GEOLOGICAL SURVEY CIRCULAR 54

July 1949

# GEOLOGY AND GROUND-WATER HYDROLOGY OF THE ANGOSTURA IRRIGATION PROJECT SOUTH DAKOTA

BY

ROBERT T. LITTLETON

WITH A SECTION ON THE MINERAL QUALITY OF WATERS

By

Herbert A. Swenson

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
GEOLOGICAL SURVEY
W. E. Wrather, Director

WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

GEOLOGICAL SURVEY CIRCULAR 54

July 1949

# GEOLOGY AND GROUND-WATER HYDROLOGY OF THE ANGOSTURA IRRIGATION PROJECT SOUTH DAKOTA

BY

ROBERT T. LITTLETON

WITH A SECTION ON THE MINERAL QUALITY OF WATERS

By

Herbert A. Swenson

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
GEOLOGICAL SURVEY
W. E. Wrather, Director

WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

CONTENTS

CONTENTS



ILLUSTRATIONS

## TABLES

GEOLOGY AND GROUND-WATER HYDROLOGY OF THE
ANGOSTURA IRRIGATION PROJECT, SOUTH DAKOTA

By Robert T. Littleton

WITH A SECTION ON THE MINERAL QUALITY OF WATERS

By Herbert A. Swenson

## ABSTRACT

The lands to be irrigated from water stored in the Angostura Reservoir are situated on the lower of two terraces along the southeast side of the Cheyenne River in northeastern Fall River County and on the terrace known as Harrison Flat in southeastern Custer County, S. Dak. The terrace deposits are composed of relatively permeable sands and gravels that rest on a shale bedrock platform. The terrace surfaces are mantled in part by slope wash derived from higher shale slopes and by wind-blown sand.

Ground water occurs under water-table conditions in the river alluvium and in terraces above the river. Although the zone of saturation in the terrace deposits is generally thin, it is essentially continuous in the area southeast of the river, and the water issues as springs in the terrace faces along the inner valley of the river and along the valleys of tributary streams cutting back into the terraces. A zone of saturation is present only in part of the Harrison Flat area, and it extends to the terrace face only along Cottonwood Creek. Wells in the unconsolidated mantle rock supply water for domestic and stock purposes, but yields are small. Abundant supplies of artesian water are available at depths ranging up to 3,000 feet but are not now utilized except at the extreme western end of the area where the bedrock aquifer is close below the surface.

The effect of applying irrigation water on the terrace lands will depend on the character of the underlying material and on the measures taken to forestall waterlogging and other undesirable effects. Terrace areas that are mantled by slope wash will be especially susceptible to waterlogging, as will valley-bottom areas mantled by colluvium that are adjacent to irrigated terraces. Periodic measurements of water

levels in observation wells will give warning of potential waterlogging in time to permit taking preventive measures.

Analyses of samples of both ground water and surface water indicate a high mineral content. In general, samples from the Cheyenne River are higher in total dissolved solids and lower in percent sodium than the ground water.

## INTRODUCTION

### Purpose and scope of investigation

This report describes an area a part of which is to be irrigated with water from the Angostura Reservoir. The lands to be irrigated are on the lower of two terraces along the southeast side of the Cheyenne River in northeastern Fall River County and on the terrace known as Harrison Flat in southeastern Custer County, S. Dak. Included are (1) a description of the topography and geology as they relate to ground-water conditions and (2) basic data pertaining to the occurrence of ground water in the Angostura irrigation project. The field investigation that provided the basis of the report was made by the writer between August 5 and November 15, 1946.

During the course of the field studies a geologic map of the area was prepared, an inventory of domestic and stock wells and springs was made, a water-level observation program was established, and test holes were drilled at strategic sites.

### Previous studies

The stratigraphy and structure of the Oelrichs quadrangle were described and mapped by Darton early in the present century,[1] and his report was used in preparing the geologic map included here. Since that time a number of studies of specific geologic problems have been made in the Black Hills region, several of which contain general references to the area covered by this report. In more recent years the Amerada Petroleum Corp. of Tulsa, Okla. has drilled 60 shallow holes within the area in conjunction with a seismic survey. The logs of these holes are not available for publication but were made available for study by the writer. Data collected by the Soil Conservation Service, United States Department of Agriculture, also were made available to the writer.

## Acknowledgments

This study was made under the general direction of O. E. Meinzer, Chief, Division of Ground Water (now Ground Water Branch), Federal Geological Survey, until December 1, 1946, on which date he was succeeded by A. N. Sayre. G. H. Taylor, regional engineer in charge of all ground-water studies in the Missouri River Basin, directly supervised the field work.

Special acknowledgment is due all those who contributed to the successful prosecution of this investigation. H. V. Hubbell and W. L. McClure, Bureau of Reclamation, United States Department of the Interior, were especially helpful and cooperative during the course of the field work. George Schmid, of the Soil Conservation Service, made available data previously collected on the project area, arranged to

1 Darton, N. H., U. S. Geol. Survey Geol. Atlas, Oelrichs folio (no. 85), 6 pp., 1902.

make available a drilling machine for test-hole drilling, and arranged to have measurements made of the water levels in observation wells after November 15, 1946. H. F. Haworth, Division of Ground Water, rendered much service during the drilling of test holes. G. A. Waring and P. C. Tychsen, Division of Ground Water, located and initially measured 27 observation wells in the area during April 1946. B. B. Weatherby and J. E. Upp, Amerada Petroleum Corp., furnished information concerning test holes drilled by that corporation. Dr. E. P. Rothrock, State Geologist of South Dakota, made available logs of two exploratory oil wells. Thanks also are due residents of the area and other persons who supplied much advice and information.

Quality-of-water studies were under the general direction of S. K. Love, Chief, Quality of Water Division (now Quality of Water Branch), and under the immediate supervision of P. C. Benedict, district engineer in charge of quality-of-water investigations in the Missouri River Basin. Analyses of samples collected for this report were made by J. G. Connor of the Federal Geological Survey. Special thanks are due the Bureau of Reclamation and the Soil Conservation Service for records of earlier analyses of surface and ground waters in the Angostura irrigation project.

Special acknowledgment is given Ray Bentall, Geologist, United States Geological Survey for his painstaking review and editing of this report and for his great assistance and help to the author.

## Well-numbering system

Wells, springs, and test holes are numbered in this report according to their location within the land subdivisions of the General Land Office survey of the area. A graphical explanation of this method of well identification is shown by figure 1. The first numeral of a well number indicates the township, the second the range, and the third the section in which a well is located. The lower-case letters following the section number indicate the location of the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third (if present) the quarter-quarter-quarter section or 10-acre tract. The letters are assigned in a counterclockwise direction, beginning in the northeast quarter of the section, quarter-quarter section, or quarter-quarter-quarter section. When more than one well is located in a 10-acre tract, consecutive numbers beginning with 1 follow the lower-case letters.

# GEOGRAPHY

## Location and extent of the area

The Cheyenne River rises in eastern Wyoming, skirts the southern end of the Black Hills uplift, and then follows a northeasterly course across southwestern South Dakota to its confluence with the Missouri River near the center of the State. The lands of the proposed Angostura irrigation project border the Cheyenne River where it first swings northeastward after skirting the southern end of the Black Hills.

(See fig. 2.) The area of the project ranges from half a mile to 3 miles in width and is about 24 miles long. It includes two distinct units, designated in this report as the "area south of the Cheyenne

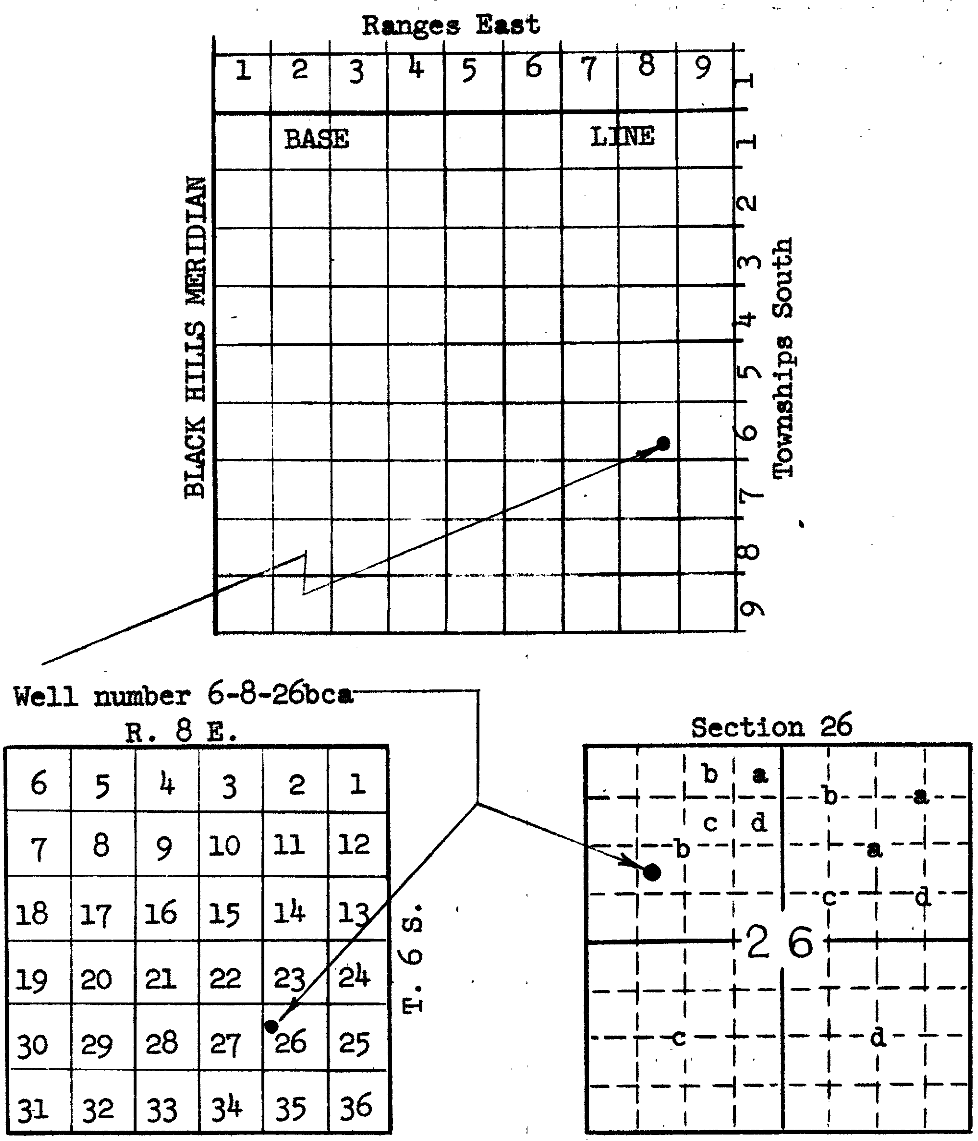



Figure 1.--Sketch showing well-numbering system.

River" and the "Harrison Flat" area. (See pls. 1 and 2.) The former area is restricted to northeastern Fall River County, whereas the latter is restricted almost wholly to southeastern Custer County.

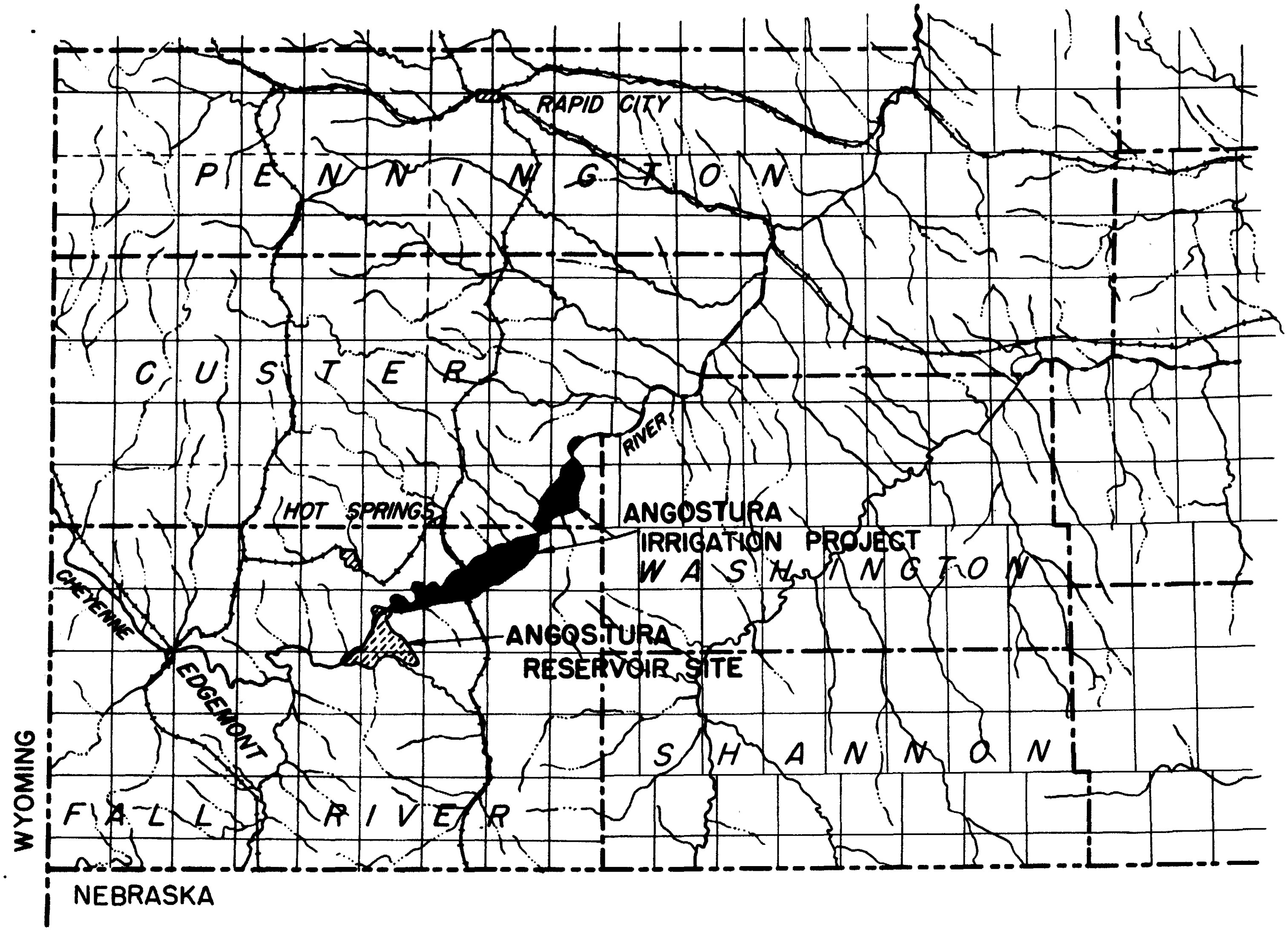



Figure 2.-Index map of south-western South Dakota showing location of Angostura irrigation project

10 0 10 20 30 40 MILES

SCALE

## Climate

Precipitation in the area covered by the proposed Angostura irrigation project is deficient for most agricultural practices. No precipitation records have been kept within the area, but weather-observation stations have been maintained at Hot Springs since 1908 and at Oelrichs since 1890. Both stations are within a distance of 20 miles from the center of the area and their records are considered reasonably representative of the climate of the Angostura irrigation project area. The average precipitation for the period of record through 1947 was 18.81 inches at Hot Springs and 18.58 inches at Oelrichs, a surprisingly small difference considering the contrasting topographic situations of the two towns. The total annual precipitation at both stations is shown in figure 3. The cumulative departure from average precipitation at both stations is shown in figure 4; in this graph the periods of higher-than-average precipitation are shown by a rising trend and the periods of less-than-average precipitation by a declining trend.

The normal or "adjusted mean" temperature at Hot Springs is 48.0° F.; at Oelrichs it is 46.8°. The highest recorded temperature at both stations is 112° F.; the lowest recorded temperature at Hot Springs is -35° F., and that at Oelrichs is -38°.

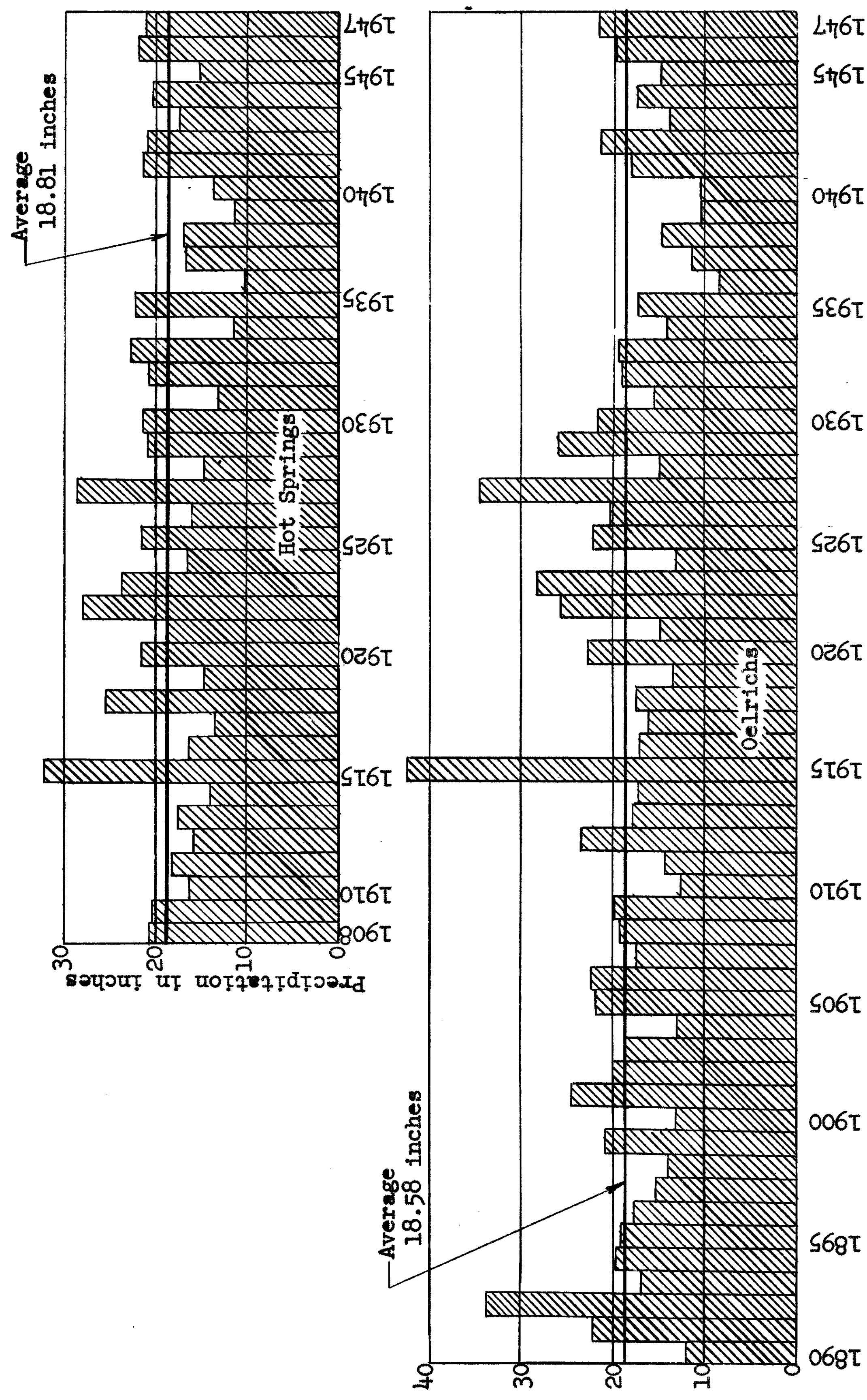



Figure 3.--Graphs showing the annual precipitation at Hot Springs and Oelrichs, South Dakota

## GEOMORPHOLOGY

The Cheyenne River flows in a meandering, sharply defined inner valley that has been entrenched in the floor of a broader, earlier-

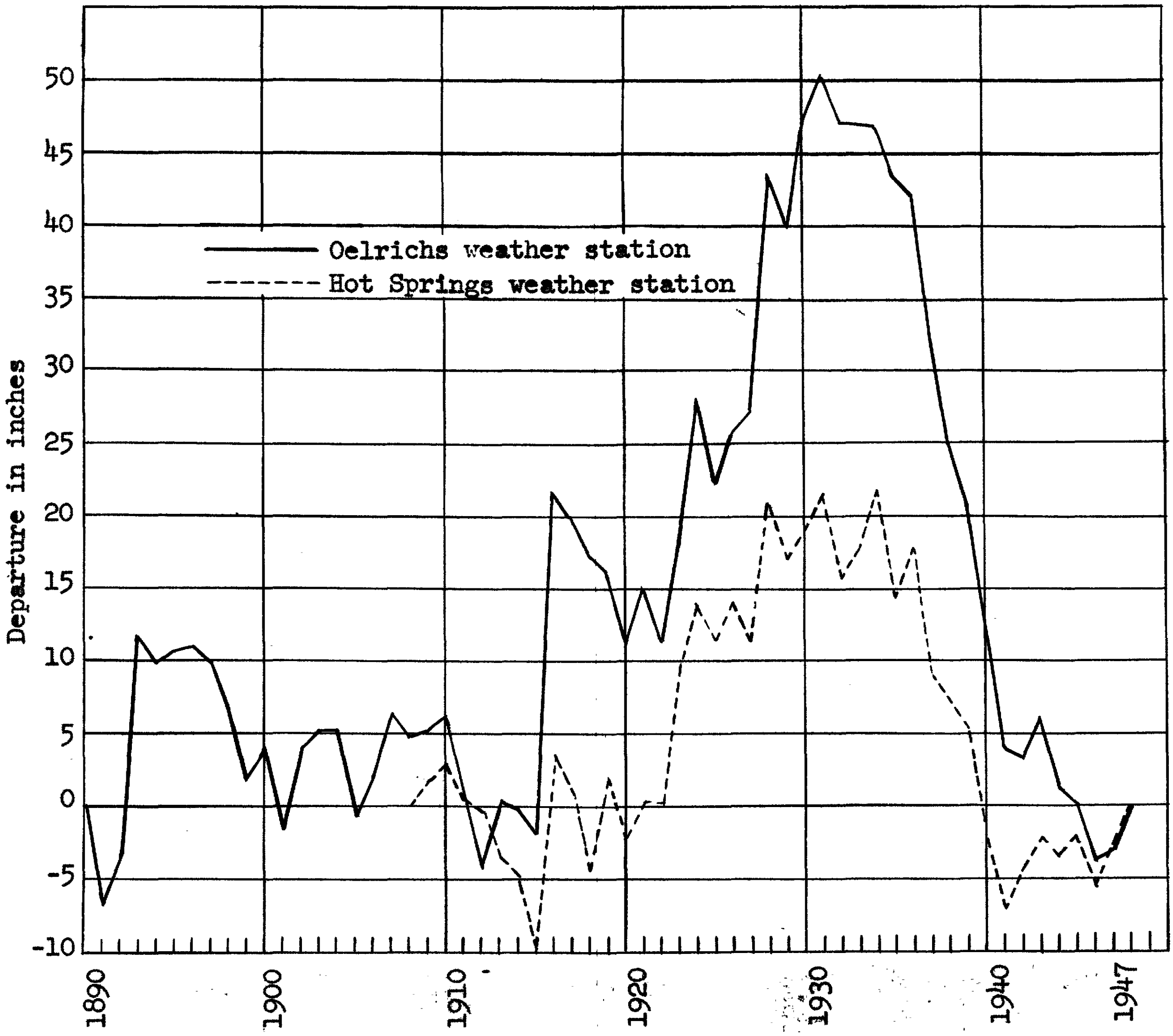



Figure 4.--Cumulative departure from average precipitation at Oelrichs and Hot Springs, South Dakota

developed valley. The floor of the inner valley is underlain by Recent alluvial deposits and isolated remnants of low terraces. Its walls are of bedrock and are capped by the alluvial sediments deposited in earlier stages of valley formation. (See figs. 5 and 6.) Alluvial fans have been built up in places where tributary streams enter the inner valley. Weathering of the inner-valley walls has resulted in the deposition of colluvium along the foot of these slopes except where meanders of the river impinge against the valley wall and create steep bluffs.

