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GROUND-WATER CONDITIONS IN THE DUTCH FLATS AREA SCOTTS BLUFF AND SIOUX COUNTIES NEBRASKA

By

H. M. Babcock and F. N. Visher

With a Section on the

CHEMICAL QUALITY OF THE GROUND WATER

By

W. H. Durum

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ABSTRACT

The report describes the geography, geology, and ground-water resources of the Dutch Flats area in Scotts Bluff and Sioux Counties, Nebr. The area comprises about 60 square miles and consists predominantly of relatively flat-lying terraces. Farming is the principal occupation in the area. The farm lands are irrigated largely from surface water; ground water is used only as a supplementary supply during drought periods. The climate in the area is semiarid, and the mean annual precipitation is about 16 inches.

The rocks exposed in the Dutch Flats area are of Tertiary and Quaternary age. A map showing the areas of outcrop of the rock formations is included in the report. Sufficient unconfined ground water for irrigation supplies is contained in the deposits of the third terrace, and wells that yield 1,000 to 2,000 gallons a minute probably could be developed.

The depth to water in the area ranges from a few feet to about 80 feet and averages about 30 feet. The depth to water varies throughout the year; it is least in the late summer when the recharge from irrigation is greatest, and it is greatest in the early spring before irrigation is begun. A map showing the depth to water in September 1949 is included in the report.

The ground-water reservoir is recharged by seepage from irrigation canals and laterals, by seepage from irrigation water applied to the farms, and, to a much lesser extent, by precipitation. In the area between Dry Sheep and Dry Spottedtail Creeks the recharge from irrigation water is estimated to have been about 56,000 acre-feet in 1949. Water is discharged from the ground-water reservoir by inflow into streams and drains, by underflow, by evapotranspiration, and by pumping of wells.

Excessive recharge to the ground-water reservoir has resulted in a rise of water levels and in turn has caused seeps in several places where the topography is favorable. The seepage could be partly remedied by lowering the water table--that is, by decreasing the recharge to, or by increasing the discharge from the ground-water reservoir. The amount of recharge could be decreased by lining the canals and laterals and by limiting the amount of water applied to the land. The discharge of ground water could be increased by installing more drains and by pumping additional water from the ground-water reservoir. The pumped water could be used for irrigation, and would thereby reduce the amount of surface water that is used in the area. Thus a balanced surface- and ground-water irrigation system could be established for the area. Lowering the water table in the Dutch Flats area will alleviate but not necessarily eliminate seepage because the water table north of the partly buried ridge of the Brule formation is a great deal higher than it is south of the ridge, and the water moves through the fractures in the Brule formation under considerable head. However, lowering the water table a few feet in the area north of the ridge will reduce this head and will thus decrease the amount of water moving through the fractures.

The analytical results of 10 samples of representative ground and surface waters in the Dutch Flats area depict waters that are hard and siliceous, but are moderately low in mineral content. Waters from shallow wells in the seeped area north of Morrill are similar both in concentration and composition to canal and drain waters in the area. All the waters are low in percentage of sodium and are of satisfactory chemical quality for irrigation or domestic use.

INTRODUCTION

Purpose and Scope of the Investigation

This investigation is one of several that are being made by the United States Geological Survey as part of the program of the Department of the Interior for the control, conservation, development, and use of the water resources of the Missouri River basin. The purpose of this study of the Dutch Flats area was to determine the following: the character, thickness, and extent of the water-bearing formations; the source, occurrence, movement, quantity, and quality of the ground water; the possibility of developing ground-water supplies for irrigation; the cause of the waterlogging in parts of the area; and the cause of the seepage along the Tri-State Canal south of the area.

This report covers the progress of the work from the beginning of the investigation in November 1948 through May 1950. The field work was done by H. M. Babcock, R. T. Littleton, J. R. Rapp, and F. N. Visher. The study was made under the general supervision of A. N. Sayre, Chief of the Ground Water Branch of the Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin, and under the immediate supervision of S. W. Lohman, district geologist for Colorado and Wyoming. The quality-of-water studies were made under the general supervision of S. K. Love, Chief of the Quality of Water Branch of the Geological Survey, and under the immediate supervision of P. C. Benedict, regional engineer in charge of the quality-of-water studies in the Missouri River basin. The water analyses were made by M. B. Florin and R. P. Orth, chemists, in the Quality of Water laboratory, Geological Survey, Lincoln, Nebr. The manuscript of this report was critically reviewed by S. W. Lohman, T. G. McLaughlin, and others.

Location and Extent of the Area

The Dutch Flats area as described in this report is a part of the Pathfinder irrigation district and is in northern Scotts Bluff and southern Sioux Counties in western Nebraska. (See fig. 1.) It lies within Tps. 23 and 24 N., Rs. 56 and 57 W., sixth principal meridian and base-line system, and covers an area of about 60 square miles. It is bounded by the Interstate Canal on the north, the Tri-State Canal on the south, Dry Sheep Creek on the west, and Spottedtail Creek on the east. The area is in the northwestern part of the High Plains section of the Great Plains physiographic province.

Methods of Investigation

Records of 75 wells in the area were obtained. Well drillers and well owners were contacted to obtain available information, but most of the information obtained was from memory and did not pertain to the yield and drawdown of the wells or to the character of the water-bearing materials that were penetrated by the wells. Sixty-eight of the wells recorded were measured using a steel tape to determine the depth to water below a fixed measuring point, generally the top of the well casing or the top of the pump base. These measurements, as well as other information about the wells, are included in a table at the end of this report. Reported data are listed for those wells that could not be measured. The altitudes of 46 of the

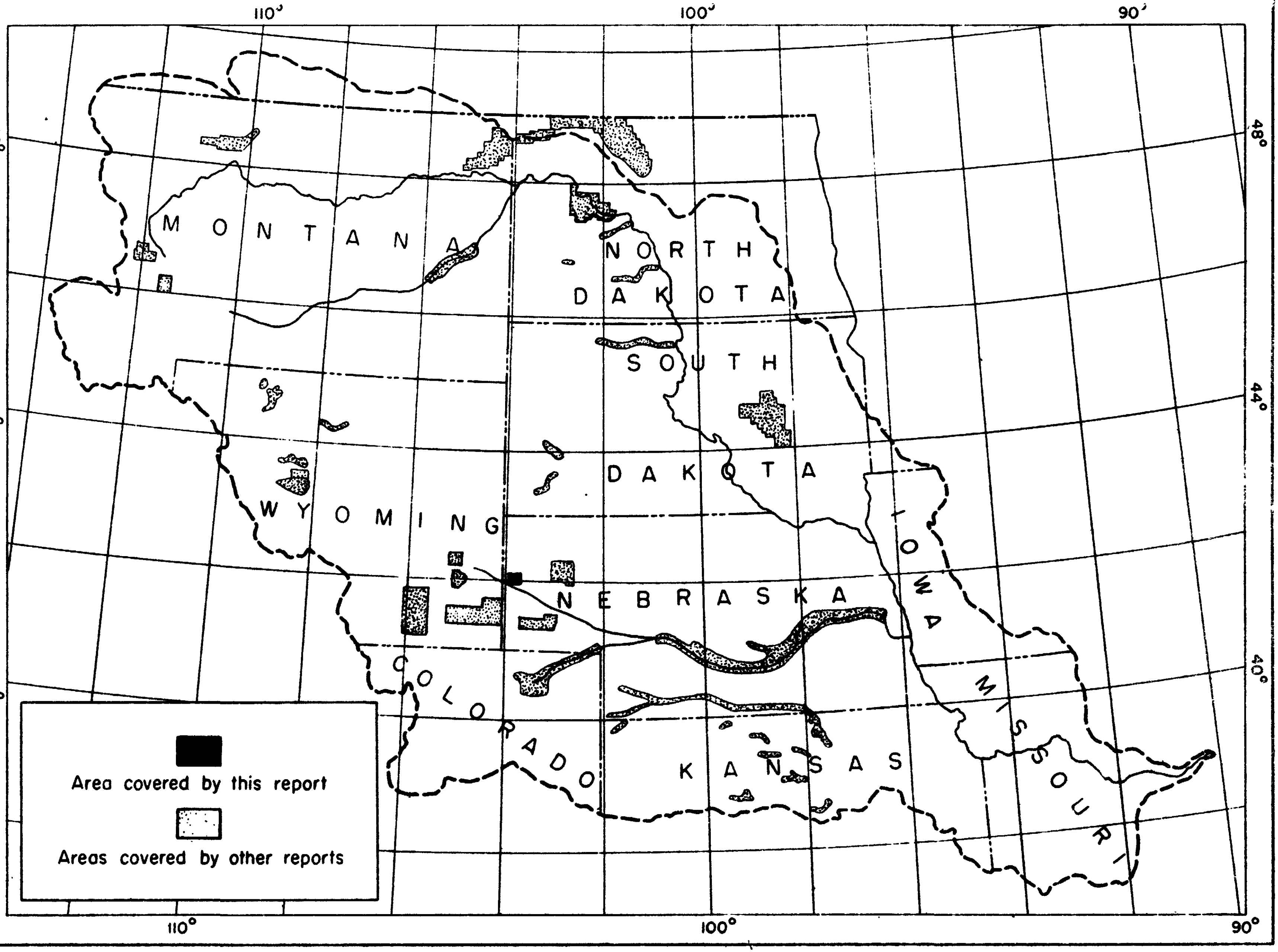

Figure 1 —Map of the Missouri River Basin showing areas in which ground-water studies have been made under Missouri Basin Development Program.

wells were determined by spirit leveling. In order to obtain information concerning the seasonal fluctuations of the water table, 28 representative wells were selected for monthly measurement of the water level. Chemical analyses were made of 10 samples of water that were collected from representative wells, drains, and canals in the area.

The geologic and hydrologic field data were recorded on aerial photographs and were later transferred to a base map that was prepared by the Pathfinder irrigation district. (See pl. 1.) The wells shown on the map were located within the sections by use of an odometer and by inspection of the aerial photographs; their locations are believed to be accurate within 0.1 mile.

Well-Numbering System

In this report, wells are numbered according to their location within the General Land Office system of land subdivision. All wells are in the sixth principal meridian and base-line system. The well number shows the location of the well by township, range, section, and position within the section. A graphical illustration of this well-numbering system is shown by figure 2. 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. The lower-case letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter. Where more than one well is in a 10-acre tract, consecutive numbers beginning with 1 are added to the well numbers.

Previous Investigations

The southern part of the Dutch Flats area lies within the Scotts Bluff quadrangle, which was mapped and described by Darton (1903). The geology, hydrology, and physiography of Scotts Bluff County were described by Wenzel, Cady, and Waite (1946). The information contained in these reports proved very helpful in making the investigation and was used freely in the compilation of this report.

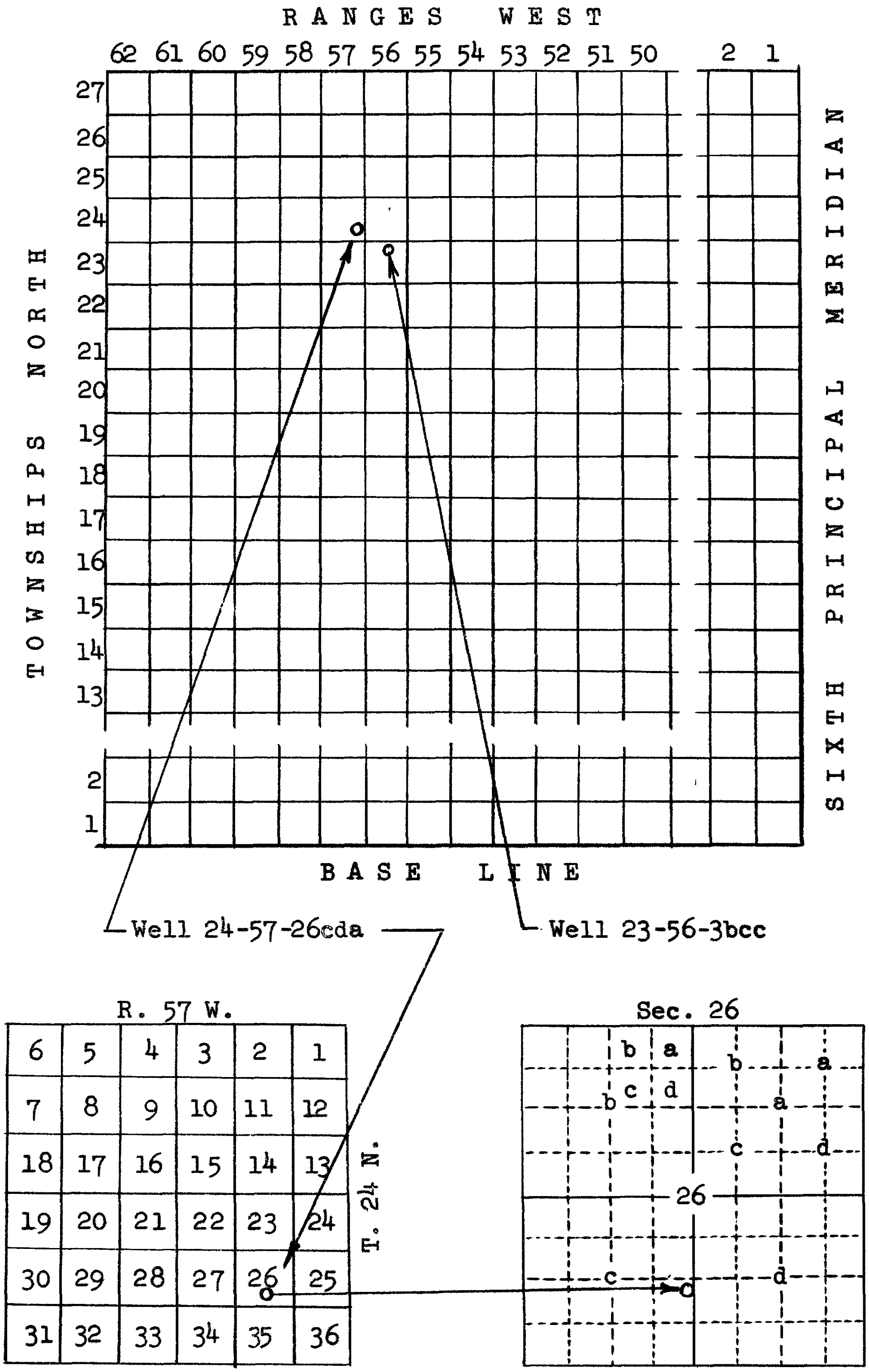

Figure 2.--Sketch showing well-numbering system.

Acknowledgments

The writers wish to express their appreciation to all those who aided in this study. Many of the residents in the area supplied information about their wells. Mr. G. H. Storm, manager of the Pathfinder irrigation district, gave helpful assistance and suggestions and permitted access to records of irrigation in the area. Personnel of the U. S. Bureau of Reclamation assisted by running levels to the observation wells in the area.

GEOGRAPHY

Climate

The climate of the Dutch Flats area is much like that of other parts of the High Plains section. It is characterized by low precipitation, high evaporation, and a wide range of temperature. The weather is somewhat variable from year to year, but usually the summers are dry and hot and the winters are very cold. Although the summer days generally are hot, the nights generally are cool because of the air movement and the low humidity.

There are no climatological stations in the area; however, the U. S. Weather Bureau maintains a station at Scottsbluff, which is about 10 miles southeast of the area. The annual precipitation during the period of record and the normal monthly precipitation for the station at Scottsbluff are shown graphically in figure 3. The normal annual precipitation for 61 years of record at Scottsbluff is 15.6 inches; the highest annual precipitation recorded is 27.5 inches (1915) and the lowest is 9.5 inches (1931). The maximum monthly precipitation occurs during May and the minimum occurs during January, when it usually takes the form of light dry snow. About 48 percent of the annual precipitation is received during April, May, and June, and only about 12 percent is received in November, December, January, and February. The summer rains occur largely as thunderstorms, which are usually sporadic and unevenly distributed. Occasionally these storms are accompanied by high winds and hail that cause considerable damage to crops.

