Gravel, medium to fine, coarse to fine sand and soft gray silt	10	70
Gravel, medium to fine and coarse to fine sand	9	79
Silt, soft, buff	4	83
Silt, soft, gray and black; contains fine sand	3	86
Limestone gravel, coarse to fine, and coarse to medium sand	11.5	97.5
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, light gray; contains some sand and sandstone	12.5	110

5-2W-28cb. Sample log of test hole in NW¹ SW¹ sec. 28, T. 2 S., R. 2 W.,
.55 mile south of section line and 9 feet east of center of road.
Drilled 1944.

	Thickness, feet	Depth, feet
QUATERNARY—PLEISTOCENE		
Recent Stage		
Alluvium		
Soil, silty, dark gray; contains some sand	3	3
Silt, clayey, yellow gray; contains some sand	2	5
Sand, coarse to fine and some fine gravel	5	10
Gravel, medium to fine and coarse to fine sand	10	20
Gravel, and sand, coarse to fine	10	30
Gravel, medium to fine, and coarse to fine sand	10	40
Gravel and sand, coarse to fine	10	50
Gravel, medium to fine and coarse to fine sand	6.5	56.5
Silt, soft, light green; contains some fine sand	.5	57
Gravel, arkosic, and sand, coarse to fine	8	65
Kansan Stage		
Meade formation		
Silt, soft, buff and green	3	68
Limestone and sandstone gravel, coarse to fine	4	72
Silt, soft, buff; contains very fine sand	3	75

5-24-28cb (Continued)

	Thickness, feet	Depth, feet
Limestone and sandstone gravel, coarse to fine	4	79
Silt, soft, buff and blue gray; contains fine sand	10	89
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, gray and gray white; contains sand, and sandstone, soft, light gray	17	106

5-2W-30bel. Sample log of test hole in the SW cor. NW $\frac{1}{4}$ sec. 30, T. 5 S., R. 2 W.,
15 feet east of the center of road, 100 feet north of railroad track.
Drilled June 11, 1954. Surface altitude 1,326.7 feet; depth-to-water
level 8.00 feet. June 12, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, sandy, brown	8	8
Sand, medium and fine; contains some coarse gravel	8	16
Sand, coarse and fine; contains some coarse gravel	8	24
Sand, fine to coarse, arkosic	6	30
Gravel, fine to medium, and fine to coarse sand	18	48
Sand, medium to coarse, arkosic	6	54
Sand, coarse, and fine to medium, arkosic gravel	6	60
Kansan Stage		
Meade formation		
Gravel, fine to medium, limestone and sandstone	6	66
Gravel, fine to medium, limestone and sandstone; contains some light-gray clay	9	75
Clay, light blue--gray	5	80
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone and ironstone, hard, brown	16	96

5-3W-8aa. Sample log of test hole near the NE cor. sec. 8., T. 5 S., R. 3 W.,
on north edge of school yard, 20 feet north of the NW corner of
school house. Drilled June 10, 1954. Surface altitude 1,423.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Peoria silt member		
Silt, black	2	2
Silt, greenish-tan; contains some caliche	7	9
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Silt, black, drilled hard (Sangamon soil)	2	11
Silt, sandy, tan to buff	46	57
Gravel, fine to medium, sandstone, and ironstone	3	60
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, bright-yellow	2	62
Clay, blue-gray	6	68
Sandstone, tan to brown	2	70

5-3W-15ab. Sample log of test hole in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, T. 5 S., R. 3 W.,
600 feet south of the NW corner of NE $\frac{1}{4}$ sec. 15. Drilled Sept. 27, 1955.
Surface altitude 1,428.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Silt, sandy, gray	3	3
Silt, light-brown	11	14
Clay, brown	4	18
Silt, sandy, buff	19	37
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, fine-grained, limonite streaks	57	94
Clay, gray to yellow	2	96
Sandstone, yellow and gray; contains some clay streaks	29	125
Clay, dark-gray	3	128
Sandstone, iron-cemented, yellow	4	132
Clay, red and gray; contains several thin streaks of lignite and sand- stone	58	190
Sandstone, lime cemented, white	10	200
Clay, pink and gray; contains a lignite streak at 246 $\frac{1}{2}$	94	294
Sandstone; contains pyrite	16	310
Clay, gray; contains thin sandstone streaks	20	330 70
Sandstone, gray; contains some clay; drilled hard	40	3

5-SW-15ab (Continued)

	Thickness, feet	Depth, feet
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, hard, blue-gray	12	382
Limestone, very hard, white	2	384

5-3W-15bd. Driller's log of test hole in SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 5 S., R. 3 W.,
2,880 feet north and 2,140 feet east of SW cor. of section. Drilled
by Air-Mads Well Company. Surface altitude 1,413.3 feet.

	Thickness, feet	Depth, feet
Clay, yellow	11	11
Clay, brown	8.5	19.5
Clay, dark blue	9.5	29
Clay, yellow, contains white streaks of soapstone	23.5	52.5
Sand, very fine	0.5	53
Clay, hard, blue	3	56
Sand, fine, tight	13	69
Shale, blue	3	72

5-3W-16bb. Sample log of test hole in the NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 5 S., R. 1 W.,

0.15 mile south of crossroads. Surface altitude 1,411.3 feet; depth-
to-water level 54.20 feet.

	Thickness, feet	Depth, feet
Road fill	.5	.5
QUATERNARY--PLEISTOCENE		
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Soil, silty, brown	0.5	1
Silt, tan and gray	62	63
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, and fragments of yellow-buff silt stone	4	67
Clay, light-gray; contains some limonite	3	70

5-35-16cb. Sample log of test hole in the NE¹ SW¹ sec. 16, T. 2 S., R. 3 E.,

0.35 mile north of SW cor. of section. Surface altitude 1,382.2 feet.

	Thickness, feet	Depth, feet
Road fill	.5	.5
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Soil, silty	4.5	5
Silt, tan and brown	25	30
Clay, sandy; contains some gravel	13	43
Gravel, medium, and coarse sand, brown	16	59
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, mottled red, gray, and yellow	6	65

S-38-17aa. Sample log of test hole near the NE cor. sec. 17, T. 5 S., R. 3 W.,
on south side of road, 300 feet west of section corner. Drilled June 10,
1954. Surface altitude 1,410.9 feet; depth-to-water level 83.70 feet
June 14, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sauborn formation--Peoria silt member		
Silt, black	2	2
Silt, greenish-gray	6	8
Illinoian Stage		
Sauborn formation--Crete sand and gravel and Loveland silt members		
Silt, blacky, black (Sangamon soil)	2	10
Silt and clay, red-brown	10	20
Silt and clay, buff to tan	26	46
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, red and tan	14	60
Clay, light-gray; contains some sandstone in lower part	10	70

5-37-20aa. Sample log of test hole in the NE cor. sec. 20, T. 5 S., R. 3 W.,

78 feet south and 7 feet west of crossroads. Surface altitude

1,368.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLISTOCENE		
Recent Stage		
Alluvium		
Soil, silty, black and brown	2	2
Silt, tan and brown	20	22
Sand, medium; contains some brown gravel	8	30
Gravel, fine, and coarse brown sand	10	40
Gravel, medium, and coarse brown sand	10	50
Sand, coarse, and fine gravel, brown	40	90
Kansan Stage		
Keade formation		
Sand, coarse, and fine gravel; contains some yellow-brown clay	3	93
Gravel, medium, limestone and sandstone, and coarse sand and yellow clay	7	100
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, very fine, sandy, yellow	10	110

5-57-21bb. Sample log of test hole in the NW 1/4 sec. 21, T. 5 S., R. 3 W.,
.15 mile south of intersection and 6 feet east of center of road.
Surface altitude 1,335.1 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Soil, silty, brown and black	2	5
Clay, silty, gray	5	10
Sand, silty, fine, and fine brown gravel	10	20
Gravel, medium, and coarse sand, gray-green	20	40
Gravel, medium, arkosic, and coarse sand, yellow, brown, and gray	40	80
Kansan Stage		
Beards formation		
Gravel, limestones and sandstone, and much clay	12	92
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, gray; contains lignite	8	100

5-34-21ob. Sample log of test hole in the NW cor. SW $\frac{1}{4}$ sec. 21, T. 5 S., R. 3 W.,
100 feet south of east-west road and 15 feet east of center of
north-south road. Surface altitude 1,352.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Soil	3	3
Sand, coarse to fine, and some medium to fine brown gravel	12	15
Gravel, fine, and coarse to fine green sand	5	20
Gravel, very coarse to fine, and some coarse to medium sand	10	30
Gravel, coarse to fine, and some medium to fine sand	10	40
Gravel, coarse to fine, and coarse sand	10	50
Gravel, fine to medium, and coarse sand	10	60
Sand, coarse to fine, and soft gray silt	10	70
Gravel, fine, coarse sand, and soft gray silt	10.5	80.5
Kansas Stage		
Kade formation		
Silt, clayey, gray	28.5	109
Gravel, medium to fine, limestone and sandstone, and coarse sand	7	116
CRETACEOUS--GULF LAG		
Dakota formation		
Clay, compact, pink and white	4	120

E-37-21cc. Sample log of test hole in the SW¹ sec. 21, T. 5 S., R. 3 W.,
106 feet south of south end of bridge and 12 feet east of center
of road. Surface altitude 1,548.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Soil, silty, brown and black	2	2
Gravel, medium, and coarse to medium sand	18	20
Gravel, coarse to medium, and coarse gray sand	50	70
Sand, medium to coarse, and medium gravel, brown and gray	8	78
Kansan Stage		
Essex formation		
Clay, very fine, sandy, gray to brown; contains some gravel	22	100
Gravel, medium to coarse, limestone and sandstone, and some yellow-buff clay	6	106
CRETACEOUS--GULFIAN		
Dakota formation		
Shale, clayey, red and white mottled	4	110

5-37-22bd. Driller's log of test hole in SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 5 S., R. 3 W.,
2,140 feet south and 2,640 feet east of SW corner of section. Drilled
by Air Made Well Company. Surface altitude 1,350.6 feet.