Two distinct terrace levels have been developed on the alluvial deposits that extend back from the crest of the inner-valley walls. Both terraces are present in the area south of the river, but in the Harrison Flat area no evidence remains of a uniform upper-terrace level. Where both terraces are preserved, bedrock is exposed in places on the slope between them. In general, the terraces present very gentle slopes toward the inner valley. Along the frontal edge of the lower terrace, gullies have been developed in places, and over much of the area the terrace deposits are masked by slope wash derived from the higher bedrock slopes and by wind-blown sand. The eolian deposits present a somewhat hummocky topography in places. Irrigation is proposed only for lands on the lower of the terraces above the inner valley.

The relations of the mantle-rock deposits to each other and to the underlying bedrock platform are shown by four geologic sections based on test drilling. (See pl. 2.)

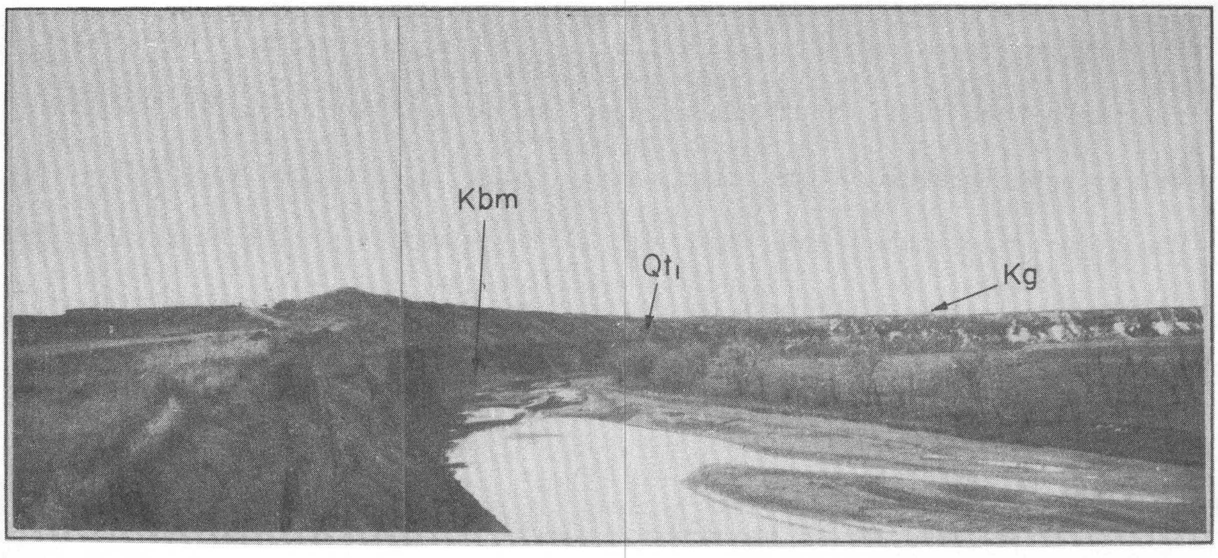



Figure 5.--Upstream view of bluffs along the Cheyenne River in secs. 9 and 10, T. 8 S., R. 6 E., showing contact between the lower-terrace deposit ($Qt_1$) and the Belle Fourche shale-Mowry shale sequence (Kbm). Greenhorn limestone (Kg) in background.

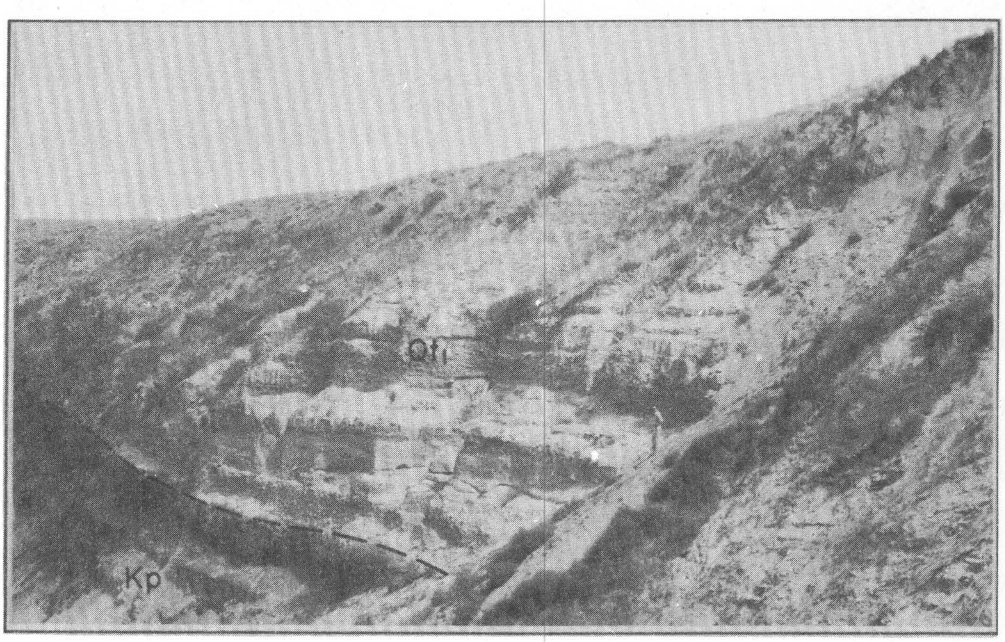



Figure 6.--Downstream view of bluffs along the Cheyenne River in the northeast corner of sec. 5, T. 8 S., R. 7 E., showing contact between the lower-terrace deposit ($Qt_1$) and the Pierre shale (Kp).

## Stratigraphy

### Cretaceous system

The Fall River sandstone is the oldest formation exposed in the area covered by this report. It consists mainly of gray to buff sandstone, which in many places is impregnated with iron oxide; streaks of conglomerate occur in the basal beds. The formation is thin-bedded at its base, massive in its middle part, and thin-bedded at the top. The thickness of the formation is about 75 feet. Although the formation underlies the entire area, it is exposed only at the extreme west end of the area where it rises on the southeast flank of the Black Hills uplift.

A shale sequence, the Mowry and Belle Fourche shales, overlies the Fall River sandstone. It is dark-colored to black and breaks into thin flakes on weathering. Lens-shaped concretions, ranging in size from a few inches to several feet, are common in the shales. In places the sequence is traversed by sandstone dikes. In the Amerada Petroleum well 1 (sec. 27, T. 8 S., R. 7 E.) the thickness of the sequence is 775 feet, and in the Mildred Voorhees well 1 (sec. 25, T. 10 S., R. 8 E.) it is 640 feet.[2] The outcrop underlies a valley that skirts the base of the outside range of the Black Hills and transects the Cheyenne River valley at the west end of the Angostura irrigation project. (See fig. 7.)

The Greenhorn limestone, overlying the shale sequence (the Mowry and Belle Fourche shales), contains a considerable amount of clay and

---

2 Unpublished logs of deep wells in Fall River County, on file in the office of the State Geologist of South Dakota.

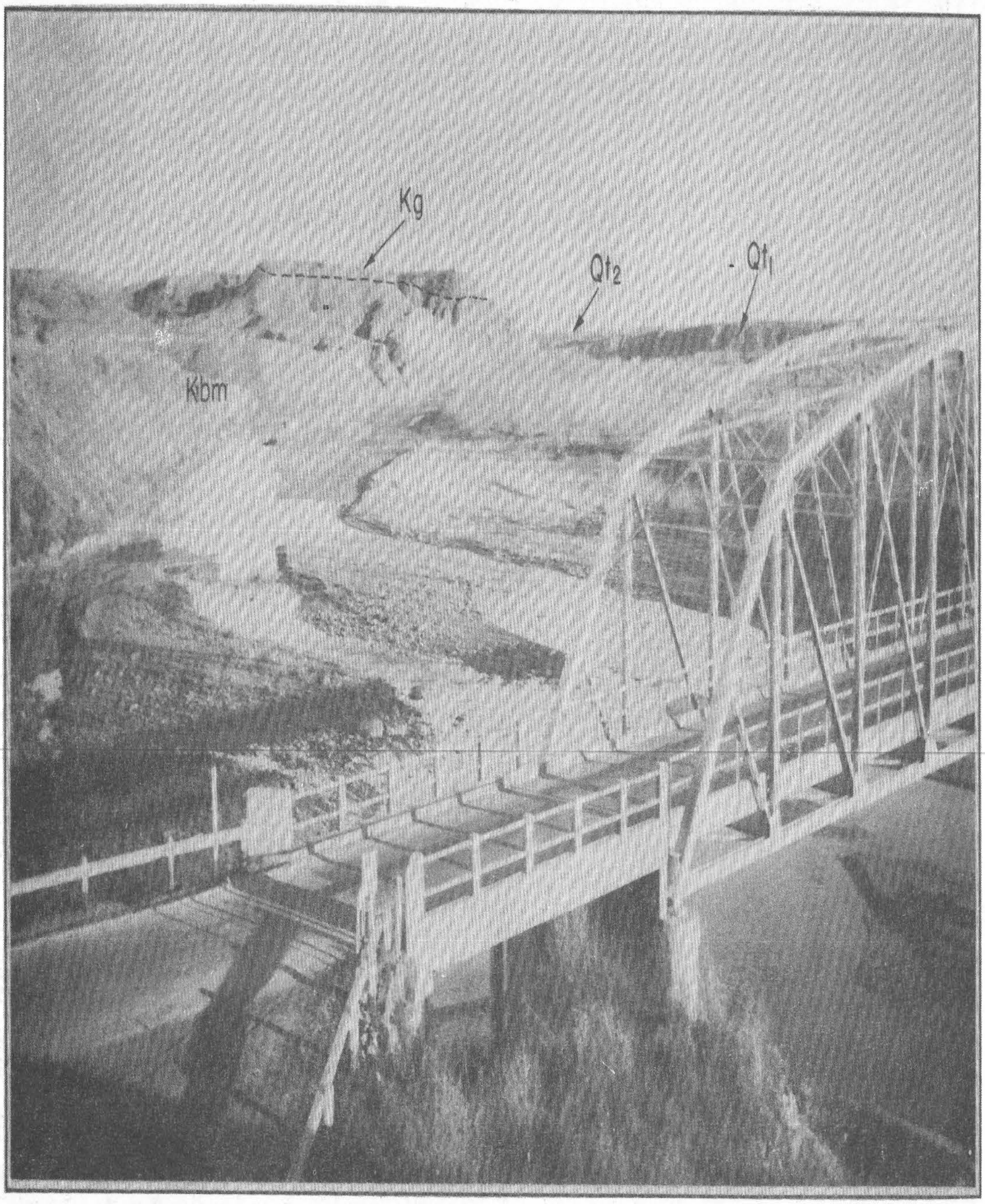



Figure 7.--Downstream view of the Mowry shale-Belle Fourche shale sequence (Kbm) and the Greenhorn limestone (Kg) in bluffs along the Cheyenne River at the western end of the Angostura irrigation project. Terrace deposits ($Qt_1$ and $Qt_2$) in the right background.

some sands. It hardens on exposure and breaks out into thin buff-colored slabs containing numerous fossils, of which Inoceramus labiatus is the most characteristic. The formation averages 50 feet in thickness. It is distinctly separated from the underlying shales, but its upper beds grade into the overlying Carlile shale.

The Carlile shale consists mainly of shales but includes two thin hard beds of sandstone and several layers containing oval concretions. It ranges in thickness from 430 to 590 feet. Its belt of outcrop cuts across the Cheyenne River valley near the west end of the project. In the area mapped for this report the Carlile shale is exposed on the north side of the river only.

The overlying Niobrara formation consists of soft shaly limestone and impure chalk and includes thin beds of hard limestone. In fresh exposures it is light gray, but on weathering it becomes a bright yellow. It averages about 200 feet in thickness.

The Pierre shale, overlying the Niobrara formation, is the youngest bedrock formation exposed in the area. It is dark bluish gray to black in fresh exposures but weathers to a light brown. At a horizon about 1,000 feet above the base of the formation are lenses of limestone that on exposure give rise to low conical buttes because of their greater resistance to weathering. The Pierre shale ranges up to 1,200 feet in thickness. It is almost continuously exposed in the inner-valley walls downstream from a point about 4 miles east of the upper end of the project and it underlies the terraces extending back from the inner-valley walls. The Pierre shale forms a sticky gumbo on weathering.

## Quaternary system

The terrace gravels in this segment of the Cheyenne River Valley were laid down by the river at the time it occupied a broad valley 75 feet or more above its present level. Two distinct terraces are recognized, but the upper one is preserved only in isolated remnants or is overlain by dune sand and slope-wash materials. The terrace deposits consist mostly of gravel and sand through which boulders as much as 4 feet in diameter are scattered. The terrace deposits range up to 45 feet in thickness and rest on a bedrock shelf, the bedrock being exposed both higher in the outer-valley walls and lower in the inner-valley walls. The lower terrace is designated on the geologic map as $Qt_1$ and the upper terrace as $Qt_2$. (See pl. 2.)

Deposits of eolian sand mantle a large proportion of the area underlain by terrace sediments. The sand is in general uniformly fine-grained and ranges in thickness up to 65 feet. It has been derived from alluvial deposits on the river flats and has been transported southeastward by the stronger prevailing winds. A typical sand-hill topography has been developed in the sandy areas.

The slope wash that overlies the terrace deposits in many places was derived from the higher bare slopes of the Pierre shale. It consists of tough gray clay, which is much as 25 feet thick near its source but thins riverward until it merges with the soil mantle developed on the terrace. The thickness of the slope wash is 4 feet or more in all the areas shown on the map (pl. 2) to be mantled by this material; areas mantled by lesser thicknesses are not represented on the map.

Colluvium derived from the valley walls occurs as wedge-shaped deposits extending outward from the foot of the walls of the inner valley. It is composed of a mixture of materials derived from exposures of bedrock and terrace gravels higher on the inner-valley walls.

Alluvial fans distinct from the alluvium underlying the flood plain and low river terraces have been recognized in a few places. These sand and gravel deposits were laid down by tributary streams where their gradient is reduced on entering the main inner valley of the Cheyenne River.

The alluvium that underlies the floor of the inner valley consists of poorly sorted gravel and sand with varying amounts of admixed silt and silty clay. It ranges in thickness up to about 20 feet beneath the low river terraces but is thinner beneath the flood plain of the river. The river terraces within the inner valley are designated in ascending order on plate 2 as Qt$\frac{1}{4}$ and Qt$\frac{1}{2}$. Areas underlain by flood-plain deposits or by alluvium not distinguished as river terraces are designated as Qal.

## Structure

The stretch of the Cheyenne River valley considered in this report has been cut into the southeastern slope of the Black Hills uplift. At the west end of the area the strike of the bedrock averages N. 8° E., but within 2 miles to the east the strike changes to approximately N. 55° E. Eastward to the lower end of the project the strike progressively changes to about N. 65° E. Dips at the west end of the area average about 8°, and except for the interruption of a local flexure about 2 miles downstream from the west end of the project, the dips decrease progressively in an eastward direction.

The structure of the bedrock has influenced the course of Cheyenne River, especially at the west end of the project area where the general direction of flow veers from almost due north to a little more than 60 degrees east of north. The river flows in this latter direction to the Custer County line, where it changes to a more northerly course for the remaining length of the project.

## GROUND WATER IN THE INNER VALLEY AND ITS TRIBUTARIES

### Source and occurrence

Ground water occurs under water-table conditions in the alluvium of the inner valley and in the alluvium of the tributary valleys. It is derived principally from precipitation and from seepage through the river or stream bed when the level of the water in the stream is above that of the water table. The saturated thickness of the materials in the inner-valley alluvium is probably nowhere greater than 15 feet, and in the inner valley it is considerably less. In places near the edges of the inner valley the bedrock floor is sufficiently high that no alluvial materials are saturated.

## Depth of the water table

In the seven wells that derive water from the alluvium of the inner valley, the depth to static water level ranged from 11 to 26 feet below land surface at the time of measurement. In places on the flood plain the depth to the water table is less than in any of the existing wells farther from the river banks. The water table was encountered at depths ranging from 5 to 15 feet in six wells drilled into the alluvium of the tributary valleys. Ground water issues at the surface as springs in at least two places (7-8-16cba and 8-6-1cda) where the underflow is forced to the surface by the underlying shale. (See table 1.)

## Direction of movement

If based on closely spaced control points, contours drawn on the water table in the river alluvium would probably present a variety of patterns and would indicate a direction of movement ranging from parallel to the downstream flow of the river to toward the river at almost a right angle. The general direction of movement, however, is toward and down the axis of the inner valley. At times when the water table is high relative to the level of the river water, ground water is discharged into the river along its banks. Conversely, the river loses water through seepage to the ground-water reservoir during high stages of river flow. However, during the greater part of the year the water table and the level of river water probably are in approximate equilibrium.

Table 1.--Records of springs in the Angostura irrigation project, South Dakota

| Spring number[1] | Owner or tenant | Topographic situation | Geologic source[2] | Use of water[3] | Altitude (feet) | Flow (gallons per minute) | Date of measurement |
|---|---|---|---|---|---|---|---|
| 6-9-8bcb | U.S. Soil Conservation Service. | Terrace face | Contact, $Qt_1$ and Kp. | S | -- | 0.24 | 9-11-46 |
| 8bcc | do | do | do | S | -- | .40 | 9-11-46 |
| 7-7-24cac | G. Evans | Head of gully | do | S | 3,031 | .80 | 9- 5-46 |
| 31ddd | O. Crossier | Gully | do | S | 3,067 | -- | -- |
| 33ada | Bert Ray | do | do | S | 3,070 | (4) | -- |
| 7-8-2acb | J. Norman | Head of gully | do | D,S | 2,975 | (5) | -- |
| 12bdd | R. Gamet | Bench | do | N | -- | -- | -- |
| 12caa | do | Head of gully | do | S | 2,923 | 1.18 | 9- 5-46 |
| 15bad | C. Hughes | Gully | do | D,S | 3,007 | 2.00 | 9- 5-46 |
| 16cbc | R. Gamet | do | Contact, Qal and Kp. | S | 3,014 | 3.00 | 9-11-46 |
| 18dad | P. Fleming | Bench | Contact, $Qt_1$ and Kp. | S | 2,982 | .46 | 9- 5-45 |
| 19caa3 | W. G. Tice | Gully | do | S | 3,018 | (6) | -- |
| 8-6-1cda | J. Petty | do | Contact, Qal and Kp. | D,S | 3,034 | 1.50 | 10- 5-46 |
| 11bca | U.S. Soil Conservation Service. | do | Contact, $Qt_1$ and Qal. | S | 3,084 | -- | -- |
| 11bdc | do | do | Contact, $Qt_1$ and Kn. | S | 3,088 | -- | -- |
| 8-7-3dac | J. Hines | Terrace face | Contact, $Qt_2$ and Kp. | D,S | 3,078 | -- | -- |
| 5bab | O. Crossier | Gully | Contact, $Qt_1$ and Kp. | S | 3,048 | -- | -- |
| 6ccd | H. Kneupple | Terrace face | do | S | 3,100 | .38 | 9-25-46 |
| 7bad | do | Slope | Contact, $Qt_2$ and Kp. | S,I | 3,183 | -- | -- |

1 See explanation of well-numbering system in body of text.

2 Kn, Niobrara formation; Kp, Pierre shale; $Qt_1$, deposits of lower terrace; $Qt_2$, deposits of upper terrace; Qal, alluvium.

3 S, Stock; D, domestic; N, not used; I, irrigation.

4 Flowing from five openings; not collected in single storage.

5 Sealed to prevent contamination.

6 General seepage; not centrally collected.

## GROUND WATER IN THE TERRACE DEPOSITS

### Source and occurrence

Ground water is contained under water-table conditions in the terrace deposits that extend back from the walls of the inner valley. At the present time water in these deposits is derived almost wholly from precipitation. The terrace deposits rest on impermeable bedrock formations, principally the Pierre shale. In the area south of the Cheyenne River the upper surface of the bedrock floor beneath the terrace deposits slopes toward the inner valley in a downstream direction. Below the terrace deposits in the Harrison Flat area, however, the bedrock surface is gently concave, with a longitudinal axis essentially parallel to the course of the river. Because the amount of recharge from precipitation is low and a natural escape is afforded in the exposed edges of the terrace faces, the thickness of the zone of saturation is dependent mainly on the configuration of the underlying bedrock surface and on the ability of the terrace materials to transmit the water downward and laterally. The greatest thicknesses of water-saturated materials generally occur in places where the water has collected in depressions on the underlying bedrock surface; and probably such thicknesses do not exceed 15 feet. In places in the area south of the Cheyenne River the zone of saturation was found to be less than 1 foot thick, and it is possible that in some parts of the area no permanent zone of saturation exists. In the Harrison Flat area the shale bedrock was penetrated in several test holes without encountering any water; hence at the time of this study the zone of saturation was not continuous over this part of the project. The ground water present in the Harrison Flat area appears to be largely restricted to a narrow belt that parallels the inner valley but lies back from the terrace face. The slope wash that mantles much of the Harrison Flat area does not readily transmit water downward; this may account in part for the thinness of the zone of saturation beneath it. In the area south of the Cheyenne River, where eolian sand mantles parts of both the upper and lower terraces as well as the intervening slope, the zone of saturation is probably continuous from the upper to the lower terrace. The slope of the water table between the two terraces probably conforms approximately to the slope of the underlying bedrock surface. Springs and seeps occur in places where the zone of saturation is interrupted by a steep slope between the two terraces. They occur, also, where the zone of saturation in the lower terrace extends to the terrace face either in the walls of the inner valley or in the walls of narrow tributary valleys that have been cut back into the terrace. All the springs have an almost continuous flow, and most have been developed for domestic use and for watering stock. Data obtained on the springs in the terrace faces are presented in table 1 (p. 20).

## Depth to the water table

The depth to water level in wells on the lower terrace in the area south of the Cheyenne River ranges from 14 to 45 feet below land surface, and on Harrison Flat it ranges from 9 to 33 feet below land surface. On the upper terrace the depth to the water table below land surface ranges from 18 to 76 feet in existing wells. The considerable range in depth to the water table is probably due more to the irregularities of the topographic surface than to any other factor; the depth to water level is least in the topographically low situations on the terrace and greatest in the topographically high situations.