The mean annual temperature is 48.5° F. The growing season is about 150 days. The last killing frost in the spring and the first killing frost in the fall were on April 18 and September 13 in 1949, respectively.

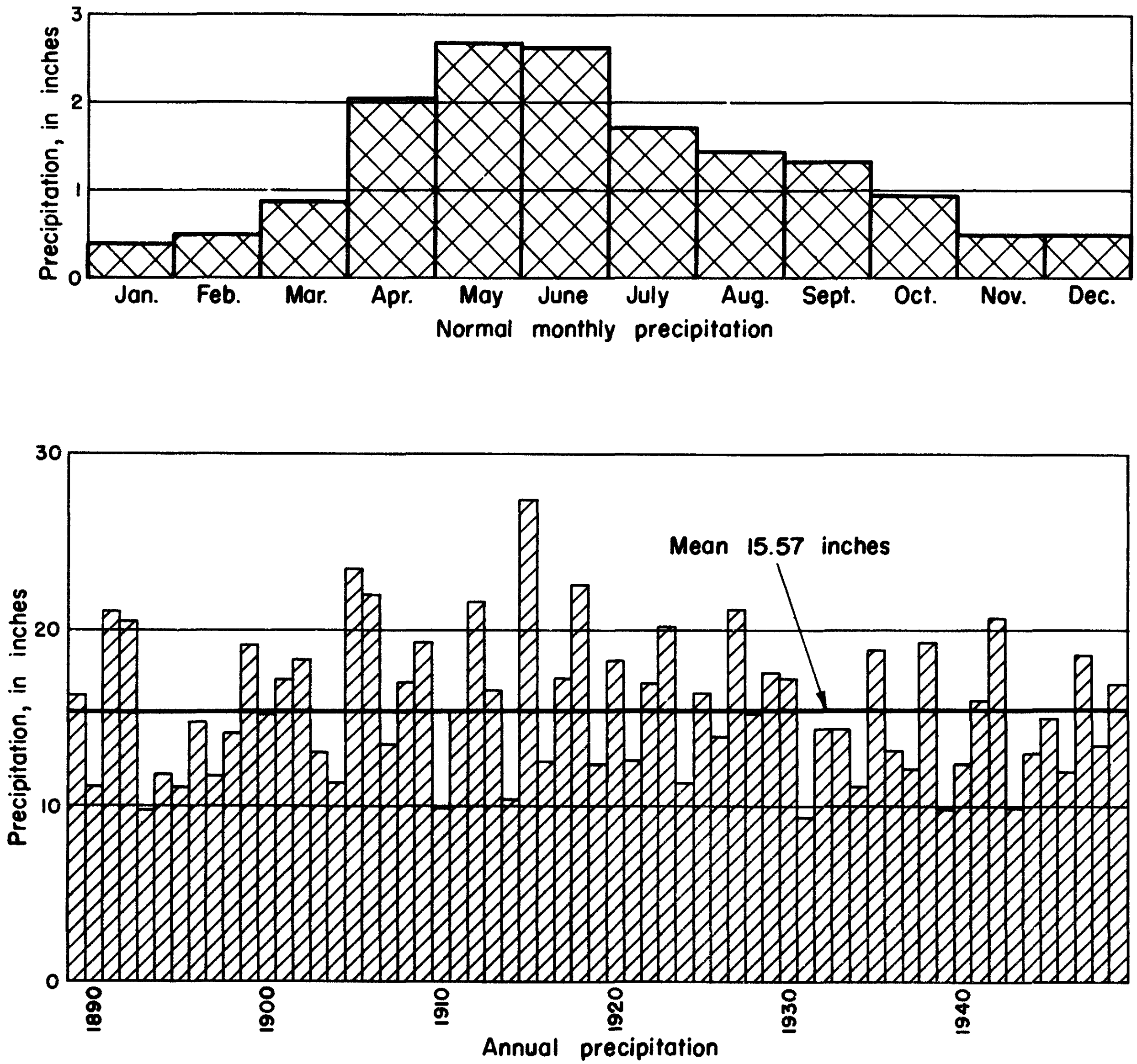

Figure 3.—Precipitation at Scottsbluff, Nebr., 1889–1949

Agriculture

The present agricultural economy of the Dutch Flats area has been developed through irrigation. Usually, surface water is sufficient for irrigation purposes, but shortages occasionally occur during periods of low runoff in the North Platte River basin. Some farmers have installed irrigation wells that are pumped during dry years for a supplementary water supply. Part of the area has become waterlogged owing to the use of irrigation water. These waterlogged areas increase in size when excessive amounts of water are used for irrigation and decrease in size when less water is used.

The irrigated lands are suitable for grasses, grains, and row crops. The main crops in the area are sugar beets, potatoes, beans, hay, and grains.

LAND FORMS

The land forms in Scotts Bluff County were extensively studied and described by R. C. Cady (Wenzel, L. K., Cady, R. C., and Waite, H. A., 1946, pp. 32-48). Inasmuch as the fourth and fifth terraces, as described by Cady, were formed entirely by small tributary streams and have a relatively steep slope, they are considered by the authors to be pediments. The following has been adapted from Cady's discussion for use in this report.

The Dutch Flats area comprises three terraces and the remnants of two pediments. In early or middle Pleistocene time the river was about 200 feet higher than at present. The river was flanked on the north by a sloping gravel-mantled pediment that extended about 500 feet above the present river. There are remnants of this surface in the northeastern part of the area about 300 feet above the river. This pediment was called the fifth terrace by Cady, but it has been designated as the second pediment above the third terrace by the authors. The headward erosion by sapping of a rejuvenated tributary drainage largely destroyed the pediment and left only isolated hills capped by gravel.

Ultimately, a new gravel-mantled pediment was developed about 50 to 100 feet lower than the older surface. Remnants of this surface are also present in the northeastern part of the area. Cady called this the fourth terrace but it is referred to in this report as the first pediment above the third terrace.

After the development of the lower pediment, a period of great downcutting produced a trench about 200 feet below the present level of the river. This trench and its tributary valleys were filled to a depth of about 300 feet to produce the third terrace that occupies most of the Dutch Flats area. A gravel-filled channel lies under the third terrace in the Dutch Flats area and approximately parallels the river. This channel may be an old tributary to the North Platte River, or it may represent an old channel of the river that was gravel-choked and abandoned before the deeper trenching began.

After the deposition of the third terrace, the river cut a second trench, which was subsequently refilled to about 50 feet above the present river level. During this time, the tributaries of the river cut valleys across the third terrace. The valleys were graded to the then existing flood plain; remnants of that flood plain are the second terrace. The valleys of Sheep, Dry Sheep, Spottedtail, and Dry Spottedtail Creeks were developed at this time.

Subsequent to the development of the second terrace, the river cut down an additional 30 feet and formed the first terrace. After the development of the first terrace, the river cut down to its present level and formed the present flood plain.

GEOLOGY IN RELATION TO GROUND WATER

Brule formation

In its typical development, the Brule formation is a pale buff or flesh-colored sandy siltstone of compact texture and massive structure; locally it is called "hardpan." The formation was called the Brule clay by Darton; however, a mechanical analysis, which is given in the Scotts Bluff report (Wenzel, L. K., Cady, R. C., and Waite, H. A., 1946, p. 67), indicates that the material is 26.6 percent fine sand, 69.4 percent silt and only 3.9 percent clay.

The Brule formation is traversed by numerous vertical to nearly vertical fractures that range in width from a few inches to several feet. The Brule is a weak, brittle formation that tends to succumb to induced tension. The weight of the overlying formations, which have now been removed by erosion, was sufficient to cause fracturing when regional warping caused relief of the lateral support. The Brule formation, which is of

Oligocene age, underlies the entire area. (See fig. 4.) It is exposed north of the Interstate Canal in the northern part of the area, in the uplands in the northeastern part of the area, and also on the southern edge of the third terrace along the Tri-State Canal. The outcrops along the Tri-State Canal are exposures of a partly buried ridge. The maximum thickness of the Brule formation before erosion is not known but, in the northeastern part of the area, it is about 300 feet thick and, in the southern part of the area, where it is covered by a thin mantle of terrace deposits (the first terrace), it is only a few feet thick.

Only a few wells in the area produce from the Brule formation. These wells supply only small amounts of water for stock and domestic use.

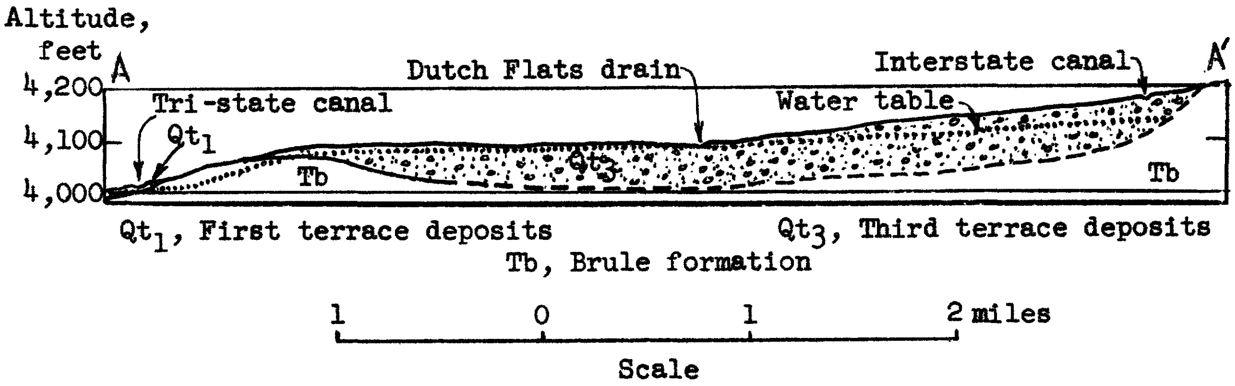

Figure 4.--Generalized north-south section across the Dutch Flats area showing geology, land surface, and water table.

Terrace Deposits

Silt, sand, and gravel of Pleistocene age fill the old channels of the North Platte River and its tributaries and underlie the terrace surfaces. The thickness of the channel fill that underlies the third terrace in the area is more than 130 feet, whereas the mantling terrace deposits generally are less than 20 feet thick. The coarse sand and gravel of the pediment surfaces in the northeastern part of the area generally are above the water table and serve only as recharge areas. The fine sand and silt of the second and first terraces, although saturated, are relatively thin and do not yield large quantities of water to wells.

The third terrace occupies most of the area between the Tri-State and Interstate Canals and between Sheep and Dry Spottedtail Creeks. The gravel, sand, and silt that underlie the third terrace are the principal water-bearing materials in the area. This deposit ranges in thickness from a few feet along the edges of the buried channel to more than 130 feet in the deepest part. Large quantities of water for irrigation, stock, and domestic use are available for development from this aquifer.

HYDROLOGIC PROPERTIES OF THE WATER-BEARING FORMATIONS

Definitions

The quantity of water that a water-bearing material will yield to wells depends principally upon the permeability and specific yield (or coefficient of storage) of the material. These properties vary greatly with change in the size, shape, number, and degree of interconnection of the interstices in the material.

The permeability of a water-bearing material is its capacity for transmitting water under pressure. The coefficient of permeability may be expressed as the number of gallons of water a day, at 60° F., that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of saturated thickness of the bed, and for each foot per mile of hydraulic gradient (Meinzer's coefficient). The coefficient of transmissibility may be expressed as the number of gallons of water a day, at the prevailing temperature, transmitted through each mile strip extending the saturated thickness of the aquifer under a hydraulic gradient of 1 foot to the mile; hence, it is the average coefficient of permeability, multiplied by the saturated thickness of the aquifer and adjusted for temperature.

The quantity of water that may be removed from storage in a saturated material depends upon the specific yield (or coefficient of storage) of the material. The specific yield of a water-bearing formation is defined as the ratio of the volume of water that a saturated aquifer will yield by gravity to the volume of the aquifer.

Brule Formation

No attempt was made by the writers to determine the water-bearing properties of the Brule formation, because a detailed analysis of this material was made by Wenzel and others (Wenzel, L. K., Cady, R. C., and Waite, H. A., 1946, pp. 83-86). The following discussion of the Brule formation is taken from their report:

"The coefficient of permeability of a sample of typical Brule, taken from a fresh road cut on the face of Scotts Bluff monument halfway between tunnels Nos. 1 and 2, and 140 feet below the contact with the Gering formation, was determined in the hydrologic laboratory of the Geological Survey to be 4. Another sample, taken at the lower portal of tunnel No. 2 had a coefficient of permeability of 7. This means that 4 or 7 gallons a day of water at 60° F. would percolate through a cross section 1 mile wide and 1 foot thick under a hydraulic gradient of 1 foot to the mile. It is evident that where the Brule formation as a whole is no more permeable than its constituent materials, the discharge through it is slight, even where the formation is thick. The cracks and fissures, however, that occur in the Brule at most places in Scotts Bluff County greatly increase the permeability of the formation, the degree of this increase depending on the number, size, and interconnection of the openings. Because their character differs so greatly from place to place, it is difficult to determine the effect of these openings on the permeability of the formation as a whole."

***

"The moisture equivalents determined in the laboratory for the two samples taken from the Brule formation were 24.9 and 20.9, respectively, an average of 22.9. Because the values fall in the higher range referred to by Piper, they can be taken to represent the approximate specific retention. The porosities of the samples were 51 and 54, an average of 52.5. Thus the average specific yield of the samples is 29.6. This indicates that a cubic foot of Brule, if allowed to drain for a long period, will yield about 0.296 cubic foot of water and will retain about 0.229 cubic foot.

"Investigations have shown that a sample of material after being saturated will not yield its water at once but the water will drain rather slowly, the rate of draining being somewhat proportional to the permeability of the material. The Brule, because of its tight character, yields water sluggishly, and several months to a year or more are doubtless required before the specific yield calculated in the laboratory is reached. As a result the quantity of water that is removed from storage by a decline of the water table in the Brule cannot be calculated from the specific yield determined in the laboratory unless the water table remains below the material for a long period. The comparatively large seasonal fluctuation of water levels in wells that tap the Brule results in part from the incomplete draining of the material during the time allowed. This means that the water table may decline for a considerable period before much water comes out of storage, except what drains from the cracks and fissures. This decline, however, will gradually slow up as the water table reaches lower stages, and a greater thickness of the formation thereby becomes available for draining."

Terrace Deposits

Pumping Test

In order to determine the coefficients of transmissibility and storage (specific yield) of the terrace deposits, a pumping test was made of well 24-57-34bad1, which is on the third terrace. The well is 24 inches in diameter and 51 feet deep. The thickness of the saturated aquifer is 48 feet. The test well was operated continuously at a rate of 1,060 gallons a minute for 13 days. During the pumping test the changes in water levels were observed in three observation wells that were located 100, 200, and 400 feet from the test well. These measurements are given in the following table. The data gathered during the pumping test were used to compute the coefficients of transmissibility and storage by the Thiem method. The computed coefficient of transmissibility was based on the prevailing temperature and was not converted to the standard temperature of 60° F.

Data on pumping test of well 24-57-34bad1

Time since pumping started, in days (t)	Observation well 100 feet from test well		Observation well 200 feet from test well		Observation well 400 feet from test well	
	Observed drawdown, in feet (s)	Corrected drawdown, in feet (s') 1/	Observed drawdown, in feet (s)	Corrected drawdown, in feet (s')	Observed drawdown, in feet (s)	Corrected drawdown, in feet (s')
0.5	3.11	3.01	1.55	1.53	0.55	0.55
1	3.72	3.58	2.04	2.00	.81	.80
2	4.33	4.14	2.58	2.51	1.19	1.18
3	4.61	4.39	2.87	2.78	1.44	1.42
5	4.97	4.71	3.20	3.09	1.69	1.66
7	5.17	4.89	3.43	3.31	1.89	1.85
10	5.39	5.09	3.68	3.54	2.14	2.09
13	5.57	5.25	3.81	3.66	2.31	2.25

1/ $s' = s - \frac{s^2}{2m}$

where m = saturated thickness of the aquifer, in feet (48 feet).