	Thickness, feet	Depth, feet
Soil, black	2	2
Clay, yellow	14	16
Sand, fine	15	29
Sand, medium coarse	15	42
Sand, coarse	23	65
Shale, light	5	70

5-37-27da. Sample log of test hole in NE¹ SE² sec. 27, T. 5 N., R. 3 W.,
.45 mile north of sec. line. Surface altitude 1,332.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, gray-black; contains much sand	2	2
Sand, coarse to fine, and some fine gravel	8	10
Gravel, fine to medium, and much medium sand	12.5	22.5
Silt, soft, blue-gray	.5	23
Sand, coarse to fine, and some medium gravel	7	30
Gravel, medium to fine, and coarse to fine sand	20	50
Gravel, fine, and coarse to fine sand	25	75
Kansan Stage		
Beards formation		
Silt, soft, buff and gray; interbedded with gravel and sand	7.5	82.5
Gravel, limestone and sandstone, and coarse to fine sand	3.5	86
Silt, soft, tan; contains much fine sand	5	91
Gravel, coarse to fine, limestone and sandstone	6.5	97.5
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, dark-gray; contains fine sand, pyrite, and hard black coal	7.5	105

5-3W-28bc. Sample log of test hole in the S¹/₄ NW¹/₄ sec. 28, T. 2 S., R. 2 W.,
115 feet north of T road to east and 2 feet east of center of road.
Surface altitude 1,349.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, clayey, black	3	3
Clay, very fine sandy, gray	4	7
Sand, medium, and fine gravel, brown	3	10
Sand, medium to coarse, brown	10	20
Gravel, medium to coarse, and coarse sand	10	30
Gravel, medium to coarse, and medium to coarse gray-green sand	24	54
Gravel, very coarse to pebbles, and pink-tan clay	6	60
Kansan Stage		
Made formation		
Clay, gray, and some limestone gravel	10	70
Gravel, coarse, limestone and sandstone, yellow-brown	16	86
CRETACEOUS--GULFIAN		
Dakota formation		
Shale, clayey, red and white	4	90

5-37-28cb. Sample log of test hole in the NW $\frac{1}{4}$ SW $\frac{1}{4}$, sec. 28, T. 2 S., R. 3 E.,

.25 mile north of SW cor. section and 9 feet east of center road.

Surface altitude 1,349.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan and Recent Stages		
Alluvium and Terrace deposits		
Soil, silty, brown and black	4	4
Gravel, fine, coarse sand, and brown and gray clay	4	8
Gravel, medium, and coarse sand, and gray-green	26	34
Gravel, coarse, and some coarse sand; contains sandstone and ironstone fragments	7	41
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, yellow, buff, and gray	6	47
Clay, yellow, red and gray	3	50

5-3W-29ad. Sample log of test hole in the SE¹ NE¹ sec. 29. T. 2 S.,

R. 3 W., 30 feet south of T road to east and 50 feet north of river.

Surface altitude 1,349.3 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Soil, silty, brown	7.5	8.5
Sand, medium; contains some brown gravel	4.5	13
Gravel, medium, and coarse sand, gray-green	19	32
Clay	2	34
Gravel, medium, and coarse sand, gray-green	18	52
Clay, silty, yellow-buff	8	60
Sand, fine, and clay, gray; contains some gravel	10	70
Kansan Stage		
Meade formation		
Gravel, medium, limestone and sandstone	21	91
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, light-gray, mottled, to red	9	100

5-37-29dd. Sample log of test hole in the SE¹ SE¹ sec. 29, T. 1 S., R. 3 W.,
300 feet north of NE municipal well at Concordia and 9 feet west of
center of road. Surface altitude 1,349.8 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY--PLEISTOCENE		
Wisconsinan and Recent Stages		
Alluvium and Terrace deposits		
Sand, very fine, and silt, brown	7	9
Gravel, fine to coarse, and coarse sand, brown	13	22
Gravel, fine to coarse, and coarse sand, gray-green	19	41
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, slightly sandy, yellow buff and gray	9	50

5-37-32ad1. Driller's log of test hole in the SE¹ NE¹ sec. 32, T. 2 S.,

R. 3 W., drilled by Layne-Western Co. Surface altitude 1,375.0 feet.

	Thickness, feet	Depth, feet
Soil	5	5
Clay	25	30
Sand, fine	5	35
Sand and gravel	15	50
Sand, fine packed	5	55
Clay	1	56
Soapstone (Dakota formation?)	2	58

5-3W-32ad2. Driller's log of test hole in the SE¹ NE¹ sec. 32, T. 2 S.,

R. 2 W., drilled by Layne-Western Co. Surface altitude 1,368.0 feet.

	Thickness, feet	Depth, feet
Soil	5	5
Clay	15	20
Sand	5	25
Sand and gravel	17	42
Sand, fine	6	48
Sand, fine, packed	4	52
Clay	3	55
Sand, fine, packed (Dakota formation?)	2	58

6-17-3aa. Sample log of test hole in the NE cor. sec. 3, T. 6 S., R. 1 W.,
on west side of road, 40 feet south of road intersection. Drilled
June 15, 1954. Surface altitude 1,278.1 feet; depth-to-water
level 6.05 feet June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, black	2.5	2.5
Sand, fine to coarse, and fine to medium gravel	60.5	63
Kansan Stage		
Meade formation		
Clay, blue-gray	9	72
Sand, fine to medium; contains con- siderable weathered sandstone	10	82
Sand, fine	21	103
CRETACEOUS--GULFIAN		
Dakota formation		
Clay; contains some sandstone and lignite	7	110

6-17-3da. Sample log of test hole in the NE cor. SE $\frac{1}{4}$ sec. 3, T. 6 S.,
 R. 1 W., on west side of road, 200 feet south of half-mile line.
 Drilled June 15, 1954. Surface altitude 1,292.8 feet; depth-to-
 water level 17.50 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Clay, black	4	6
Clay, gray to tan	14	20
Clay, black	6	26
Sand, fine to medium, and fine, arkosic, gravel	5	31
Gravel, fine to coarse, arkosic, and medium to coarse sand	12	43
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland members		
Clay, sandy, red-tan	8	51
Sand, fine, reddish-tan	4	55
CRETACEOUS--GULFIAN		
Dakota formation		
Clay, light-gray	9	64
Sandstone, fine-grained, light-tan	6	70

6-17-10ad. Sample log of test hole in the SE cor. NE¹ sec. 10, T. 6 S., R. 1 W., on west road shoulder at half-mile line. Augered June 16, 1954. Surface altitude 1,333.1 feet; depth-to-water level 40.80 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Peoria silt member		
Silt, clayey, dark-gray	4	6
Silt, clayey, light-gray	3	9
Silt, clayey, yellow-gray	4	13
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland silt members		
Silt, clayey, reddish-brown	10	23
Silt, coarse, reddish-brown	10	33
Silt, tan; contains fine sand	26	59

6-1W-11bb. Sample log of test hole in the NW¹ NW¹ sec. 11, T. 6 S., R. 1 W., on south side of road about 800 feet east of section corner. Drilled June 16, 1954. Surface altitude 1,334.7 feet; depth-to-water level 48.60 feet June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Peoria silt member		
Silt, black	2	2
Silt, soft, tan (loess)	12	14
Illinoian Stage		
Sanborn formation--Crete sand and gravel and Loveland members		
Silt, blocky, black (Sangamon soil)	3	17
Silt and clay, reddish-tan	6	23
Silt, sandy, tan	20	43
Silt, sandy, tan to gray	22	65
Silt and clay, very sandy; contains some sand and limestone gravel	9	74
Silt and clay, blocky, dark-gray (soil?)	2	76
Clay; contains some weathered sandstone gravel	5	81
Sand, fine; contains some ironstone gravel	12	93
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, red and light-tan; contains some clay	17	110

6-1E-2ba3. Driller's log of test hole in the NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 6 S.,

R. 1 E. Near the site of Clifton City wells. Drilled by Lavne-
Western Co.

	Thickness, feet	Depth, feet
Soil	4	4
Clay	24	28
Sand, fine, gray	2	30
Sand, coarse, gray	3	33
Sand and gravel, gray	10	43
Clay	1	44
Sand, fine	2	46
Sand, coarse, gray, and gravel on shale	16	62

6-1E-2bb. Sample log of test hole in the NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 6 S., R. 1 E., on east side of road at Slow sign south of Vining, .2 mile south of sec. corner. Drilled June 17, 1954. Surface altitude 1,272.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	3	3
Silt, tan	3	6
Clay, sticky, tan to gray	7	13
Clay, slightly sandy, dark-gray	7	20
Clay, sandy, soft, light-gray	3	23
Sand, fine to coarse, and fine to medium gravel	14	37
Clay, greenish-gray	23	60
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, greenish-gray and black	9	69
Dolomite, light-gray	1	70

6-13-2cc. Sample log of test hole near the SW cor. sec. 2, on east side of road, 200 feet north of sec. corner. Drilled June 17, 1954. Surface altitude 1,256.8 feet; depth-to-water level 7.10 feet June 18, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, black	3	3
Sand, fine to coarse, and fine to medium gravel	13	16
Clay, blue-gray	4	20
Gravel, medium, and coarse arkosic sand	37	57
Kansan Stage		
Meade formation		
Sand, medium to coarse, and fine to medium limestone and arkosic gravel	6	63
Gravel, fine to medium; mostly sandstone and limestone	4	67
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, platy, black and gray	3	70