## Direction of movement

Ground-water movement in the lower terrace of the area south of the Cheyenne River is toward the inner valley and at a slight downstream angle. In general, the slope of the water table in much of the lower terrace is approximately equal to or slightly greater than the slope of the underlying bedrock surface. Near points of issue such as springs in the terrace face, however, the direction of movement is locally changed. Springs and seeps are common in the terrace face along the inner valley and in the valley walls of the tributary streams that have cut into the terrace below the level of the water table.

In places where the water table is continuous from the higher terrace to the lower terrace, the direction of ground-water movement is approximately the same as the direction of the greatest topographic slope -- that is, directly toward the inner valley.

Movement of the ground water in the remnants of the higher terrace is also toward the inner valley, but irregularities in the direction of the slope of the underlying bedrock surface control the local direction of movement.

Bedrock is exposed on the slope between the two terraces in places, and the water table is not continuous down the slope from the higher to the lower terrace. In some places ground water in the upper-terrace deposits issues as springs and seeps at points along the contact with the underlying bedrock.

In the Harrison Flat area the direction of ground-water movement ranges from toward the river at the southwest end of the area to parallel to and slightly away from the inner valley in that part of the area between the main inner valley and the tributary valley of Cottonwood Creek.

## GROUND WATER IN THE BEDROCK FORMATIONS

### Source and occurrence

Water is confined under artesian pressure in several formations that underlie the Angostura irrigation project. The more accessible of the artesian aquifers are the Fall River and Lakota sandstones, both of Lower Cretaceous age. These two sandstones, which are separated by about 125 feet of impervious beds (Fuson shale and Minnewaste limestone), crop out in a wide belt that completely encircles the Black Hills uplift. The formations dip away from the central part of the uplift, and beneath the area covered by this report they dip in a southeasterly direction. The water in these formations is derived partly by absorption of rain falling on the outcrop area and partly by seepage from streams crossing the outcrop area. The Lakota sandstone is the more productive of the two, but the Fall River sandstone contains a moderate supply of water. Other artesian aquifers occur at greater depths.

As the Fall River sandstone is exposed at the extreme western end of the project area, it is encountered at relatively shallow depths in the western part of the area. The depth to the top of the Fall River sandstone increases to about 2,700 feet[3] at a point about 5 miles downstream from Oral. However, the depth to this aquifer decreases to less than 2,500 feet under the Harrison Flat area.

## Relation of pressure surface to land surface

Darton[4] has indicated that throughout the area of the project the pressure surface of waters confined under artesian head in the bedrock aquifers is at a higher altitude than the topographic surface. Provided that the artesian head has not declined significantly in recent years, flowing wells may be expected in much of the area if they are drilled to a productive formation.

Well 8-6-17ccd, 221 feet deep, encountered water under sufficient head to raise it to a level 54 feet below land surface. The log kept by the drillers is given below. Geologic correlations are by the writer.

---

3 Darton, N. H., op. cit., Artesian water sheet.
4 Idem.

Log of well at construction camp near site of Angostura dam
[Drilled by Lewis Brothers Drilling Co., Hill City, S. Dak., for the Utah Construction Co.]

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, red (Recent) | 4½ | 4½ |
| Lakota sandstone (Cretaceous): | | |
| Sandstone, red; calcareous in upper 5 feet; seep of water at 70 feet | 76 | 80½ |
| Shale, moderately hard, dark-gray | 47½ | 128 |
| Sandstone, hard, red | 8 | 136 |
| Shale, soft, dark-gray | 42 | 178 |
| Sandstone, hard | 11 | 189 |
| Unkpapa sandstone (Jurassic): | | |
| Shale, dark-gray | 3 | 192 |
| Sandstone, soft, cream-colored; increased inflow of water | 23 | 215 |
| Limestone (?) | 6 | 221 |

## Direction of movement

Water in the bedrock aquifers moves in the direction of greatest dip, which, under the area of this report, ranges from almost due east at the southwest end of the project to southeast under the middle and northeast parts of the area.

# MINERAL QUALITY OF THE WATERS

By Herbert A. Swenson

## Introduction

The composition of ground waters in the Angostura project was determined in order to define the chemical character of these waters prior to extensive irrigation development. Later studies should reveal any changes in mineral content due to mixing of ground waters with irrigation water diverted from the Cheyenne River.

For this study, chemical analyses were made of ground waters from the area south of the Cheyenne River and from the Harrison Flat area north of the river. (See pl. 1.) Most of the water samples were obtained from dug wells ranging in depth from 9.4 to 88 feet. Concentrations of dissolved solids ranged from 246 to 3,260 parts per million. Hardness as calcium carbonate ranged from 95 parts per million for a spring water to 946 parts for a water from an 88-foot dug well. Practically all well waters sampled were used for domestic purposes and were high in mineral content. Farmers and ranchers using these waters frequently complained of heavy deposits of salts in pipe lines to kitchens, as well as coatings inside cooking utensils.

Also included in this section are a brief comparison of earlier salinity measurements for 23 well waters analyzed by the Soil Conservation Service and a general discussion, with special reference to percent sodium, of the relation of fluctuations in Cheyenne River flows to the chemical character of the river water.

## Mineral constituents in solution

The characteristics and dissolved mineral constituents of ground waters discussed in the following paragraphs include those found in quantities sufficient to have a practical effect on the value of the waters for irrigation and domestic uses.

### pH

The degree of acidity or alkalinity of water, as indicated by the hydrogen-ion concentration, or pH, is related to the corrosive properties of water. The value pH, which represents the negative logarithm of the number of moles of ionized hydrogen per liter of water, should also be known so that proper treatment for coagulation may be made at water-treatment plants. A pH value of 7.0 indicates that the water is neither acid nor alkaline. For practical purposes, the pH scale may be used with reference to acidity and alkalinity as a temperature scale is used with reference to heat conditions. The pH of most natural waters is between 6.0 and 8.0. Some alkaline waters have pH values greater than 8.0, and waters containing free mineral acid have values less than 4.5. The pH of water indicates its activity toward metal surfaces, and as the pH increases, the corrosiveness of the water decreases. Values of pH ranged from 7.8 to 8.8 in the 10 samples of ground water analyzed by the Geological Survey for this report.

## Iron

Iron is dissolved from many rocks and soils and frequently from the iron pipes through which the water flows. Iron in water in the home is objectionable because it makes stains on porcelain or enameled fixtures and on clothing and other fabrics. Water furnished to domestic consumers preferably should not contain more than 0.3 part per million of iron. On exposure to air, water that contains more than 1 part per million of iron soon becomes turbid with the insoluble compound produced by oxidation; surface waters therefore rarely contain as much as 1 part per million of dissolved iron. Ground waters and certain spring waters, however, frequently contain several parts per million of dissolved iron until they are brought in contact with air. Ground waters sampled in the Angostura area contain from 0.10 to 0.40 part per million of iron.

## Calcium

Calcium is dissolved from practically all rocks but particularly from limestone, dolomite, gypsum, and gypsiferous shales. Calcium and magnesium make water hard and are the active agents in forming boiler scale. Most waters associated with granite or siliceous sands contain less than 10 parts per million of calcium; many waters from limestone contain from 30 to 100 parts; and waters that leach deposits of gypsum may contain several hundred parts. Maximum and minimum values for ground waters are 228 and 20 parts per million of calcium, respectively, in the analyses given in this report.

### Magnesium

Magnesium is dissolved from many rocks, particularly from dolomitic types. Its effects are similar to those of calcium, but waters that contain much magnesium and chloride are likely to be corrosive. The magnesium in soft waters may amount to only 1 part or 2 parts per million, but water in areas that contain large quantities of dolomite or other magnesium-bearing rocks may contain from 20 to 100 or more parts per million of magnesium. Magnesium values range from 10 to 96 parts per million in the samples of ground water collected in the Angostura irrigation project.

### Sodium and potassium

Sodium and potassium are dissolved from practically all rocks. For most surface waters in humid regions, sodium and potassium make up only a small part of the dissolved mineral matter. However, in many semiarid sections of the western United States, such as southwestern South Dakota, sodium is often the predominant basic radical in the more highly mineralized waters. Waters that carry more than 50 or 100 parts per million of sodium and potassium may require careful operation of steam boilers to prevent foaming. Where sodium salts make up most of the composition, the water may not be satisfactory for irrigation, and a few waters contain so much sodium that they are unfit for nearly all uses. A more detailed discussion of the sodium effect in irrigation waters is given under the heading "Percent sodium." In the analyses given for ground waters in this report, values for sodium and potassium range from 10 to 616 parts per million.

## Carbonate and bicarbonate

Carbonate and bicarbonate occur in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Carbonate is not present in appreciable quantities in many natural waters. The bicarbonate in waters that come from relatively insoluble rocks may amount to less than 10 parts per million; many waters from limestone contain from 200 to 400 parts per million. Results for bicarbonate in ground waters sampled in this study are fairly uniform, ranging from 207 to 416 parts per million.

## Sulfate

Sulfate is dissolved in large quantities from gypsum in beds of shale and from deposits of sodium sulfate. It is also formed by the oxidation of sulfides of iron and is therefore present in considerable quantities in water from mines. Sulfate in waters that contain much calcium and magnesium causes the formation of hard scale in steam boilers and may increase the cost of softening the water. Extremes in sulfate content, with results ranging from 22 to 1,810 parts per million, were found by analysis of the ground-water samples.

## Chloride

Chloride is dissolved in small quantities from rock materials in most parts of the country. The chloride content has little effect on the use of the water unless it is present in excessive quantities, as in brines. Surface waters in humid regions are usually low in chloride, whereas streams in arid or semiarid regions may have several hundred parts per million of sodium chloride that has been leached from the soil and rocks, especially where they receive return drainage from irrigated lands. Drinking waters containing much over 500 parts per million of chloride have a characteristic salty taste. The chloride concentration of ground waters sampled in the Angostura irrigation project was low, ranging from 5 to 40 parts per million.

## Fluoride

Fluoride may be present in some rocks to about the same extent as chloride. However, the quantity present in natural waters is usually much less than that of chloride. Fluoride in water is known to be associated with the dental effect known as mottled enamel if the water is used for drinking by young children during calcification or formation of the teeth. This condition becomes more noticeable as the quantity of fluoride in water increases above 1 part per million. It is reported that the incidence of dental caries (decay of teeth) is decreased or prevented by quantities of fluoride that are not sufficient to cause permanent disfigurement from mottled enamel. The fluoride content of samples of ground waters analyzed for this report was less than 1 part per million.

## Nitrate

Nitrate in water may indicate previous contamination by sewage or other organic matter, as it represents the final stage of oxidation in the nitrogen cycle. The quantities of nitrate usually present have no effect on the value of water for ordinary uses. Nitrate results for ground waters ranged from 0.0 to 83 parts per million. The high value of 83 was reported for a well water of which no use was made.

## Boron

The boron content of an irrigation water is of great importance for many crops. Some crops,[5] such as beans, are very sensitive to an excess of boron, whereas others, such as sugar beets, will tolerate large quantities. A water containing more than 2.0 parts per million of boron will, in time, usually cause trouble with many crops. The boron concentration of sampled ground waters did not exceed 0.3 part per million.

5 Magistad, O. C., and Christiansen, J. E., Saline soils, their nature and management: U. S. Dept. Agr. Circ. 707, p. 9, Sept. 1944.

## Dissolved solids

The quantity reported as dissolved solids--the residue on evaporation--consists mainly of the dissolved mineral constituents in the water. It may also contain some organic matter and water of crystallization. Waters with less than 500 parts per million of dissolved solids are usually satisfactory for domestic and some industrial uses. Waters with more than 1,000 parts per million of dissolved solids are likely to be unsuitable for most domestic and industrial uses. Waters containing several thousand parts per million are sometimes successfully used for irrigation when irrigation practices permit removal of soluble salts through the application of large volumes of water on well-drained lands. As pointed out by Magistad and Christiansen, for a class-1 irrigation water otherwise suitable for most plants under most conditions the dissolved solids preferably should not exceed 700 parts per million. The dissolved solids ranged from 246 to 3,260 parts per million in the samples analyzed for this study.

## Hardness

Hardness is the characteristic of water that receives most attention with reference to industrial and domestic use. It is recognized by the quantity of soap required to produce a lather, by the formation of the insoluble curd that is objectionable in all washing processes, and by the deposits of insoluble salts formed when a water is heated or evaporated. Hardness is caused almost entirely by calcium and magnesium and is reported as calcium carbonate ($CaCO_3$) equivalent to the calcium and magnesium. The hardness caused by calcium and magnesium equivalent to the bicarbonate or carbonate in a water is called carbonate hardness; the hardness caused by other compounds of calcium and magnesium is called noncarbonate hardness.

Water that has less than 60 parts per million of hardness is usually regarded as soft and suitable for most purposes without further softening. Hardness between 60 and 120 parts per million does not seriously interfere with the use of water for most purposes except for use in high-pressure steam boilers and in some industrial processes. Waters with hardness ranging from 120 to 200 are considered hard, and laundries and industries may profitably soften the supply if the hardness is in the upper ranges. Water with hardness beyond 200 parts per million usually requires some treatment for removal of hardness before it is satisfactory for most purposes. Ground waters sampled in the Angostura irrigation project had hardness values ranging from 95 to 964 parts per million.

## Percent sodium

The proportion of sodium to other basic constituents in a water has a bearing on the suitability of the water for irrigation. Percent sodium is defined as the result obtained by dividing the equivalents per million of sodium by the equivalents per million of cations (usually calcium, magnesium, sodium, and potassium) and multiplying by 100. Waters in which the percent sodium is more than 60 may be injurious when applied to certain types of soils, particularly when adequate drainage is not provided.

The ratio of sodium to other bases in an irrigation water is important because the quantities of cations absorbed in a soil are governed by the quantities of these cations in the irrigation water or soil solution. The relative quantities of calcium and sodium absorbed in a soil greatly modify its physical properties and its permeability to water. An irrigation water having a high sodium percentage will, after a time, give rise to a soil having a large proportion of replaceable sodium in the colloid. It has been reported[6] that even on sandy soils with good drainage, waters of 85 percent sodium or higher will give rise to impermeable soils after prolonged use. The percent sodium in ground waters analyzed in this study varied considerably, ranging from 11 to 85.

## Quality of the ground waters

### General

Ten samples of ground water were taken from wells or springs in the Angostura project and were analyzed for mineral content. The results of the chemical analyses are given in table 2, where sampling points are listed in west-to-east order. Wells 8-6-17ccd to 7-8-21ddc, inclusive, are in the area south of the Cheyenne River, and the re-

6 Magistad, O. C., and Christiansen, J. E., op. cit., p. 8.

Table 2.--Chemical analyses, in parts per million, and related physical measurements of ground water in the Angostura irrigation project, South Dakota

[Well numbers are listed in west-to-east order]

| Well number | Date of collection | Depth (in feet) | Diameter (in inches) | pH | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium and Potassium (Na + 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 | Non-carbonate | |
| 8-6-17ccd | 9-26-46 | 221 | 6 | 8.0 | 0.15 | 91 | 73 | 42 | 258 | 370 | 14 | 0.7 | 0.0 | 0.2 | 794 | 527 | 315 | 15 |
| 8-6-3ddd | 9-29-46 | 58 | 8 | 8.1 | .10 | 90 | 34 | 226 | 246 | 606 | 14 | .7 | 2.8 | .3 | 1160 | 364 | 162 | 57 |
| 8-6-13aac | 9-26-46 | 11.7 | 24 | 7.9 | .10 | 89 | 40 | 56 | 292 | 223 | 13 | .7 | 83 | .1 | 723 | 386 | 147 | 24 |
| 7-7-24cac1 | 9-26-46 | 30 | 36 | 7.8 | .40 | 35 | 12 | 173 | 322 | 220 | 12 | .5 | 1.6 | .3 | 624 | 137 | 0 | 73 |
| 7-8-21ddc | 9-17-46 | 88 | 48 | 7.9 | .10 | 228 | 96 | 616 | 378 | 1810 | 40 | .9 | 62 | .3 | 3260 | 964 | 654 | 58 |
| 7-8-2acb | 9-11-46 | Spring | - | 8.8 | .10 | 20 | 11 | 241 | 381 | 247 | 18 | .5 | 29 | .3 | 836 | 95 | 0 | 85 |
| 6-8-25dab | 9-5-46 | - | 48 | 8.0 | .10 | 48 | 16 | 10 | 207 | 22 | 5.0 | .2 | 10 | .1 | 246 | 186 | 16 | 11 |
| 6-8-24ddc | 9-5-46 | 41.3 | 48 | 7.8 | .10 | 35 | 10 | 129 | 338 | 101 | 15 | .5 | 5.0 | .1 | 491 | 128 | 0 | 69 |
| 6-9-18acc1 | 9-12-46 | 9.4 | 36 | 8.1 | .10 | 60 | 14 | 110 | 343 | 130 | 16 | .6 | 6.6 | .3 | 542 | 207 | 0 | 54 |
| 6-9-18dcc2 | 9-5-46 | 37.3 | 48 | 8.0 | .10 | 44 | 14 | 228 | 416 | 254 | 37 | .6 | 5.7 | .3 | 882 | 167 | 0 | 75 |

maining wells and a spring that was sampled are in the Harrison Flats region north of the river.

The dissolved solids of the ground waters analyzed ranged from 246 to 3,260 parts per million, with an arithmetic mean of 956 parts. This mean is in close agreement with the value of 1,160 parts per million that represents the average concentration of 23 well waters previously reported by the Soil Conservation Service for wells in the Angostura irrigation project. Hardness of the ground waters except that for spring 7-8-2acb, exceeds 120 parts per million. With increasing salinity, sodium is usually the predominant cation and sulfate the predominant anion. This relation is shown for sodium in figure 8, where concentrations of individual cations are plotted against the sum of dissolved solids. As shown in this figure, sodium increases in fairly direct proportion to the dissolved solids after the concentration of solids has reached about 600 parts per million, but calcium and magnesium have little relation to concentration. A similar relationship is found for sulfate in figure 9 which shows that sulfate is the predominant anion after the concentration of solids has reached approximately 600 parts per million and that it increases roughly in proportion to the concentration of dissolved solids. Little relation was observed in values for carbonate (calculated from bicarbonate) and chloride to increased mineral content.

The increase in dissolved solids above 600 parts per million is generally due to the addition of sodium and sulfate. This is more easily seen in analyses 8-6-3ddd and 7-8-21ddc in figure 14, where

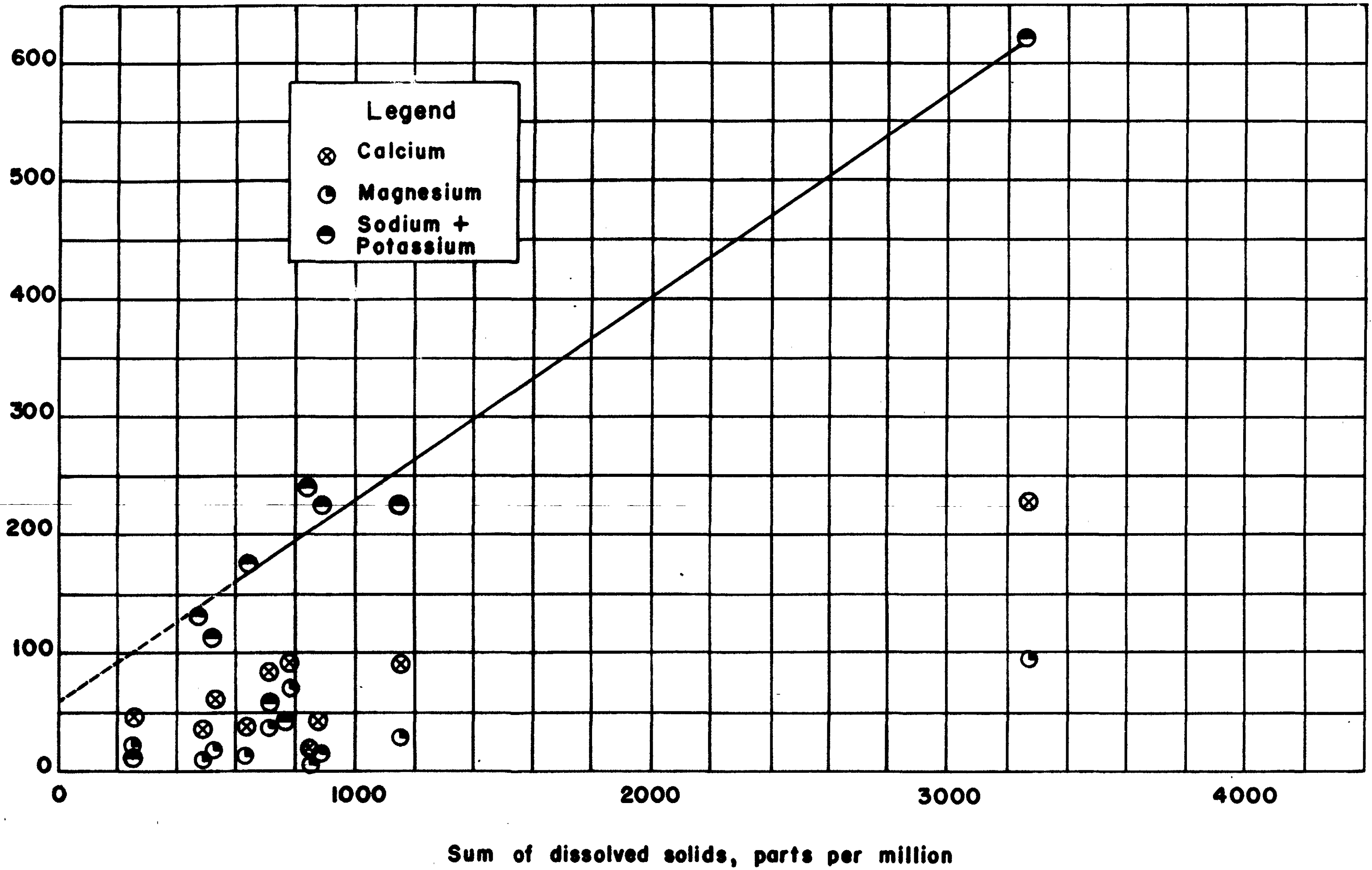



Figure 8.- Relation of calcium, magnesium, and sodium plus potassium to the sum of dissolved solids in ground waters, Angostura Irrigation Project, South Dakota.