The Thiem method of determining the transmissibility of a water-bearing material involves the analysis of the decline in water level during the pumping period in two or more observation wells near a pumping well. The method is based on the assumptions that, with a constant rate of pumping, approximate equilibrium is established, that very little water is removed from storage close to the well, that water percolates toward the pumped well from all directions equally, and that the same quantity of water percolates toward the well through each of the series of concentric cylindrical sections around the pumped well. The derivation of the general Thiem formula has been discussed by Wenzel (1942, p. 81), and a graphical solution of the Thiem formula has been discussed by Jacob (1944).

The Thiem formula may be written:

$$T = \frac{527.7Q \log_{10} r_2/r_1}{s'_1 - s'_2}$$

in which

T = coefficient of transmissibility (as previously defined);
Q = discharge of pumped well, in gallons a minute;
r = distance of observation wells from the pumped well, in feet;
s = observed drawdown of water level in the observation wells, in feet;
s' = adjusted drawdown of water level in the observation wells, in feet, and is equal to $s - \frac{s^2}{2m}$.

In the above equation, let $\Delta s'$ be that value of $s'_1 - s'_2$ for which the value of $\log_{10} r_2/r_1$ is unity (that is, $\Delta s'$ corresponds to one log cycle of r_2/r_1). The equation then becomes

$$T = \frac{527.7Q}{\Delta s'}.$$

The value $\Delta s'$ is determined by inspection from the semi-log graph in which values of the adjusted drawdowns on cartesian coordinates have been plotted against corresponding values of the distance from the test well on logarithmic coordinates. From figure 5, the value $\Delta s'$ is found to be 4.99 feet. T can be computed by the simplified formula:

$$T = \frac{527.7Q}{\Delta s'} = \frac{527.7 \times 1{,}060}{4.99} = 112{,}000 \text{ gallons a day per foot.}$$

The specific yield is computed by the formulae:

$$S = \frac{0.3\ Tt}{r_e^2}; \quad S' = S\left[\frac{(m - s)}{m}\right]$$

in which S = apparent coefficient of storage;
S' = specific yield (as previously defined);
s = observed drawdown at the geometric mean distance, in feet;
m = saturated thickness of the aquifer, in feet;
t = time since pump started, in days;
r_e = maximum extent of cone of depression at time (t), in feet.

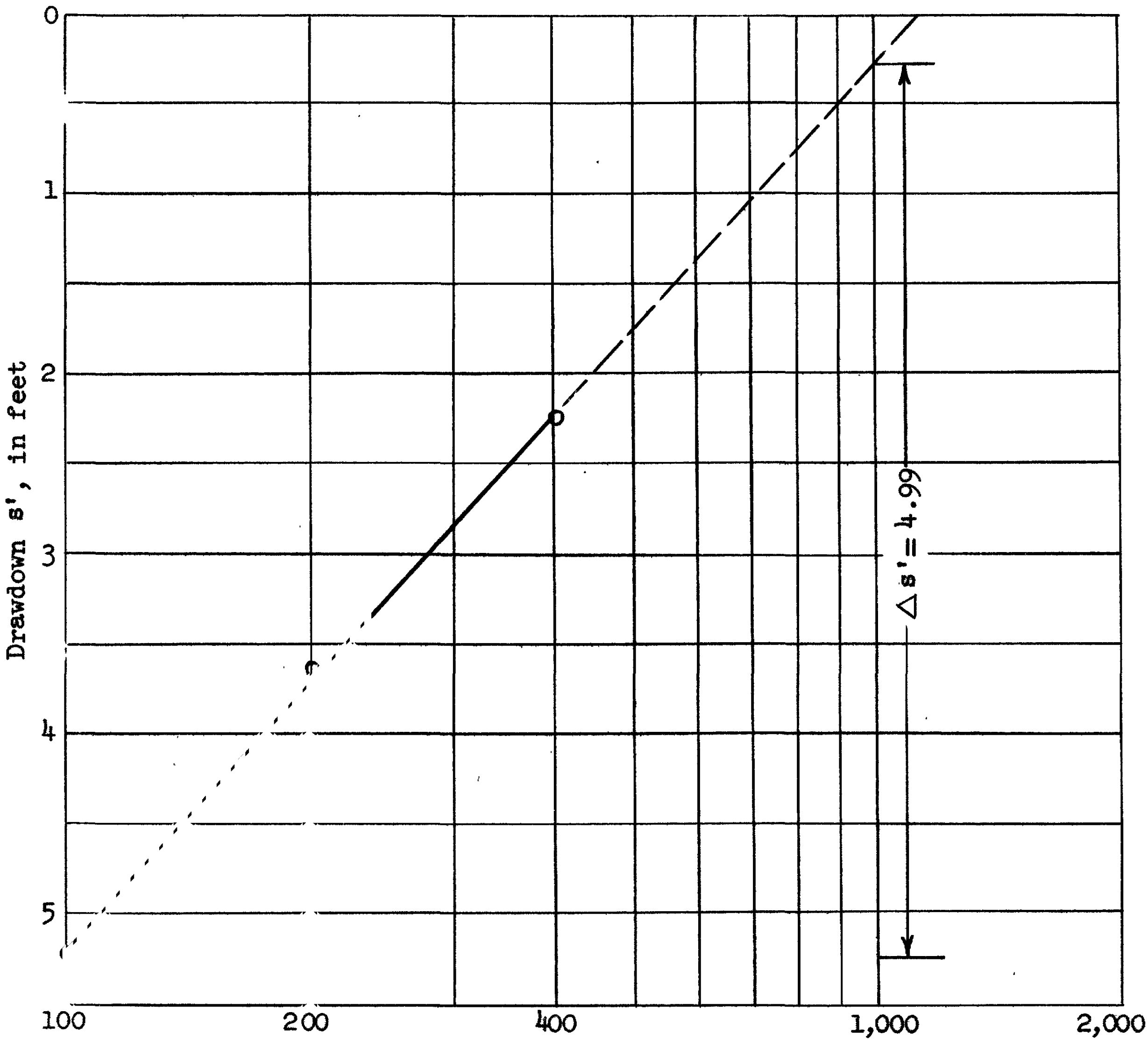

Figure 5.--Semi-log graph for pumping test of well 24-57-34bad1 showing adjusted drawdowns in wells plotted against the distance of the observation wells from pumping well. Well pumped 13 days at 1,060 gallons per minute.

In the semi-log graph, r_e was found by inspection to be 1,150 feet; it is that value of r for which s' = 0. (See fig. 5.) From the equations on page 15:

$$S = \frac{0.3 \times 112{,}000 \times 13}{1{,}150^2} = 0.33$$

and

$$S' = 0.33 \left(\frac{48 - 3.81}{48}\right) = 0.304.$$

The specific yield was determined by this method for several periods of pumping. The computed specific yield became larger as the period of pumping increased. When pumping started, only part of the water contained in the interstices of the sediments drained out immediately. As pumping continued, additional water gradually drained out of the sediments; hence, the computed specific yield increased with time. Values computed from data that were obtained near the end of the test more nearly represent the true specific yield of the material. A graph of the specific yields plotted against the periods of pumping results in a smooth curve. (See fig. 6.) By extending this curve, the probable true specific yield is indicated to be about 32 percent.

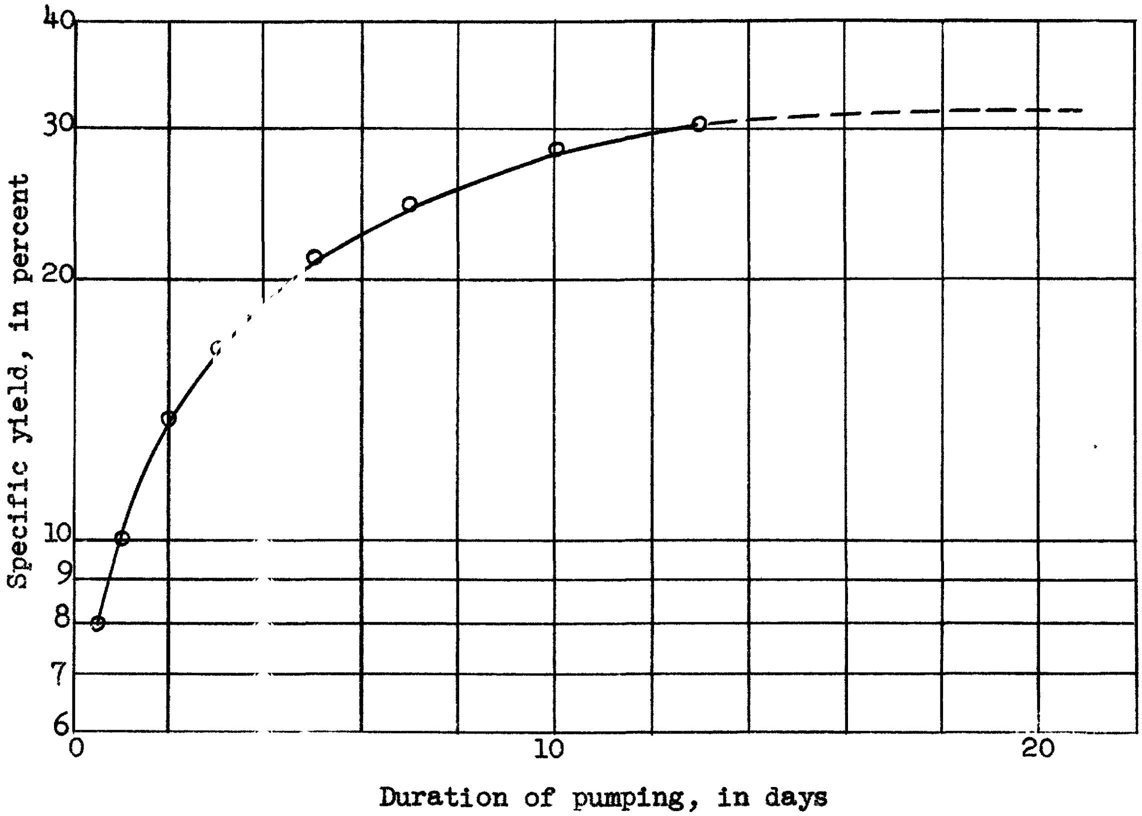

Figure 6.--Graph showing relation between computed specific yield and duration of pumping period for well 24-57-34bad1.

Interference between Wells

As soon as a pump begins discharging water from a well under water-table conditions, the water table in the vicinity of the well is lowered, and a hydraulic gradient toward the well is established. The water table assumes a form comparable to that of an inverted cone--the well is at the apex of the cone. At the beginning, most of the water that is pumped from the well is derived by dewatering materials close to it. As pumping is continued, the material near the well is gradually dewatered; the gradient allows approximately the amount of water that is being pumped to be transmitted to the well; and the water is derived from ever increasing distances from the well. Thus, the cone of depression continues to expand, and the water table within the cone continues to decline gradually. The development of the cone may be altered if water is added to the formation by natural or artificial recharge.

After the pumping of a well is stopped, water continues to percolate toward the well for a time because the hydraulic gradient is still in that direction; the water gradually refills the well and the adjacent material that was dewatered by pumping. As the material near the well is refilled, the hydraulic gradient decreases, and the recovery of the water level in the well becomes progressively slower. A general equalization of water levels eventually takes place over the affected area; the water table tends to assume its original form, although it may remain temporarily or permanently lower than before water was withdrawn. In areas where irrigation wells are closely spaced, pumping lifts are greatly increased by this interference between wells.

Specific Capacity of Wells

The specific capacity of a well is defined as the number of gallons a minute that a well yields for each foot of drawdown. Under water-table conditions, this relation is constant only when the drawdown is a small fraction of the saturated thickness of the aquifer; it also varies with differences in the construction and development of wells. However, a comparison of specific capacities is useful in the estimation of the relative efficiency of wells and of the permeability of formations.

Available data reported for wells in the third terrace deposits indicate that the specific capacities for these wells range from 33 to 275 gallons a minute per foot of drawdown and average 141 gallons a minute per foot of drawdown. (See following table.)

Depth, yield, drawdown, and specific capacity of irrigation and drainage wells in the Dutch Flats area

[Based on reported data]

Well number	Depth (feet)	Yield (gallons a minute)	Drawdown (feet)	Specific capacity (gallons a minute per foot of drawdown)
23-57-3abb	82	1,100	4	275
-3abc	72	1,100	5	220
24-56-31cda	92	1,100	30	33
-32bba	110	750	20	38
-33bcb	87	1,200	10	120
24-57-16bca	112	1,200	7	171
-21bab	107	1,100	5	220
-26cda	85	1,400	7	200
-34adb	90	1,400	11	127
-34bad1	51	1,060	a/ 15.4	69
-35bcb	84	1,000	6	167
-35cbb	87	1,500	28	54

a/ Measured.

SOURCE OF GROUND WATER

In the Dutch Flats area, the main recharge to the ground-water reservoir is derived from seepage from irrigation canals and irrigated lands and from precipitation.

Recharge from Precipitation

In comparison to seepage from irrigation water, the direct penetration of precipitation in the area is not an important source of recharge. Water-level fluctuations that are caused by precipitation generally are obscured by the much larger fluctuations that are caused by irrigation seepage. (See fig. 7.)

Precipitation probably contributes less than 1 inch of water annually to the ground-water reservoir directly; this is not more than 5 percent of the total precipitation.

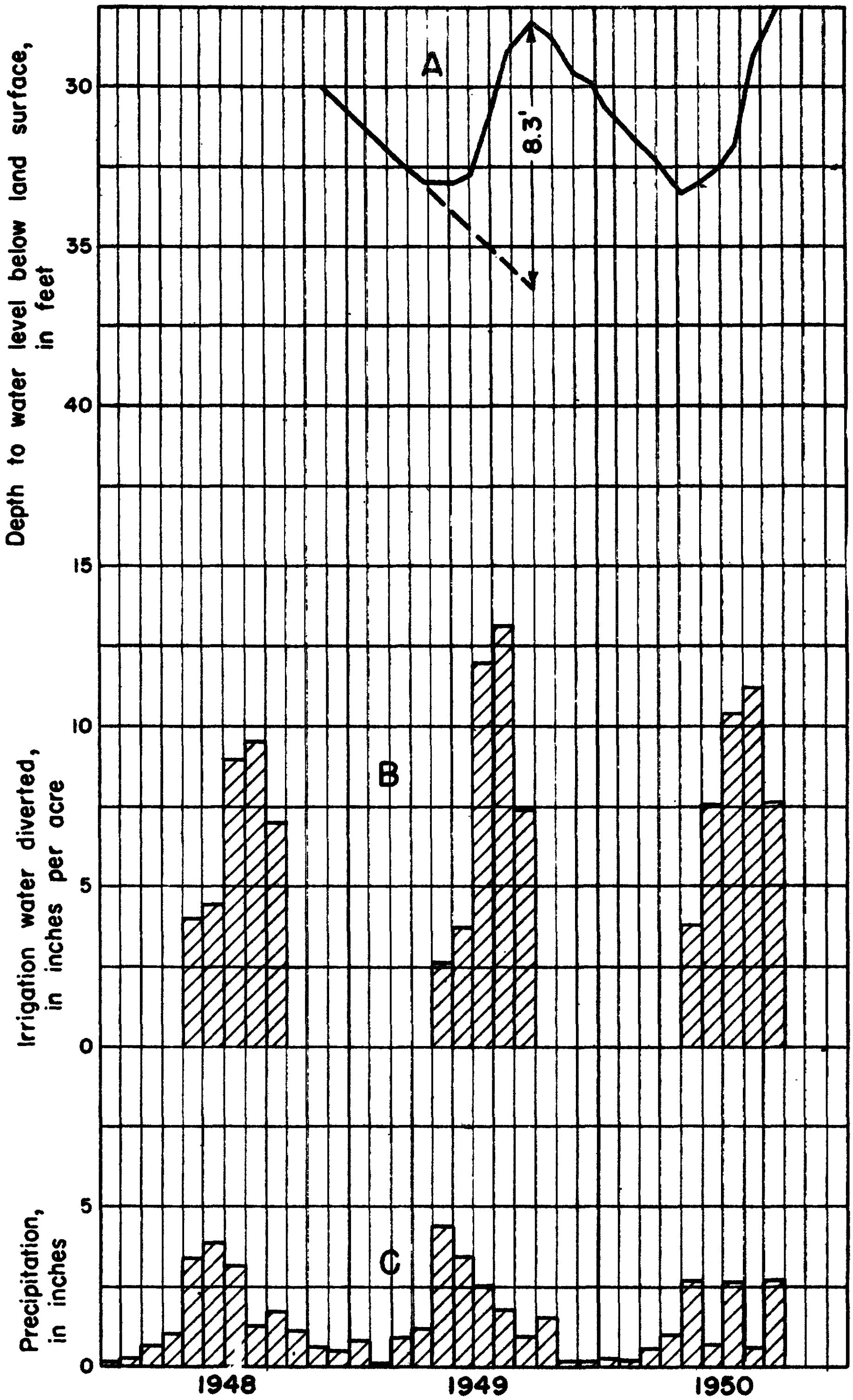

Figure 7.—Hydrographs showing (A) the average water level in 16 wells in the third terrace deposits between Dry Sheep Creek and Dry Spottedtail Creek, (B) water diverted for irrigation from Interstate Canal between Dry Sheep Creek and Dry Spottedtail Creek, and (C) monthly precipitation at Scottsbluff, Nebr.