6-1E-11bc. Sample log of test hole in the S¹ T¹ sec. 11. T. 6 S., R. 1 E.,
on east side of road .3 mile south of sec. corner, at north end of
row of large cottonwood trees. Drilled June 18, 1954. Surface
altitude 1258.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLKISTOCENE		
Recent Stage		
Alluvium		
Silt, black	2	2
Silt, tan	3	5
Sand, fine to coarse, and fine to medium, arkosic gravel	12	17
Clay, sandy, blue	3	20
Sand, fine to coarse, and fine to medium, arkosic gravel	39	59
Kansan Stage		
Meade formation		
Clay, yellow	1	60
Gravel, fine to medium; much sandstone and limestone	8	68
Clay, yellow; contains some sandstone and limestone gravel	1	69
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, platy, blue-black	1	70

6-1E-14bb. Sample log of test hole in the NW¹ NW¹ sec. 14, T. 6 S., R. 1 E.,
on east side of road, 25 feet south of where road turns west. Drilled
June 18, 1954. Surface altitude 1,267.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Dune sand		
Sand, fine	7	7
Alluvium		
Silt, and very fine sand	3	10
Silt, very soft, light-tan	2	12
Clay, gray	3	15
Silt, black	3	18
Silt, light-tan	8	26
Sand, very fine	4	30
Gravel, arkosic, medium to coarse, and coarse sand	26	56
Sand and gravel, arkosic; mixed with green clay	4	60
Gravel, arkosic, fine to medium, and fine to coarse sand	10	70
Kansan Stage		
Meade formation		
Gravel, chiefly limestone and sandstone, fine to medium, and coarse sand	6	76
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, platy, blue-black	1	77

6-1E-15da. Sample log of test hole in the NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 6 S., R. 1 E.,
on west side of road, about 250 feet north of quarter-mile hedge row.
Drilled June 18, 1954. Surface altitude 1,261.2 feet; depth-to-water
level 22.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Clay and silt, black	2	2
Clay, silty, tan	3	5
Clay, tough, black	2	7
Silt, sandy, tan	13	20
Sand, fine to coarse, arkosic, and fine gravel	10	30
Gravel, fine to medium, arkosic, and fine to coarse sand	30	60
PERMIAN--LEONARDIAN		
Wellington formation		
Limestone, gray	3	63

6-1E-22aa. Sample log of test hole in the NE¹/₄ NE¹/₄ sec. 22, T. 6 S.,

R. 1 E., on west side of road, midway between abandoned farm house
on east and house on west. Drilled June 22, 1954. Surface altitude
1,263.0 feet; depth-to-water level 27.40 feet June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, clayey, black	2	2
Silt, tan	6	8
Clay, gray	10	18
Clay, very sandy, light-gray	3	21
Clay, sandy, pinkish-tan	4	25
Sand, fine to coarse, and fine to medium gravel	35	60
Sand, fine to coarse, fine to medium gravel, and yellow clay	3	63
PERMIAN--LEONARDIAN		
Wellington formation		
Limestone, hard, dark-gray	0.5	63.5

6-2E-31cd. Sample log of test hole in the SE¹ SW¹ sec. 31, T. 6 S.,
R. 2 E., on north side of road 15 feet west of drive to house on
hill south of road. Drilled June 22, 1954. Surface altitude
1,253.8 feet; depth-to-water level 29.30 June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	2	2
Silt, sandy, gray to tan	9	11
Clay, silty; contains some sand and ironstone	15	26
Sand, fine	7	33
Clay, sandy, tan	3	36
Sand, fine to coarse	8	44
Clay, yellow	3	47
PERMIAN--LEONARDIAN		
Wellington formation		
Shale or soft limestone, gray to black	1	48

6-2E-31dc. Sample log of test hole in the SW¹ SE¹ sec. 31, T. 6 S.,

R. 2 E., on north side of road about 500 feet east of drive to house
on north side of road. Drilled June 22, 1954. Surface altitude
1,232.9 feet; depth-to-water level 18.62 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	7	7
Silt, sandy, tan	5	12
Clay, blue-gray	3	15
Sand, fine to coarse; and fine to medium arkosic gravel	29	44
Clay, greenish-gray	2	46
Sand, fine to coarse, and fine to medium gravel	14	60
Sand, fine to medium arkosic	5	65
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, dark gray; grades downward into harder shale and limestone	5	70

6-2E-32cc. Sample log of test hole in the SW cor. sec. 32, in center of old roadbed, 35 feet north of sec. corner. Drilled June 22, 1954. Surface altitude 1,225.6 feet; depth-to-water level 5.01 feet June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, tan	2	2
Sand, fine to coarse, and fine to medium, arkosic gravel	48	50
Sand, fine to medium; contains some green clay and sandstone gravel	10	60
Kansan Stage		
Meade formation		
Sand, fine to medium; contains much native gravel and shale	9	69
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, black	11	80

6-2E-32cd. Sample log of test hole in the SE¹ SW¹ sec. 22, T. 6 S., R. 2 E., at end of trail leading east along section line toward Republican River. Drilled June 23, 1954. Surface altitude 1,233.7 feet; depth-to-water level 9.80 feet June 25, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, black	2	2
Silt, tan	4	6
Sand, fine to medium	4	10
Sand, fine to coarse, and fine to medium arkosic gravel	29	39
Clay, blocky, green	10	49
Sand and gravel, fine to medium	12	61
Clay, silty and sandy, dark-gray	2	63
Kansan Stage		
Meade formation		
Gravel, fine to medium, mostly native; some thin clay streaks	6	69
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, micaceous, sandy, light-gray	1	70

6-2E-32dd. Sample log of test hole in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 32, T. 6 S.,
 R. 2 E., on north side of road, 175 feet east of creek bridge.
Drilled June 23, 1954. Surface altitude 1,225.2 feet; depth-to-
water level 7.40 feet June 28, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt, black	3	3
Silt, tan	6	9
Silt, sandy, black	5	14
Sand, fine to coarse, and fine to medium arkosic gravel	36	50
Clay, tan to gray	4	54
Kansan Stage		
Meade formation		
Gravel, fine to medium, native, some yellow clay	12	66
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, blue-gray	4	70

6-2E-33cd. Sample log of test hole in the SE¹ SW¹ sec. 33, T. 6 S., R. 2 E.,
on south side of road, 40 feet east of railroad track. Drilled
June 24, 1954. Surface altitude 1,236.9 feet; depth-to-water level
21.30 feet.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	2	2
Silt, tan	5	7
Silt, sandy, tan; contains snail shells	8	15
Sand, fine to medium, arkosic	19	34
Sand, medium to coarse, and fine to medium, arkosic gravel	36	70
Kansan Stage		
Meade formation		
Sand, fine to coarse, mostly native	5	75
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, blocky, light-gray	5	80

6-2E-34cd. Sample log of test hole in the SE cor. of SW¹ sec. 34, T. 6 S., R. 2 E., on north side of road, 100 feet west of bridge across drainage ditch. Drilled June 22, 1954. Surface altitude 1,239.2 feet; depth-to-water level 24.50 feet June 28, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	2	2
Silt, tan	9	11
Clay, hard, gray	3	14
Clay, sandy, tan	14	28
Sand, fine to coarse, and fine arkosic gravel	16	44
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, slightly calcareous, blue-gray and tan	2	46

7-2E-3bb. Sample log of test hole in the NW cor. sec. 3, T. 7 S., R. 2 E.
in edge of field south of road, 40 feet east of sec. corner. Drilled
June 25, 1954. Surface altitude 1,237.9 feet; depth-to-water level
23.10 feet June 28, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation--Terrace deposits		
Silt, black	3	3
Silt, tan	8	11
Clay, compact, tan	5	16
Clay, compact, dark-gray	2	18
Clay, sandy, tan	6	24
Sand, fine to coarse, and fine to medium arkosic gravel	23	3 47
Clay	2	49
Sand, fine to coarse, and fine to medium, arkosic gravel	8	57
Clay, green	4	61
Gravel, fine to medium arkosic	8.5	69.5
PERMIAN--LEONARDIAN		
Wellington formation		
Shale, dark-gray	10.5	80

7-2E-6bb. Sample log of test hole in the NW $\frac{1}{4}$ sec. 6, T. 7 S., R. 2 E.,
about 25 feet west of west side of old school house foundation.
Drilled October 13, 1954. Surface altitude 1,315.0 feet, depth-
to-water level 82.20 feet October 22, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Illinoian Stage		
Clay, sandy, reddish-tan	4	4
Clay, sandy, buff	11	15
Clay, sandy, yellow	9	24
CRETACEOUS--GULFIAN		
Dakota formation		
Sandstone, very fine grained, loosely cemented, white to yellow	26	50
Sandstone or sand, fine, brown; contains some mica and ironstone	38	88
PERMIAN--LEONARDIAN		
Wellington formation		
Clay, light-gray	5	93
Shale, hard, platy, somewhat calcareous, dark greenish-gray	9	102
Shale, light greenish-gray	11	113
Shale, hard, platy, dark greenish-gray	5.5	118.5
Shale, hard, platy, very dark-gray to black	13.5	132
Shale, platy, alternately hard and soft, very dark-gray to black	8	140

8-2E-10aa2. Sample log of test hole in the NE¹ sec. 10, T. 8 S., R. 2 E., on west side of road, about 175 feet south of culvert. Drilled June 28, 1954. Surface altitude 1,194.6 feet; depth-to-water level 11.80 feet June 30, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Recent Stage		
Alluvium		
Silt and clay, tan	5	5
Silt, black	1	6
Silt, tan	4	10
Sand, fine to coarse, and fine to medium, arkosic gravel	10	20
Gravel, medium to coarse, arkosic	8	28
PERMIAN--WOLF CAMPION		
Odell shale		
Shale, blocky, blue-gray	12	40

8-3E-17ba. Sample log of test hole in the NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 8 S., R. 3 E., in east borrow pit, 20 feet south of entrance to C. E. Millen farm. Drilled June 28, 1954. Surface altitude 1.179.3; depth-to-water level 9.10 feet June 30, 1954.