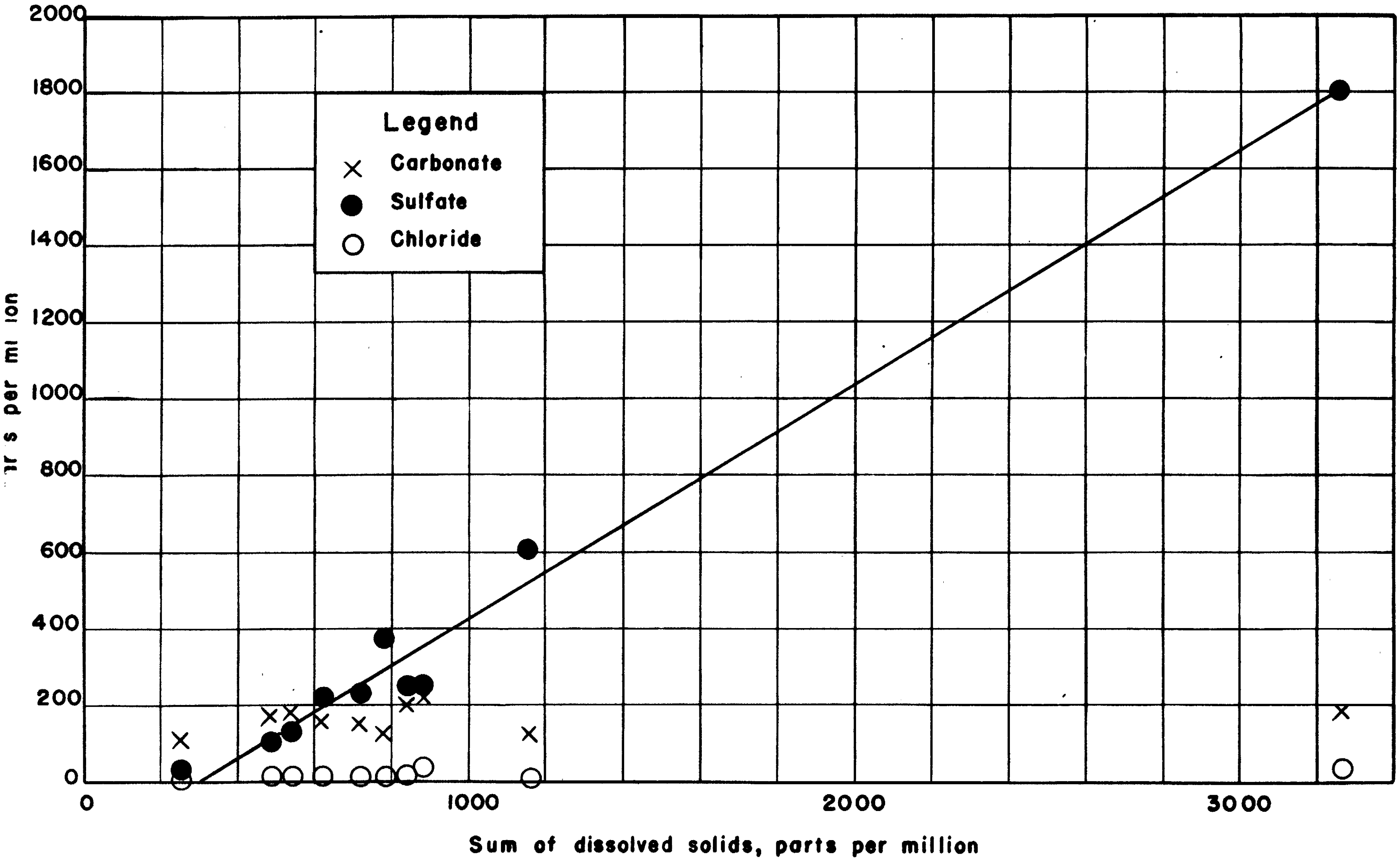



Figure 9.- Relation of carbonate, sulfate, and chloride to the sum of dissolved solids in ground waters, Angostura Irrigation Project, South Dakota

analytical results are expressed in equivalents per million, the heights of the respective diagrams being proportional to the concentration in equivalents.

## Area south of the Cheyenne River

The sample from well 8-6-17ccd, a drilled well 221 feet deep drawing water from the Lakota and Unkpapa sandstones, contained 794 parts per million of dissolved solids, including an appreciable amount of magnesium sulfate. (See fig. 10.) This water, used as a domestic supply by the Utah Construction Co., has a hardness of 527 parts per million, which greatly exceeds the limits considered desirable for most domestic purposes.

Sodium sulfate makes up most of the mineral content of the sample from well 8-6-3ddd, a 58-foot dug well used for domestic purposes. This well draws water from the sands and gravels of the lower terrace. The hardness of 364 parts per million, largely calcium bicarbonate, shows this sample to be a very hard water.

Wells 8-6-13aac and 7-7-24cacl, both shallow, yield waters of similar concentration but of different composition. The sample from well 8-6-13aac, dug 11.7 feet into eolian sand, contains 723 parts per million of dissolved solids, and has a hardness of 386 parts. The well is not used. Well 7-7-24cacl is a 30-foot dug well that obtains water from the lower-terrace sands and gravels and is used for domestic purposes. The dissolved-solids concentration of the water

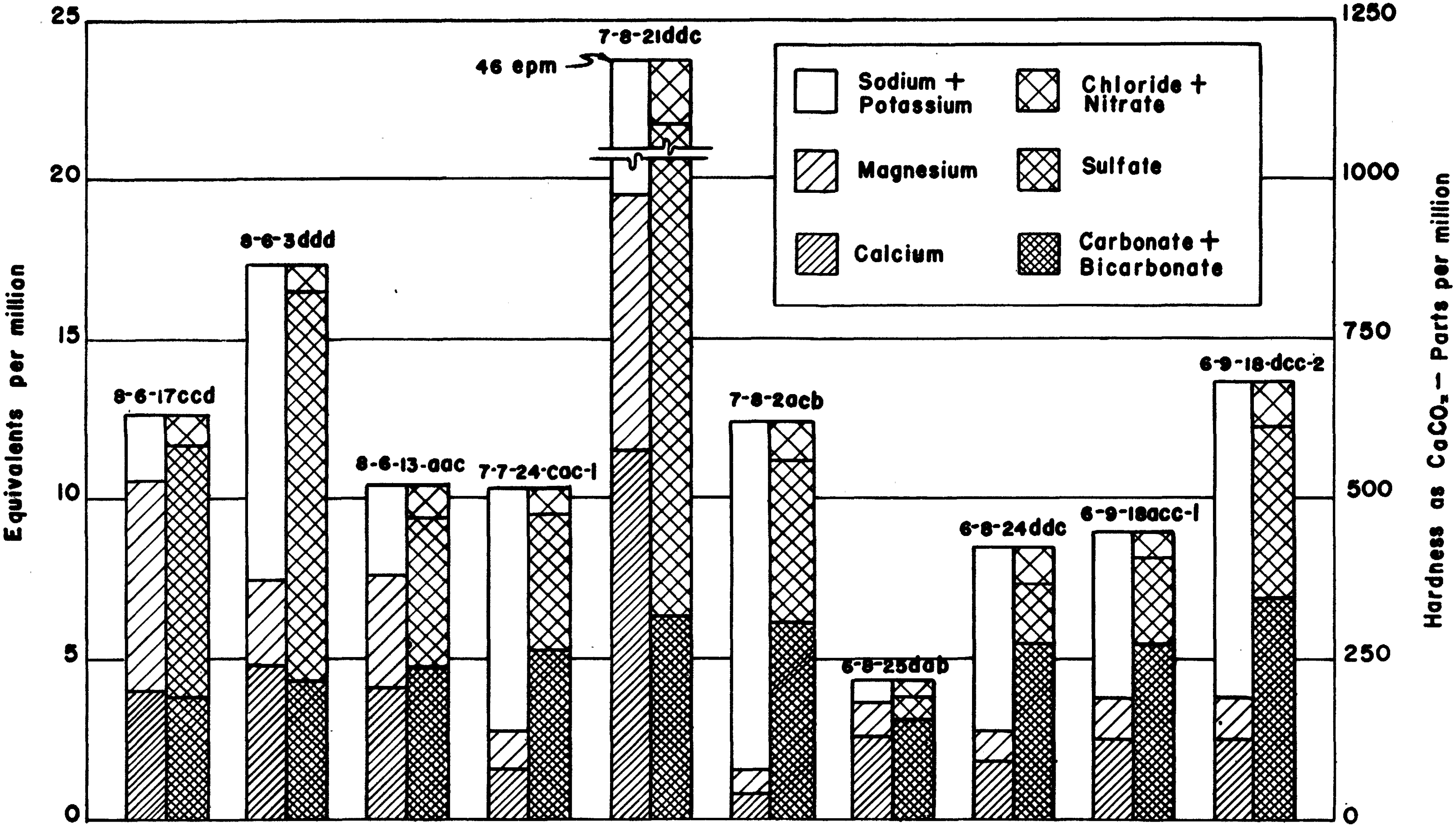



Figure 10.- Principal mineral constituents present in ground waters of the Angostura Irrigation Project, South Dakota.

sample from this well was 624 parts per million, but its hardness was considerably less than half that of the water from 7-6-13aac. Sodium salts account for much of the mineral content of the sample from well 7-7-24cacl.

Of the ground waters collected in the Angostura irrigation project and analyzed for this report, the water from well 7-8-21ddc, with 3,260 parts per million of dissolved solids, is the most highly mineralized. This water, used for domestic and stock purposes, is obtained from an 88-foot dug well in the upper-terrace sands and gravels. With 964 parts per million of total hardness, this water is also the hardest of those sampled. Sodium comprises 58 percent of all cations, and considerable sodium sulfate is present.

## Harrison Flat

The sample of water obtained from spring 7-8-2acb is rather highly mineralized, having 836 parts per million of dissolved solids. It is quite soft, however, the hardness of 95 parts per million being the lowest for all ground waters sampled in the Angostura project. Considerable sodium bicarbonate and sodium sulfate are present.

The water from well 6-8-25dab, a dug well of undetermined depth in the lower-terrace sands and gravels, has the least concentration of dissolved solids of all ground waters considered in this report. This water contains 246 parts per million of dissolved solids, most of which is calcium bicarbonate, and is used for domestic and stock purposes.

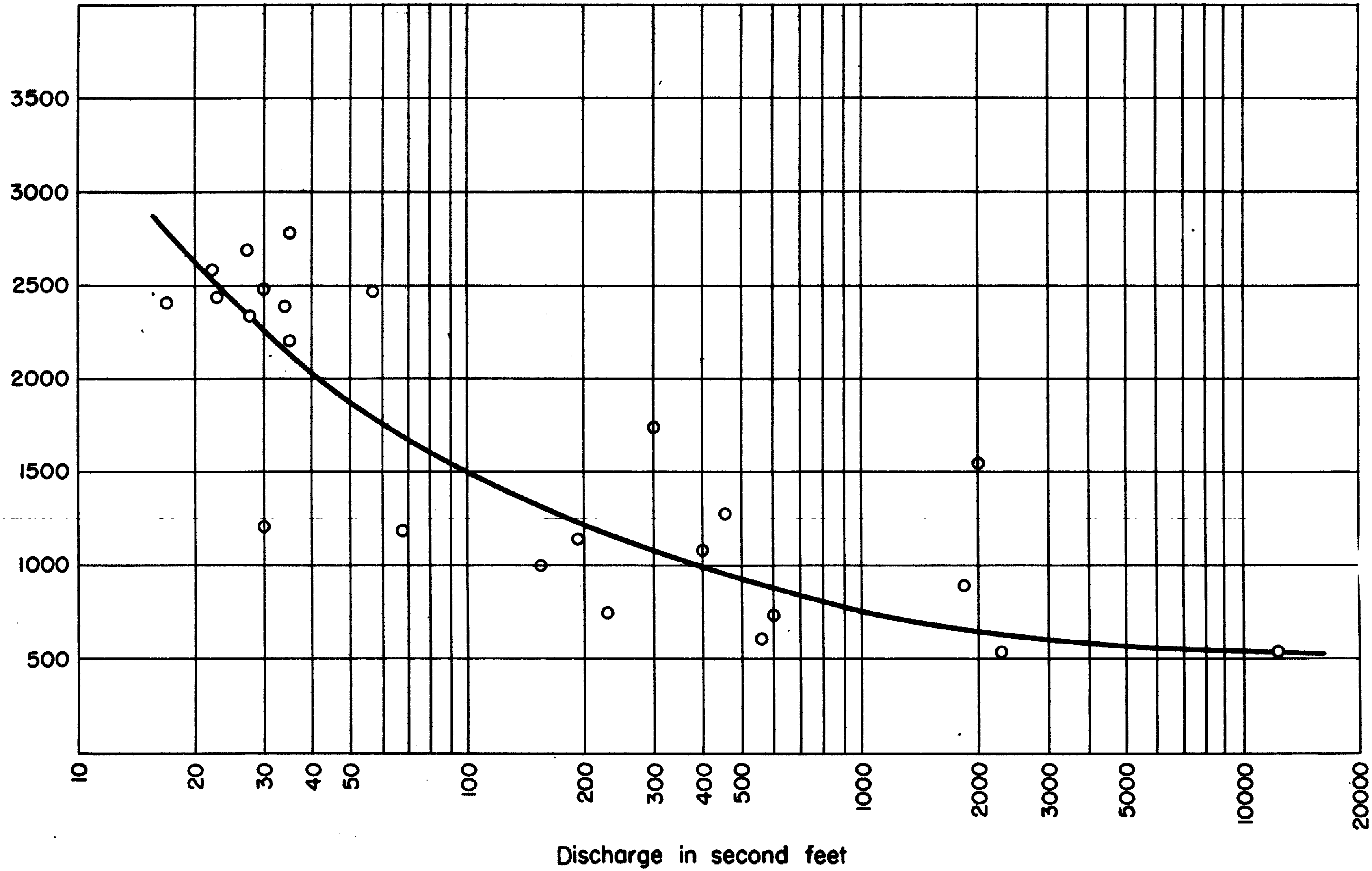
The samples from wells 6-8-24ddc and 6-9-18accl are very similar in both dissolved-solids concentration and composition. The first was obtained from a dug well 41.3 feet deep, that penetrates the lower-terrace sands and gravels. This water contained 491 parts per million of dissolved solids and is used for domestic and stock purposes. The sample of water from well 6-9-18accl, a dug well 9.4 feet deep drawing from the alluvium, contained 542 parts per million of dissolved solids. It is used for domestic purposes. Both samples contained more sodium than calcium and magnesium combined.

Well 6-9-18dcc2, a dug well 37.3 feet deep, obtains water from the lower-terrace sands and gravels. Sodium salts make up most of the chemical composition, and the dissolved-solids content of 882 parts per million marks this water as definitely mineralized. The water is used for domestic and stock purposes.

## Quality of the surface water

Irrigation water to be diverted from the Cheyenne River will normally provide some artificial recharge to the ground-water reservoir. Mixing of the surface and ground waters should modify the concentration as well as the present chemical composition of well waters in this area.

Cheyenne River water near Hot Springs, S. Dak., carries considerable mineral matter in solution, particularly during low flows. The relation of the mineral content of the river water to discharge is shown graphically in figure 11, where it is seen that the higher concentrations




igure 11.—Study of the relationship between dissolved solids and discharge of the Cheyenne River, Angostura Irrigation Project, South Dakota.

of dissolved solids are obtained with the lower discharges.

Although the surface water is highly mineralized, values of percent sodium were found to be fairly low. For 25 analyses of samples of water collected from the Cheyenne River near Hot Springs during the period 1941-46 at various stages of flow, the percent sodium ranged from 2 to 41. Little relation was found between percent sodium and discharge, as can be seen by reference to figure 12.

With respect to sodium content, Scofield[7] has said:

> The significance of this characteristic of the salt complex in irrigation water lies in the results of reactions of base exchange on the physical properties of the soil. If the dissolved salts are preponderantly those of calcium and magnesium, i. e., if the percent sodium is low, then the reactions of base exchange are in the direction of maintaining good tilth and good permeability in the soil. On the other hand if the percentage of sodium is high the consequent reactions of base exchange in the soil tend in the direction of the replacement of calcium and magnesium by sodium in the exchange complex with the results that the soil becomes deflocculated and impermeable to water. Experience indicates that if the sodium percentage is below 50 there is little danger of impairing seriously the physical condition of the soil. If it is above 60, such danger exists. The critical ratio is believed to lie between 50 and 60.

On the basis of Scofield's classification, water from the Cheyenne River near Hot Springs should have little tendency to impair the physical condition of the soil, assuming proper drainage. It should be noted, however, that any land would probably be injured by the best of natural waters if irrigated with them for a long period of time without natural or artificial drainage, for most irrigation waters

7 Scofield, C. S., South coastal basin investigation, quality of irrigation waters: California Dept. Public Works Bull. 40, 1933.

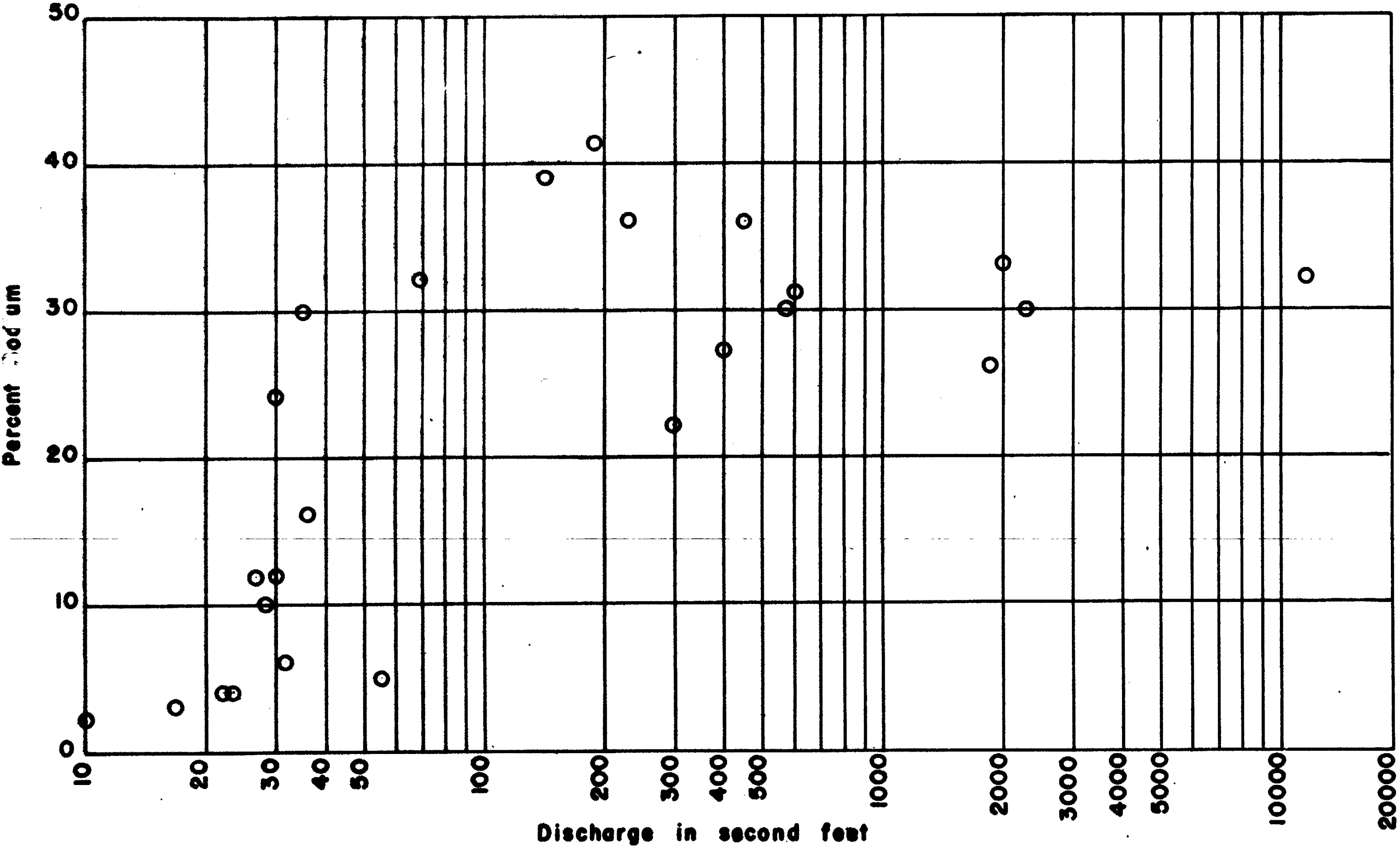



Figure 12.- Study of the relationship between percent sodium and discharge of the Cheyenne River, Angostura Irrigation Project, South Dakota.

contain sufficient mineral content to cause gradual accumulation of salts if drainage is not adequate.

## Summary

Both ground and surface waters in the Angostura project are rather highly mineralized and hard, the river water being characterized by relatively low values of percent sodium. Well waters are used almost exclusively for domestic and stock purposes. The analyses of selected ground waters sampled from wells lying in the area south of the Cheyenne River and in the Harrison Flat region provide information on the salinity of these waters prior to irrigation development. On the basis of the greater mineralization of river waters, mixing of surface water with ground water will probably increase the mineral content of most existing ground-water supplies. Chemical analyses of both ground and surface waters, if made concurrently with the application of irrigation water, will show any change in the quality of the ground waters.

## PROBABLE EFFECT OF IRRIGATION ON GROUND-WATER CONDITIONS

The application of irrigation water on the terrace areas over a period of years will have varied results, depending on the permeability of the material underlying the irrigated land and on measures taken to forestall undesirable effects.

Water applied to areas underlain by a considerable thickness of impermeable slope wash soon will become waterlogged unless adequate drainage is provided at the outset of irrigation; the use of the smallest practicable amounts of irrigation water may help to alleviate this condition. In the areas where the permeable terrace materials are close below the surface, a gradual rise of the water table will take place. The water table will first approach the surface over areas of shallow bedrock, and if it rises to a level permitting discharge by evaporation, remedial measures will be required to lower the water table and prevent deposition of minerals in concentrations injurious to plant growth. The rise in the water table also will result in the increased flow of existing springs and in the formation of new springs along the terrace faces. This in turn may result in an acceleration of the rate of slumping along the edges of the inner valley. Uncontrolled seepage along the terrace faces may result in waterlogging of the bottom lands of the inner valley, especially those mantled by colluvium, unless drainage is provided. Some terrace areas are underlain by a sufficient thickness of permeable sands and gravels with adequate outlets for drainage to prevent waterlogging; however, a close watch of the ground-water levels under all land should be kept after irrigation begins so that threatening high water tables may be discovered and remedial action taken before damage to the land occurs.

The practice of irrigation will increase the amount of ground water available to wells in the greater part of the area, but because of the poor quality of the Cheyenne River water, which is to be used for irrigation, the quality of the ground water will likely become even worse than it is now.

## FLUCTUATIONS OF WATER LEVELS IN WELLS

Measurements of the depth to water in wells in the Angostura irrigation project are given in the following table. Measurements from April through October 1946 were made by the Geological Survey; those from November 1946 through August 1947 were made by the Soil Conservation Service; and those after August 1947 were made by the Bureau of Reclamation. Pertinent data for all observation wells are listed in table 5 (see p. 89). Locations of all wells except 5-10-13aa, 5-10-7ac, 5-10-9bc, and 5-10-18ba, which are outside the area proper, are shown on plate 1.