Recharge by Seepage from Irrigation Canals and Irrigated Lands

The greatest recharge to the ground-water reservoir in the area is from seepage from the canals, from the laterals, and from the irrigation water that is applied to the farm lands. This recharge is well illustrated by the fluctuation of water levels in wells. A hydrograph of the average water level in 16 wells in the part of the Dutch Flats area between Dry Sheep Creek and Dry Spottedtail Creek (fig. 7) shows a general seasonal fluctuation; the water level rises from June to September and declines during the intervening months. The average rise of water levels shown in figure 7 was about 5 feet from the beginning of June to the end of September 1949. Most of this rise was caused by seepage from canals and irrigated fields. However, the rise in water levels does not reflect the magnitude of the seepage losses, because discharge from the ground-water reservoir continued throughout the period of rising water levels; the rise indicates only that the recharge exceeded the discharge.

If the downward trend of the hydrograph during the winter is projected until the time when the water levels actually reached the seasonal high, the average water level that presumably would have been reached if the winter discharge-recharge relation had continued to September would be about 36.3 feet below the land surface. However, recharge increased during the summer, and the water level rose to a depth 28 feet below the land surface; this is a gross average rise of about 8.3 feet. This gross rise in average water level was computed on the basis that the rate of discharge during the winter continued through the summer. Because of greater losses from evaporation and transpiration and because the hydraulic gradient is steeper, the discharge from the ground-water reservoir increases during the summer. Consequently, the gross average rise in water level probably is slightly higher than the 8.3 feet indicated. If the average gross rise in water level is 8.3 feet and the specific yield is 32 percent (determined by the pumping test), the recharge is 2.7 feet of water per acre, or 53,200 acre-feet of water for that part of the area (about 20,000 acres) between Dry Sheep and Dry Spottedtail Creeks. Most of this recharge is by seepage from irrigation canals and irrigated lands, and only a very small part is from direct penetration of precipitation.

An estimate was made of the total recharge from irrigation seepage in the Pathfinder irrigation district. According to the records of this district for the 10-year period 1940-49 (Storm, G. H., 1949, p. 20), an average of 55 percent of the water that was diverted into the canal and lateral system of the entire district was lost by seepage in transit to the farms. The evaporation and transpiration losses along the canals and laterals were not considered as they represent only a very small part of the total loss. The use of water for irrigation of farm lands in the Pathfinder irrigation district generally is large. This is due in part to over-irrigation and in part to the high permeability of the soil. No attempt was made to determine how much of the water actually used for irrigation seeps to the ground-water reservoir, but the recharge is possibly as much as 25 percent of the amount applied. Studies that were made in the Safford Valley, Ariz. (Turner, S. F., and others, 1941, p. 28), show that about one-fourth of the water applied to the land was recharged to the ground-water reservoir. Assuming 25 percent of the water applied to the farms seeps to the ground-water reservoir, then about 66 percent of all the water diverted by the Pathfinder irrigation district recharges the ground-water reservoir.

The estimated total recharge from irrigation seepage in the part of the Pathfinder irrigation district that is between Dry Sheep and Dry Spotted-tail Creeks (about 20,000 acres) was computed in the following manner for 1949. A loss of 29,800 acre-feet of water in the 12.9-mile stretch of the Interstate Canal in this area was determined from seepage studies that were made by the U. S. Bureau of Reclamation (1948). The seepage loss in the canal during 1949 was assumed to be about the same as it was during 1948. In 1949, 63,810 acre-feet of water were diverted from the Interstate Canal into the laterals in this area, of which 46,090 acre-feet of water were diverted from the laterals for use on the irrigated fields. The difference of 17,720 acre-feet between the amount diverted into the laterals and the amount delivered to the fields represents the approximate seepage loss from the laterals. About 25 percent of the remaining 46,090 acre-feet of irrigation water that was applied to the land, or about 11,500 acre-feet of water, was assumed to recharge the ground-water reservoir. Therefore, in this area the estimated total recharge from canal, lateral, and irrigation seepage was about 59,000 acre-feet.

Because the results obtained from both the seepage-data method and the method of multiplying the average gross rise in water level by the specific yield are based on assumptions that could not be checked directly, the average of the two results, or 56,000 acre-feet of water, may be assumed to be a more accurate figure for total recharge to the area.

MOVEMENT OF GROUND WATER

The movement of ground water depends upon the permeability of the aquifer and on the hydraulic gradient of the water table. Darcy's law states that the velocity of the ground water is directly proportional to the permeability of the rock and to the hydraulic gradient, and the quantity of ground water that moves through an aquifer depends upon the rate of movement of the water and on the cross-sectional area through which the water percolates. The direction of the movement of the ground water generally is shown by a water-table contour map. A contour on the water table is a line along which all points have the same altitude. The maximum difference of hydrostatic pressure (the hydraulic gradient) is at right angles to the contours; hence, the water moves perpendicular to the contour lines, and the slope, or hydraulic gradient, of the water table is measured along the direction of this maximum difference in pressure.

The approximate shape of the water table in the Dutch Flats area is shown by the water-table contours on plate 1. As a basis for the construction of the contour map, the altitude of the water table was determined at most of the observation wells. The measuring-point altitudes were determined by instrumental leveling from bench marks that were previously established by the Geological Survey, the Coast and Geodetic Survey, or the Bureau of Reclamation. The location and altitude of the wells and the depth to water in the wells are given in table 3.

In the area shown on plates 1 and 2, the water table generally slopes southward; a few irregularities are caused by discharge into streams and by changes in the permeability and thickness of the aquifer. The contours show that ground water flows into Dry Sheep, Dry Spottedtail, and Spottedtail Creeks, and to a lesser extent, into Akers Draw and Dutch Flats Drain. These streams have a large sustained flow that is derived mainly from the ground-water reservoir.

In the southern part of the area, a buried ridge of the Brule formation is a partial barrier to the southward flow of the ground water, and the general direction of flow is diverted toward the east. The ridge is not a complete barrier to the movement of ground water, however, as some water moves through fractures in the Brule formation and, where the top of the ridge is lower than the water table, some water flows over the formation. The movement of water through fractures in the Brule formation largely is the cause of the extensive seep in secs. 9 and 10, T. 23 N., R. 57 W. Where the ground water moves over the Brule ridge, the cross-sectional area through which the water must pass is small; consequently, the transmissibility is reduced. This causes an impounding of ground water and a rise in water table until ground water is discharged at the surface in the form of seeps. This condition is most evident along Akers Draw.

GROUND-WATER DISCHARGE

Ground water is discharged from the underground reservoir of the Dutch Flats area by evapotranspiration, by seepage into streams and drains, by wells, and by underflow that leaves the area.

Evapotranspiration

The amount of water discharged by evapotranspiration varies with the season, the rate being greatest during the growing season when the temperatures are highest. Where the water table is high and the capillary fringe extends to the land surface, water from the zone of saturation is discharged into the atmosphere by evaporation and transpiration. Where the capillary fringe does not extend to the surface, evaporation is relatively unimportant, but the roots of plants may continue to extract water. During this investigation, no data were obtained on the quantity of ground water discharged through evapotranspiration, but this discharge probably is large in areas where the water table is at or near the surface. Cady (Cady, R. C., and Scherer, O. J., 1946, p. 61) cites data, which were obtained by the Conservation and Survey Division of the University of Nebraska, that show that 4 feet of water was transpired by arrowhead, wild rice, bulrush, and cattail in Cherry County, Nebr., between July 9 and September 20, 1937; an equivalent amount was transpired by swamp grasses and tall meadow grasses during the same period in areas where the water table was about 3 feet below the land surface.

Streams and Drains

Most of the water that is discharged from the ground-water reservoir in the Dutch Flats area leaves the area through streams and drains and eventually flows into the North Platte River. No attempt was made during this investigation to determine the amount of this discharge, but it is evidently large. For the entire Pathfinder irrigation district, however, records show that, in 1926, 362,345 acre-feet of water were applied to land in the district, and 173,470 acre-feet of seepage returned to the streams and drains. In addition to the seepage that leaves the area, an unmeasured, but probably fairly large amount of ground water is discharged from the area as underflow.

A study of the Platte River in Colorado, Wyoming, and Nebraska was submitted to Congress in November 1933 (Congressional documents, 1933); it shows that between 67 and 74 percent of the water diverted from the North Platte River between Whalen Dam, Wyo., and Bridgeport, Nebr., is returned to the river.

Irrigation and Drainage Wells

There are 29 irrigation and 3 drainage wells in the area. Generally the irrigation wells are used to supplement the surface-water supply only during exceptionally dry years. Information on the operation of these wells is given in table 3. The lowest reported yield is 750 gallons a minute and the highest is 1,800 gallons a minute. The average annual pumpage from these wells probably is not more than a few thousand acre-feet.

Underflow

The water-table contours on plate 1 indicate that the general movement of ground water is to the southeast. Ground water that is not intercepted by the streams and drains continues on toward the North Platte River as underflow. No attempt was made to determine the amount of this underflow, but it is undoubtedly large.

DEPTH TO GROUND WATER

A map was prepared showing the depths to water for September 1949. (See pl. 2.) The data for the map were obtained by the superposition of the topographic map on the water-table contour map. An irregular distribution of the various depths to water is shown by this map. Inasmuch as the water table is a fairly regular, nearly plane surface, most of the variations in depth to water are due to the irregularities of the land surface.

The depth to water in the area ranges from a few feet to about 80 feet and averages about 30 feet. Depths to water levels in 68 wells are given in column 13 of table 3. Although no early records are available, it is evident that now the water table is several feet higher than it was before irrigation began. The depth to the water table varies throughout the year; it is least in the late summer when recharge from irrigation is highest and is greatest in the early spring before irrigation is begun.

FLUCTUATIONS OF THE WATER TABLE

In order to observe the fluctuations of the water table in the area, 28 wells were selected for periodic observation. Water-level measurements in these wells are given in table 1 (p. 48).

The stage of the water table indicates the quantity of water in storage in the ground-water reservoir in much the same manner as the water level in a surface reservoir indicates the amount of water in storage in the reservoir. Thus, the changes in the ground-water level indicate changes in storage in the ground-water reservoir. Fluctuations of the water level show the net recharge to and discharge from the ground-water reservoir for a given period; the recharge is contributed by rainfall and irrigation seepage, and the discharge is due to the withdrawal of water by pumping for irrigation, to natural drainage, and to evapotranspiration.

The rise of water levels in the Dutch Flats area largely is due to seepage from canals and irrigated fields. The rise caused by the penetration of rainfall to the zone of saturation is obscured to a large extent by the much larger rise caused by the seepage of irrigation water. The decline of the water levels results from the percolation of water into streams and drains and from the withdrawal of water by evapotranspiration. The small amount of pumping in the area probably has only local effect on the water table.

The fluctuations of the water table in the area are shown by hydrographs in figures 7 and 8. The hydrograph of the average depths to water in 16 wells in the Dutch Flats area (fig. 7) shows that, in the area that is underlain by the third terrace deposits, the decline of the water table is checked as soon as irrigation water is applied to the land. After a few weeks, the recharge from irrigation is sufficient to overbalance the natural discharge and causes the water table to rise. In 1949 water was applied to the land on May 2, but the average water level did not begin to rise until about June 10. This long delay in the rise of the water table is accounted for largely by the exceptionally small amount of irrigation water supplied during May and part of June. The water table rose continuously from June 10 to the end of September, when irrigation was discontinued for the season; at that time the water table had risen an average of 5 feet. The water table declined from the seasonal high in September 1949 until the first of May 1950, at which time the level was approximately the same as the low of 1949.

Water levels in wells near the Interstate Canal show a greater fluctuation than water levels in wells farther away from the canal. Also, water levels in wells near the canal begin to rise earlier in the season, because the canal is filled with water about 1 month before irrigation is begun. The

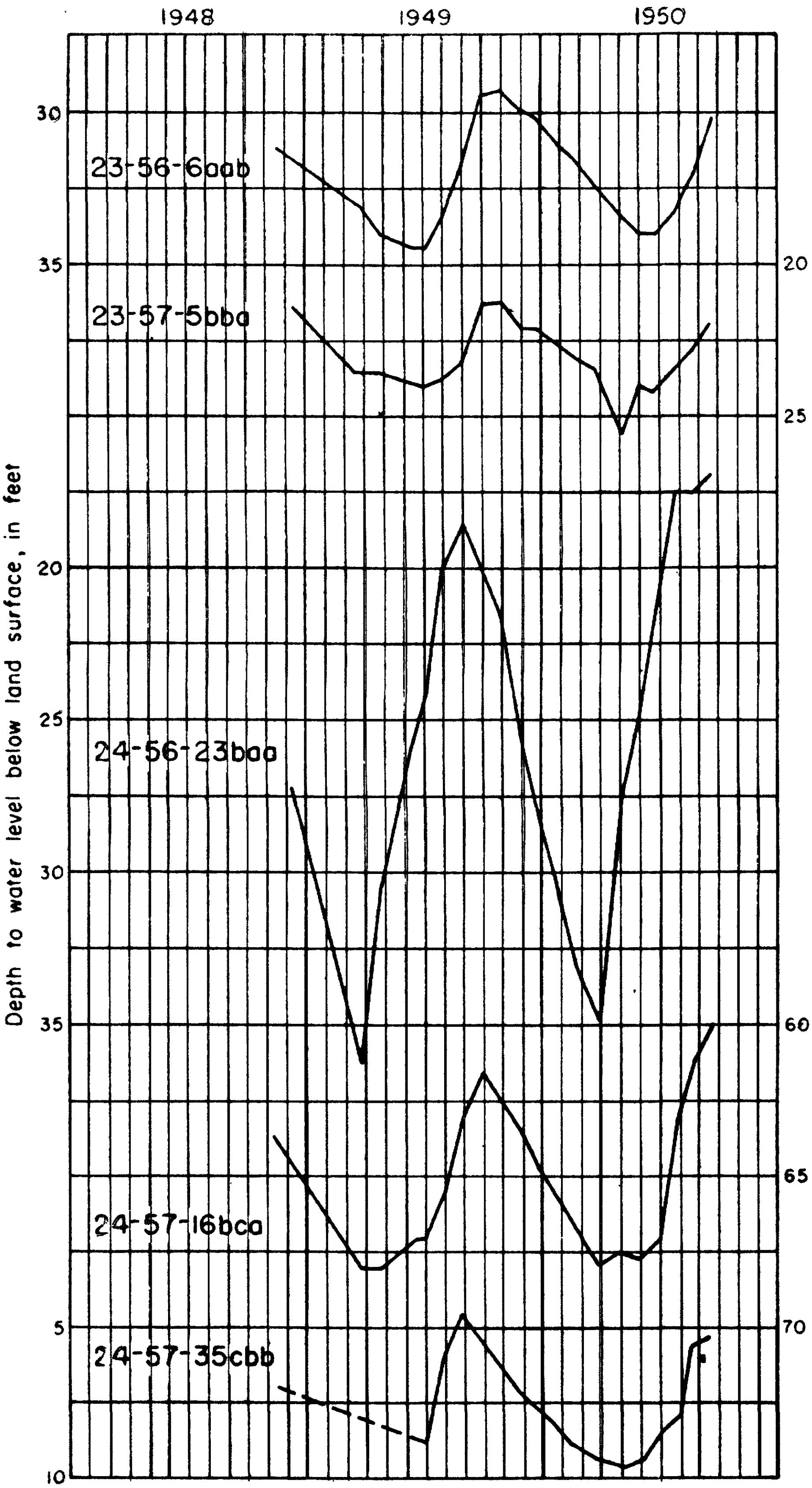

Figure 8—Hydrographs showing fluctuations of water levels in the Dutch Flats area, Nebr.

early rise can be seen by a comparison of the hydrograph of well 24-57-16bca, which is in the third terrace deposits near the canal, with the hydrographs of wells 23-56-6aab, 23-57-5bba, and 24-57-35cbb, which are in the third terrace deposits farther away from the canal. (See fig. 8.)