	Thickness, feet	Depth, feet
QUATERNARY--PLEISTOCENE		
Wisconsinan Stage		
Sanborn formation-- Terrace deposits		
Silt, brown	6	6
Sand, fine to coarse, and fine to medium, arkosic gravel	24	30
Sand, fine to coarse and fine, arkosic gravel	12	42
PERMIAN--WOLFCAMPION		
Nolans limestone		
Limestone, trace of chert, yellow to gray 2		44

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TABLE 21 --Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Di- ameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet (6)
			(1)	(2)		(3)			(4)	(5)			(6)			
5-1W-11cc	T. 5 S., R. 1 W. SW SW sec. 11	U.S. Geological Survey	Dr.	86.0	4	N	Sand and gravel	Terrace deposits	N	O	Land Surface	0.0	1354.0	35.80	6-25-54	Test hole log.
5-1W-13cc	SW SW sec. 13	Anna Resco	Dr.	71.4	6	GI	Sandstone	Dakota formation	Cy,W	S	Base of pump	0.8	1335.9	42.62	8-31-54	
5-1W-14cc	SW SW sec. 14	U.S. Geological Survey	A	25	4	N	Sand	Terrace deposits	N	O	Land surface	0.0	1303.7	18.30	6-17-54	On public road, test hole log.
5-1W-16da	NE SE sec. 18	F. J. Feight	Dr.	39.8	6	GI	Sand and gravel	do	Cy,W	S	Base of pump	0.2	1340.1	27.21	8-31-54	
5-1W-19cc1	SW SW sec. 19	F. Martin	Dr.	25.7	18	GI	do	Alluvium	Ce,G	I	Top of casing	0.3	1285.5	8.00	10-26-55	
5-1W-19cc2	SW SW sec. 19	do	Dr.	38.5	18	S	do	do	Ce,G	I	do	0.5	1289.7	11.10	10-26-55	
5-1W-20dd1	SE SE sec. 20	U.S. Geological Survey	A	19.0	4	N	do	do	N	O	Land surface	0.0	1294.5	15.80	4-14-54	On public road.
5-1W-20dd2	SE SE sec. 20	do	A	19.0	4	N	do	do	N	O	do	0.0	1293.9	14.80	4-14-54	do
5-1W-22dd	SE SE sec. 22	do	Dr.	83.0	4	N	do	Terrace deposits	N	O	do	0.0	1312.4	35.80	6-16-54	On public road, test hole log.
5-1W-25dd	SE SE sec. 25	do	A	29.0	4	N	do	do	N	O	do	0.0	1286.0	23.00	4-15-54	On public road.
5-1W-26ad1	SE NE sec. 26	City of Clyde	Dr.	158	12	S	Sandstone	Dakota formation	T,E	P	---	0.0	1294.4	---	---	South well.
5-1W-26ad2	SE NE sec. 26	do	Dr.	158	12	S	do	do	T,E	P	---	0.0	---	---	---	North well.
5-1W-26cb	NW SW sec. 26	---	Dr.	60.0	4	N	Sand and gravel	Terrace deposits	N	O	Land surface	0.0	1279.4	7.00	6-16-54	Test hole log.
5-1W-30aa	NE NE sec. 30	Bennet	Dr.	50.0	18	GI	Sand and gravel	Alluvium	Ce,T	I	Top of casing	0.6	1285.5	9.00	10-26-55	
5-1W-30dc	SW SE sec. 30	H. St. Pierre	Dr.	70.6	18	GI	do	do	T,B	I	Hole in pump base	0.7	1287.3	11.20	10-26-55	Estimated yield 1200 gpm.
5-1W-31bd	SE NW sec. 31	Harley Gram	Dr.	78	18	GI	do	Terrace deposits	T,T	I	do	1.0	1305.2	22.60	10-26-55	Estimated yield 800 gpm.
5-1W-32cc	SW SW sec. 32	L. Goering	Dr.	98.0	18	GI	do	do	T,T	I	do	1.0	1307.6	27.70	9-21-55	
5-1W-33cb	NW SW sec. 33	U.S. Geological Survey	A	24.0	4	N	do	do	N	O	Land surface	0.0	1296.4	19.40	4-13-54	On public road.
5-1W-34aa	NE NE sec. 34	do	Dr.	100.0	4	N	do	do	N	N	do	0.0	1286.0	---	---	Test hole log.
5-1W-35bc	SW NW sec. 35	do	Dr.	100.0	4	N	do	Alluvium	N	N	do	0.0	1281.0	---	---	do
5-1W-36ad	SE NE sec. 36	do	A	14.0	4	N	do	Terrace deposits	N	O	do	0.0	1275.4	13.30	4-15-54	On public road.
5-1W-36dd	SE SE sec. 36	do	A	14.0	4	N	do	do	N	O	do	0.0	1276.3	13.30	4-15-54	do

TABLE 21 —Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 5 S., R. 2 W.</u>															
5-2N-7dd	SE SE sec. 7	J. A. Janson	Dr	103.0	6	GI	Sandstone	Dakota formation	Cy,W	S	Base of pump	1.0	1433.1	35.75	8-31-54	
5-2N-13cc	SW SW sec. 13	U.S. Geological Survey	A	34.0	4	N	Sand and gravel	Terrace deposits	N	O	Land surface	0.0	1318.4	27.60	4-14-54	On public road.
5-2N-15cb	NW SW sec. 15	J. W. Decker	Du	58.5	48	R	Sandstone	Dakota formation	Cy,W	S	Base of pump	0.5	1359.1	52.23	8-31-54	
5-2N-15cd	SE SW sec. 15	U.S. Geological Survey	A	24.0	4	N	Sand and gravel	Terrace deposits	N	O	Land surface	0.0	1317.9	19.50	4-14-54	On public road.
5-2N-15dd	SE SE sec. 15	do	A	24.0	4	N	do	do	N	O	do	0.0	1313.4	17.50	4-14-54	do
5-2N-16dc	SW SE sec. 16	do	A	19.0	4	N	do	do	N	O	do	0.0	1320.3	18.70	4-14-54	do
5-2N-17cc	SW SW sec. 17	do	A	49.0	4	N	Sandstone	Dakota formation	N	O	do	0.0	1355.8	34.70	4-14-54	do
5-2N-17dc	SW SE sec. 17	do	A	34.0	4	N	Sand	Terrace deposits	N	O	do	0.0	1338.7	32.70	4-14-54	do
5-2N-17dd	SE SE sec. 17	do	A	24.0	4	N	do	do	N	O	do	0.0	1325.8	17.90	4-14-54	do
5-2N-19cb	NW SW sec. 19	do	Dr	75.0	4	N	Sand and gravel	Alluvium	N	N	---	---	---	---	Test hole log.	
5-2N-20cc	SW SW sec. 20	D. Morgan	Dr	45.2	18	GI	do	do	T,T	I	Hole in base of pump	1.0	1317.5	7.40	9-21-55	
5-2N-21bb	NW NW sec. 21	W. E. Johnson	Dr	35.2	18	GI	do	Terrace deposits	N	I	Top of casing	1.2	1325.2	20.30	10-26-55	New well, pump not installed.
5-2N-21da	NE SE sec. 21	U.S. Geological Survey	A	14.0	4	N	Sand	Alluvium	N	O	Land surface	0.0	1306.6	9.80	4-14-54	On public road.
5-2N-22bd	SE NW sec. 22	do	A	14.0	4	N	do	do	N	O	do	0.0	1307.6	11.20	4-14-54	do
5-2N-22ca	NE SW sec. 22	Pierce	Dr	55.4	18	GI	Sand and gravel	do	Co,T	I	do	1.5	1306.4	10.91	10-26-55	Estimated yield 600 gpm.
5-2N-25bb	NW NW sec. 25	U.S. Geological Survey	A	14.0	4	N	Sand	do	N	O	do	0.0	1294.3	8.20	4-13-54	On public road.
5-2N-25bc1	SW NW sec. 25	D. Garlow	Dr	85	18	GI	Sand and gravel	Terrace deposits	T,T	I	Hole in base of pump	0.4	1304.6	22.15	10-26-55	Estimated yield 1200 gpm.
5-2N-25cc2	SW NW sec. 25	U.S. Geological Survey	A	24.0	4	N	Sand	do	N	O	Land surface	0.0	1307.1	20.80	4-13-54	On public road.
5-2N-25cd1	NW SW sec. 25	W. T. Wright	Dr	65.0	18	GI	Sand and gravel	do	T,E	I	Base of pump	0.6	1305.5	21.50	10-27-54	
5-2N-25cb2	NW SW sec. 25	U.S. Geological Survey	A	24.0	4	N	Sand	do	N	O	Land surface	0.0	1305.5	18.8	4-13-54	On public road.
5-2N-25cc	SW SW sec. 25	W. T. Wright	Dr	72.0	18	GI	Sand and gravel	do	T,B	I	Hole in pump base.	0.2	1304.8	22.42	10-11-55	Pumping test made 10-11-55.
5-2N-25da	NE SE sec. 25	Mailleux	Dr	68.4	18	S	do	do	T,T	I	Base of pump	2.0	1304.2	27.65	10-27-54	