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface

5-9-13aa.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 24, 1946 | Dry at 37.7 | Aug. 9, 1946 | Dry at 37.7 | Nov. 14, 1946 | Dry at 37.7 |
| June 4 | do. | | | | |

5-10-7ac.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 24, 1946 | 15.41 | Aug. 9, 1946 | 15.10 | Nov. 14, 1946 | 14.99 |
| June 4 | 15.42 | | | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

5-10-9bc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 24, 1946 | 9.11 | Aug. 9, 1946 | 6.84 | Nov. 14, 1946 | 7.80 |
| June 4 | 6.44 | | | | |

5-10-18ba.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 24, 1946 | 14.17 | Aug. 9, 1946 | 14.39 | Nov. 14, 1946 | 14.58 |
| June 4 | 13.65 | | | | |

6-8-13aad.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 15.75 | Jan. 6, 1947 | 15.89 | Aug. 5, 1947 | 15.47 |
| June 4 | 15.74 | 31 | 16.27 | Dec. 10 | 14.60 |
| Aug. 9 | 13.85 | Feb. 27 | 15.48 | Mar. 31, 1948 | 14.55 |
| Sept. 5 | 15.88 | Mar. 31 | 15.88 | Apr. 29 | 15.52 |
| Oct. 1 | 15.86 | May 1 | 15.89 | May 27 | 15.52 |
| 29 | 15.88 | June 5 | 15.88 | July 2 | 16.20 |
| Nov. 29 | 15.89 | July 2 | 15.88 | 29 | 15.65 |

6-8-24ddc.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 37.22 | Jan. 6, 1947 | 37.25 | Dec. 10, 1947 | 36.90 |
| June 5 | 37.24 | 31 | 37.20 | Mar. 3, 1948 | 37.07 |
| Aug. 9 | 37.33 | Feb. 27 | 37.22 | Apr. 29 | 37.07 |
| Sept. 5 | 37.24 | Mar. 31 | 37.24 | May 27 | 37.10 |
| Oct. 1 | 37.28 | May 1 | 37.26 | July 2 | 38.00 |
| 29 | 37.26 | June 4 | 37.26 | 28 | 37.12 |
| Nov. 29 | 37.22 | July 2 | 37.20 | | |

6-8-25dab.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 33.22 | Jan. 31, 1947 | 32.91 | Mar. 31, 1948 | 32.15 |
| June 5 | 32.90 | Feb. 27 | 33.09 | Apr. 29 | 32.55 |
| Oct. 1 | 32.39 | Mar. 31 | 33.09 | May 27 | 32.42 |
| 29 | 33.31 | May 1 | 33.01 | July 2 | 33.00 |
| Nov. 29 | 33.04 | July 2 | 32.12 | 29 | 32.58 |
| Jan. 6, 1947 | 32.96 | | | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

6-8-26aac.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 36.32 | Jan. 6, 1947 | 36.45 | Aug. 5, 1947 | 33.48 |
| June 5 | 36.64 | 31 | 36.47 | Dec. 10 | 34.70 |
| Aug. 9 | 36.63 | Feb. 27 | 36.55 | Mar. 31, 1948 | 34.20 |
| Sept. 5 | 37.48 | Mar. 28 | 36.82 | Apr. 29 | 34.07 |
| Oct. 1 | 36.80 | May 1 | 36.44 | May 27 | 34.04 |
| 29 | 36.48 | June 4 | 36.46 | July 2 | 35.70 |
| Nov. 29 | 36.74 | July 2 | 31.41 | 29 | 33.97 |

6-9-8ccb.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 35.10 | Jan. 6, 1947 | 35.19 | Aug. 5, 1947 | 35.27 |
| June 4 | 35.11 | 31 | 35.21 | Dec. 10 | 35.19 |
| Aug. 9 | 35.15 | Feb. 27 | 35.22 | Mar. 31, 1948 | 35.12 |
| Sept. 5 | 35.16 | Mar. 31 | 35.24 | Apr. 29 | 35.10 |
| Oct. 1 | 35.16 | May 1 | 35.24 | May 27 | 35.15 |
| 29 | 35.18 | June 5 | 35.26 | July 2 | 35.90 |
| Nov. 29 | 35.20 | July 2 | 35.26 | 29 | 35.10 |

6-9-8dcc2.

| | | | | | |
|---|---|---|---|---|---|
| Sept. 10, 1946 | 17.75 | Mar. 31, 1947 | 17.91 | Mar. 31, 1948 | 16.40 |
| Oct. 29 | 17.77 | May 1 | 17.93 | Apr. 29 | 16.36 |
| Nov. 29 | 17.80 | June 5 | 17.95 | May 27 | 16.43 |
| Jan. 6, 1947 | 17.79 | July 2 | 17.78 | July 2 | 17.70 |
| 31 | 17.84 | Aug. 5 | 17.07 | 29 | 16.40 |
| Feb. 27 | 17.84 | Dec. 10 | 16.33 | | |

6-9-18acc2.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 21, 1946 | 8.48 | Mar. 31, 1947 | 7.48 | Mar. 31, 1948 | 7.61 |
| Oct. 1 | 8.31 | May 1 | 8.25 | Apr. 29 | 7.62 |
| 29 | 8.21 | June 5 | 8.31 | May 27 | 7.73 |
| Nov. 29 | 8.22 | July 2 | 5.88 | July 2 | 8.60 |
| Jan. 6, 1947 | 8.19 | Aug. 5 | 6.92 | 29 | 7.78 |
| 31 | 8.18 | Dec. 10 | 6.43 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

6-9-18dcc2.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 23, 1946 | 32.50 | Jan. 6, 1947 | 32.46 | Aug. 5, 1947 | 32.32 |
| June 4 | 32.44 | 31 | 32.52 | Dec. 10 | 32.02 |
| Aug. 9 | 32.55 | Feb. 27 | 32.46 | Feb. 20, 1948 | 32.57 |
| Sept. 5 | 32.48 | Mar. 28 | 32.47 | Mar. 31 | 31.92 |
| Oct. 1 | 32.45 | May 1 | 32.61 | Apr. 29 | 31.93 |
| 29 | 32.46 | June 5 | 32.48 | May 27 | 31.99 |
| Nov. 29 | 32.47 | July 2 | 32.46 | | |

6-9-18ddd.

| | | | | | |
|---|---|---|---|---|---|
| Oct. 28, 1946 | 7.80 | Jan. 31, 1947 | 8.41 | Apr. 30, 1947 | 9.06 |
| Nov. 29 | 8.22 | Feb. 27 | 8.68 | June 5 | 8.64 |
| Jan. 3, 1947 | 8.31 | Mar. 31 | 8.78 | July 2 | caved |

6-9-19bda.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 21, 1946 | 32.79 | Mar. 31, 1947 | 34.28 | Feb. 20, 1948 | 31.92 |
| Sept. 30 | 32.82 | May 1 | 34.70 | Mar. 31 | 31.99 |
| Oct. 29 | 32.97 | June 5 | 32.45 | Apr. 29 | 31.80 |
| Nov. 29 | 33.51 | July 2 | 33.07 | May 27 | 31.76 |
| Jan. 6, 1947 | 33.54 | Aug. 5 | 32.79 | July 2 | 33.50 |
| 31 | 33.57 | Dec. 10 | 32.16 | 29 | 31.68 |
| Feb. 28 | 34.48 | | | | |

6-9-20bcc.

| | | | | | |
|---|---|---|---|---|---|
| Oct. 28, 1946 | 9.57 | Jan. 31, 1947 | 8.57 | June 5, 1947 | 10.19 |
| 29 | 9.05 | Feb. 27 | 9.00 | July 2 | 8.74 |
| Nov. 29 | 8.29 | Mar. 31 | 9.39 | Aug. 5 | 7.12 |
| Jan. 6, 1947 | 8.37 | May 1 | 9.84 | | |

6-9-20bcd.

| | | | | | |
|---|---|---|---|---|---|
| Sept. 10, 1946 | 10.27 | Feb. 27, 1947 | 10.72 | Dec. 10, 1947 | 9.20 |
| Oct. 1 | 10.51 | Mar. 28 | 10.81 | Mar. 31, 1948 | 9.39 |
| 29 | 10.55 | May 1 | 10.87 | Apr. 29 | 9.40 |
| Nov. 29 | 10.64 | June 5 | 10.80 | May 27 | 9.42 |
| Jan. 6, 1947 | 10.65 | July 2 | 10.10 | July 2 | 9.80 |
| 31 | 10.66 | Aug. 5 | 9.14 | 29 | 9.28 |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

7-7-25ccc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 11.63 | Jan. 30, 1947 | 11.29 | Oct. 25, 1947 | 10.89 |
| June 3 | 11.04 | Feb. 27 | 11.32 | Dec. 16 | 10.74 |
| Aug. 8 | 11.25 | Mar. 28 | 11.34 | Mar. 31, 1948 | 10.73 |
| Sept. 4 | 11.31 | Apr. 29 | 11.17 | Apr. 29 | 10.76 |
| Oct. 2 | 11.30 | June 4 | 11.25 | May 27 | 10.79 |
| Nov. 1 | 11.27 | July 1 | 10.34 | July 2 | 11.60 |
| 29 | 11.28 | Aug. 4 | 10.53 | 28 | 10.32 |
| Jan. 3, 1947 | 11.38 | | | | |

7-7-26adc.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 16, 1946 | 38.45 | Sept. 30, 1946 | 37.13 | | |

7-7-27bab.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 16, 1946 | 18.66 | Mar. 28, 1947 | 18.85 | Feb. 16, 1948 | 18.32 |
| Oct. 2 | 18.70 | Apr. 29 | 18.89 | Mar. 31 | 18.26 |
| Nov. 1 | 18.73 | June 4 | 18.81 | Apr. 29 | 18.23 |
| Dec. 2 | 18.86 | July 1 | 18.45 | May 27 | 18.30 |
| Jan. 3, 1947 | 19.01 | Aug. 4 | 18.78 | July 2 | 19.40 |
| 30 | 18.76 | Oct. 25 | 18.28 | 28 | 18.26 |
| Feb. 27 | 18.79 | Dec. 16 | 18.33 | | |

7-7-33daa.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 8, 1946 | 37.46 | Sept. 4, 1946 | 37.27 | Jan. 31, 1947 | 37.21 |

7-7-34aba.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 19.55 | Jan. 3, 1947 | 20.29 | Aug. 4, 1947 | 15.46 |
| June 3 | 17.34 | 30 | 19.30 | Oct. 25 | 20.67 |
| Aug. 8 | 18.59 | Feb. 27 | 20.38 | Dec. 16 | 20.55 |
| Sept. 4 | 20.19 | Mar. 28 | 19.86 | May 27, 1948 | 17.80 |
| Oct. 2 | 21.23 | Apr. 29 | 20.02 | July 2 | 19.80 |
| Nov. 1 | 20.97 | June 4 | 19.60 | 28 | 17.08 |
| Dec. 2 | 20.18 | July 1 | 15.85 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

7-7-35baa.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Aug. 16, 1946 | 28.27 | Feb. 27, 1947 | 28.43 | Dec. 16, 1947 | 28.13 |
| Sept. 4 | 28.28 | Mar. 28 | 28.33 | Feb. 20, 1948 | 28.25 |
| Oct. 2 | 28.27 | Apr. 29 | 28.35 | Mar. 31 | 28.21 |
| Nov. 1 | 28.28 | June 4 | 28.35 | Apr. 29 | 28.18 |
| 29 | 28.28 | July 1 | 28.29 | May 27 | 28.16 |
| Jan. 3, 1947 | 28.57 | Aug. 4 | 28.24 | July 2 | 29.00 |
| 30 | 28.30 | Oct. 25 | 28.22 | 28 | 28.09 |

7-8-10cba.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 19, 1946 | 12.80 | Mar. 28, 1947 | 13.93 | Feb. 20, 1948 | 13.00 |
| Sept. 30 | 15.16 | Apr. 29 | 13.96 | Mar. 31 | 12.76 |
| Nov. 1 | 14.06 | June 4 | 14.08 | Apr. 29 | 12.82 |
| 29 | 14.00 | July 2 | 12.45 | May 27 | 13.01 |
| Jan. 3, 1947 | 13.96 | Aug. 4 | 13.12 | July 2 | 13.40 |
| 30 | 13.94 | Oct. 25 | 13.05 | 28 | 13.44 |
| Feb. 27 | 13.91 | Dec. 16 | 12.84 | | |

7-8-11ccd.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 34.27 | Dec. 16, 1947 | 29.45 | Apr. 27, 1948 | 29.47 |
| June 5 | 29.84 | Feb. 20, 1948 | 29.44 | July 2 | 31.30 |
| Aug. 8 | 31.06 | Mar. 31 | 29.91 | 28 | 29.29 |
| Oct. 25, 1947 | 30.35 | | | | |

7-8-14cdd.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 48.10 | Jan. 30, 1947 | 48.46 | Dec. 16, 1947 | 48.14 |
| June 5 | 48.57 | Feb. 28 | 48.50 | Feb. 20, 1948 | 48.14 |
| Aug. 8 | 48.55 | Mar. 28 | 48.43 | Mar. 31 | 48.12 |
| Sept. 5 | 48.55 | Apr. 29 | 48.42 | Apr. 29 | 48.13 |
| Oct. 2 | 48.49 | June 4 | 48.44 | May 27 | 48.13 |
| Nov. 1 | 48.47 | July 2 | 48.41 | July 2 | 49.90 |
| 29 | 48.48 | Aug. 4 | 48.36 | 28 | 48.11 |
| Jan. 3, 1947 | 48.46 | Oct. 25 | 48.17 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

7-8-17cbc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 29.04 | Jan. 30, 1947 | 25.05 | Oct. 25, 1947 | 24.88 |
| June 3 | 25.45 | Feb. 27 | 25.07 | Dec. 16 | 24.38 |
| Aug. 8 | 25.21 | Mar. 28 | 25.10 | Mar. 31, 1948 | 24.90 |
| Sept. 5 | 24.89 | Apr. 29 | 25.01 | Apr. 29 | 25.08 |
| Oct. 2 | 25.52 | June 4 | 25.07 | May 27 | 25.10 |
| Nov. 1 | 25.05 | July 1 | 24.02 | July 2 | 26.00 |
| 24 | 25.07 | Aug. 5 | 24.39 | 28 | 25.15 |
| Jan. 3, 1947 | 25.04 | | | | |

7-8-19cab.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Sept. 5, 1946 | 13.73 | Mar. 28, 1947 | 13.64 | Feb. 20, 1948 | 13.30 |
| 30 | 13.71 | Apr. 29 | 13.71 | Mar. 31 | 13.34 |
| Nov. 1 | 13.72 | June 4 | 13.80 | Apr. 29 | 13.41 |
| 29 | 13.53 | July 1 | 12.83 | May 27 | 13.50 |
| Jan. 3, 1947 | 14.15 | Aug. 4 | 13.15 | July 2 | 14.15 |
| 30 | 13.67 | Oct. 25 | 13.34 | 28 | 13.42 |
| Feb. 27 | 13.63 | Dec. 16 | 13.08 | | |

7-8-20ddc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 71.00 | Jan. 31, 1947 | 71.39 | Dec. 16, 1947 | 71.17 |
| June 3 | 71.27 | Feb. 28 | 71.34 | Feb. 20, 1948 | 71.02 |
| Aug. 8 | 71.43 | Mar. 28 | 71.36 | Mar. 31 | 70.95 |
| Sept. 4 | 71.32 | Apr. 29 | 71.69 | Apr. 29 | 70.89 |
| Oct. 2 | 71.34 | June 4 | 71.43 | May 27 | 71.14 |
| Nov. 1 | 71.32 | July 1 | 71.39 | July 2 | 72.00 |
| 29 | 71.57 | Aug. 4 | 71.43 | 28 | 70.55 |
| Jan. 3, 1947 | 71.29 | Oct. 25 | 71.54 | | |

7-8-21ddc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 62.69 | Feb. 28, 1947 | 61.74 | Dec. 16, 1947 | 61.67 |
| June 5 | 62.20 | Mar. 28 | 61.60 | Feb. 20, 1948 | 61.56 |
| Aug. 8 | 62.10 | Apr. 29 | 61.66 | Apr. 29 | 61.46 |
| Sept. 4 | 62.21 | June 4 | 61.67 | May 27 | 61.47 |
| Oct. 2 | 62.00 | July 1 | 61.63 | July 2 | 62.90 |
| Nov. 1 | 62.05 | Aug. 4 | 61.29 | 28 | 61.42 |
| Jan. 3, 1947 | 62.58 | Oct. 25 | 61.65 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

7-8-29ccc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Aug. 20, 1946 | 72.31 | Mar. 20, 1947 | 72.32 | Feb. 20, 1948 | 71.74 |
| Sept. 30 | 72.30 | Apr. 29 | 72.34 | Mar. 31 | 72.27 |
| Nov. 1 | 72.31 | June 4 | 72.34 | Apr. 29 | 72.28 |
| 29 | 72.31 | July 1 | 72.30 | May 27 | 72.33 |
| Jan. 3, 1947 | 72.31 | Aug. 4 | 72.25 | July 2 | 73.00 |
| 30 | 72.32 | Oct. 25 | 72.25 | 28 | 72.24 |
| Feb. 27 | 72.31 | Dec. 16 | 72.27 | | |

7-8-31bba.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 19, 1946 | 54.85 | Sept. 4, 1946 | 54.66 | Nov. 1, 1946 | 54.79 |
| June 3 | 54.64 | Oct. 2 | 54.64 | Nov. 29 | 54.75 |
| Aug. 8 | 54.70 | | | | |

7-8-33bbb.

| | | | | | |
|---|---|---|---|---|---|
| June 5, 1946 | 23.45 | Feb. 27, 1947 | 18.03 | Dec. 16, 1947 | 18.00 |
| Aug. 8 | 18.57 | Mar. 28 | 18.19 | Feb. 20, 1948 | 18.31 |
| Sept. 4 | 18.35 | Apr. 29 | 18.07 | Mar. 31 | 18.37 |
| Oct. 2 | 18.33 | June 4 | 18.05 | Apr. 29 | 18.58 |
| Nov. 1 | 18.03 | July 2 | 18.08 | May 27 | 18.65 |
| 29 | 18.00 | Aug. 4 | 17.85 | July 2 | 19.90 |
| Jan. 3, 1947 | 18.11 | Oct. 25 | 17.94 | 28 | 18.62 |
| 30 | 18.03 | | | | |

8-6-1bad.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 13, 1946 | 22.90 | Mar. 28, 1947 | 23.28 | Feb. 16, 1948 | 23.21 |
| Sept. 4 | 23.23 | Apr. 29 | 23.28 | Mar. 31 | 23.22 |
| Nov. 1 | 23.25 | June 4 | 23.28 | Apr. 29 | 23.18 |
| Dec. 2 | 23.27 | July 1 | 23.28 | May 27 | 23.18 |
| Jan. 3, 1947 | 23.18 | Aug. 4 | 23.30 | July 2 | 23.50 |
| 30 | 23.30 | Oct. 25 | 23.27 | 28 | 23.15 |
| Feb. 28 | 23.25 | Dec. 11 | 23.25 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

8-6-3ddd.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Aug. 28, 1946 | 44.45 | Dec. 2, 1946 | 44.54 | Jan. 31, 1947 | 44.50 |
| Nov. 1 | 44.47 | Jan. 3, 1947 | 44.51 | Feb. 28 | Well sealed. |

8-6-9dca.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 41.20 | Jan. 31, 1947 | 42.63 | Dec. 11, 1947 | 42.81 |
| June 3 | 42.24 | Feb. 27 | 42.57 | Feb. 16, 1948 | 42.62 |
| Aug. 7 | 42.19 | Mar. 31 | 42.56 | Mar. 31 | 42.14 |
| Sept. 4 | 42.20 | Apr. 29 | 43.50 | Apr. 29 | 42.25 |
| Oct. 2 | 42.49 | June 4 | 42.35 | May 27 | 42.05 |
| Nov. 1 | 42.54 | 30 | 42.52 | July 2 | 43.60 |
| Dec. 2 | 42.56 | Aug. 4 | 42.43 | 28 | 42.05 |
| Jan. 3, 1947 | 42.52 | Oct. 25 | 42.98 | | |

8-6-10daa.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 39.12 | Jan. 31, 1947 | 39.27 | Dec. 11, 1947 | 39.06 |
| June 3 | 39.29 | Feb. 28 | 39.27 | Feb. 16, 1948 | 39.04 |
| Aug. 7 | 39.26 | Mar. 28 | 39.28 | Mar. 31 | 39.00 |
| Sept. 4 | 39.30 | Apr. 29 | 39.25 | Apr. 29 | 39.05 |
| Oct. 2 | 39.30 | June 4 | 39.25 | May 27 | 38.95 |
| Nov. 1 | 39.23 | 30 | 39.25 | July 2 | 39.50 |
| Dec. 2 | 39.30 | Aug. 4 | 39.14 | 28 | 38.84 |
| Jan. 3, 1947 | 39.31 | Oct. 25 | 39.12 | | |

8-6-13aac.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| June 3, 1946 | 7.84 | Feb. 28, 1947 | 8.44 | Dec. 11, 1947 | 7.45 |
| Aug. 7 | 8.69 | Mar. 28 | 8.41 | Feb. 16, 1948 | 7.65 |
| Sept. 4 | 8.65 | Apr. 29 | 8.37 | Mar. 31 | 7.48 |
| Oct. 2 | 7.99 | June 4 | 8.36 | Apr. 29 | 7.46 |
| Nov. 1 | 8.49 | 30 | 7.01 | May 27 | 7.60 |
| Dec. 2 | 8.49 | Aug. 4 | 7.31 | July 2 | 9.00 |
| Jan. 3, 1947 | 8.49 | Oct. 25 | 7.66 | 28 | 7.77 |
| 31 | 8.43 | | | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

8-6-13bad.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Aug. 7, 1946 | 10.28 | Mar. 28, 1947 | 10.27 | Feb. 20, 1948 | 9.15 |
| Oct. 2 | 10.36 | Apr. 29 | 10.25 | Mar. 31 | 9.07 |
| Nov. 1 | 10.27 | June 4 | 10.21 | Apr. 29 | 9.03 |
| Dec. 2 | 10.28 | 30 | 9.27 | May 27 | 9.00 |
| Jan. 3, 1947 | 10.33 | Aug. 4 | 8.70 | July 2 | 9.70 |
| 31 | 10.27 | Oct. 25 | 9.45 | 28 | 9.17 |
| Feb. 28 | 10.25 | Dec. 11 | 9.25 | | |

8-6-15bdcl.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 20, 1946 | 76.28 | Mar. 31, 1947 | 73.50 | Dec. 11, 1947 | 66.34 |
| Sept.30 | 77.61 | Apr. 29 | 73.62 | Feb. 16, 1948 | 67.50 |
| Nov. 1 | 74.21 | June 4 | 74.12 | Apr. 29 | 69.19 |
| Dec. 2 | 73.50 | 30 | 73.97 | May 27 | 69.64 |
| Jan. 3, 1947 | 73.87 | Aug. 4 | 74.01 | July 2 | 70.50 |
| 31 | 73.41 | Oct. 25 | 66.53 | 28 | 70.05 |
| Feb. 28 | 75.18 | | | | |

8-6-16aba.