The large seasonal fluctuations of water levels in wells that penetrate the Brule formation are caused in part by the incomplete draining of the aquifer between irrigation seasons. The water table may decline for a considerable period before much water, except that which drains from cracks and fissures, comes out of storage. As soon as water is recharged to the formation, the cracks and fissures are readily filled with water, and the water levels rise rapidly. The water level in well 24-56-23baa (fig. 8), which is in the Brule formation, began rising rapidly near the end of March 1949 and reached a peak about the end of August.

DEVELOPMENT OF GROUND WATER

Data were obtained for all the irrigation and drainage wells that were equipped with pumping plants, but no attempt was made to obtain data for all the domestic and stock wells which, in general, yield only a few gallons a minute and usually are pumped only for short periods when water is needed.

All the 32 irrigation and drainage wells in the area supply water from the third terrace deposits along the North Platte River. The irrigation wells are used chiefly as an auxiliary supply of water for irrigation and generally are used only during exceptionally dry years. These wells usually pump only a few thousand acre-feet of water a year; however, they could probably pump not less than 20,000 to 25,000 acre-feet of water annually, if they were operated throughout the irrigation season. This would be sufficient to supply about one-half of the irrigation water that is needed for the Dutch Flats area. Wells that yield 1,000 to 2,000 gallons a minute probably could be developed in some places, if selection of the sites were preceded by adequate test drilling to determine the maximum thickness of saturated terrace deposits.

If large-scale ground-water development is undertaken in the area, the water table will decline, some of the seeps will disappear, and ground-water losses due to evapotranspiration will be less.

The total cost of pumping water from wells includes the cost of power, the cost of drilling the well and installing the pump, and the cost of maintenance and operation. The cost of power is the main consideration in the determination of the operating cost of pumping ground water. During the pumping test on well 24-57-34badl, the amount of electric power required to pump an acre-foot of water was computed to be 1.6 kilowatt-hours per foot of lift. The electric motor and pump had an over-all efficiency of 64 percent. The amount of electric power required to pump an acre-foot of water in the Dutch Flats area is comparable to the amount required in other areas. During a detailed study of the ground-water resources of Deer Valley, Ariz. (Bluhm, F. I., and Walcott, H. N., 1949, p. 9), it was determined that 1.8 kilowatt-hours were required to lift one acre-foot of water a height of one foot. The over-all efficiency of the pumping plants used in these tests probably was somewhat less than the 64 percent computed during the test in the Dutch Flats area.

SEEPAGE

The application of irrigation water in the area has caused a rise in the water table and an increase in the amount of lateral percolation of ground water. As a result springs and seeps have appeared in places where the topography is favorable. The seep area in parts of secs. 27 and 28, T. 24 N., R. 57 W., is caused by the intersection of the water table and the low part of the broad valley that constitutes the third terrace surface. This seep developed early in the history of the irrigation project; three drainage wells were drilled in 1920 in an attempt to remedy the situtation. These wells have been operated during each irrigation season since their installation, but apparently they have not been very effective; the combined discharge from the three pumps is only about 800 acre-feet annually. The water pumped from the wells is discharged into the Dutch Flats Drain.

Seeps also have developed on the first terrace south of the Tri-State Canal. The first-terrace deposits are thin and have a relatively low coefficient of permeability; hence, they do not transmit water readily. Where the partly buried ridge of the Brule formation lies below the water table or is traversed by cracks or fractures, ground water moves from the highly permeable third-terrace deposits to the less permeable first-terrace deposits and is forced to the surface causing seeps. The seeps north of the town of Morrill largely are due to water that moves through the fractures in the Brule formation, whereas, the seeps to the east in sec. 12, T. 23 N., R. 57 W., and in sec. 18, T. 23 N., R. 56 W., are due to water moving over the Brule barrier.

Because the seeps are caused by excessive ground-water recharge, any decrease in recharge would tend to decrease the seeped areas. Ground-water recharge could be decreased by lining the canals and laterals or by applying less water to the irrigated lands. Seep areas also could be reduced by installing additional drains or by pumping more water from the ground-water reservoir. Water pumped from the ground-water reservoir could be used for irrigation, thereby decreasing the amount of surface water needed. A combined ground- and surface-water irrigation system would be developed that would maintain the water table at a depth that would cause part of the seeped areas to disappear. The seep area in the central part of the Dutch Flats area could be eliminated in this way. However, the seeps below the Tri-State Canal would not entirely dry up, but conditions probably would be greatly improved.

CHEMICAL CHARACTER OF THE WATER

Purpose and Scope of the Investigation

Complete chemical analyses were made of 10 samples of ground and surface waters collected by F. N. Visher in September, October, and November of 1949. The brief discussion that follows is based on the results of analyses of these samples. The discussion embraces quality of water as related to surface seepage, drainage, and domestic and agricultural use. This information will provide a basis for any future comprehensive quality-of-water sampling program.

Chemical Quality of the Water

Ground Water

Four samples of ground water were collected in connection with the reconnaissance study of the ground-water resources in the area. (See fig. 9.) Three of the samples were obtained from drainage wells that pump water from the third terrace for the purpose of lowering the water table and reducing seepage in the area north of Morrill. One sample was obtained from the Brule formation north of Morrill.

The results of analyses, both in parts per million and in equivalents per million, are presented in the following tables. The wells sampled are listed by location numbers and geologic source.

The water from the four wells is very similar and is characterized by moderately low concentrations of dissolved solids--principally calcium and

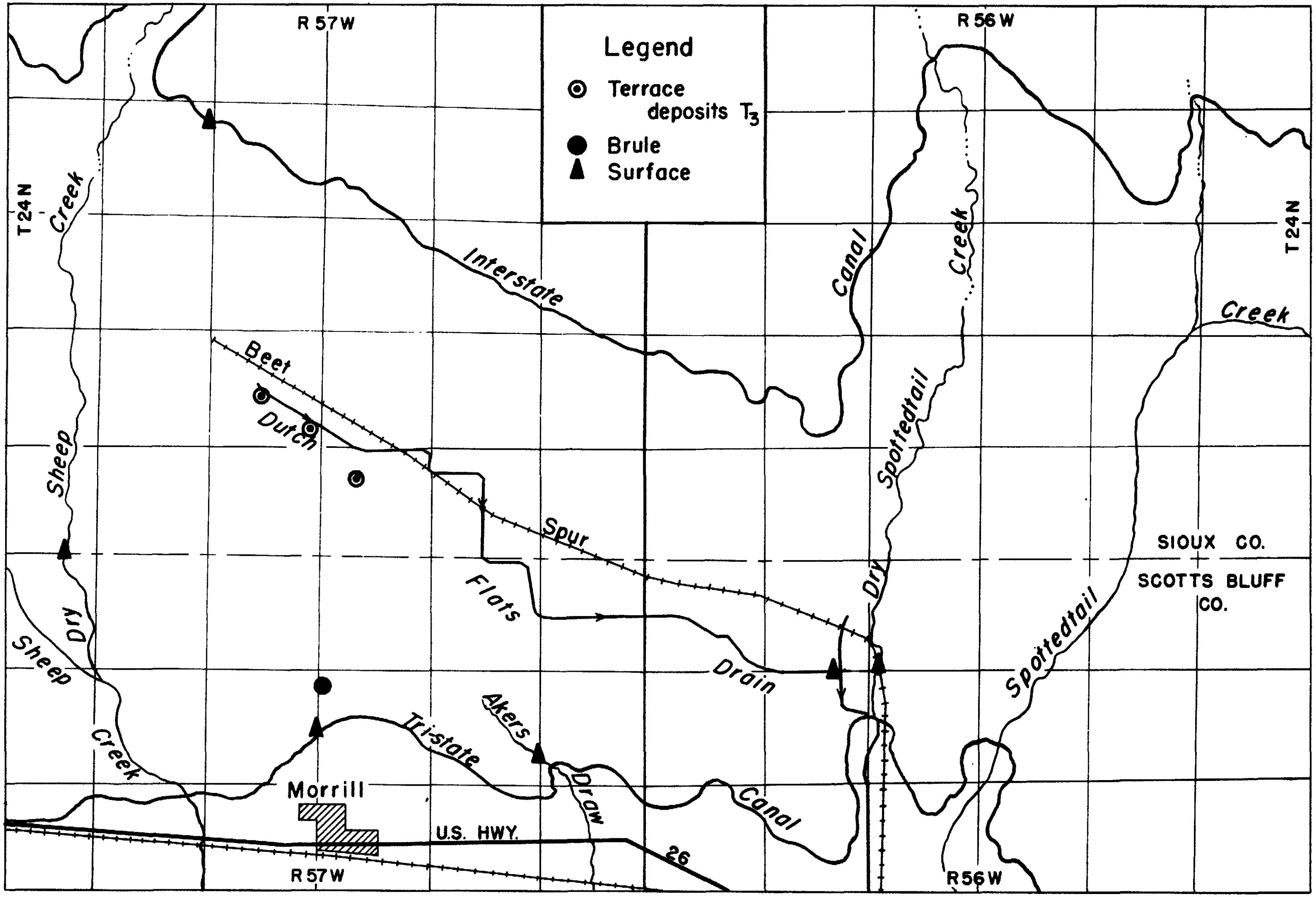

Figure 9.— Map showing sampling points in the Dutch Flats area, Nebr.

Mineral constituents, in parts per million, and related physical measurements of waters, Dutch Flats area, Nebr.

Source	Date of collection	Depth of well (feet)	Temperature (°F.)	pH	Specific conductance (micromhos at 25° C.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium
																			Total	Noncarbonate	
Terrace deposits (T3)																					
24-57-28caa	9-15-49	62	..	7.4	700	59	0.02	70	15	60	6.4	256	133	12	...	13	0.40	524	236	26	35
24-57-28dda	10-11-49	59	..	8.2	555	53	.06	52	13	42	6.4	212	80	10	0.4	13	.20	408	184	10	32
24-57-34bad1	10-11-49	51	54	7.4	733	54	.02	82	14	56	6.4	285	128	12	.4	16	.50	542	262	28	31
Brule formation																					
23-57-10bbb	9-22-49	34	..	7.2	794	52	.40	91	20	54	3.2	300	139	12	.8	27	.40	592	310	64	27
Canals																					
Interstate Canal, 6 miles north of Morrill	10-11-49	..	..	7.8	578	14	.02	57	19	45		168	153	10	.8	6.0	.30	414	220	82	31
Tri-State Canal, 1 mile north of Morrill	9-30-49	..	..	7.3	757	27	.02	71	18	68	4.8	245	164	16	.8	4.5	.40	512	251	50	37
Drains																					
Akers Draw, 2 miles east of Morrill	11- 1-49	..	55	7.5	733	47	.02	76	20	47	11	283	135	12	.8	11	.40	534	272	40	26
Dutch Flats Drain, 5 miles northeast of Morrill	11- 1-49	..	53	7.5	834	62	.02	94	21	57	11	328	154	14	1.2	11	.50	618	321	52	27
Creeks																					
Dry Sheep Creek, 4 miles northwest of Morrill	11- 1-49	..	50	7.8	639	54	.02	72	15	43	5.6	234	128	12	...	1.2	.30	486	241	49	27
Dry Spottedtail Creek, 5½ miles northeast of Morrill	11- 1-49	..	52	7.4	650	66	.02	72	14	44	4.8	221	127	12	1.2	6.6	.30	490	237	56	28

bicarbonate and to a lesser extent, sodium and sulfate. The dissolved solids range from 408 to 592 parts per million, and the hardness ranges from 184 to 310 parts per million. The percentage of sodium is low, ranging from 27 to 35. Samples obtained from the terrace deposits contained less than 0.10 part per million of iron, whereas the sample from the Brule formation (23-57-10bbb, 34 feet deep) had 0.40 part per million of iron.

Mineral constituents, in equivalents per million, of waters, Dutch Flats area, Nebr.

Well or surface location	Na + K	Ca	Mg	SO_4	Cl, F, NO_3	HCO_3
Terrace deposits (T_3)						
24-57-28caa	2.78	3.50	1.23	2.76	0.55	4.20
24-57-28dda	1.98	2.60	1.07	1.67	.51	3.47
24-57-34bad1	2.62	4.12	1.16	2.65	.62	4.63
Brule formation						
23-57-10bbb	2.43	4.54	1.65	2.89	.81	4.92
Canals						
Interstate Canal, 6 miles north of Morrill	1.96	2.84	1.56	3.19	.42	2.75
Tri-State Canal, 1 mile north of Morrill	3.06	3.52	1.47	3.44	.56	4.05
Drains						
Akers Draw, 2 miles east of Morrill	2.34	3.86	1.67	2.76	.56	4.55
Dutch Flats Drain, 5 miles northeast of Morrill	2.76	4.71	1.73	3.20	.64	5.36
Creeks						
Dry Sheep Creek, 4 miles northwest of Morrill	2.02	3.60	1.23	2.66	.36	3.83
Dry Spottedtail Creek, 5½ miles northeast of Morrill	2.03	3.59	1.15	2.64	.51	3.62

All the samples of ground water contained considerable silica. The concentration of silica (SiO_2) ranged from 52 to 59 parts per million. The single sample from the Brule formation was somewhat harder than samples from the terrace deposits. Concentrations of chloride, fluoride, and boron were low in the samples from both sources. As the nitrate concentration of 27 parts per million in the Brule water was about twice that found in the waters from the terrace deposits, it can be presumed that the difference in nitrate probably was due to contamination by surface seepage.

The similarities in chemical character of the waters from the several sources can be more easily seen in the bar diagram in figure 10, where equivalents per million of the major ions are shown in a vertical column. The results of analyses are also expressed diagrammatically on a trilinear graph in figure 10, in which percentages of equivalents per million of the anions are plotted. The close proximity of the plotted points is an indication of the similarities in the chemical character of the water.

Relation of Chemical Quality of the Ground and Surface Waters

Samples were obtained from six canals, drains, and creeks in the area. (See fig. 9.) The mineral contents of these waters were similar to those found in the ground-water samples. The difference in content of dissolved solids in the water of the Interstate Canal (414 p.p.m.) and the Tri-State Canal (512 p.p.m.) probably was the result of return irrigation flows. Other than a lower content of nitrate and silica and a somewhat higher ratio of sulfate to total anions, the chemical character of irrigation water as represented by the samples from the two canals closely resembles that of the ground water in the terrace deposits and Brule formation. These results give some indication that in the seeped area north of Morrill no appreciable change has taken place in the mineral content of the water as the water moves downward to shallow aquifers. Furthermore, the water that moves back to the ground surface either through fractures in the Brule formation or from the terrace deposits (as represented by the sample from Akers Draw) is not appreciably changed in mineral content.