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
	<u>T. 5 S., R. 2 W.</u>															
5-2W-26aa1	NE NE sec. 26	Marvin Cleveland	Dr	75.0	18	GI	Sand and gravel	Terrace deposits	T,T	I	Land surface	0.0	1306.4	21.30	10-26-55	
5-2W-26aa2	NE NE sec. 26	U.S. Geological Survey	Dr	110.0	4	N	do	Alluvium	N	N	do	0.0	1306.0	---	---	Test hole log.
5-2W-26ad	SE NE sec. 26	Marvin Cleveland	Dr	80.4	18	GI	do	Terrace deposits	T,T	I	Base of pump	0.6	1306.9	21.85	10-27-54	Owner reports 6 ft. of drawdown after continuous pumping at 1100-gpm.
5-2W-28aa	NE NE sec. 28	U.S. Geological Survey	A	14.0	4	N	do	Alluvium	N	O	Land surface	0.0	1304.9	8.00	4-14-54	On public road.
5-2W-28cb	NW SW sec. 28	do	Dr	106.0	4	---	do	do	---	---	---	---	---	---	---	Test hole log.
5-2W-30bb	NW NW sec. 30	do	A	14.0	4	N	Sand	do	N	O	Land surface	0.0	1326.3	7.50	4-9-54	On public road.
*5-2W-30bc1	SW NW sec. 30	U.S. Geological Survey	Dr	96.0	4	N	Sand and gravel	Alluvium	N	O	do	0.0	1326.7	8.00	6-12-54	Test hole log.
5-2W-30bc2	SW NW sec. 30	Charbonneau	Dr	39.5	14	S	do	do	Ce,B	I	Top of casing	0.0	1326.8	9.15	10-26-55	Estimated yield 800 gpm.
5-2W-30cb	NW SW sec. 30	U.S. Geological Survey	A	12.0	4	N	do	do	N	O	Land surface	0.0	1324.6	10.60	4-9-54	On public road.
5-2W-31bb	NW NW sec. 31	do	A	20.0	4	N	do	do	N	O	do	0.0	1330.9	12.50	4-9-54	do
5-2W-31bc	SW NW sec. 31	do	A	29.0	4	N	Sand	Terrace deposits	N	O	do	0.0	1341.5	22.60	4-9-54	do
5-2W-32ad	SE NE sec. 32	do	A	29.0	4	N	do	do	N	O	do	0.0	1330.5	23.60	4-13-54	do
5-2W-32cb	NW SW sec. 32	Walter Doyen	Dr	50.0	18	GI	Sand and gravel	do	T,B	I	Hole in pump base	1.0	1338.0	29.00	10-26-55	Estimated yield 750 gpm.
5-2W-32da	NE SE sec. 32	U.S. Geological Survey	A	29.0	4	N	Sand	do	N	O	Land surface	0.0	1333.1	25.20	4-13-54	On public road.
5-2W-32cb	NW SE sec. 32	Tom McDaniels	Dr	54	18	GI	Sand and gravel	do	T,B	I	Hole in pump base	1.0	1334.7	25.00	10-26-55	Estimated yield 1000 gpm.
5-2W-32dd	SE SE sec. 32	U.S. Geological Survey	A	39.0	4	N	Sand	do	N	O	Land surface	0.0	1344.3	38.30	4-13-54	On public road.
5-2W-34aa	NE NE sec. 34	F. Wentz	Dr	80.8	18	GI	Sand and gravel	do	T,B	I	Hole in pump base	1.5	1312.8	22.92	10-26-55	Estimated yield 1500 gpm.
5-2W-35aa	NE NE sec. 35	U.S. Geological Survey	A	24.0	4	N	Silt	do	N	O	Land surface	0.0	1303.6	17.30	4-13-54	On public road.
5-2W-36bc1	SW NW sec. 36	do	A	29.0	4	N	Sand	do	N	O	do	0.0	1309.9	22.20	4-13-54	do
5-2W-36bc2	SW NW sec. 36	B. Garlow	Dr	39.8	18	S	Sand and gravel	do	T,T	I	Hole in pump base	1.5	1305.8	23.20	10-26-55	Estimated yield 330 gpm.
	<u>T. 5 S., R. 3 W.</u>															
5-3W-8aa	NE NE sec. 8	U.S. Geological Survey	Dr	70.0	4	N	Gravel	Terrace deposits	N	O	Land surface	0.0	1423.4	---	---	Test hole log. Not shown on Plate 5.
5-3W-14dd	SE SE sec. 14	School District	Dr	66.8	5	GI	Sandstone	Dakota formation	Cy,H	D	Base of pump	0.4	1384.7	53.11	8-31-54	

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Depth to water level below land surface, feet (6)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
	(1)	(2)	(3)	(4)	(5)	(6)			(4)	(5)			(6)			
	T. 5 S., R. 3 W.															
*5-3W-15ab	NW NE sec. 15	U.S. Geological Survey	Dr	384.0	4	N	Sandstone	Dakota formation	N	N	Land surface	0.0	1428.6	---	---	Test hole log.
5-3W-15bd	SE NW sec. 15	---	Dr	72.0	4	---	Clay and sand	---	---	---	do	---	1413.3	---	---	Driller's test hole log.
5-3W-16bb	NW NW sec. 16	U.S. Geological Survey	Dr	70.0	4	N	Silt	Terrace deposits	N	0	do	0.0	1411.3	54.20	9/44	Test hole log. Not shown on Plate 5.
5-3W-16cb	NW SW sec. 16	do	Dr	65.0	4	N	Sand and gravel	do	N	0	do	0.0	1382.2	---	---	do
5-3W-17aa	NE NE sec. 17	do	Dr	70.0	4	N	Silt	do	N	0	do	0.0	1410.9	53.70	6-14-54	do
5-3W-20aa	NE NE sec. 20	do	Dr	110.0	4	N	Sand and gravel	Alluvium	N	0	do	0.0	1368.1	---	---	do
5-3W-21bb	NW NW sec. 21	do	Dr	100.0	4	N	do	do	N	0	do	0.0	1355.1	---	---	do
5-3W-21cb	NW SW sec. 21	do	Dr	120.0	4	N	do	do	N	0	do	0.0	1352.0	---	---	do
5-3W-21cc	SW SW sec. 21	do	Dr	110.0	4	N	do	do	N	0	do	0.0	1348.8	---	---	do
*5-3W-22bc	SE NW sec. 22	War Prison Camp	Dr	78.0	18	C	do	do	N	N	Top of casing	---	---	---	---	Water too salty to use.
5-3W-22bd	SE NW sec. 22	---	Dr	70.0	4	---	Sand	---	---	---	Land surface	---	1350.6	---	---	Driller's test hole log.
5-3W-23cb	NW SW sec. 23	Bureau of Reclamation	J	20.8	3/4	GI	Sand and gravel	Alluvium	N	0	Top of pipe	1.5	1340.0	8.97	9-1-54	Observation well.
5-3W-23da	NE SE sec. 23	U.S. Geological Survey	A	29.0	4	N	Sand	Terrace deposits	N	0	Land surface	0.0	1340.5	19.80	4-9-54	On public road.
5-3W-23dd	SE SE sec. 23	do	A	9.0	4	N	Sand and gravel	Alluvium	N	0	do	0.0	1325.4	5.50	4-9-54	do
5-3W-24ad	SE NE sec. 24	do	A	34.0	4	N	do	Terrace deposits	N	0	do	0.0	1324.7	74.00	4-9-54	do
5-3W-24cc	SW SW sec. 24	do	A	9.0	4	N	do	Alluvium	N	0	do	0.0	1325.9	4.20	4-9-54	do
5-3W-27da	NE SE sec. 27	do	Dr	105.0	4	N	do	do	N	N	do	0.0	1332.0	---	---	Test hole log.
5-3W-27dd	SE SE sec. 27	do	A	14.0	4	N	do	do	N	0	do	0.0	1337.5	9.00	4-12-54	On public road.
5-3W-28bc	SW NW sec. 28	do	Dr	90.0	4	N	do	do	N	0	do	0.0	1349.8	---	---	Test hole log. Not shown on Plate 5.
5-3W-28cb	NW SW sec. 28	do	Dr	50.0	4	N	do	do	N	0	do	0.0	1349.9	---	---	do
5-3W-29ad	SE NE sec. 29	do	Dr	100.0	4	N	do	do	N	0	do	0.0	1349.3	---	---	do
5-3W-29dd	SE SE sec. 29	do	Dr	50.0	4	N	do	Alluvium and Terrace deposits	N	0	do	0.0	1349.8	---	---	do
5-3W-32ad1	SE NE sec. 32	---	Dr	58.0	4	N	do	Terrace deposits	N	0	do	0.0	1375.0	---	---	Driller's test hole log. Not shown on Plate 5.
5-3W-32ad2	SE NE sec. 32	---	Dr	58.0	4	N	do	do	N	0	do	0.0	1368.0	---	---	do
5-3W-34aa1	NE NE sec. 34	U.S. Geological Survey	A	9.0	4	N	Sand	Alluvium	N	0	do	0.0	1337.8	7.70	4-12-54	On public road.
5-3W-34aa2	NE NE sec. 34	do	A	14.0	4	N	do	do	N	0	do	0.0	1337.9	12.80	4-12-54	do
5-3W-34ad	SE NE sec. 34	do	A	29.0	4	N	do	Terrace deposits	N	0	do	0.0	1349.5	19.00	4-12-54	do
5-3W-34da	NE SE sec. 34	do	A	27.0	4	N	do	do	N	0	do	0.0	1350.4	25.50	4-12-54	do
5-3W-35ab	NW NE sec. 35	Tolliver	Dr	64.8	18	GI	Sand and gravel	Alluvium	N	I	Top of casing	0.4	1342.8	16.70	10-26-55	New well, pump not installed.
5-3W-36ab	NW NE sec. 36	G. Fredrickson	Dr	85	18	GI	do	do	T,B	I	Hole in pump base	2.0	1338.4	17.20	10-26-55	
5-3W-36da	NE SE sec. 36 T. 5 S., R. 1 E.	U.S. Geological Survey	A	39.0	4	N	Sand	Terrace deposits	N	0	Land surface	0.0	1345.9	19.60	4-12-54	On public road.
5-1E-32bc	SW NW sec. 32 T. 6 S., R. 1 W.	C. Wickland	Dr	42.	18	GI	do	do	T,T	I	do	0.0	1275.6	21.00	10-25-55	
6-1W-1ad	SE NE sec. 1	U.S. Geological Survey	A	19.0	4	N	Sand and gravel	Alluvium	N	0	do	0.0	1270.5	14.30	4-15-54	On public road.
6-1W-1cc	SW SW sec. 1	L. St. Pierre	Dr	---	18	GI	do	Terrace deposits	T,B	I	Hole in base of pump	0.2	1290.6	20.00	10-25-55	
6-1W-2aa	NE NE sec. 2	L. A. Christian	Dr	56.7	18	GI	do	do	N	I	Top of casing	1.0	1275.9	9.20	10-25-55	New well.