| | | | | | |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 39.50 | Feb. 4, 1947 | 39.82 | Dec. 11, 1947 | 39.52 |
| June 3 | 39.56 | 28 | 39.71 | Feb. 16, 1948 | 39.41 |
| Aug. 7 | 39.59 | Mar. 31 | 39.73 | Mar. 21 | 39.32 |
| Sept. 4 | 39.62 | Apr. 29 | 39.78 | Apr. 29 | 39.25 |
| Oct. 2 | 39.62 | June 4 | 40.12 | May 27 | 39.20 |
| Nov. 1 | 39.67 | 30 | 39.72 | July 2 | 40.70 |
| Dec. 2 | 39.68 | Aug. 4 | 39.79 | 28 | 39.35 |
| Jan. 6, 1947 | 39.96 | Oct. 25 | 39.61 | | |

8-6-17ccd.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 13, 1946 | 56.36 | Aug. 30, 1946 | 54.25 | Sept.26, 1946 | 54.05 |

8-6-17dcb.

| | | | | | |
|---|---|---|---|---|---|
| Aug. 13, 1946 | 43.45 | Oct. 3, 1946 | 39.08 | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

8-7-4ccc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 36.50 | Mar. 31, 1947 | 39.69 | Mar. 31, 1948 | 38.65 |
| June 3 | 39.28 | Apr. 30 | 39.65 | Apr. 29 | 37.97 |
| Aug. 8 | 39.59 | June 30 | 39.05 | May 27 | 38.60 |
| Oct. 2 | 39.32 | Aug. 5 | 39.52 | July 2 | 39.70 |
| Nov. 1 | 39.45 | Oct. 25 | 39.17 | 28 | 38.63 |
| Dec. 2 | 39.29 | Dec. 11 | 38.95 | | |

8-7-5acc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Aug. 13, 1946 | 45.26 | Mar. 28, 1947 | 45.47 | Feb. 16, 1948 | 44.99 |
| Sept. 30 | 45.23 | Apr. 29 | 45.61 | Mar. 31 | 44.98 |
| Nov. 1 | 45.25 | June 4 | 45.62 | Apr. 29 | 44.94 |
| Dec. 2 | 45.43 | July 1 | 45.33 | May 27 | 44.92 |
| Jan. 6, 1947 | 45.34 | Aug. 4 | 45.18 | July 2 | 45.50 |
| 30 | 45.35 | Oct. 25 | 45.08 | 28 | 44.72 |
| Feb. 28 | 45.51 | Dec. 11 | 45.03 | | |

8-7-6dcd.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 34.05 | Jan. 30, 1947 | 34.17 | Dec. 11, 1947 | 33.32 |
| June 3 | 34.03 | Mar. 28 | 34.19 | Feb. 16, 1948 | 34.64 |
| Aug. 7 | 34.04 | Apr. 30 | 34.89 | Mar. 31 | 34.79 |
| Sept. 4 | 33.92 | June 4 | 35.02 | Apr. 29 | 34.73 |
| Oct. 2 | 34.01 | July 1 | 34.11 | May 27 | 34.74 |
| Nov. 1 | 34.00 | Aug. 4 | 33.87 | July 2 | 35.60 |
| Dec. 2 | 34.08 | Oct. 25 | 33.60 | 28 | 34.83 |
| Jan. 3, 1947 | 34.07 | | | | |

8-7-7bbb2.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| Apr. 22, 1946 | 6.44 | Jan. 30, 1947 | 6.36 | Dec. 11, 1947 | 5.30 |
| June 3 | 5.20 | Feb. 28 | 6.12 | Feb. 16, 1948 | 5.67 |
| Aug. 7 | 7.98 | Apr. 29 | 5.94 | Mar. 31 | 5.22 |
| Sept. 4 | 6.89 | June 4 | 6.25 | Apr. 29 | 5.27 |
| Oct. 2 | 6.36 | July 1 | 2.83 | May 27 | 5.53 |
| Nov. 1 | 6.26 | Aug. 4 | 5.77 | July 2 | 6.80 |
| Dec. 2 | 6.50 | Oct. 25 | 5.85 | 28 | 6.77 |
| Jan. 3, 1947 | 6.37 | | | | |

Table 3.--Records of ground-water levels in the Angostura irrigation project, South Dakota, in feet below land surface--Continued

8-7-8dcc.

| Date | Water level | Date | Water level | Date | Water level |
|---|---|---|---|---|---|
| June 5, 1946 | 17.51 | Feb. 28, 1947 | 16.92 | Dec. 11, 1947 | 16.06 |
| Aug. 8 | 17.21 | Mar. 28 | 16.96 | Feb. 16, 1948 | 16.15 |
| Sept. 5 | 16.57 | Apr. 29 | 16.99 | Mar. 31 | 16.20 |
| Oct. 2 | 17.08 | June 4 | 17.04 | Apr. 29 | 16.24 |
| Nov. 1 | 17.16 | 30 | 16.74 | May 27 | 16.21 |
| Dec. 2 | 17.17 | Aug. 4 | 15.47 | July 2 | 16.12 |
| Jan. 3, 1947 | 16.82 | Oct. 25 | 15.95 | 28 | 15.87 |
| 31 | 16.84 | | | | |

## TEST DRILLING

The drilling of test holes revealed the character of the unconsolidated mantle deposits, the depth to the water table, and the depth to bedrock in parts of the area for which this information could not otherwise be obtained. A total of 87 test holes were drilled, all by a Buda auger equipped with 30 feet of auger stem. Logs of these test holes were kept by the writer at the time of drilling and are given in the table below. The altitude of the land surface at the site of each test hole was determined from topographic plane-table sheets made by the Bureau of Reclamation and is given in the table of records of wells and test holes. (See table 5, p. 85.)

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota

6-8-24aba. 1,848 feet west of NE. cor. sec. 24.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey | 4 | 4 |
| Clay, brown to buff, hard, alkaline, soapy-appearing | 2 | 6 |
| Clay, dark-brown, hard, alkaline | 2 | 8 |
| Clay, slightly gritty, buff, very hard | 6 | 14 |
| Sand, dirty, with some gravel | 6 | 20 |
| Sand, fine to medium, fairly clean, with some gravel | 4 | 24 |
| Sand, fine to medium, dark-brown | 6 | 30 |
| No water encountered. | | |

6-8-24acd. 2,620 feet south and 1,848 feet west of NE. cor. sec. 24.

| | | |
|---|---|---|
| Soil, clayey | 1 | 1 |
| Clay, brown to buff, hard | 4 | 5 |
| Clay, buff, hard, alkaline | 1 | 6 |
| Clay, brown to buff, hard, alkaline | 4½ | 10½ |
| Clay, silty to sandy, buff, alkaline | 5 | 15½ |
| Sand, medium, dirty, with some gravel | 3½ | 19 |
| Sand, fine to coarse; some gravel; layer of coarse gravel and pebbles at 24 feet | 5 | 24 |
| Sand and gravel | 6 | 30 |
| No water encountered. | | |

6-8-24add. 2,600 feet south and 22 feet west of NE. cor. sec. 24.

| | | |
|---|---|---|
| Soil, clayey, dark-brown, hard | 4 | 4 |
| Clay, silty, hard | 5 | 9 |
| Clay, brown to buff, hard | 2 | 11 |
| Sand, coarse, with some fine gravel | 4 | 15 |
| Sand and fine gravel, dirty, with some coarse gravel | 4 | 19 |
| Gravel and sand, fine to coarse, dirty | 9 | 28 |
| Sand, coarse, clean | 4 | 32 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-8-24bdd. 2,620 feet south and 2,930 feet west of NE. cor. sec. 24.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, brown, hard, alkaline | 6 | 6 |
| Silt, clayey, hard, alkaline | 2 | 8 |
| Clay, brown to buff, hard | 6½ | 14½ |
| Clay, olive to dark-brown, very hard | 3 | 17½ |
| Clay, sandy, with some gravel; hard | 1½ | 19 |
| Sand, fine to coarse, dirty, with a little gravel | 11 | 30 |
| No water encountered. | | |

6-8-24cdd. 2,640 feet west and 60 feet north of SE. cor. sec. 24.

| | | |
|---|---|---|
| Soil, clayey; alkaline at 4 feet | 9 | 9 |
| Clay, hard, brownish, greasy-appearing | 2 | 11 |
| Gravel, dirty, with pebbles up to 3 inches in diameter | 2 | 13 |
| Gravel, sandy | 12 | 25 |
| Sand, fine, silty | 6 | 31 |
| No water encountered. | | |

6-8-26bbb. 80 feet east and 80 feet south of NW. cor. sec. 25.

| | | |
|---|---|---|
| Soil; crumbly clay; slightly gritty from 3 to 4 feet | 4 | 4 |
| Clay, sandy; alkaline to 6½ feet; less sandy at 8 feet | 9½ | 13½ |
| Silt, sandy, with pebbles and gritty clay; very hard drilling | 1 | 14½ |
| Clay, with soft layers; some iron staining | 1½ | 16 |
| Silt | 2 | 18 |
| Clay, hard | 2 | 20 |
| Clay, silty | 7 | 27 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-8-25cba. 2,560 feet north and 1,300 feet east of SW. cor. sec. 25.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, silty and clayey | 4 | 4 |
| Clay, brown, compact | 3 | 7 |
| Clay, silty | 2 | 9 |
| Clay, compact, dry | 1½ | 10½ |
| Clay, silty | 2½ | 13 |
| Sand and gravel, dirty, with scattered coarse pebbles | 2 | 15 |
| Sand, coarse, and gravel, with a few large pebbles; loose; drilled easily | 15 | 30 |
| No water encountered. | | |

6-8-35acb. 1,500 feet south and 2,620 feet west of NE. cor. sec. 35.

| | | |
|---|---|---|
| Soil, clayey, heavy | 3½ | 3½ |
| Gravel, sandy and silty, dirty | 1½ | 5 |
| Gravel, coarse, with some sand; pebbles 4 to 5 inches in diameter | 11 | 16 |
| Sand, fine to coarse, with some gravel; dirty | 11½ | 27½ |
| Gravel, clayey | 1½ | 29 |
| Shale, weathered (Pierre) | 1 | 30 |
| No water encountered. | | |

6-8-36bbb. 10 feet east, 10 feet south of NW. cor. sec. 36.

| | | |
|---|---|---|
| Soil, clayey, dark-brown | 2½ | 2½ |
| Sand, fine, with scattered pebbles; dirty | 4½ | 7 |
| Sand, with some gravel; a few large pebbles up to 2 inches in diameter | 4 | 11 |
| Sand, with coarse gravel; scattered pebbles up to 3 inches in diameter below 15 feet | 11 | 22 |
| Sand, clayey to silty | 2 | 24 |
| Clay, reddish-brown | 1 | 25 |
| Sand, with coarse gravel, dirty | 7 | 32 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-5dbd. 1,900 feet north and 1,560 feet west of SE. cor. sec. 5.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy | 2 | 2 |
| Sand, fine, silty, hard, alkaline | 6 | 8 |
| Sand, fine to coarse, with some fine gravel | 7 | 15 |
| Sand, coarse, with fine to coarse gravel; a few large pebbles between 15 and 25 feet | 17 | 32 |
| No water encountered. | | |

6-9-5dcc. 2,048 feet west and 25 feet north of SE. cor. sec. 5.

| | | |
|---|---|---|
| Soil, sandy clay | 1 | 1 |
| Clay, gritty brown, hard | 2 | 3 |
| Sand, coarse, with scattered pebbles | 2 | 5 |
| Sand, with some gravel; some large pebbles; loose | 10½ | 15½ |
| Gravel, fine to coarse; large pebbles | 4½ | 20 |
| Gravel, fine to coarse, pebbles up to 4 inches in diameter | 8 | 28 |
| Sand, fine | 1½ | 29½ |
| Shale, hard, compact, blue-gray (Pierre) | 1 | 30½ |
| Depth to water, 28.2 feet below land surface. | | |

6-9-8adc. 2,640 feet south and 1,280 feet west of NE. cor. sec. 8.

| | | |
|---|---|---|
| Soil, sandy | 1½ | 1½ |
| Sand, silty, compact, alkaline | 4 | 5½ |
| Sand, fine to coarse, with some gravel | 4 | 9½ |
| Sand, coarse, with some coarse gravel | 7½ | 17 |
| Shale, dark blue-gray; upper few inches weathered (Pierre) | 3 | 20 |
| Water at about 16 feet; slumping of hole prevented accurate measurement of the depth to water. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-8ccc. 11 feet east of SW. cor. sec. 8.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy and clayey, brown | 1½ | 1½ |
| Sand | 2½ | 4 |
| Sand, coarse, fairly clean, with a little gravel. | 6 | 10 |
| Sand and fine to coarse gravel; loose | 7 | 17 |
| Gravel, fine to coarse, and sand; scattered small shale fragments in lower part | 15 | 32 |
| Depth to water, about 31 feet below land surface; slumping of hole prevented accurate measurement of depth to water. | | |

6-9-8cdc. 1,330 feet east and 10 feet north of SW. cor. sec. 8.

| | | |
|---|---|---|
| Soil, sandy | 1 | 1 |
| Clay, gritty | 1 | 2 |
| Sand, fine to medium, loose | 2 | 4 |
| Sand, coarse, with a little gravel; clean | 9 | 13 |
| Sand, coarse, with some gravel | 1½ | 14½ |
| Shale, weathered, olive-colored | 2½ | 17 |
| Shale, dark-gray, very slightly weathered (Pierre) | 1 | 18 |
| Thin zone of saturation penetrated; slumping prevented measurement of depth to water. | | |

6-9-8daa. 275 feet west and 2,630 feet north of SE. cor. sec. 8.

| | | |
|---|---|---|
| Soil, sandy and clayey | 2½ | 2½ |
| Sand, with some gravel | 2½ | 5 |
| Sand, with fine to coarse gravel | 2 | 7 |
| Clay, olive-drab, with scattered shale fragments. | 3 | 10 |
| Shale, olive-drab to blue-gray, hard (Pierre) | 5 | 15 |
| No water encountered. | | |

6-9-8dbb. 18 feet east and 9 feet south of fence corner at center of sec. 8.

| | | |
|---|---|---|
| Soil, sandy and clayey | 2 | 2 |
| Sand, fine | 6 | 8 |
| Sand, coarse, with some gravel; clean | 2 | 10 |
| Gravel, fine to coarse, loose | 5 | 15 |
| Gravel, fine to coarse; some pebbles | 10 | 25 |
| Sand, coarse; very loose at 25 feet | 7 | 32 |
| Water at bottom of hole; slumping prevented measurement of depth to water. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-8dcc. 2,770 feet east and 25 feet north of SW. cor. sec. 8.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy, brown, loose | 1 | 1 |
| Clay, brown | 1 | 2 |
| Sand, fine, with some coarser material; dirty; loose | 3 | 5 |
| Sand, coarse, with a little coarse gravel; loose | 8½ | 13½ |
| Shale, blue-gray; upper part slightly weathered but lower part fresh (Pierre) | 5½ | 19 |
| No water encountered. | | |

6-9-8ddd. 60 feet west and 50 feet north of SE. cor. sec. 8.

| | | |
|---|---|---|
| Soil, sandy and clayey | 2 | 2 |
| Sand, fine to coarse; gravel at 4 feet; loose | 3 | 5 |
| Sand, with large proportion of coarse gravel; loose | 5 | 10 |
| Shale, olive to greenish-gray, grading downward to dark blue-gray (Pierre) | 5 | 15 |
| No water encountered. | | |

6-9-17bcc. 2,500 feet south and 30 feet east of NW. cor. sec. 17.

| | | |
|---|---|---|
| Soil, sandy and clayey, dark-brown | 1½ | 1½ |
| Clay, silty, hard | 1 | 2½ |
| Sand, fine to coarse, with some coarse gravel; dirty | 4½ | 7 |
| Sand, coarse, and some gravel | 3 | 10 |
| Sand and fine gravel, with some very coarse gravel | 2 | 12 |
| Sand and gravel, with scattered very large pebbles | 1½ | 13½ |
| Shale, weathered, greenish-gray | 1½ | 15 |
| Shale, blue-gray, hard (Pierre) | 2 | 17 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-17bdd. 2,565 feet south and 2,482 feet east of NW. cor. sec. 17.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, with some coarse gravel; hard; alkaline | 3 | 3 |
| Pebbles | 1½ | 4½ |
| Shale (weathered zone), light-brown to buff with olive cast; iron streaks common below 10 feet | 7½ | 12 |
| Shale, dark-gray (Pierre) | 7 | 19 |
| Water level on Oct. 25, 1946 (4½ hours after hole was completed), 8.20 feet; on Oct. 28, 7.90 feet; on Oct. 29, 7.96 feet. | | |

6-9-17cdc. 1,848 feet east and 35 feet south of SW. cor. sec. 17.

| | | |
|---|---|---|
| Clay, wet, sticky | 2½ | 2½ |
| Gravel, fine, dirty | 1½ | 4 |
| Sand and gravel | 2 | 6 |
| Clay, silty, blue-gray; contains small shale fragments and grades downward into shale; wet; sticky | 6 | 12 |
| Shale, blue-gray | 3 | 15 |

6-9-18ccc. 80 feet north and 80 feet east of SW. cor. sec. 18.

| | | |
|---|---|---|
| Clay, tough | 3 | 3 |
| Clay, silty, buff to brown; quite alkaline to depth of about 6 feet | 3 | 6 |
| Clay, silty, buff | 3½ | 9½ |
| Clay, brown, with scattered pebbles; hard | 1½ | 11 |
| Gravel, fine, sandy, dirty, loose | 4 | 15 |
| Gravel, mostly fine, with layers of coarse to very coarse gravel; scattered pebbles, loose. | 5 | 20 |
| Gravel, fine, sandy, with some coarse to very coarse gravel; loose | 4 | 24 |
| Sand, coarse, with some fine gravel; clean; loose. | 4 | 28 |
| Sand, fine to coarse, buff, clean | 4 | 32 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-18dcc1. 2,630 feet east and 30 feet north of SW. cor. sec. 18.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, dark-brown, compact | 2 | 2 |
| Clay, brown, with some fine gravel; hard | 1 | 3 |
| Sand, silty to clayey, buff | 2 | 5 |
| Sand, fine, dirty, loose | 2 | 7 |
| Sand, fine to coarse, with fine to coarse gravel; loose | 4 | 11 |
| Sand, coarse, with fine gravel; some coarse gravel; loose | 7 | 18 |
| Sand, coarse, and coarse gravel; some large pebbles; loose | 9 | 27 |
| Same as above but contains more large pebbles and a few shale fragments; loose | 5 | 32 |
| Water level, about 32 feet; slumping of hole prevented accurate measurement of depth to water. | | |

6-9-18ddd. 20 feet north and 36 feet west of SE. cor. sec. 18.

| | | |
|---|---|---|
| Soil, clayey | 2 | 2 |
| Sand, silty to clayey, alkaline | 1 | 3 |
| Sand and gravel, hard, compact | 2 | 5 |
| Clay, silty, buff to gray to light greenish-brown; plastic | 7 | 12 |
| Clay, silty, light-brown to buff, with shale pebbles; plastic | 5 | 17 |
| Shale, dark-gray | 1 | 18 |
| Water level, 8.75 feet. | | |

6-9-19adc. 2,640 feet north and 1,320 feet west of SE. cor. sec. 19.

| | | |
|---|---|---|
| Soil, sandy, brown | 1 | 1 |
| Clay, gritty, hard | 2½ | 3½ |
| Sand, silty, compact | 1½ | 5 |
| Sand, fine to medium, with some gravel | 2 | 7 |
| Sand, coarse, with scattered pebbles; clean; loose | 4 | 11 |
| Sand, coarse, to fine gravel, with a few shale pebbles in lower part | 7 | 18 |
| Shale, weathered | 2 | 20 |
| Shale, dark blue-gray to black | 2 | 22 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-19caa. 2,625 feet north and 2,340 feet east of SW. cor. sec. 19.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, dark-brown | 2 | 2 |
| Clay, silty to sandy, brown to buff, alkaline | 1½ | 3½ |
| Clay, brown | 1½ | 5 |
| Sand, fine to coarse, dirty | 2 | 7 |
| Gravel and coarse sand, with scattered large pebbles 2 to 3 inches in diameter; loose | 3 | 10 |
| Gravel, fine to coarse, poorly sorted, loose | 3 | 13 |
| Sand, fine to coarse, yellow-brown, clean, loose | 2 | 15 |
| Sand, coarse, to fine gravel, with some coarse gravel and scattered large pebbles | 11½ | 26½ |
| Sand, coarse, with a few shale pebbles | 5½ | 32 |
| Depth to water, 24.8 feet. | | |

6-9-19cdc. 1,320 feet east and 25 feet north of SW. cor. sec. 19.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, dark-brown, compact | 1½ | 1½ |
| Clay, buff, hard | 2 | 3½ |
| Sand, silty, with some coarse gravel | 1½ | 5 |
| Sand, with some gravel; loose | 1 | 6 |
| Gravel and sand, dirty, loose | 7 | 13 |
| Sand, coarse, with some gravel from 20 to 25 feet | 12 | 25 |
| Sand, silty and somewhat clayey, with some fine gravel; contains a few shale pebbles | 7 | 32 |
| Water level, about 30 feet; slumping of hole prevented accurate measurement of depth to water. | | |

6-9-19ddc. 1,300 feet west and 36 feet north of SE. cor. sec. 19.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy | 1 | 1 |
| Soil, clayey | 1 | 2 |
| Sand, silty, alkaline | 2 | 4 |
| Sand, fine, with some gravel | 3 | 7 |
| Sand, fine, with some gravel; loose | 5 | 12 |
| Sand, medium, with clayey silt streak from 13 to 13½ feet | 1½ | 13½ |
| Sand, coarse, with layers of pebbles | 7½ | 21 |
| Shale, olive-colored, weathered | 2 | 23 |
| Shale, dark blue-gray to black, hard, (Pierre) | 1 | 24 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-20bcc. 2,425 feet south and 22 feet east of NW. cor. sec. 20.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey, dark-brown | 1 | 1 |
| Clay, silty to sandy | 2½ | 3½ |
| Sand, fine to coarse, with some layers of gravel and scattered pebbles; dirty | 1½ | 5 |
| Sand and gravel, some very coarse; dirty | 1½ | 6½ |
| Clay, slightly silty, greenish-gray, tough, plastic. | 3½ | 10 |
| Clay, light-brown to gray, with scattered shale fragments; tough | 5 | 15 |
| Clay, with numerous embedded shale fragments; tough. | 4 | 19 |
| Shale, dark blue-gray (Pierre) | 5 | 24 |
| Depth to water on Oct. 25, 1946 (6 hours after completion) 18.1 feet. See table 5 for additional measurements. | | |

6-9-29bad. 137 feet northwest of northwest end of Cheyenne River bridge, 10 feet west of center line of road, 25 feet south of cattle gate, 250 feet northwest of northwest bank of Cheyenne River.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy | 1 | 1 |
| Sand, silty, buff | 2 | 3 |
| Sand, fine to medium | 3 | 6 |
| Sand, coarse, with some coarse gravel; scattered large pebbles | 4 | 10 |
| Sand and very coarse gravel, loose | 4 | 14 |
| Shale, dark blue-gray to black (Pierre) | 1½ | 15½ |
| Zone of saturation above shale; slumping of hole prevented measurement of depth to water. | | |