As the Dutch Flats Drain (see fig. 9) receives the water pumped from the three drainage wells sampled in the terrace deposits, the drain water would be expected to be similar in chemical character to the water from the three wells. There was some increase in dissolved solids downstream.

The chemical character of the water in Dry Sheep and Dry Spottedtail Creeks, which receive considerable amounts of ground water inflow, was not much different from other water sampled.

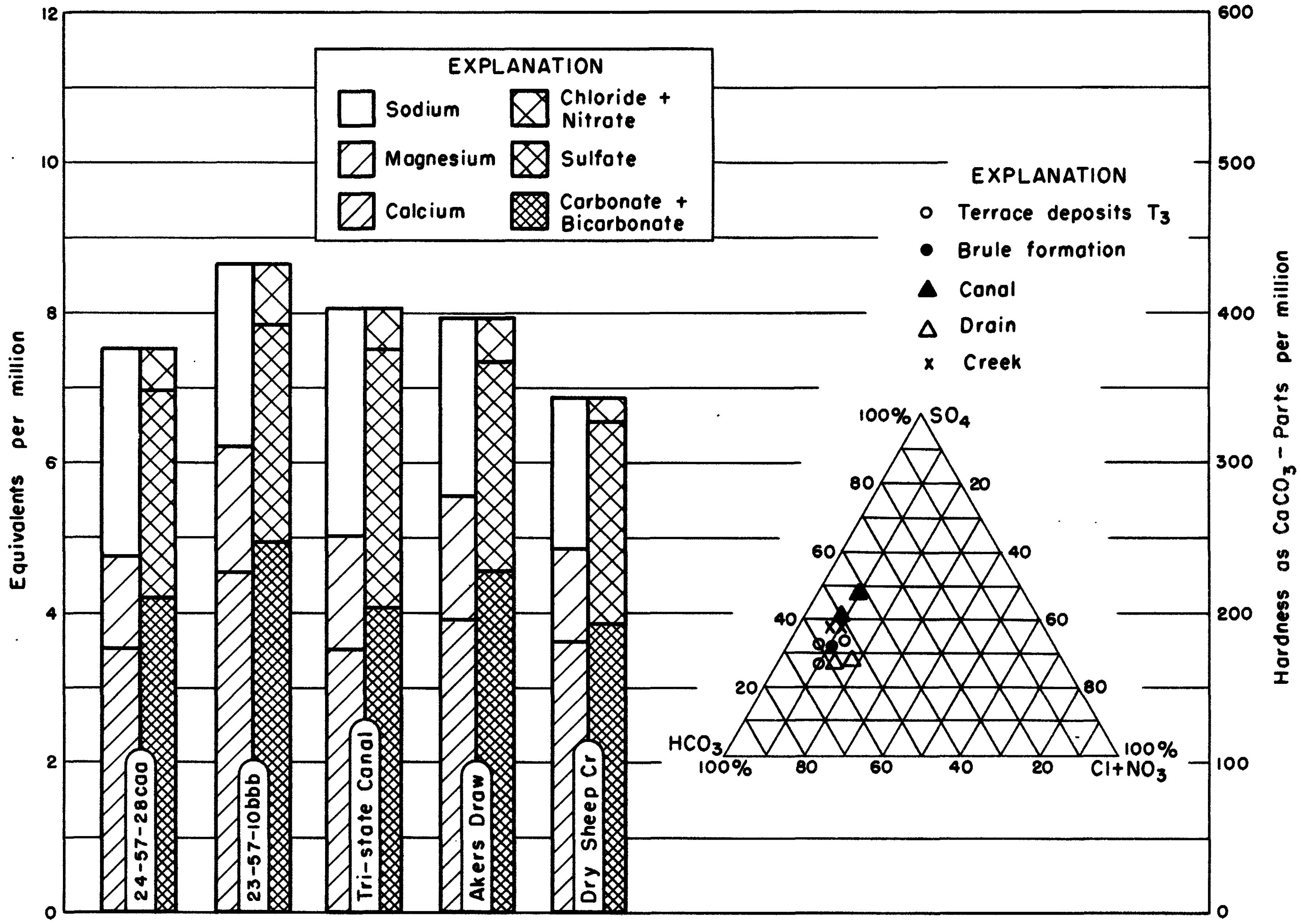

Figure 10.—Principal mineral constituents and percentages of reacting values of acid radicals, Dutch Flats area, Nebr.

Relation of Quality of Water to Use

Generally, water is considered satisfactory for most domestic purposes if the concentration of dissolved solids is less than 500 parts per million and the iron content is less than a few tenths of 1 part per million. The three drainage wells in the terrace deposits have no present domestic use. Although the water from this source is somewhat hard for domestic and culinary uses, it is of satisfactory chemical quality for drinking.

Well 23-57-10bbb, which taps the Brule formation, supplies water for both domestic and stock use. The iron content of this water, however, is somewhat higher than is desirable for domestic supplies.

The analytical data indicate the suitability for irrigation use of water from the third terrace deposits and from the Brule formation. Wilcox (1948, p. 27) evaluates the analysis of a water that is proposed for irrigation by the percentage of sodium and by electrical conductivity (a measure of the total ions in solution). By this method all the ground and surface water sampled in the area rate "excellent" or "good." The usual methods of evaluating the chemical quality of irrigation water may not continue to be applicable to the Dutch Flats area if high water-table conditions persist.

At present the salt content of the ground water does not seem to be increasing appreciably as a result of irrigation practices. The drainage wells operating in the seeped area north of Morrill yield water of excellent quality. However, investigations in other irrigated areas in the Missouri Basin have indicated that seasonal fluctuations in the ground-water level may be accompanied by changes in the chemical quality of the water. Such possible changes in the Dutch Flats area could be observed by a more comprehensive quality-of-water investigation.

LOGS OF WELLS

Logs of wells were obtained from the well drillers and from the well owners. These logs are presented in table 2, p. 45. Because it was not possible to verify the logs by the examination of the drilling samples, the logs are given in the drillers' terminology. However, the logs are believed to be reasonably accurate, and they probably give a fairly good description of the materials that were penetrated.

WELL INVENTORY

Records were obtained for 75 wells in the area. The locations of these wells are shown on plate 1. The available pertinent data for all wells that are shown on the map are given in table 3, p. 49. It was not possible to obtain measurements of the depth or water level in many of the wells, and the data given in the table for these wells were reported by the owner or driller of the well.

CONCLUSIONS

The Dutch Flats area is underlain largely by terrace deposits of the North Platte River and its tributaries. The Brule formation, which underlies the terrace deposits, is exposed at the surface in the northern and northeastern parts of the area; along the southern margin of the area it occurs as a partly buried ridge. This ridge serves as a partial barrier to the southward movement of ground water in the area.

Unconfined ground water is contained in the third terrace deposits in sufficient quantities for irrigation supplies, and wells that yield 1,000 to 2,000 gallons a minute probably could be developed. The first and second terrace deposits also contain unconfined ground water but, as these deposits are thin and generally have a low permeability, they do not yield large quantities of water to wells. The Brule formation has a very low coefficient of permeability and will not transmit water readily except where it contains fractures.

The main source of recharge to the ground-water reservoir is seepage from the canals and laterals and from irrigation water that is applied to the farms. In the area between Dry Spottedtail and Dry Sheep Creeks, the total recharge was estimated to be about 56,000 acre-feet in 1949; about half of this recharge came from seepage from the Interstate Canal.

The excessive recharge to the ground-water reservoir has resulted in a rise in water levels and has caused seeps to appear in several places where the topography is favorable. The seep area that developed in parts of secs. 27 and 28, T. 24 N., R. 57 W., is due to the intersection of the water table and the low part of the broad valley that constitutes the third terrace surface. This seep area could be drained by lowering the water table a few feet --that is, either by decreasing the recharge or by increasing the discharge of ground water in the area. The amount of recharge could be decreased by lining the canals and laterals and by decreasing the amount of water applied to the land. The discharge of ground water could be increased by installing more drains and by pumping additional water from the ground-water reservoir. The pumped water could be used for irrigation and, thus, the amount of surface water that is needed for this purpose would be reduced. Consequently, a balanced surface- and ground-water irrigation system could be established for the area. The establishment of a balanced surface- and ground-water irrigation system in the area would probably necessitate the drilling of additional irrigation wells. The selection of sites for these wells should be preceded by adequate test drilling in order to determine the most advantageous locations.

Lowering the water table in the Dutch Flats area will alleviate the seeps below the Brule ridge in the southern part of the area, but it probably will not completely eliminate them. The water table north of the Brule ridge is much higher than it is south of the ridge; the resulting gradient causes the water to move through the fractures in the formation under considerable head. Lowering the water table north of the ridge would reduce the gradient and would thus decrease the amount of water that moves through the fractures. The periodic measurement of water levels in observation wells should be continued. Also, the water in the area should be chemically analyzed periodically in order to warn against the possibility of a high mineral content in the soil and ground water.

The results of analyses of 10 samples of ground and surface water in the Dutch Flats area indicate general similarity both in chemical character and composition. All the water was of moderately low mineral content; the content of dissolved solids ranged from 408 to 618 parts per million, and the hardness ranged from 184 to 321 parts per million. The terrace deposits yield water that contains small quantities of the minor constituents--iron, fluoride, nitrate, and boron--and are of satisfactory chemical quality for domestic and irrigation use. Although otherwise similar to water from the terrace deposits, water from the Brule formation has a higher content of iron than is considered desirable for domestic supplies.

The salt content of drainage water, as represented by Akers Draw, Dutch Flats Drain, and Dry Sheep and Dry Spottedtail Creeks, does not seem to have increased as a result of irrigation practices.

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Table 1.--Water levels in observation wells

23-56-5cdd.

Date	Water level	Date	Water level	Date	Water level
Dec. 17, 1948	10.79	June 15, 1949	11.70	Sept.30, 1949	9.22
Mar. 22, 1949	11.67	July 1	11.48	Oct. 26	9.58
Apr. 28	11.98	Aug. 31	9.75	Dec. 21	10.52

23-56-6aab.

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1948	30.91	Sept.30, 1949	29.44	May 1, 1950	33.50
Mar. 23, 1949	33.05	Oct. 26	29.24	29	34.17
Apr. 27	33.95	Nov. 28	29.88	June 22	34.00
June 15	34.55	Dec. 21	30.12	July 17	33.22
July 1	34.63	Jan. 13, 1950	31.19	Aug. 20	32.02
28	33.54	Feb. 20	31.67	Sept.21	30.19
Aug. 31	31.77	Mar. 24	32.51		

23-56-8ccc.

Date	Water level	Date	Water level	Date	Water level
Aug. 12, 1937	39.00	July 1, 1949	41.60	Sept.30, 1949	34.02
Dec. 16, 1948	43.79	28	36.05	Oct. 26	37.18
Mar. 22, 1949	45.19	Aug. 31	33.90	Nov. 28	40.95
June 15	44.20				

23-56-9aaa.

Date	Water level	Date	Water level	Date	Water level
Aug. 12, 1937	38.95	June 10, 1949	40.28	Sept.30, 1949	34.77
Dec. 15, 1948	38.06	July 1	40.26	Oct. 26	35.60
Mar. 22, 1949	39.74	28	38.65	Nov. 28	36.78
Apr. 27	41.50	Aug. 31	36.65	Dec. 21	37.53

23-57-1cbc.

Date	Water level	Date	Water level	Date	Water level
Nov. 22, 1948	43.30	Aug. 31, 1949	33.87	May 1, 1950	39.61
Mar. 22, 1949	41.44	Sept.30	33.23	29	39.15
Apr. 28	39.31	Oct. 26	34.46	June 22	38.37
June 15	38.67	Nov. 28	35.78	July 17	37.10
July 1	38.52	Dec. 21	36.45	Sept.21	33.13
28	36.20	Jan. 13, 1950	37.28		

Table 1.--Water levels in observation wells--Continued

23-57-2abb.

Date	Water level	Date	Water level	Date	Water level
July 22, 1937	15.16	Aug. 31, 1949	10.26	Feb. 20, 1950	15.03
Mar. 22, 1949	15.32	Sept.30	10.97	May 1	16.19
Apr. 28	15.97	Oct. 26	11.83	29	15.48
June 10	14.84	Nov. 28	13.06	June 22	15.09
July 1	16.14	Dec. 21	13.60	Aug. 20	13.75
28	12.74	Jan. 13, 1950	14.15	Sept.21	14.15

23-57-3dba.

Nov. 24, 1948	11.62	Sept.30, 1949	8.60	May 1, 1950	17.00
Mar. 22, 1949	15.82	Oct. 26	10.20	29	16.05
Apr. 28	16.65	Nov. 28	11.87	June 22	14.58
June 10	15.00	Dec. 21	12.97	July 17	10.92
July 1	13.59	Jan. 13, 1950	13.85	Aug. 20	9.34
28	10.58	Feb. 20	15.15	Sept.21	8.17
Aug. 31	7.95	Mar. 24	16.06		

23-57-5bba.

Aug. 13, 1937	18.96	Aug. 31, 1949	23.03	Mar. 24, 1950	23.43
Dec. 14, 1948	21.28	Sept.30	21.28	May 1	25.73
Mar. 23, 1949	23.63	Oct. 26	21.27	29	23.93
Apr. 27	23.47	Nov. 28	22.05	June 22	24.21
June 10	23.78	Dec. 21	22.08	Aug. 20	22.72
30	24.08	Jan. 13, 1950	22.45	Sept.21	21.84
July 28	23.87	Feb. 20	22.96		

23-57-5ddd.

Nov. 15, 1948	21.88	June 30, 1949	27.86	Oct. 26, 1949	19.99
Mar. 22, 1949	27.27	Aug. 31	19.51	Dec. 21	23.17
June 10	28.27	Sept.30	18.75		

23-57-9ccb.

Mar. 22, 1949	50.40	Aug. 31, 1949	43.82	Dec. 21, 1949	54.11
Apr. 27	56.03	Sept.30	47.86	Jan. 27, 1950	50.04
June 30	48.77	Oct. 26	48.99	Feb. 20	50.81
July 28	46.01	Nov. 28	53.42	Mar. 24	52.59

Table 1.--Water levels in observation wells--Continued

23-57-10bbb.

Date	Water level	Date	Water level	Date	Water level
Nov. 27, 1948	13.00	Aug. 31, 1949	13.51	Jan. 27, 1950	16.00
Mar. 22, 1949	19.72	Sept.30	11.61	Feb. 20	18.94
June 1	21.28	Oct. 26	12.41	Mar. 24	20.48
30	18.80	Dec. 21	15.55	May 1	21.83
July 28	15.71				

23-57-11ddc.

Dec. 16, 1948	16.66	July 1, 1949	17.65	Oct. 26, 1949	15.30
Mar. 22, 1949	17.27	28	14.82	Nov. 28	15.92
Apr. 27	17.48	Aug. 31	12.79	Dec. 21	16.57
June 15	17.62	Sept.30	14.39		

24-56-21acc.

Dec. 15, 1948	36.25	July 28, 1949	23.40	Dec. 21, 1949	33.73
Mar. 22, 1949	37.67	Aug. 31	19.86	Jan. 13, 1950	35.09
Apr. 27	35.59	Sept.30	24.14	Feb. 20	36.56
June 10	29.27	Oct. 26	28.02	Mar. 24	36.36
July 1	27.96	Nov. 28	32.29	May 1	33.33

24-56-23baa.

Dec. 9, 1948	27.31	Sept.30, 1949	19.79	Mar. 24, 1950	34.84
Mar. 22, 1949	36.46	Oct. 26	21.52	May 1	27.41
Apr. 27	30.24	Nov. 28	25.69	29	25.04
June 10	25.94	Dec. 21	28.32	June 22	21.43
July 1	24.16	Jan. 13, 1950	30.55	July 17	17.30
28	20.10	23	33.47	Aug. 20	17.48
Aug. 31	18.38	Feb. 20	33.17	Sept.21	16.84

24-56-27bcc.