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Di- ameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 6 S., R. 1 W.</u>															
*6-1W-3aa	NE NE sec. 3	U.S. Geological Survey	Dr	110.0	4	---	Sand and gravel	Alluvium	N	O	Land surface	0.0	1276.1	6.05	6-25-54	Test hole log.
6-1W-3da	NE SE sec. 3	do	Dr	70.0	4	N	do	Terrace deposits	N	O	do	0.0	1292.8	17.50	6-25-54	do
6-1W-3dd	SE SE sec. 3	do	A	50.0	4	N	do	do	N	O	do	0.0	1325.9	38.60	6-15-54	On public road.
6-1W-4bb	NW NW sec. 4	Franklin Day	Dr	69.3	18	GI	do	do	T,B	I	Hole in pump base	1.3	1305.0	23.00	10-27-54	Pumping test made 10-11-55.
6-1W-5aa1	NE NE sec. 5	U.S. Geological Survey	A	29.0	4	N	do	do	N	O	Land surface	0.0	1301.8	23.50	4-13-54	On public road.
6-1W-5aa2	NE NE sec. 5	do	A	29.0	4	N	do	do	N	O	do	0.0	1302.5	23.20	4-13-54	do
6-1W-10ad	SE NE sec. 10	do	A	59.0	4	N	Sand	do	N	O	do	0.0	1331.1	40.80	6-16-54	On public road, test hole log.
*6-1W-10cc	SW SW sec. 10	F. Bachand	Dr	87	6	S	Sandstone	Dakota formation	Cy,E	D,S	do	0.0	1357.4	63	---	
6-1W-11bb	NW NW sec. 11 <u>T. 6 S., R. 2 W.</u>	U.S. Geological Survey	Dr	110.0	4	N	Sand	Terrace deposit	N	O	do	0.0	1334.7	48.60	6-25-54	Test hole log.
6-2W-1cc	SW SW sec. 1 <u>T. 6 S., R. 1 E.</u>	School District	Dr	79.5	6	GI	do	do	Cy,H	D	Base of pump	0.5	1366.8	40.32	8-26-54	
6-1L-1ba	NE NE sec. 1	U.S. Geological Survey	A	29.0	4	N	Sand	Terrace deposits	N	O	Land surface	0.0	1266.6	22.70	4-16-54	Did not reach bedrock.
6-1L-1bc	SW NW sec. 1	Northern Natural Gas Co.	Dr	50	16	S	Sand and gravel	do	T,E	Ind	do	0.0	1264.0	22	---	Four nearly identical wells.
6-1L-2ab	NW NE sec. 2	U.S. Geological Survey	A	29.0	4	N	do	do	N	O	do	0.0	1269.1	25.00	4-16-54	Did not reach bedrock.
6-1L-2ac	SW NE sec. 2	F. Turner	Dr	70.0	18	GI	Sand and gravel	Terrace deposits	T,T	I	Hole in pump base	0.2	1265.4	22.01	10-12-55	Aquifer test run 10-13-55.
*6-1L-2ba1	NE NW sec. 2	City of Clifton	Dr	65.0	12	S	do	do	T,E	P	Land surface	0.0	1268.4	21	4-5-40	
6-1L-2ba2	NE NE sec. 2	do	Dr	66	12	S	do	do	T,E	P	do	0.0	1267.9	---	---	
6-1L-2ba3	NE NW sec. 2	---	Dr	62.0	4	N	do	---	N	N	---	---	---	---	---	Driller's test hole log.
6-1L-2bb	NW NW sec. 2	U.S. Geological Survey	Dr	70.0	4	N	do	Terrace deposits	N	N	Land surface	0.0	1272.0	---	---	Test hole log.
6-1L-2bc	SW NW sec. 2	C. Nelson	Dr	56.5	18	GI	do	do	T,T	I	Hole in pump base	2.0	1261.6	10.17	10-25-55	Drilled in 1955. Not used that season.
*6-1L-2cc	SW SW sec. 2	U.S. Geological Survey	Dr	70.0	4	N	do	Alluvium	N	O	Land surface	0.0	1256.8	7.10	6-18-54	Test hole log.
6-1L-2db	NW SE sec. 2	C. Anderson	Dr	60.4	18	GI	do	Terrace deposits	T,T	I	Hole in pump base	0.2	1264.5	23.07	10-25-55	
6-1L-3aa	NE NE sec. 3	U.S. Geological Survey	A	29.0	4	N	Sand	do	N	O	Land surface	0.0	1269.9	24.50	4-16-54	Did not reach bedrock.

TABLE 21 --Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Depth to water level below land surface, feet (6)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
	<u>T. 6 S., R. 1 E.</u>															
6-1E-3ab	NW NE sec. 3	U.S. Geological Survey	A	29.0	4	N	Sand	Terrace deposits	N	O	Land surface	0.0	1270.8	18.00	4-16-54	Did not reach bedrock.
6-1E-3ad	SE NE sec. 3	do	A	14.0	4	N	do	do	N	O	do	0.0	1260.9	10.70	4-16-54	do
6-1E-3dd	SE SE sec. 3	do	A	9.0	4	N	do	Alluvium	N	O	do	0.0	1256.8	7.20	4-16-54	do
6-1E-4aa	NE NE sec. 4	do	A	34.0	4	N	Sand and gravel	Terrace deposits	N	O	do	0.0	1272.1	19.20	4-15-54	do
6-1E-4ab	NW NE sec. 4	do	A	24.0	4	N	Sand	do	N	O	do	0.0	1271.8	20.70	4-15-54	do
6-1E-4bb	NW NW sec. 4	do	A	24.0	4	N	do	do	N	O	do	0.0	1272.7	19.10	4-15-54	do
6-1E-5ab	NW NE sec. 5	do	A	24.0	4	N	Sand and gravel	do	N	O	do	0.0	1275.2	18.80	4-15-54	do
6-1E-6aa	NE NE sec. 6	do	A	19.0	4	N	do	do	N	O	do	0.0	1270.2	14.70	4-15-54	do
6-1E-6ab	NW NE sec. 6	do	A	19.0	4	N	Sand	do	N	O	do	0.0	1272.2	13.00	4-15-54	do
6-1E-10ad	SE NE sec. 10	do	A	14.0	4	N	do	Alluvium	N	O	do	0.0	1258.3	10.20	4-16-54	do
6-1E-11bc	SW NW sec. 11	do	Dr	70.0	4	N	do	do	N	N	do	0.0	1258.3	---	---	Test hole log.
6-1E-14bb	NW NW sec. 14	do	Dr	77.0	4	N	do	do	N	N	do	0.0	1267.0	---	---	do
6-1E-15aa	NE NE sec. 15	do	A	59.0	4	N	do	Terrace deposits	N	O	do	0.0	1267.0	27.60	4-16-54	Did not reach bedrock.
6-1E-15ad	SE NE sec. 15	do	A	30.0	4	N	do	do	N	O	do	0.0	1261.2	27.10	4-16-54	do
*6-1E-15da	NE SE sec. 15	do	Dr	65.0	4	---	do	do	N	O	do	0.0	1261.2	22.00	6-18-54	Test hole log.
6-1E-15dd	SE SE sec. 15	do	A	29.0	4	N	do	do	N	O	do	0.0	1261.3	23.40	4-16-54	Did not reach bedrock.
6-1E-16dd	SE SE sec. 16	School District	Dr	86.1	5	GI	Sandstone	Dakota formation	Cy,H	D	Base of pump	0.2	1339.6	52.69	9-3-54	
6-1E-17cb	NW SW sec. 17	J. O. Lewis	Dr	53.2	6	GI	do	do	Cy,W	S	do	1.0	1304.2	28.55	9-2-54	
6-1E-22aa	NE NE sec. 22	U.S. Geological Survey	Dr	63.5	4	N	Sand	Terrace deposits	N	O	Land surface	0.0	1263.0	27.40	6-25-54	Test hole log.
6-1E-22ad	SE NE sec. 22	do	A	34.0	4	N	do	do	N	O	do	0.0	1266.3	31.20	4-16-54	Did not reach bedrock.
6-1E-24ab	NW NE sec. 24	C. Pederson	Dr	66.0	18	GI	Sand and gravel	do	T,B	I	Hole in pump base	0.3	1252.8	23.87	10-25-55	Estimated yield about 1100 gpm.