6-9-29cca. 1,045 feet east and 800 feet north of SW. cor. sec. 29.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, silty clay | 1½ | 1½ |
| Silt, grading downward to clayey silt at 4 feet | 3½ | 5 |
| Sand and gravel, dirty, becoming coarser at 7 feet | 3 | 8 |
| Shale, dark blue-gray (Pierre) | 1 | 9 |
| Depth to water between 5 and 6 feet; slumping prevented accurate measurement of depth to water. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

6-9-30acb. 1,930 feet south and 2.520 feet west of NE. cor. sec. 30.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy to gravelly | 2 | 2 |
| Sand, coarse, with some gravel | 2 | 4 |
| Sand, dirty; large number of scattered shale fragments | 2 | 6 |
| Sand, dirty, with scattered shale fragments and some coarse gravel | 4 | 10 |
| Sand, with large amount of reworked shale | 2 | 12 |
| Sand, coarse, fairly clean; lower part contains shale fragments | 3 | 15 |
| Clay, light-brown to olive-colored | 10 | 25 |
| Sand; contains clay | 3 | 28 |
| Clay, light-brown to olive-colored | ½ | 28½ |
| No water encountered. | | |

6-9-30dba. 2,600 feet north and 1,850 feet west of SE. cor. sec. 30.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, silty clay | 2½ | 2½ |
| Silt, grading downward to fine sand | 5½ | 8 |
| Gravel, with some sand | 12 | 20 |
| Shale, dark blue-gray | ½ | 20½ |
| Water level probably between 12 and 14 feet; slumping of hole prevented accurate measurement of depth to water. | | |

7-7-23dab. 2,640 feet north and 1,320 feet west of SE. cor. sec. 23.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy and silty | 3 | 3 |
| Clay, silty, alkaline (hardpan) | 2 | 5 |
| Silt and fine sand; coarser at 9½ feet; dirty | 9 | 14 |
| Sand and gravel | 3 | 17 |
| Gravel | 1 | 18 |
| Sand and gravel | 3 | 21 |
| Shale, weathered, admixed with sand and gravel | 2½ | 23½ |
| Shale, fresh (Pierre) | ½ | 24 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-7-25aaa. 25 feet south and 25 feet west of NE. cor. sec. 25.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey and slightly gritty; alkali increases downward | 5½ | 5½ |
| Sand, dirty, grading downward to clean, yellow, fine, uniform sand; coarser at 7½ feet; gravel layer at 9 feet | 3½ | 9 |
| Sand, coarse, fairly clean, with some gravel; gravel layers at 16 and 20 feet | 12 | 21 |
| Sand, gravelly, with layer of gravel at 26 feet | 9 | 30 |
| Zone of saturation penetrated between 25 and 28 feet; slumping of hole prevented accurate measurement of depth to water. | | |

7-7-25abb. 2,640 feet west of NE. cor. sec. 25.

| | | |
|---|---|---|
| Soil, clayey, gritty | 2 | 2 |
| Sand, fine-grained, dirty | 3½ | 5½ |
| Clay | ½ | 6 |
| Sand, fine-grained, dirty | 3½ | 9½ |
| Sand, coarse | 2 | 11½ |
| Gravel | ½ | 12 |
| Sand, coarse | 5 | 17 |
| Gravel | ½ | 17½ |
| Sand and gravel | 12½ | 30 |
| No water encountered. | | |

7-7-25cdd. 2,520 feet east and 25 feet north of SW. cor. sec. 25.

| | | |
|---|---|---|
| Soil, sandy and clayey | 2½ | 2½ |
| Sand, fine, dirty | 2 | 4½ |
| Clay, silty | 2 | 6½ |
| Sand, fine, moist, dirty | 1½ | 8 |
| Clay, slightly sandy | 10 | 18 |
| Sand, uniformly fine-grained, brownish-yellow | 6 | 24 |
| Sand, fine to medium, grading downward to coarse gravel | 6 | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-7-25daa. 2,390 feet north and 24 feet west of SE. cor. sec. 25.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy, grading downward to fine-grained, dirty sand | 5½ | 5½ |
| Clay, gritty | 2½ | 8 |
| Sand, fine, grading downward to medium-grained sand; dirty | 9½ | 17½ |
| Gravel, grading downward to coarser sand and fine gravel | 12½ | 30 |
| No water encountered. | | |

7-7-25dbb. Center of sec. 25.

| | | |
|---|---|---|
| Clay, slightly gritty; alkaline from 3 to 4 feet | 5½ | 5½ |
| Sand, fine, dirty, with clayey streak from 7½ to 9 feet | 3½ | 9 |
| Sand, fine | 8½ | 17½ |
| Gravel and coarse sand with layer of gravel at 23 feet | 12½ | 30 |
| No water encountered. | | |

7-7-26abb. 2,640 feet west of NE. cor. sec. 26.

| | | |
|---|---|---|
| Soil, clayey | 3 | 3 |
| Sand, fine, with gravel layer at 4½ feet | 2 | 5 |
| Sand, medium, with some gravel | 5½ | 10½ |
| Gravel, coarse, with boulders | 1 | 11½ |
| No water encountered. Hole abandoned because of boulders. | | |

7-7-26ccc. SW. cor. of sec. 26.

| | | |
|---|---|---|
| Soil, sandy clay | 2 | 2 |
| Sand, fine | 6½ | 8½ |
| Sand, medium; clean except for dirty streak at 15 feet | 8½ | 17 |
| Gravel | ½ | 17½ |
| Sand and gravel | 12½ | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-7-26cdd. 2,640 feet east and 40 feet north of SW. cor. sec. 26.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy | 1 | 1 |
| Soil, clayey and somewhat gritty, forming hardpan | 1½ | 2½ |
| Sand, fine, with clayey streak from 7½ to 8 feet and coarser sand at 9 feet | 6½ | 9 |
| Sand, medium | 6 | 15 |
| Gravel | ½ | 15½ |
| Sand and gravel | 9 | 24½ |
| Gravel | ½ | 25 |
| Sand and gravel | 5 | 30 |
| Shale (Pierre) | 1 | 31 |
| Zone of saturation penetrated between 26 and 27 feet; slumping prevented accurate measurement of depth to water. | | |

7-7-26dab. 2,600 feet north and 1,320 feet west of SE. cor. sec. 26.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey; alkaline at 2½ feet; forms hardpan | 3 | 3 |
| Sand, fine | 4 | 7 |
| Silt, powdery | 2½ | 9½ |
| Sand, fine, grading downward to medium-grained sand at 15 feet | 19½ | 29 |
| Gravel | ½ | 29½ |
| Sand and gravel | ½ | 30 |
| No water encountered. | | |

7-7-27acb. 1,373 feet south and 2,640 feet west of SE. cor. sec. 27.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, silty | ½ | ½ |
| Soil, clayey | 2½ | 3 |
| Clay, silty | ½ | 3½ |
| Silt | ½ | 4 |
| Clay, gritty | 1 | 5 |
| Silt | 3 | 8 |
| Gravel, clayey | 3 | 11 |
| Sand and gravel, dirty | 1 | 12 |
| Gravel, fine, in matrix of dark-blue clay | 1½ | 13½ |
| Shale, blue-gray (Pierre) | 1 | 14½ |
| Water level at 10.88 feet on completion of hole; water-level rising slowly. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-7-27ccc. 250 feet north of SW. cor. sec. 27.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy, and clayey, with some reworked gravel | 1 | 1 |
| Clay, silty | 2½ | 3½ |
| Sand, fine, dirty; slightly cleaner at 12½ feet | 11 | 14½ |
| Gravel and coarse sand; heavy gravel at 16 feet | 2 | 16½ |
| Shale, bluish-gray (Pierre) | 3½ | 20 |
| Water level at about 15 feet; slumping prevented accurate measurement of depth to water. | | |

7-7-33cdc. 1,550 feet east of SW. cor. sec. 33.

| | | |
|---|---|---|
| Soil, sandy, with small amount of clay | 1½ | 1½ |
| Sand, fine | 1½ | 3 |
| Sand, fine, dirty | 9 | 12 |
| Sand, medium to coarse, dirty | 3 | 15 |
| Sand and gravel, with clayey streaks | 5 | 20 |
| Sand and gravel | 2 | 22 |
| Gravel and coarse clean sand | 8 | 30 |
| No water encountered. | | |

7-7-33ddd. 190 feet west of SE. cor. sec. 33.

| | | |
|---|---|---|
| Soil, clayey, with some fine grit | 2 | 2 |
| Sand, fine, clayey, light-colored | 6 | 8 |
| Sand, medium to coarse | 4 | 12 |
| Sand and coarse gravel | 3 | 15 |
| Gravel and medium- to coarse-grained sand | 3 | 18 |
| Sand and gravel | 12 | 30 |
| No water encountered. | | |

7-7-34cbb. 2,635 feet north of SW. cor. sec. 34.

| | | |
|---|---|---|
| Soil, clayey, gritty | 1½ | 1½ |
| Clay, sandy | 3½ | 5 |
| Sand, fine | 4 | 9 |
| Gravel, dirty | ½ | 9½ |
| Sand, coarse | 5½ | 15 |
| Sand and coarse gravel | 15 | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-7-35bda. 2,640 feet east and 1,690 feet south of NW. cor. sec. 35.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy | 5 | 5 |
| Sand, fine, dirty | 11 | 16 |
| Gravel, grading downward to medium-grained sand and gravel | 14 | 30 |
| Shale, weathered | 1 | 31 |
| Water level, about 18.5 feet. | | |

7-7-35cad. 2,640 feet east and 1,742 feet north of SW. cor. sec. 35.

| | | |
|---|---|---|
| Soil, sandy | 1 | 1 |
| Sand, uniformly fine-grained | 27 | 28 |
| Sand, medium, and fine gravel | 2 | 30 |
| No water encountered. | | |

7-7-35ccd. 845 feet east and 15 feet north of SW. cor. sec. 35.

| | | |
|---|---|---|
| Soil | ½ | ½ |
| Sand, fine | 19½ | 20 |
| Sand, coarse, and fine gravel | 6 | 26 |
| No water encountered. | | |

7-7-35dcc. 2,060 feet west and 25 feet north of SE. cor. sec. 35.

| | | |
|---|---|---|
| Soil, sandy and clayey, compact | 3 | 3 |
| Sand, fine | 22 | 25 |
| Gravel and coarse-grained sand | 5 | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-8-11cad. 1,320 feet north and 2,640 feet east of SW. cor. sec. 11.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy and clayey | ½ | ½ |
| Sand, fine | 12 | 12½ |
| Gravel, grading downward to medium-grained sand | 3½ | 16 |
| Gravel | ½ | 16½ |
| Sand, medium | 4½ | 21 |
| Gravel, coarse | ½ | 21½ |
| Sand and gravel | 8½ | 30 |
| No water encountered. | | |

7-8-11cdd. 2,640 feet east and 45 feet north of SW. cor. sec. 11.

| | | |
|---|---|---|
| Sand, clayey | 1½ | 1½ |
| Sand, with some gravel; gravel streak at 4½ feet | 3½ | 5 |
| Sand, medium to coarse; gravel streak at 12 feet | 7½ | 12½ |
| Sand and gravel | 2½ | 15 |
| Sand, medium to coarse | 9 | 24 |
| Water table encountered between 25 and 30 feet; slumping of hole prevented accurate measurement of depth to water. | | |

7-8-14bab. 1,410 feet east and 25 feet south of NW. cor. sec. 14.

| | | |
|---|---|---|
| Sand, fine | 8½ | 8½ |
| Sand, medium, with gravel layer at 12 feet | 4 | 12½ |
| Sand, coarse, with layers of gravel at 18 feet and at 23½ feet | 17½ | 30 |
| Zone of saturation penetrated at about 29 feet; slumping of hole prevented accurate measurement of depth to water. | | |

7-8-15cdc. 1,520 feet east and 25 feet north of SW. cor. sec. 15.

| | | |
|---|---|---|
| Soil, sandy, grading downward to fine-grained dirty sand; cleaner and slightly coarser at 8 feet | 13 | 13 |
| Gravel and coarse sand, with scattered pebbles up to 4 inches in diameter | 13 | 26 |
| Sand, coarse, with some gravel | 2 | 28 |
| Shale, weathered (Pierre) | 2 | 30 |
| Zone of saturation penetrated at about 28 feet; slumping of hole prevented accurate measurement of depth to water. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-8-16ccc. 13 feet north and 18 feet east of SW. cor. sec. 16.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey | ½ | ½ |
| Gravel, dirty, becoming cleaner at 3 feet | 4½ | 5 |
| Sand, fine to medium | 8 | 13 |
| Sand, coarse; gravel layers at 16 and 22 feet | 11 | 24 |
| Shale, weathered | 2 | 26 |
| Water level at 9.5 feet. | | |

7-8-17dcd. 1,900 feet west of SE. cor. sec. 17.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, sandy loam | 1 | 1 |
| Clay | 3 | 4 |
| Sand, fine | 6 | 10 |
| Gravel and coarse sand | 20 | 30 |
| Water level between 25 and 30 feet; slumping prevented accurate measurement of depth to water. | | |

7-8-18cdc. 1,300 feet east of the SW. cor. sec. 18.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, gritty, clayey | 1 | 1 |
| Silt, powdery | 4 | 5 |
| Gravel, with large pebbles; dirty | 2 | 7 |
| Hole abandoned because of large boulder. Log of shot hole nearby indicates shale within a depth of 10 feet. No water encountered. | | |

7-8-19add. 2,640 feet north of SE. cor. sec. 19.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, clayey | 1 | 1 |
| Clay, dark-colored, sticky; some alkali at 3½ feet | 3 | 4 |
| Sand, fine, dirty; cleaner at 7 feet | 9½ | 13½ |
| Gravel and sand | 16½ | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-8-19cbb. 2,640 feet north of SW. cor. sec. 19.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, gritty, clayey (hardpan) | 3½ | 3½ |
| Silt, powdery | 2½ | 6 |
| Sand, fine, with gravel layer at 8 feet | 2 | 8 |
| Sand, coarse, grading downward to sand and gravel | 11 | 19 |
| Sand, fine | 1 | 20 |
| Sand and gravel | 10 | 30 |
| Zone of saturation penetrated between 26 and 28 feet; slumping prevented accurate measurement of depth to water. | | |

7-8-19cdd. 2,640 feet east and 8 feet north of SW. cor. sec. 19.

| | | |
|---|---|---|
| Soil, clayey | ½ | ½ |
| Sand, with boulders at 2½ feet | 2 | 2½ |
| Gravel and coarse, dirty sand; gravel layer at 16 feet | 16½ | 19 |
| Sand, fine, loose | 11 | 30 |
| Drilled as if in saturated material from 25 to 30 feet. | | |

7-8-20ccc. 634 feet east and 30 feet north of SW. cor. sec. 20.

| | | |
|---|---|---|
| Soil, clayey, slightly gritty | 1½ | 1½ |
| Sand, fine | 11½ | 13 |
| Sand and gravel | 17 | 30 |
| No water encountered. | | |

7-8-21acc. 2,640 feet north and 2,160 feet west of SE. cor. sec. 21.

| | | |
|---|---|---|
| Soil, clayey | ½ | ½ |
| Clay, gritty | 3 | 3½ |
| Sand, fine, with clayey streaks at 7 and 8½ feet; clean, uniformly grained sand at 9 feet; dirty streak at 14 feet | 26½ | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-8-21adc. 860 feet west and 2,640 feet north of SW. cor. sec. 22.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil | ½ | ½ |
| Clay, slightly gritty | 1½ | 2 |
| Sand, fine; dirty and powdery at 5 feet; coarser between 14 and 30 feet | 28 | 30 |
| No water encountered. | | |

7-8-22aab. 1,300 feet west and 18 feet south of NE. cor. sec. 22.

| | | |
|---|---|---|
| Soil, clayey | 1½ | 1½ |
| Sand, fine, dirty | 5½ | 7 |
| Clay | 1 | 8 |
| Sand, dirty | 3 | 11 |
| Sand, clayey | ½ | 11½ |
| Sand, dirty; gravel layer at 28 feet | 18½ | 30 |
| No water encountered. | | |

7-8-22cab. 1,540 feet east and 2,640 feet north of SW. cor. sec. 22.

| | | |
|---|---|---|
| Soil, clayey, dark-colored; increasingly alkaline below 3 feet | 5½ | 5½ |
| Sand, uniformly fine, dirty; slightly clayey streak from 9 to 9½ feet; cleaner sand at 14 feet | 17½ | 23 |
| Sand, clayey | 5 | 28 |
| Sand, medium-to fine-grained | 2 | 30 |
| No water encountered. | | |

7-8-28bbb. 18 feet north and 50 feet east of NW. cor. sec. 28.

| | | |
|---|---|---|
| Soil, clayey; slightly gritty at 3 feet | 4 | 4 |
| Sand, clayey | 1½ | 5½ |
| Clay, gritty, soapy-appearing; alkaline from 7 to 15 feet, with irregular streaks of fine sand | 12 | 17½ |
| Sand, uniformly fine | 2½ | 20 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

7-8-29aac. 1,300 feet south and 1,320 feet west of NE. cor. sec. 29.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, slightly to moderately gritty, soapy-appearing; contains streaks of silt | 25 | 25 |
| Sand, fine, somewhat dirty | 5 | 30 |
| No water encountered. | | |

7-8-30aac. 1,300 feet west and 1,300 feet south of NE. cor. sec. 30.

| | | |
|---|---|---|
| Soil, clayey | ½ | ½ |
| Clay, in part gritty and alkaline; dark-colored; forms hardpan | 10½ | 11 |
| Clay, silty, alkaline | 3½ | 14½ |
| Sand, uniformly fine | 10½ | 25 |
| Gravel, fine, and medium-grained sand | 5 | 30 |
| No water encountered. | | |

7-8-30bdc. 2,640 feet north and 1,320 feet east of SW. cor. sec. 30.

| | | |
|---|---|---|
| Soil, clayey, in part gritty and alkaline; forms hardpan | 8 | 8 |
| Clay, sandy | 4 | 12 |
| Sand, fine-grained, dirty, with some clayey silt | 5 | 17 |
| Clay, soapy in appearance | 2 | 19 |
| Clay, silty | 7 | 26 |
| Sand, fine, dirty; contains some gravel pebbles | 3½ | 29½ |
| No water encountered. | | |

7-8-30ccc. 475 feet east and 10 feet north of SW. cor. sec. 30.

| | | |
|---|---|---|
| Soil, heavy clay | 1 | 1 |
| Sand, fine | 16 | 17 |
| Clay, sandy | 1½ | 18½ |
| Sand, clayey from 27 to 30 feet | 11½ | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

8-6-1daa. 2,112 feet north and 27 feet west of SE. cor. sec. 1.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, alkaline, bentonitic at 2 feet; grades downward to blue clay | 7 | 7 |
| Clay, slightly gritty, light bluish-gray; smells of hydrogen sulphide | 11½ | 18½ |
| Shale (Pierre) | ½ | 19 |
| The area is probably site of former slough. Water seeped into hole slowly; hole caved before water stopped rising. | | |

8-6-1dac. 1,373 feet north, 1,056 feet west of SE. cor. sec. 1.

| | | |
|---|---|---|
| Soil, silty, clayey | 2 | 2 |
| Silt and silty clay, light-brown | 2½ | 4½ |
| Clay, silty | 1½ | 6 |
| Silt, clayey; alkaline in part | 2½ | 8½ |
| Silt, with clayey streak at 12 feet | 7 | 15½ |
| Gravel | ½ | 16 |
| Clay, gritty | 9½ | 25½ |
| Shale (Pierre) | 2½ | 28 |
| Water level, 15.85 feet. | | |

8-6-1dbb. 8 feet south and 12 feet east of center of sec. 1.

| | | |
|---|---|---|
| Soil, sandy | 2 | 2 |
| Clay, silty; light color grading downward to dark color | 10 | 12 |
| Sand and coarse gravel; large pebbles; boulder encountered at 20 feet | 8 | 20 |
| No water encountered. | | |

8-6-1ddd. 72 feet north and 78 feet west of SE. cor. sec. 1.

| | | |
|---|---|---|
| Soil, clayey, dark-colored | 2 | 2 |
| Sand, fine, with few scattered pebbles | 12 | 14 |
| Sand, medium | 2 | 16 |
| Gravel | 1 | 17 |
| Clay, slightly gritty, light-brown | 2 | 19 |
| Sand, clayey | 11 | 30 |
| Water level, 24.45 feet. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

8-6-9ddd. 51 feet north and 60 feet west of fence cor. at SE. cor. sec. 9.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Soil, silty and clayey, light-colored | 4 | 4 |
| Gravel | 1 | 5 |
| Sand and gravel; boulders at 18 feet | 13 | 18 |
| No water encountered. | | |

8-6-16abb. 2,640 feet west and 8 feet south of NE. cor. sec. 16.

| | | |
|---|---|---|
| Soil, sandy and clayey | 3 | 3 |
| Clay, silty, with scattered small pebbles; hard-pan | 1½ | 4½ |
| Gravel, silty, with scattered large pebbles | ½ | 5 |
| Sand and gravel, with layers of very coarse gravel at 9½ and 13 feet; boulders at 18½ feet | 13½ | 18½ |
| No water encountered. | | |

8-6-16bdd. 120 feet north and 420 feet west of center of sec. 16.

| | | |
|---|---|---|
| Soil | 1 | 1 |
| Silt, dirty, grading downward to fine-grained, dirty sand | 12½ | 13½ |
| Gravel | 1 | 14½ |
| Sand, medium, with some gravel, grading downward to coarser sand and gravel | 15½ | 30 |
| No water encountered. | | |

8-7-3bbc. 1,200 feet south and 15 feet east of NW. cor. sec. 3.

| | | |
|---|---|---|
| Soil, clayey; gritty at 2½ feet | 4 | 4 |
| Sand, fine, grading downward to medium-grained sand | 9 | 13 |
| Sand and gravel, grading downward to coarse gravel | 2 | 15 |
| Gravel, coarse, with scattered large pebbles | 4 | 19 |
| Sand and gravel, coarse | 11 | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

8-7-4dbb. 12 feet east of center sec. 4.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, fine-grained | 24 | 24 |
| Sand, medium-grained | 2 | 26 |
| Sand, coarse-grained, with scattered pebbles | 4 | 30 |
| No water encountered. | | |

8-7-4dda. 980 feet north and 20 feet west of SE. cor. sec. 4.

| | | |
|---|---|---|
| Soil, sandy loam | 1 | 1 |
| Sand, very fine grained, somewhat clayey; dirty | 3 | 4 |
| Silt, clayey; hardpan | 2 | 6 |
| Sand, fine, dirty | 3 | 9 |
| Clay, sandy | 2 | 11 |
| Sand, uniformly fine-grained | 19 | 30 |
| No water encountered. | | |

8-7-5bdd. Center sec. 5.

| | | |
|---|---|---|
| Soil, clayey, slightly gritty | 1 | 1 |
| Sand, fine, dirty | 6½ | 7½ |
| Sand, fine, clayey | 5 | 12½ |
| Sand, coarse, with some gravel | 2½ | 15 |
| Gravel, coarse, with some dirty sand | 4½ | 19½ |
| Gravel, coarse, with large pebbles | 10½ | 30 |
| No water encountered. | | |

8-7-5dda. 845 feet north of SE. cor. sec. 5.

| | | |
|---|---|---|
| Soil, clayey and slightly sandy | 8 | 8 |
| Sand, fine | 3 | 11 |
| Clay, sandy | 1 | 12 |
| Sand, uniformly fine-grained, with scattered pebbles; grades downward to coarser sand | 18 | 30 |
| No water encountered. | | |

Table 4.--Logs of test holes in the Angostura irrigation project, South Dakota--Continued

8-7-6dad. 1,340 feet north of SW. cor. sec. 5.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, dirty in upper part........................ | 13½ | 13½ |
| Gravel........................................... | ½ | 14 |
| Sand, coarse, clean, with gravel and scattered large pebbles at 19 and 26 feet................. | 16 | 30 |
| No water encountered. | | |

8-7-6dcc. 2,640 feet west of SE. cor. sec. 6.

| | | |
|---|---|---|
| Silt, white and powdery, grading downward to fine sand........................................... | 16 | 16 |
| Sand, coarse, with some gravel; gravel layer at 27 feet.......................................... | 14 | 30 |
| No water encountered. | | |

8-7-6ddd. SE. cor. sec. 6.

| | | |
|---|---|---|
| Soil, sandy...................................... | 1 | 1 |
| Sand, uniformly fine-grained, grading downward to slightly coarser sand......................... | 29 | 30 |
| No water encountered. | | |

## WELL INVENTORY

An inventory was made of all existing wells located within the area. By far the greater number of these are dug wells situated on the lower of the two terraces above the inner valley. The depth of the wells on the terraces ranges from 10 to 73 feet, usually being dependent on the depth at which shale bedrock was encountered. A few of the wells, which penetrated only thin zones of saturation, were dug several feet into the shale in order to provide a small reservoir for storage of additional water. One well (7-8-29ccc) does not penetrate a zone of saturation, but was dug about 60 feet into the shale bedrock in order to provide catchment of seepage from the overlying sand during periods of rainfall or melting snow.