Dec. 9, 1948	51.80	July 28, 1949	36.33	Dec. 21, 1949	51.98
Mar. 22, 1949	52.33	Aug. 31	35.93	Jan. 13, 1950	53.93
Apr. 27	54.69	Sept.30	41.92	Feb. 20	52.50
June 10	46.01	Oct. 26	49.77	Mar. 24	52.80
July 1	37.30	Nov. 28	51.14	May 1	52.68

Table 1.--Water levels in observation wells--Continued

24-56-30cdd.

Date	Water level	Date	Water level	Date	Water level
Dec. 17, 1948	42.22	Aug. 31, 1949	43.39	Oct. 26, 1949	40.43
July 1, 1949	45.90	Sept.30	41.86	Dec. 21	41.68
28	45.16				

24-56-32bba.

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1948	78.52	Sept.30, 1949	77.80	May 1, 1950	86.48
Mar. 23, 1949	81.32	Oct. 26	77.10	29	84.09
Apr. 27	81.40	Nov. 28	78.29	June 22	83.69
June 10	84.27	Dec. 21	79.30	July 17	81.70
July 1	84.13	Jan. 13, 1950	80.38	Aug. 20	78.20
28	82.58	Feb. 20	82.08	Sept.21	76.21
Aug. 31	80.11	Mar. 24	82.42		

24-56-33bcb.

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1948	32.95	Sept.30, 1949	31.21	Mar. 24, 1950	35.66
Mar. 22, 1949	35.82	Oct. 26	31.41	May 1	36.47
Apr. 27	36.30	Nov. 28	32.32	29	36.48
June 15	39.30	Dec. 21	32.98	June 22	37.14
July 28	35.42	Jan. 13, 1950	33.57	July 17	34.55
Aug. 31	32.94	Feb. 20	34.75		

24-57-16bca.

Date	Water level	Date	Water level	Date	Water level
Nov. 4, 1948	63.59	Sept.30, 1949	61.61	May 1, 1950	67.56
Mar. 23, 1949	68.12	Nov. 28	63.66	29	67.83
Apr. 27	68.17	Dec. 21	64.72	June 22	67.15
June 13	67.03	Jan. 13, 1950	65.59	July 17	63.20
30	67.17	Feb. 20	66.64	Aug. 20	61.04
July 28	65.54	Mar. 24	68.03	Sept.21	59.94
Aug. 31	63.05				

24-57-18ddc.

Date	Water level	Date	Water level	Date	Water level
Nov. 4, 1948	2.06	July 28, 1949	4.85	Dec. 21, 1949	2.47
Mar. 23, 1949	4.00	Aug. 31	3.33	Jan. 13, 1950	2.72
Apr. 27	4.87	Sept.30	1.98	Feb. 20	3.29
June 13	5.59	Oct. 26	1.85	Mar. 24	3.58
30	5.67	Nov. 28	2.12	May 1	4.61

Table 1.--Water levels in observation wells--Continued

24-57-21aba.

Date	Water level	Date	Water level	Date	Water level
Nov. 4, 1948	51.94	Nov. 28, 1949	52.58	May 29, 1950	58.86
June 30, 1949	58.27	Dec. 21	53.41	June 22	57.76
July 28	56.70	Jan. 13, 1950	54.66	July 17	55.92
Aug. 31	54.45	Feb. 20	56.58	Aug. 20	52.87
Sept.30	51.55	Mar. 24	57.24	Sept.21	49.39
Oct. 26	51.38	May 1	58.36		

24-57-26ddd.

Nov. 24, 1948	24.75	Aug. 31, 1949	23.87	Mar. 24, 1950	25.50
Dec. 17	25.98	Sept.30	22.50	May 1	26.47
Mar. 23, 1949	26.34	Oct. 26	22.62	29	26.54
Apr. 27	26.36	Nov. 28	23.46	June 22	26.52
June 10	26.58	Dec. 21	23.90	July 17	25.95
July 1	25.78	Jan. 13, 1950	24.92	Aug. 20	24.71
28	25.53	Feb. 20	25.18	Sept.21	22.76

24-57-27aaa.

Nov. 24, 1948	33.67	Sept.30, 1949	32.78	Mar. 24, 1950	35.94
Mar. 23, 1949	36.71	Oct. 26	33.19	May 1	37.07
Apr. 27	36.85	Nov. 28	33.47	29	35.59
June 13	37.26	Dec. 21	33.76	June 22	37.18
July 1	40.73	Jan. 13, 1950	34.05	Aug. 20	35.32
28	39.13	Feb. 20	35.02	Sept.21	33.20
Aug. 31	34.88				

24-57-31ccb.

Aug. 13, 1937	10.47	July 28, 1949	13.81	Dec. 21, 1949	13.57
Dec. 10, 1948	13.62	Aug. 31	13.45	Jan. 13, 1950	14.04
Mar. 23, 1949	14.13	Sept.30	13.23	Feb. 20	14.22
Apr. 27	14.29	Oct. 26	13.22	Mar. 24	14.33
June 10	13.84	Nov. 28	13.64	May 1	14.42
30	14.38				

Table 1.--Water levels in observation wells--Continued

24-57-33bbd.

Date	Water level	Date	Water level	Date	Water level
Dec. 17, 1948	29.99	Oct. 26, 1949	27.40	May 1, 1950	32.46
Apr. 27, 1949	32.24	Nov. 28	28.55	29	32.70
June 13	32.44	Dec. 21	29.30	June 22	30.57
30	32.37	Jan. 13, 1950	30.02	July 17	29.72
July 28	29.85	Feb. 20	30.98	Aug. 20	27.69
Aug. 31	26.96	Mar. 24	31.70	Sept.21	26.18
Sept.30	26.35				

24-57-34cbb.

Date	Water level	Date	Water level	Date	Water level
Nov. 16, 1948	8.67	Nov. 28, 1949	9.17	May 29, 1950	13.32
July 1, 1949	11.56	Dec. 21	9.93	June 22	11.72
28	6.20	Jan. 13, 1950	10.67	July 17	8.92
Aug. 31	5.71	Feb. 20	11.80	Aug. 20	6.75
Sept.30	6.87	Mar. 24	12.54	Sept.21	5.74
Oct. 26	7.96	May 1	13.30		

24-57-35cbb.

Date	Water level	Date	Water level	Date	Water level
Nov. 16, 1948	7.09	Nov. 28, 1949	7.33	May 29, 1950	9.47
July 1, 1949	8.83	Dec. 21	7.85	June 22	8.40
28	6.12	Jan. 13, 1950	8.34	July 17	7.62
Aug. 31	4.84	Feb. 20	8.90	Aug. 20	5.73
Sept.30	5.53	Mar. 24	9.28	Sept.21	5.48
Oct. 26	6.36	May 1	9.77		

24-57-36daa.

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1948	34.45	Sept.30, 1949	32.91	Nov. 28, 1949	33.58
July 1, 1949	32.95	Oct. 26	32.91	Dec. 21	33.98
28	36.79				

Table 2.--Drillers' logs of wells in the Dutch Flats area, Nebraska

23-57-2abb.

	Thickness (feet)	Depth (feet)
Sand and gravel............................	50	50
Brule formation............................	.8	50.8

Table 2.--Drillers' logs of wells in the Dutch Flats area, Nebraska--Con.

23-57-3abb.

	Thickness (feet)	Depth (feet)
Sand and gravel..............................	81	81
Brule formation..............................	1	82

23-57-3abc.

Sand and gravel..............................	71	71
Brule formation..............................	1	72

23-57-4dca.

Soil...	9	9
Sand, fine...................................	2	11
Brule formation..............................	36	47

24-56-30bdd.

Sand and gravel..............................	129	129
Brule formation..............................	1	130

24-56-32bba.

Soil...	12	12
Sand and gravel..............................	97	109
Brule formation..............................	1	110

24-57-16bca.

Sand and gravel..............................	111	111
Brule formation..............................	1	112

24-57-17cdd.

Soil, sandy..................................	11	11
Silt and cobbles.............................	1.5	12.5
Sand and silt, sandy.........................	16	28.5
Gravel, medium, clean........................	44.5	73

Table 2.--Drillers' logs of wells in the Dutch Flats area, Nebraska--Con.

24-57-18ddc.

	Thickness (feet)	Depth (feet)
Sand....................................	7	7
Silt with cobbles.......................	1	8
Gravel..................................	4	12

24-57-21bab.

Sand....................................	31	31
Clay, blue to black.....................	9	40
Gravel..................................	67	107

24-57-21dad.

Soil, sand and silt.....................	4	4
Silt and cobbles........................	4	8
Sand, coarse, and gravel................	20	28
Sand, coarse............................	62	90

24-57-25dda.

Sand, fine to coarse....................	50	50
Gravel..................................	26	76

24-57-26ddd.

Sand and gravel.........................	98	98
Brule formation.........................	1	99

24-57-28caa.

Soil....................................	6	6
Clay, yellow............................	1	7
Sand and clay...........................	2	9
Gravel..................................	17	26
Rock, loose.............................	3	29
Sand, coarse............................	4	33
Sand and clay...........................	2	35
Gravel and sand.........................	1	36
Gravel..................................	19	55
Sand, fine..............................	7	62

Table 2.--Drillers' logs of wells in the Dutch Flats area, Nebraska--Con.

24-57-28dda.

	Thickness (feet)	Depth (feet)
Soil	2	2
Loam, sandy	6	8
Gravel, fine	17	25
Gravel, coarse	3	28
Rock, loose	2	30
Gravel, heavy	5	35
Clay, sandy	3	38
Gravel, medium	20	58
Sand	1	59

24-57-34bad1.

Soil	3	3
Soil and clay	3	6
Gravel, coarse, and sand	34	40
Clay	6	46
Gravel	5	51
Brule formation (?)	..	51

Table 3.--Records of wells in the Dutch Flats area, Nebraska

Well number: See text for description of well-numbering system.
Type of well: B, bored well; Dn, driven well; Dr, drilled well; Du, dug well.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land-surface datum.
Type of casing: C, concrete, brick, or tile pipe; P, iron or steel pipe.
Geologic source: Qt_2, second terrace deposit; Qt_3, third terrace deposit; Qp_1, first pediment deposit; Tb, Brule formation.
Method of lift (first letter): C, cylinder; Cf, centrifugal; J, jet; N, none; T, turbine.
Type of power (second and third letter): E, electric motor; G, gasoline or diesel engine; H, hand operated; N, none; W, windmill.
Use of water: D, domestic; Dr, drainage; I, irrigation; N, none; O, observation; S, stock.
Measuring point: Edp, end of discharge pipe; Hph, hole in pump housing; Ls, land surface; Tbc, top of board cover; Tc, top of casing; Tcu, top of curb; Tpb, top of pump base.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: Ca, sample collected for chemical analyses; D, discharge in gallons a minute (E, estimated; M, measured; R, reported); DD, drawdown in feet while discharging at the preceding rate; L, log of well given in table 2; T, temperature in degrees Fahrenheit.

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
23-56-3bcc	Pearl M. Hertz........	Dr	91	4	P	Qt_3	C,H	D,S	Ls	....	4,103.9	62.82	12-17-48	
-5cdd	C. W. Tute...........	Du	20	6	P	Qt_3	Cf,E	D,S	Tc	-2.5	4,029.8	8.29	12-17-48	
-6aab	Carl Gompert.........	Dr	.....	18	P	Qt_3	T,G	I,O	Tpb	+.7	4,088.4	31.61	11-23-48	
-7ccb	Henery Zigler........	Dn	.....	8	P	Qt_3	T,G	I	Tpb	0	4,067.5	22.65	11-22-48	D1,400E
-7ddd	W. W. Cline..........	Dr	115	4	P	Tb	C,E	D,S	Tc	-5.5	....	41.83	11-19-48	
-8add	J. Gompert...........	Dr	.....	6	P	Qt_3	N	N	Tc	0	4,008.8	8.57	11-18-48	
-8ccc	J. E. Scott..........	Dr	82	4	P	Tb	C,W	D,S	Tc	+.5	4,051.2	39.50	8-12-37	
-9aaa	School Dist..........	Dr	49.3	3	P	Qt_3	J,E	D,O	Tbc	+.3	4,047.5	38.36	12-15-48	
-9abb	H. Dittenber.........	Dr	.....	6	P	Qt_3	C,E	D,S	Tc	-6.5	....	10.62	11-19-48	
23-57-1cbc	Unknown..............	Dr	.....	18	P	Qt_3	T,G	I,O	Tpb	+.4	4,082.5	43.70	11-22-48	
-1ddc	E. E. Plummer........	Dr	.....	..	..	Qt_3	T,G	I	Tpb	+.3	....	40.42	11-22-48	
-2aaa	C. Thomas............	Dr	26	6	P	Qt_3	N	N	Tc	0	4,082.8	9.46	11-16-48	
-2abb	C. A. Hanlon.........	Dr	50.8	24	P	Qt_3	Cf,G	I,O	Edp	+1.0	4,081.6	16.32	3-22-49	L
-3abb	J. E. Jenson.........	Dr	82	18	P	Qt_3	T,G	I	Tpb	+.3	4,093.4	17.77	11-16-48	D1,100R,DD4,L
-3abc	G. Brown.............	Dr	72	24	P	Qt_3	T,G	I	Tpb	0	....	13.35	11-16-48	D1,100R,DD5,L
-3dba	Mr. Andrews..........	Dr	57	36	P	Qt_3	Cf,G	I,O	Tc	+2.8	4,090.2	14.42	11-24-48	
-4acb	O. F. Cooke..........	Dr	44	..	P	Qt_3	Cf,E	I	Tc	0	....	12.09	11-18-48	
-4adc	.....do..............	Dr	44	8	P	Qt_3	C,E	S	Tc	-3.6	....	12.09	11-18-48	