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet (6)
			(1)	(2)		(3)			(4)	(5)						
<u>T. 6 S., R. 1 E.</u>																
6-1E-24bc	SW NW sec. 24	C. E. Sundgren	Dr	95.0	18	GI	Sand and gravel	Terrace deposits	T,B	I	Hole in pump base	1.3	1254.5	22.00	10-25-55	Estimated yield about 2000 gpm.
6-1E-25aa	NE NE sec. 25	U.S. Geological Survey	A	24.0	4	N	Sand	do	N	0	Land surface	0.0	1248.9	21.80	4-16-54	Did not reach bedrock.
6-1E-25ba	NE NW sec. 25	do	A	24.0	4	N	do	do	N	0	do	0.0	1250.8	21.20	4-16-54	do
6-1E-26aa	NE NE sec. 26	do	A	29.0	4	N	do	do	N	0	do	0.0	1254.1	20.50	4-16-54	do
6-1E-26ba	NE NW sec. 26	do	A	39.0	4	N	Sand and gravel	do	N	0	do	0.0	1267.7	36.00	4-16-54	do
6-1E-26dc	SW SE sec. 26	do	A	39.0	4	N	Clay	Terrace deposits and colluvium	N	0	do	0.0	1261.9	20.80	4-19-54	Lower 20 feet penetrated was red clay.
6-1E-26dd	SE SE sec. 26	do	A	24.0	4	N	Sand	do	N	0	do	0.0	1252.4	19.50	4-19-54	Did not reach bedrock.
6-1E-36ba	NE NW sec. 36	U.S. Geological Survey	A	29.0	4	N	Sand	Terrace deposits	N	0	Land surface	0.0	1250.1	23.60	4-19-54	do
<u>T. 6 S., R. 2 E.</u>																
6-2E-19ab	NW NE sec. 19	U.S. Geological Survey	A	14.0	4	N	Sand	Alluvium	N	0	Land surface	0.0	1240.1	9.10	4-20-54	Did not reach bedrock.
6-2E-20ab	NW NE sec. 20	do	A	19.0	4	N	do	Terrace deposits	N	0	do	0.0	1247.5	16.80	4-20-54	do
6-2E-20bb	NW NW sec. 20	do	A	14.0	4	N	do	Alluvium	N	0	do	0.0	1238.6	9.00	4-20-54	do
6-2E-28cd	SE SW sec. 28	do	A	19.0	4	N	do	Terrace deposits	N	0	do	0.0	1246.1	13.80	4-20-54	do
6-2E-29ac	SW NE sec. 29	Millies	Dr	40.5	18	GI	do	Alluvium	Ce,T	I	Top of casing	0.3	1242.8	9.00	10-25-55	Yields about 1000 gpm.
6-2E-29da	NE SE sec. 29	do	Dr	53.5	18	GI	do	do	Ce,T	I	do	0.3	1242.4	10.00	10-25-55	do
6-2E-29dd	SE SE sec. 29	U.S. Geological Survey	A	9.0	4	N	do	do	N	0	Land surface	0.0	1239.9	7.80	4-20-54	Did not reach bedrock.
6-2E-30cc	SW SW sec. 30	do	A	19.0	4	N	do	Terrace deposits	N	0	do	0.0	1244.8	18.10	4-19-54	do
6-2E-30dc	SW SE sec. 30	do	A	24.0	4	N	do	do	N	N	do	0.0	1243.5	18.70	4-19-54	do
6-2E-31cd	SE SW sec. 31	do	Dr	48.0	4	N	do	do	N	0	do	0.0	1253.8	29.30	6-25-54	Test hole log.
6-2E-31dc	SW SE sec. 31	do	Dr	70.0	4	N	do	do	N	0	do	0.0	1232.9	18.62	6-22-54	do
6-2E-32ab	NW NE sec. 32	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1239.3	9.60	4-20-54	Did not reach bedrock.
6-2E-32bb	NW NW sec. 32	do	A	24.0	4	N	do	Terrace deposits	N	0	do	0.0	1241.5	18.30	4-19-54	do

TABLE 21 -Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 6 S., R. 1 E.</u>															
*6-2E-32cc	SW SW sec. 32	U.S. Geological Survey	Dr	80.0	4	N	Sand	Alluvium	N	O	Land surface	0.0	1225.6	5.01	6-25-54	Test hole log.
6-2E-32cd	SW SW sec. 32	do	Dr	70.0	4	N	Sand and gravel	do	N	O	do	0.0	1233.7	9.80	6-25-54	do
6-2E-32dd	SE SE sec. 32	do	Dr	70.0	4	N	do	do	N	O	do	0.0	1225.2	7.40	6-28-54	do
*6-2E-33cd	SE SW sec. 33	do	Dr	80.0	4	N	Sand	Terrace deposits	N	O	do	0.0	1236.9	21.30	6-24-56	do
6-2E-33dc	SW SE sec. 33	Bill Silver	Dr	69.6	18	GI	Sand and gravel	do	T,NG	I	Hole in pump base	1.5	1241.2	24.20	10-25-55	Yields about 1000 gpm.
6-2E-34ab	NW NE sec. 34	U.S. Geological Survey	A	44.0	4	N	Clay	Colluvium(?)	N	O	Land surface	0.0	1306.9	36.20	4-20-54	May have reached Dakota formation.
6-2E-34bb	NW NW sec. 34	do	A	34.0	4	N	Sand	Terrace deposits	N	O	do	0.0	1258.1	30.00	4-20-54	Did not reach bedrock.
6-2E-34cd	SE SW sec. 34	do	Dr	46.0	4	N	do	do	N	O	do	0.0	1239.2	24.50	6-28-54	Test hole log.
	<u>T. 7 S., R. 2 E.</u>															
7-2E-3bb	NW NW sec. 3	U.S. Geological Survey	Dr	80.0	4	N	Sand and gravel	Terrace deposits	N	O	Land surface	0.0	1237.9	23.10	6-28-54	Test hole log.
7-2E-3cc	SW SW sec. 3	City of Morganville	Dr	53	12	S	Gravel	do	T,E	P	do	0.0	1228.3	22	---	Near water tower.
*7-2E-4dd	SE SE sec. 4	do	Dr	57	12	S	do	do	T,E	P	do	0.0	1231.4	20	---	Four blocks west of water tower.
7-2E-6bb	NW NW sec. 6	U.S. Geological Survey	Dr	140.0	4	N	Sandstone	Dakota	N	O	do	0.0	1315.0	82.20	10-22-54	Test hole log.
7-2E-7ab	NW NE sec. 7	do	A	14.0	4	N	Sand	Alluvium	N	O	do	0.0	1224.4	12.10	4-20-54	Did not reach bedrock.
7-2E-7ad	SE NE sec. 7	do	A	14.0	4	N	do	do	N	O	do	0.0	1221.5	11.50	5-26-54	do
7-2E-7dc	SW SE sec. 7	do	A	45.0	4	N	do	Terrace deposits	N	O	do	0.0	1245.1	32.50	5-26-54	do
7-2E-8ac1	SW NE sec. 8	do	A	14.0	4	N	do	Alluvium	N	O	do	0.0	1218.8	12.10	4-20-54	do
7-2E-8ac2	SW NE sec. 8	do	A	19.0	4	N	do	do	N	O	do	0.0	1217.5	9.80	4-20-54	do
7-2E-9ab	NW NE sec. 9	do	A	39.0	4	N	do	Terrace deposits	N	O	do	0.0	1232.1	18.80	4-20-54	do
7-2E-9bd	SE NW sec. 9	do	A	24.0	4	N	do	do	N	O	do	0.0	1224.5	17.20	4-20-54	do
7-2E-10ab	NW NE sec. 10	do	A	34.0	4	N	do	do	N	O	do	0.0	1230.1	22.40	4-20-54	do

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Di- ameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 7 S., R. 2 E.</u>															
7-2E-10bb	NW NW sec. 10	U.S. Geological Survey	A	24.0	4	N	Sand	Terrace deposits	N	O	Land surface	0.0	1225.3	17.00	4-20-54	Did not reach bedrock.
7-2E-11ab	NW NE sec. 11	do	A	29.0	4	N	do	do	N	O	do	0.0	1236.6	12.30	4-20-54	do
7-2E-14cd	SE SW sec. 14	do	A	29.0	4	N	do	do	N	O	do	0.0	1219.3	19	5-25-54	do
7-2E-15cd	SE SW sec. 15	do	A	23.0	4	N	do	do	N	O	do	0.0	1221.2	22.70	4-21-54	do
7-2E-15dd	SE SE sec. 15	do	A	19.0	4	N	do	do	N	O	do	0.0	1220.2	18.50	5-25-54	do
7-2E-16cd	SE SW sec. 16	do	A	14.0	4	N	do	do	N	O	do	0.0	1212.9	12.00	4-21-54	do
7-2E-16dd	SE SE sec. 16	do	A	39.0	4	N	do	do	N	O	do	0.0	1227.9	23.50	4-21-54	do
7-2E-18aa	NE NE sec. 18	do	A	30.0	4	N	do	do	N	O	do	0.0	1230.7	22.00	5-26-54	do
7-2E-18dd	SE SE sec. 18	do	A	34.0	4	N	do	do	N	O	do	0.0	1233.3	25.00	5-26-54	do
7-2E-21ac	SW NE sec. 21	L. H. Eickerman	Dr	53.0	18	GI	Sand and gravel	do	N	N	Top of casing	0.3	1212.0	10.95	10-25-55	Unused irrigation well.
7-2E-21bb	NW NW sec. 21	U.S. Geological Survey	A	24.0	4	N	Sand	do	N	O	Land surface	0.0	1218.3	14.70	4-21-54	Did not reach bedrock.
7-2E-23aa	NE NE sec. 23	do	A	34.0	4	N	do	do	N	O	do	0.0	1227.0	30.30	5-26-54	do
7-2E-28da	NE SE sec. 28	Cecil Cole	Dr	10.5	6	GI	Sand and gravel	do	Ce,T	I	Top of casing	1.2	1206.4	10.50	10-28-55	A four well battery.
7-2E-34aa	NE NE sec. 34	U.S. Geological Survey	A	34.0	4	N	Sand	do	N	O	Land surface	0.0	1214.9	22.20	5-26-54	Did not reach bedrock.
7-2E-34ba1	NE NW sec. 34	do	A	26.0	4	N	do	do	N	O	do	0.0	1212.7	19.20	5-26-54	do
7-2E-34ba2	NE NW sec. 34	do	A	29.0	4	N	do	do	N	O	do	0.0	1214.4	22.00	5-25-54	do
7-2E-35aa	NE NE sec. 35	do	A	29.0	4	N	do	do	N	O	do	0.0	1212.7	23.50	5-26-54	do
7-2E-35ab	NW NE sec. 35	do	A	29.0	4	N	do	do	N	O	do	0.0	1214.2	24.20	5-26-54	do
7-2E-36aa	NE NE sec. 36	do	A	34.0	4	N	do	do	N	O	do	0.0	1217.5	31.00	5-26-54	do
7-2E-36ba	NE NW sec. 36	do	A	24.0	4	N	do	do	N	O	do	0.0	1209.5	22.00	5-26-54	do
	<u>T. 7 S., R. 3 E.</u>															
7-3E-19aa	NE NE sec. 19	C. Engquist	Dr	76.0	6	GI	Limestone	Nolans limestone	Cy,W	S	Base of pump	0.1	1233.3	35.75	10-26-54	

TABLE 21 --Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center.

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Diameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 7 S., R. 3 E.</u>															
*7-3E-29cd	SE SW sec. 29	Nicholas Schlitz	Dr	76.6	5	GI	Limestone	Nolans limestone	Cy,W	S	Base of pump	0.3	1286.2	39.25	10-26-54	
7-5E-31dd	SE SE sec. 31	T. Gerrits	Dr	57.0	18	S	Sand and gravel	Terrace deposits	T,T	I	Top of casing	1.3	1205.2	26.26	10-28-55	Estimated yield 500 gpm. Drilled to limestone. No log.
	<u>T. 8 S., R. 2 E.</u>															
8-2E-1ah	NW NE sec. 1	G. Dittmar	Dr	64.0	18	S	Sand and gravel	Terrace deposits	T,G	I	Top of casing	1.0	1205.2	23.70	10-26-54	Estimated yield 1500 gpm. Drilled to limestone. No log.
8-2E-1dc	SW SE sec. 1	U.S. Geological Survey	A	29.0	4	N	Sand	do	N	O	Land surface	0.0	1204.8	25.60	5-27-54	Did not reach bedrock.
8-2E-1dd	SE SE sec. 1	do	A	34.0	4	N	do	do	N	O	do	0.0	1201.8	26.40	5-27-54	do
8-2E-2cc	SW SW sec. 2	G. Dittmar	Dr	48.2	18	S	Sand and gravel	Alluvium	T,G	I	Base of pump	0.2	1193.3	11.80	9-30-54	Drilled to limestone. No log.
8-2E-4da	NE SE sec. 4	J. B. Kamphaus	Dr	81.0	6	GI	Limestone	Winfield limestone	Cy,W	S	do	1.2	1270.6	67.65	9-30-54	
8-2E-5aa	NE NE sec. 5	Eric Swenson	Dr	76.3	6	GI	do	do	Cy,W	S	do	0.3	1250.1	21.04	9-30-54	
8-2E-10aa1	NE NE sec. 10	U.S. Geological Survey	A	19.0	4	N	Sand	Alluvium	N	O	Land surface	0.0	1198.2	16.10	5-27-54	Did not reach bedrock.
8-2E-10aa2	NE NE sec. 10	do	Dr	40.0	4	N	Sand and gravel	do	N	O	do	0.0	1194.6	11.80	6-30-54	Test hole. log.
8-2E-10dd	SE SE sec. 10	do	A	75.0	4	N	do	Terrace deposits	N	O	do	0.0	1216.1	40.00	6-8-54	Hit shale at 74 feet.
8-2E-11aa1	NE NE sec. 11	do	A	29.0	4	N	do	do	N	O	do	0.0	1205.5	20.10	5-27-54	Did not reach bedrock.
8-2E-11aa2	NE NE sec. 11	H. Walker	Dr	57.0	16	S	Sand and gravel	do	T,G	I	Top of casing	1.0	1206.4	25	---	Estimated yield 1600 gpm.
8-2E-11ad	SE NE sec. 11	do	Dr	40.0	16	GI	do	Alluvium	Ce,G	I	do	1.0	1193.2	12	---	Estimated yield 600 gpm.
8-2E-11da	NE SE sec. 11	do	Dr	42.0	16	GI	do	do	Ce,G	I	do	1.0	1193.8	12	---	Estimated yield 600 gpm.
	<u>T. 8 S., R. 3 E.</u>															
8-3E-4ab	NW NE sec. 4	W. A. Piper	Dr	118.2	6	GI	Limestone	Winfield limestone	Cy,W	S	Base of pump	0.5	---	78.85	8-19-54	
8-3E-7ad1	SE NE sec. 8	City of Clay Center	Dr	55	18	S	Gravel	Terrace deposits	T,E	P	---	---	---	22	---	North utility park well.
8-3E-7ad2	SE NE sec. 8	do	Dr	55	18	S	do	do	T,E	P	Land surface	0.0	1185.9	22	---	Center utility park well. 20 ft. drawdown after 4 hrs. at 90 gpm.
8-3E-7ad3	SE NE sec. 8	do	Dr	55	18	S	do	do	T,E	P	do	0.0	1187.4	22	---	South utility park well. 14 ft. drawdown after 8 hrs. at 850 gpm.
8-3E-8bc1	NW NW sec. 8	Swift and Company	Dr	65	8	S	do	do	T,E	Ind.	---	---	---	25	---	Goes to bedrock. Pumps 120 gpm 24 hours/day.

TABLE 21.—Records of wells and augered and drilled test holes in Republican Valley between Concordia and Clay Center

Well No.	Location	Owner or tenant	Type of well	Depth of well, feet	Di- ameter of well, in.	Type of casing	Principal water-bearing bed		Method of lift	Use of water	Measuring point			Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)	
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			Depth to water level below land surface, feet
			(1)	(2)		(3)			(4)	(5)			(6)			
	<u>T. 8 S., R. 3 E.</u>															
8-3E-8bc2	SW NW sec. 8	Coca Cola Company	Dr	56	7	S	Gravel	Terrace deposits	J, E	Ind.	Land surface	0.0	1198.0	26	----	Yields about 50 gpm.
8-3E-8bd	SE NW sec. 8	City of Clay Center	Dr	60	16	S	do	do	T, E	P	do	---	---	---	---	Dexter Park well. Reported drawdown of 4 ft. after 8 hrs at 500 gpm.
8-3E-8cc	SW SW sec. 8	U.S. Geological Survey	A	29	4	N	do	do	N	O	do	0.0	1195.0	26.90	6-4-54	At corner of 6th and Mable St
*8-3E-8db	NW SE sec. 8	City of Clay Center	Dr	58	16	S	Sand and gravel	do	T, E	P	do	0.0	---	28	---	At 8th and McBratney Sts.
8-3E-16cd	SE SW sec. 16	Steinbach	Dr	22.2	6	GI	do	Alluvium	Ce, B	I	Top of casing west well	1.0	1161.9	8.50	10-28-55	Battery of 3 wells, yields 350 gpm. Wells go to shale.
8-3E-17ba	NL NW sec. 17	U.S. Geological Survey	Dr	44.0	4	N	do	Terrace deposits	N	O	Land surface	0.0	1179.3	9.10	6-30-54	Test hole log.
8-3E-17bb	NW NW sec. 17	do	A	14.0	4	N	Sand	Alluvium	N	O	do	0.0	1172.3	13.20	5-27-54	Did not reach bedrock.
8-3E-17cc	SW SW sec. 17	do	A	19.0	4	N	do	do	N	O	do	0.0	1179.2	13.00	5-27-54	do
8-3E-21bb	NW NW sec. 21	Marshall	Dr	42.3	12	S	Gravel	Terrace deposits	Ce, T	I	Top of casing	-3.6	1160.7	12.40	10-28-55	Yields about 500 gpm.

* Chemical analysis given in Table 16.

1. A, Auger hole; Dr, Drilled; Lu, Dug; J, Jetted.

2. Measured depths given in feet and tenths, reported depths given in feet.

3. C, Concrete; GI, Galvanized iron; N, None; R, Rock; S, Steel.

4. Type of pump: Ce, Centrifugal; Cy, Cylinder; N, None; T, Turbine. Type of Power: B, Butane engine; E, Electric motor; G, Gasoline engine; N, None; NG, Natural gas engine; T, Tractor; W, Wind.

5. D, Domestic; I, Irrigation; Ind., Industrial; N, None; O, Observation; P, Public supply; S, Stock.

6. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.