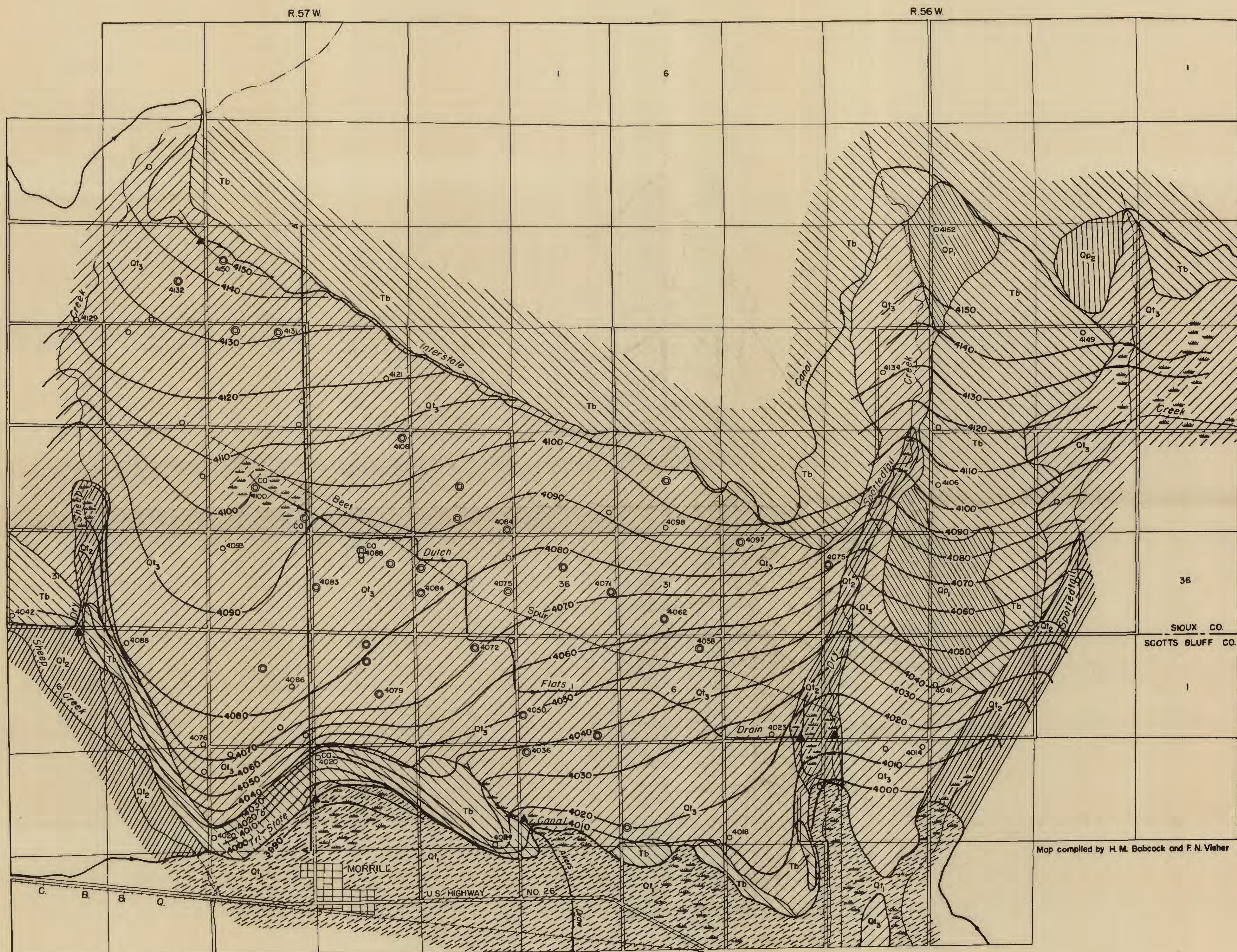
Table 3.--Records of wells in the Dutch Flats area, Nebraska--Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
23-57-4dca	L. G. Shultz.........	Dr	47	8	P	Tb	J,E	D,S	Ls	....	....	23	11-17-48	L
-4ddd	Jim Craige...........	Dr	120	6	P	Tb	N	N	Tbc	0	4,102.8	16.26	11-18-48	
-5bba	Andrew Oleson........	Dr	142.3	4	P	Tb	C,H	O	Tc	+1.1	4,112.6	20.06	8-13-37	T57.5
-5ddd	L. E. Collums........	Dr	74	6	P	Qt_3	C,G	D,S	Tcu	+1.0	4,095.8	22.88	11-15-48	
-8aad	R. Meter.............	Dr	.....	6	P	Tb?	Cf,E	D,S	Tc	-2.0	....	5.47	12-10-48	
-9bba	R. Curry.............	Dr	180	6	P	Tb?	C,H	D	Tcu	0	....	18.76	11-15-48	
-9ccb	.....do..............	Dr	.....	6	P	Tb	C,H	D,O	Tc	+.5	4,068.5	50.90	3-22-49	
-10bbb	C. W. Sanger.........	..	34	5	P	Tb	C,W	D,S	Hph	+1.4	4,032.8	14.40	11-27-48	Ca
-11ddc	Paul Pointeven.......	Dr	.....	5	P	Tb	C,H	O	Tc	+.3	4,048.3	16.96	12-16-48	
-12bbb	C. Hoyt..............	Du	65	18	P	Qt_3	T,G	I	Edp	+2.0	4,088.6	53.83	11-22-48	
24-56-15bbb	S. W. Schomp.........	Dr	40	6	P	Qp_1?	C,W	D,S	Tc	+.1	4,184.2	22.40	12- 9-48	
-21acc	Edgar Johnson........	Dr	.....	5	P	Qt_3?	C,H	O	Tc	+.3	4,157.6	36.55	12-15-48	
-22ccc	Mr. Zimmerman........	Dr	34.5	6	P	Tb	C,W	D,S	Tc	+.5	....	33.30	11-23-48	
-23baa	Unknown..............	Dr	.....	5	P	Tb	N	O	Tc	+.5	4,168.2	27.81	12- 9-48	
-26cbd	Henry Mgol...........	Dr	65	4	P	Tb	C,W,E	D,S	Tc	-5.0	....	54.96	12-15-48	
-27bcc	I. L. Sayre..........	Dr	100	6	P	Tb	C,W	D,S	Tc	+1.0	4,147.1	52.80	12- 9-48	
-30bdd	W. J. Hamilton.......	Dr	130	10	P	Qt_3	T,G	I	Tpb	+.2	....	78.78	12-17-48	L
-30cdd	.....do..............	Dr	65	4	P	Qt_3	C,H	D,O	Tc	+2.0	4,137.9	44.22	12-17-48	
-31cda	A. E. Amundsen.......	Dr	92	18	P	Qt_3	T,G	I	Tpb	0	4,093.8	31.84	11-23-48	D1,000R, DD30
-32bba	S. H. Perkins........	Dr	110	18	P	Qt_3	T,G	I,O	Tpb	+.5	4,174.1	79.02	11-23-48	D750E, DD20,L
-33bcb	Phillip Strauch......	Dr	87	18	P	Qt_3	T,G	I,O	Tpb	0	4,106.7	32.95	11-23-48	D1,200R, DD10
-34ddd	Bill Piper...........	Dr	100	6	P	Tb	C,W	D,S	Tc	+.2	....	28.63	11-23-48	
-35bdd	Floyd Rose...........	Dr	40	5	P	Qt_2?	C,H	D	Tc	+3.0	....	35.81	12-15-48	
24-57-8bdd	Esh Bros.............	Dr	142	6	P	Tb	C,W	D,S	Ls	....	....	50	3-23-49	
-16bca	A. Johnson...........	Du,Dr	112	48	P	Qt_3	T,G	I,O	Tpb	+.7	4,212.0	64.29	11- 4-48	D1,200R,DD7,L
-17cdd	Robert Johnson.......	Dr	73	6	P	Qt_3	Cf,E	D,S	Ls	....	....	39	11- 4-48	L
-17dab	Dale Flock...........	Dr	123	18	P	Qt_3	T,E	I	Tpb	0	4,299.4	66.09	3-23-49	
-18ddc	R. Johnson...........	B	12	6	P	Qt_3	C,W	S,O	Tc	+2.6	4,133.9	4.66	11-14-48	L
-20bab	.....do..............	B	63	8	P	Qt_3	C,W	S	Tc	+.5	4,175.2	42.09	11- 4-48	

-20ddc	A. L. Nichols........	Dr	60	6	P	Qt3	C,H	D,S	Tc	+.5	....	28.99	12- 9-48	
-21aba	P. Kirkpatrick.......	Dr	.....	18	P	Qt3	T,G	I,O	Tpb	0	4,182.8	51.94	11- 4-48	
-21bab	C. P. Fox............	Dr	107	18	P	Qt3	T,E	I	Tpb	+.9	4,181.0	48.93	11- 4-48	D1,100R,DD5,L
-21dad	Fred Atteberry.......	Dr	90	6	P	Qt3	.....	D,S	Ls	....	....	38	1937	L
-21ddd	P. Remender..........	Dr	80	6	P	Qt3	C,H	D	Tc	+1.0	....	44.86	12- 9-48	
-22adc	Gideon Larson........	Dr	200	5	P	Qt3	C,W	S	Tc	+1.0	4,199.1	67.90	11-23-48	
-25dda	Mr. Hamilton.........	Dr	76	6	P	Qt3	C,H	D,S	Ls	....	....	50	1948	L
-26caa	G. Hedgecock.........	Dr	96	18	P	Qt3	T,G	I	Tpb	0	....	32.12	11-24-48	
-26dca	Henery Stuckart......	Dr	85	36	P	Qt3	T,G	I	Tpb	0	4,110.2	19.20	11-24-48	D1,400R, DD 7
-26ddd	Mr. Trout............	Dr	99	18	P	Qt3	T,G	I,O	Edp	+4.0	4,110.5	29.98	12-17-48	L
-27aaa	J. Van Dyck..........	Dr	62	36	P	Qt3	T,E	I,O	Tpb	0	4,140.4	33.67	11-24-48	
-28caa	Pathfinder Irr. Dist.	Dr	62	24	C	Qt3	T,E	Dr	Tc	0	4,101.0	.....	....	D1,100E, Ca,L
-28dda	.....do..............	Dr	59	24	C	Qt3	T,E	Dr	Tc	0	4,096.0	.....	....	D1,100E, Ca,L
-29add	Gilbert Hess.........	Dr	35	6	P	Qt3	C,W	D,S	Tc	+.5	....	19.60	12-19-48	
-31ccb	Miss Pollard.........	Dr	.....	6	P	Qt2	C,W,H	S,O	Tc	+1.3	4,056.9	14.92	12-10-48	
-34adb	Fred Seaggin.........	Du,Dr	90	24	P	Qt3	T,E	I	Tbc	0	....	6.54	11-16-48	D1,400R, DD11
-34bad1	Pathfinder Irr. Dist.	Dr	51	24	C	Qt3	T,E	Dr	Tbc	+1.0	4,092.0	3.77	10-23-49	T54, D1,060M, DD15.4, Ca, L
-34bad2	U. S. Geol. Survey...	Dn	16	1	P	Qt3	N	O	Tc	+1.4	....	5.80	10-23-49	
-34bad3	.....do..............	Dn	12	1	P	Qt3	N	O	Tc	+1.0	....	5.92	10-23-49	
-34bad4	.....do..............	Dn	11	1	P	Qt3	N	O	Tc	+.5	....	6.19	10-23-49	
-34cbb	J. P. Newman.........	Dr	80	24	P	Qt3	T,G	I,O	Tpb	0	....	8.67	11-16-48	D1,800R
-35aad	Mr. Trout............	B	50	6	P	Qt3	C,E,W	S	Tc	-.5	4,093.3	13.84	11-24-48	
-35bcb	J. H. Lenhart........	Dr	84	18	P	Qt3	T,G	I	Edp	+.9	....	9.42	11-24-48	D1,000R, DD 6
-35cbb	R. L. Lenhart.......:	Dr	87	24	P	Qt3	T,E	I,O	Tpb	0	4,089.7	7.09	11-16-48	D1,500R, DD28
-35daa	W. J. Hamelton.......	Dr	.....	18	P	Qt3	T,E	I	Tpb	+.1	4,088.7	12.11	11-23-48	
-36bda	N. B. Spencer........	Dr	81	18	P	Qt3	T,G	I	Tpb	0	....	39.52	11-23-48	
-36daa	W. H. Flint..........	Dr	.....	..	..	Qt3	T,E	I,O	Tpb	+.8	4,105.1	35.25	11-23-48	T56

U.S. GEOLOGICAL SURVEY

CIRCULAR 126 PLATE I



Base compiled from aerial photographs and map prepared by the Pathfinder Irrigation District

EXPLANATION

Qt1 — First terrace deposit. Sand and silt. Yields small quantities of water to wells.

Qt2 — Second terrace deposit. Sand and silt. Yields small quantities of water to wells.

Qt3 — Third terrace deposit. Gravel, sand, and silt. Principal water-bearing material in the area. Yields large quantities of water to irrigation and drainage wells.

Qp1 — First pediment. Sand and gravel mantle. Yields small quantities of water to wells. Generally is above water table.

Qp2 — Second pediment. Sand and gravel mantle. Yields small quantities of water to wells. Generally is above water table.

Tb — Brule formation. Predominantly siltstone. Yields moderate quantities to wells where fissures are encountered.

4100 — Contours on water table in feet above mean sea level, September 1949. Based on insturmental levels.

○ Stock, domestic, or unused well. Number refers to altitude of water level.

◎ Irrigation or drainage well. Number refers to altitude of water level.

▲ Stream sampled for chemical analysis.

CO Well sampled for chemical analysis.

Seep area.

A—A' Line of generalized section in figure 4

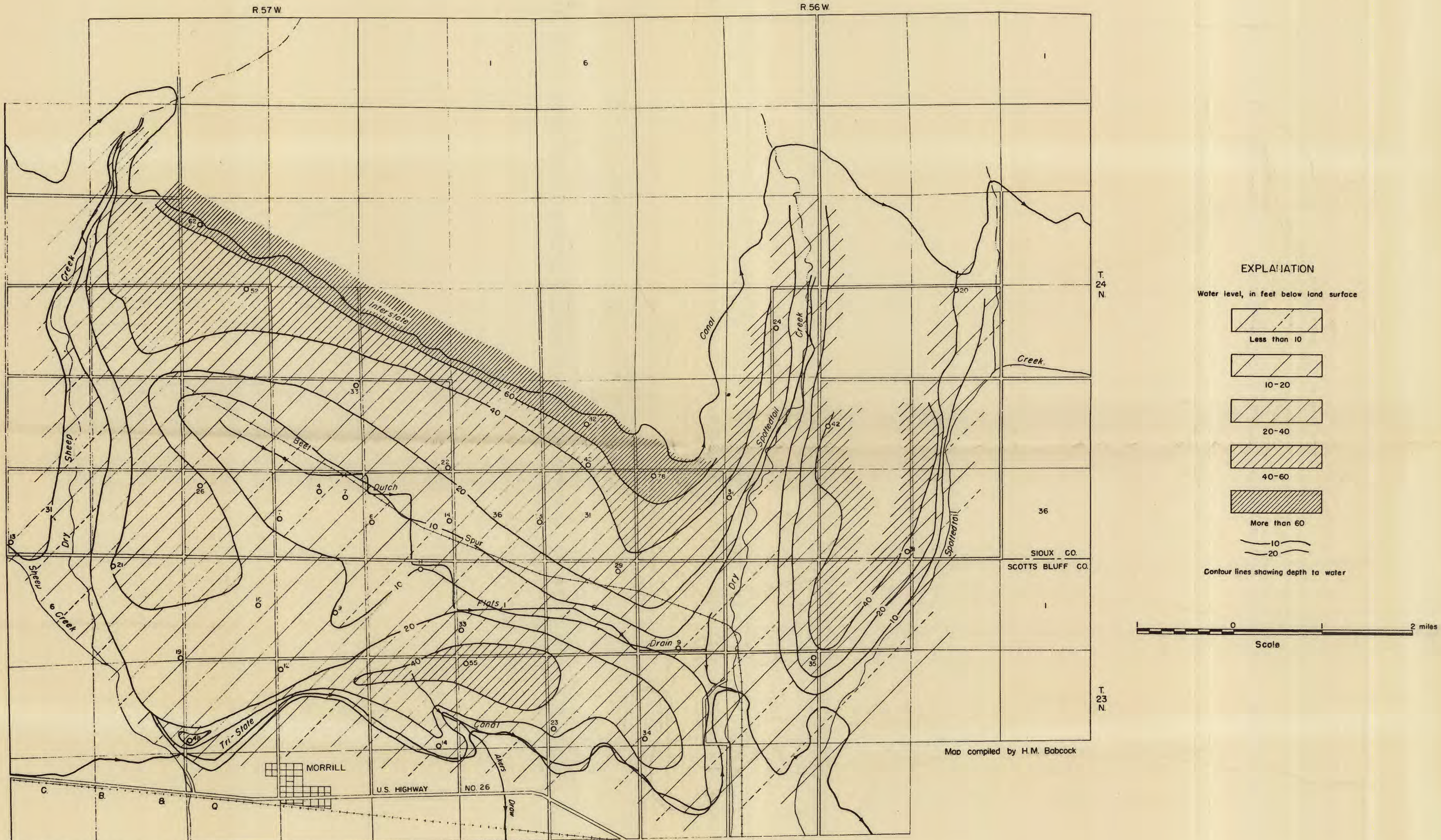
1 0 1 2 miles

Scale

MAP OF THE DUTCH FLATS AREA, SCOTTS BLUFF AND SIOUX COUNTIES, NEBR.

Showing areal geology, location of wells, and water-table contours

GPO 82-8000144



Base compiled from aerial photographs and map prepared by the Pathfinder Irrigation District

MAP OF THE DUTCH FLATS AREA

Showing the depths to water as of September 1949 and the locations of wells for which records are given

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