All the wells currently in use are equipped with cylinder-type pumps which either are powered by the wind or are hand-operated. It is believed that none yields more than 50 gallons per minute; most of them probably yield less than 10 gallons per minute.

Data pertaining to each well appear in the table of well and test-hole records which follows.

Table 5.--Records of wells and test holes, Angostura irrigation project, South Dakota

Table 5.--Records of wells and test holes, Angostura irrigation project, South Dakota

| Well number[1] | Owner or tenant | Type of well[2] | Depth of well (feet)[3] | Diameter of well (inches) | Type of casing[4] | Geologic source[5] | Method of lift[6] | Use of water[7] | Measuring point: Description | Measuring point: Height above land surface (feet) | Measuring point: Altitude above mean sea level (feet)[8] | Depth to water level below measuring point (feet)[9] | Date of measurement 1946 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| 5-9-13ba | H. C. Bell | Du | 37.7 | 72 | W | - | N | N | Top of cover | 0.0 | 2,850. | Dry | 4-24 |
| 5-10-7ac | - | Du | 16.2 | 20 | T | - | N | N | Top of casing | .7 | 3,010. | 16.11 | 4-24 |
| 9bc | Sprouse | Du | 15 | - | - | - | CY | D | Base of pump | 1.2 | 2,960. | 10.31 | 4-24 |
| 18ba | D. K. Bell | Du | 16.8 | 60 | R | - | CY | S | Top of cover | .2 | 2,810. | 14.37 | 4-24 |
| 6-8-13aad | William Sneider | Du | 17.6 | 60 | C | Qal | - | - | Top of curb | .8 | 2,962.52 | 16.55 | 4-23 |
| 24aba | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 2,998. | - | - |
| 24acd | do | B | 30.0 | 7 | - | - | - | - | do | - | 2,999. | - | - |
| 24add | do | B | 32.0 | 7 | - | - | - | - | do | - | 2,993. | - | - |
| 24bdd | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,004. | - | - |
| 24cdd | do | B | 31.0 | 7 | - | - | - | - | do | - | 2,999. | - | - |
| 24ddc | Earl Mohler | Du | 41.3 | 48 | R | Qtl | CY,W | D,S | Base of pump | 1.0 | 2,996.55 | 38.22 | 4-23 |
| 25bbb | Test hole | B | 27.0 | 7 | - | - | - | - | Land surface | - | 3,025. | - | - |
| 25cba | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,008. | - | - |
| 25dab | H. W. Mohler | Du | - | 48 | C | Qtl | CY,W | D,S | Base of pump | 1.0 | 2,994.24 | 34.22 | 4-23 |
| 26aac | - | Du | 37.9 | 48 | R | - | - | - | Top of curb | .3 | 3,040.99 | 36.62 | 4-23 |
| 35acb | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,015. | - | - |

See footnotes at end of table.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-8-36bbb | Test hole | B | 32.0 | 7 | - | - | - | - | Land surface | - | 3,007. | - | - |
| 6-9- 5dbd | do | B | 32.0 | 7 | - | - | - | - | do | - | 2,958. | - | - |
| 5dcc | do | B | 30.5 | 7 | - | Qtl | - | - | do | - | 2,958. | 10/28.20 | 10-28 |
| 8adc | do | B | 20.0 | 7 | - | Qtl | - | - | do | - | 2,959. | - | - |
| 8ccb | U. S. Government | Du | 39.0 | 60 | C | Qtl | CY,H | N | Top of curb | 1.1 | 2,974.88 | 36.2 | 4-23 |
| 8ccc | Test hole | B | 32.0 | 7 | - | Qtl | - | - | Land surface | - | 2,972. | - | - |
| 8cdc | do | B | 18.0 | 7 | - | Qtl | - | - | do | - | 2,968. | - | - |
| 8daa | do | B | 15.0 | 7 | - | - | - | - | do | - | 2,952. | - | - |
| 8dbb | do | B | 32.0 | 7 | - | Qtl | - | - | do | - | 2,965. | - | - |
| 8dcc1 | do | B | 19.0 | 7 | - | Qtl | - | - | do | - | 2,966. | - | - |
| 8dcc2 | U. S. Government | Du | 20.7 | 48 | - | Qtl | - | - | Top of platform | .3 | 2,965.55 | 18.05 | 9-10 |
| 8ddd | Test hole | B | 15.0 | 7 | - | - | - | - | Land surface | - | 2,959. | - | - |
| 17bcc | do | B | 17.0 | 7 | - | - | - | - | do | - | 2,975. | - | - |
| 17bdd | do | B | 19.0 | 7 | - | Qtl | - | - | do | - | 2,963. | 7.90 | 10-28 |
| 17cdc | do | B | 15.0 | 7 | - | - | - | - | do | - | 2,968. | - | - |
| 18acc1 | U. S. Government | Du | 9.4 | 36 | - | Qal | P,H | D | Top of casing | -4.3 | 2,940. | 2.55 | 8-21 |
| 18acc2 | do | Du | - | 60 | C | Qal | - | - | Top of well | .4 | 2,952.41 | 8.88 | 8-21 |
| 18ccc | Test hole | B | 32.0 | 7 | - | - | - | - | Land surface | - | 2,989. | - | - |
| 18dcc1 | do | B | 32.0 | 7 | - | Qtl | - | - | do | - | 2,984. | - | - |
| 18dcc2 | L. J. Berfiend | Du | 37.3 | 48 | C | Qtl | CY,H | D,S | Base of pump | 1.5 | 2,985.53 | 34.00 | 4-23 |
| 18ddc | School district | Du | 27.5 | 60 | C | Qtl | CY,H | D | Top of curb | .9 | 2,982.75 | 25.45 | 10-1 |
| 18ddd | Test hole | B | 18.0 | 7 | - | Qtl | - | - | Land surface | - | 2,972. | 7.80 | 10-28 |
| 19adc | do | B | 22.0 | 7 | - | - | - | - | do | - | 2,976. | - | - |
| 19bda | U. S. Government | Du | 32.0 | 48 | C | Qtl | CY,H | D | Top of casing | .5 | 2,988.42 | 33.29 | 8-21 |
| 19caa | Test hole | B | 32.0 | 7 | - | Qtl | - | - | Land surface | - | 2,981. | 10/24.80 | 10-24 |
| 19cdc | do | B | 32.0 | 7 | - | Qtl | - | - | do | - | 2,984. | - | - |
| 19ddc | do | B | 24.0 | 7 | - | - | - | - | do | - | 2,978. | - | - |
| 20bcc | do | B | 24.0 | 7 | - | Qtl | - | - | do | - | 2,976. | 9.57 | 10-28 |
| 20bcd | U. S. Government | Du | 12.0 | 42 | C | Qtl | - | - | Top of curb | .2 | 2,977. | 10.74 | 9-10 |

See footnotes at end of table.

Table 5.--Records of wells and test holes, Angostura irrigation project, South Dakota--Continued

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-9-29bad | Test hole | B | 15.5 | 7 | - | Qal | - | - | Land surface | - | 2,822. | - | - |
| 29cca | do | B | 9.0 | 7 | - | Qal | - | - | do | - | - | - | - |
| 30acb | do | B | 28.5 | 7 | - | - | - | - | do | - | 2,860. | - | - |
| 30dba | do | B | 20.5 | 7 | - | Qal | - | - | do | - | 2,840. | - | - |
| 7-7-23acd | John Rodecap | Du | 26 | 48 | C | Qal | CY,W | D | Base of rail | .0 | 2,946. | 22.70 | 4-30 |
| 23dab | Test hole | B | 24.0 | 7 | - | - | - | - | Land surface | - | 2,947. | - | - |
| 24cacl | George Evans | Du | 30 | 40 | C | Qtl | CY,H | D | Top of casing | .0 | 3,057. | 28.22 | 9-5 |
| 25aaa | Test hole | B | 30.0 | 7 | - | Qtl | - | - | Land surface | - | 3,061. | - | - |
| 25abb | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,067. | - | - |
| 25ccc | U. S. Government | Du | 13 | 48 | W | Qal | CY,H | N | Base of pump | .4 | 3,067. | 12.03 | 4-19 |
| 25cdd | Test hole | B | 30 | 7 | - | - | - | - | Land surface | - | 3,091. | - | - |
| 25daa | do | B | 30 | 7 | - | - | - | - | do | - | 3,080. | - | - |
| 25dbb | do | B | 30 | 7 | - | - | - | - | do | - | 3,076. | - | - |
| 26abb | do | B | 11.5 | 7 | - | - | - | - | do | - | 3,045. | - | - |
| 26adc | U. S. Government | Du | 39 | 36 | C | Qtl | - | N | Top of cover | 0.0 | 3,073. | 38.45 | 8-16 |
| 26ccc | Test hole | B | 30 | 7 | - | - | - | - | Land surface | - | 3,087. | - | - |
| 26cdd | do | B | 30 | 7 | - | - | - | - | do | - | 3,084. | - | - |
| 26dab | do | B | 30 | 7 | - | - | - | - | do | - | 3,077. | - | - |
| 27acb | do | B | 14.5 | 7 | - | Qal | - | - | do | .0 | 2,942. | 10.88 | 11-14 |
| 27bab | Cliff Fleming | Du | 21.7 | 48 | C | Qal | CY,H | N | Top of platform | .6 | 2,955. | 19.26 | 8-16 |
| 27ccc | Test hole | B | 20.0 | 7 | - | Qal | - | - | Land surface | - | 2,982. | - | - |
| 33cdc | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,111. | - | - |
| 33daa | Bert Ray | Du | 45 | 48 | C | Qtl | CY,W | D,S | Top of platform | 1.1 | 3,095. | 38.37 | 9-4 |
| 33ddd | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,104. | - | - |
| 34aba | C. E. Chamberlin | Du | 23.7 | 24 | C | Qal | CY,H | I | Top of cover | .2 | 2,971. | 19.75 | 4-22 |
| 34cbb | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,095. | - | - |
| 35baa | A. W. Gamet | Du | 31.7 | 36 | R | Qtl | CY,G | S | Top of cover | .0 | 3,084. | 28.27 | 8-16 |
| 35bda | Test hole | B | 30.0 | 7 | - | Qtl | - | - | Land surface | - | 3,096. | - | - |
| 35cad | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,104. | - | - |

See footnotes at end of table.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-7-35ccd | Test hole | B | 26.0 | 7 | - | - | - | - | Land surface | - | 3,101. | - | - |
| 35dcc | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,102. | - | - |
| 7-8-10cba | Dan Moiser | Du | 16.1 | 36 | C,R | Qal | CY,W | D | Top of platform | 0.6 | 2,886.65 | 13.40 | 8-16 |
| 11cad | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,023. | - | - |
| 11ccd | Worth Gamet | Du | 38 | 48 | C | Qtl | CY,W | D,S | Top of curb | .7 | 3,023. | 34.97 | 4-19 |
| 11cdd | Test hole | B | 30.0 | 7 | - | Qtl | - | - | Land surface | - | 3,024. | - | - |
| 12cba | Robert Gamet | Du | 35.5 | 24 | C | - | - | N | - | - | - | - | - |
| 14bab | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,025. | - | - |
| 14cdd | Ward Gamet | Du | 57.5 | 24 | C | Qes | CY,W | S | Top of cover | 2.1 | 3,066. | 50.2 | 4-19 |
| 15cdc | Test hole | B | 30.0 | 7 | - | Qt2 | - | - | Land surface | - | 3,043. | - | - |
| 16ccc | do | B | 26.0 | 7 | - | Qal | - | - | do | .0 | 3,034. | 9.50 | 11-8 |
| 17cbc | Paul Fleming | Du | 35 | 48 | C | Qtl | CY,H | D,S | Base of pump | 2.0 | 3,038. | 31.04 | 4-19 |
| 17dcd | Test hole | B | 30.0 | 7 | - | Qtl | - | - | Land surface | - | 3,040. | - | - |
| 18cdc | do | B | 7.0 | 7 | - | - | - | - | do | - | 3,049. | - | - |
| 19add | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,054. | - | - |
| 19caa | W. G. Tice | Du | 35 | 36 | C | Qtl | - | - | do | - | 3,052. | 32 | 8-16 |
| 19cab | do | Du | 16.1 | 25 | C | Qtl | N | S | Top of casing | 1.85 | 3,043.15 | 15.58 | 9-5 |
| 19cbb | Test hole | B | 30.0 | 7 | - | Qtl | - | - | Land surface | - | 3,054. | - | - |
| 19cdd | do | B | 30.0 | 7 | - | - | - | - | - | - | 3,050. | - | - |
| 19dcd | Ed Hagerman | Du | 46.0 | 36 | C | Qtl | CY,W | D,S | Top of cover | 1.7 | 3,071. | 43.88 | 8-13 |
| 20ccc | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,066. | - | - |
| 20ddc | Robert Gamet | Du | 71.5 | 48 | C | Qes | CY,G | D,S | Top of cover | .0 | 3,103. | 71.0 | 4-19 |
| 21acc | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,070. | - | - |
| 21adc | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,072. | - | - |
| 21ddc | John Eng | Du | 88 | 48 | W | Qt2 | CY,W | D,S | Base of pump | 1.1 | 3,099. | 63.79 | 4-19 |
| 22aab | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,062. | - | - |
| 22cab | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,070. | - | - |
| 28bbb | do | B | 20.0 | 7 | - | - | - | - | do | - | 3,084. | - | - |
| 29aac | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,098. | - | - |

See footnotes at end of table.

Table 5.--Records of wells and test holes, Angostura irrigation project, South Dakota--Continued

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-8-29ccc | U. S. Government | Du | 73.3 | 48 | C | - | CY,W | N | Top of cover | 0.0 | 3,120. | 62.31 | 8-20 |
| 30aac | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,077. | - | - |
| 30bdc | do | B | 29.5 | 7 | - | - | - | - | do | - | 3,086. | - | - |
| 30cbb | W. B. Tice | Du | 55 | 48 | C | - | CY,W | D,S | - | - | 3,086. | 52. | 4-19 |
| 30ccc | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,098. | - | - |
| 31bba | A. J. Sedar | Du | 58.0 | 60 | C | - | CY,W | D,S | Base of pump | .4 | 3,109. | 55.25 | 4-19 |
| 31dbb | - | Du | 18.8 | 60 | C | - | N | N | Top of cover | .7 | - | 18.40 | 8-20 |
| 33bbb | - | Du | - | 48 | C | - | CY,W | N | do | 1.1 | 3,157.84 | 24.55 | 6-5 |
| 8-6- 1bad | U. S. Government | Du | 26.3 | 60 | R | Qal | N | N | Top of platform | 1.5 | 3,042. | 24.40 | 8-13 |
| 1daa | Test hole | B | 18.5 | 7 | - | Kp(w) | - | - | Land surface | .0 | 3,052. | 16.00 | 11-5 |
| 1dac | do | B | 28.0 | 7 | - | Qal | - | - | do | .0 | 3,057. | 14.45 | 11-5 |
| 1dbb | do | B | 20.0 | 7 | - | - | - | - | do | - | 3,045. | - | - |
| 1ddd | do | B | 30.0 | 7 | - | Qalf | - | - | do | .0 | 3,069. | 24.45 | 11-5 |
| 3ddd | Al Billups | Dr | 58 | 8 | S | Qtl | CY,H | D | Top of casing | .5 | 3,135. | 44.95 | 8-28 |
| 9aab | Frank Parsons | Du | 30.3 | 5 | - | Qal | N | D | Top of box | 2.6 | - | 24.98 | 8-13 |
| 9dca | U. S. Government | Du | 44.6 | 36 | C,R | Qtl | N | N | Top of curb | .4 | 3,149. | 41.60 | 4-22 |
| 9ddd | Test hole | B | 18.0 | 7 | - | - | - | - | Land surface | - | 3,145. | - | - |
| 10daa | U. S. Government | Du | 42.1 | 48 | W | Qtl | CY,H | N | Base of pump | .5 | 3,135. | 39.62 | 4-22 |
| 12aad | Albert Judd | Du | 19 | 48 | R | Qes | CY,H | D | do | .5 | 3,126. | 24.40 | 8-13 |
| 13aac | A. J. Kieffer | Du | 11.7 | 24 | C | Qes | N | N | Top of casing | .0 | 3,207.96 | 7.84 | 6-3 |
| 13bad | do | Du | 13.0 | 24 | R | Qes | CY,H | D | Top of curb | .3 | 3,213.49 | 10.58 | 8-7 |
| 14aba | Roy Pierce | Du | 29.1 | 48 | R | Qes | CY,W | D,S | Top of platform | .5 | 3,197. | 24.65 | 9-6 |
| 15bdc1 | W. J. Beck | Du | 160. | 8 | S | - | CY,H | D,S | Top of casing | 1.5 | 3,244.41 | 10/77.78 | 8-20 |
| 15bdc2 | do | Du | 25. | 36 | C | Qes | CY,H | D,S | Top of platform | .6 | 3,233.94 | 19.91 | 9-4 |
| 16aba | Hot Springs, S. D., Airport | Dr | 120. | 6 | S | - | CY,H | D | Top of casing | .3 | 3,149. | 39.80 | 4-22 |
| 16abb | Test hole | B | 18.5 | 7 | - | - | - | - | Land surface | - | 3,149. | - | - |
| 16bdd | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,160. | - | - |

See footnotes at end of table.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-6-17ccd | Utah Construction Co. | Dr | 221. | 8 | S | Lka, Ju | T,E | D | Top of casing | 1.7 | 3,117.93 | 56.08 | 8-13 |
| 17dcb | C. W. Kolterman | Dr | 60 | 6 | S | - | CY,H | D,S | do | .6 | 3,133. | 44.05 | 8-13 |
| 8-7- 1bcb | George Thompson | Dr | 15 | 24 | S | Qal | N | N | do | 1.0 | 3,118.05 | 5.65 | 5-5 |
| 2aaa | U. S. Government | Du | 15.4 | 36 | W | Qal | N | N | Top of platform | .7 | 3,111.41 | 15.23 | 9-22 |
| 3bbc | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,102. | - | - |
| 3cbb | U. S. Government | Du | 41.0 | 36 | - | - | - | - | do | - | 3,118. | Dry | - |
| 4ccc | Ira Graves | B | 42.5 | 18 | T | Qes | CY,W | D,S | Base of pump | 1.3 | 3,139. | 37.80 | 4-22 |
| 4dbb | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,121. | - | - |
| 4dda | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,137. | - | - |
| 5acc | Ed Hagerman | Du | 49.3 | - | - | Qtl | CY,H | N | Top of platform | .5 | 3,116. | 45.76 | 8-13 |
| 5bdd | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,114. | - | - |
| 5dda | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,129. | - | - |
| 6aad | U. S. Government | Du | 44.9 | 36 | C | Qtl | CY,W | D,S | Top of curb | .5 | 3,105. | 37.95 | 8-13 |
| 6dad | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,122. | Dry | - |
| 6dcc | do | B | 30.0 | 7 | - | - | - | - | do | - | 3,130. | - | - |
| 6dcd | Anson Mills | Du | 37.3 | 48 | C | Qtl | CY,W | D,S | Top of curb | 1.4 | 3,129. | 35.45 | 4-22 |
| 6ddd | Test hole | B | 30.0 | 7 | - | - | - | - | Land surface | - | 3,158. | - | - |
| 7bbb1 | Herman Kneuple | Du | 17 | 36 | W | Qes, Qt2 | CY,H | N | Top of platform | .8 | 3,116. | 14.71 | 9-30 |
| 7bbb2 | do | Du | - | 48 | C | Qes, Qt2 | CY,H | D,S | Base of pump | 2.2 | 3,112. | 8.64 | 4-22 |
| 8ccc | Hazel Reigler | Du | 41.0 | 36 | R | Qes | CY,G | D,S | Top of platform | .6 | 3,225. | 37.51 | 8-19 |
| 8cdb | do | Du | 25 | 48 | C | Qes | N | N | Top of curb | 1.7 | 3,212. | 20.43 | 8-19 |
| 8dcc | do | Du | 21.2 | 36 | T | Qes | N | N | Base of pump | 1.6 | 3,234. | 19.11 | 6-5 |
| 9abb | William Cosgrove | Du | 30.6 | 36 | S | Qes | CY,H | D,S | do | 1.0 | 3,160. | 27.89 | 8-20 |

See footnotes on following page.

Table 5.--Records of wells and test holes, Angostura irrigation project, South Dakota--Continued

Footnotes:

1 See text for description of well-numbering system.

2 B, bored well; Dr, drilled well; Du, dug well.

3 Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.

4 C, concrete; R, rock; S, steel; T, tile; W, wood.

5 Qal, alluvium; Qalf, alluvial gravels; Qt1, sand and gravel of lower terrace; Qt2, sand and gravel of upper terrace; Qes, eolian sand; Kp, Pierre shale; Lka, Lakota sandstone; Ju, Unkpapa sandstone; Kp(w), Pierre shale, weathered zone.

6 Method of lift: CY, cylinder; N, none; p, pitcher pump. Type of power: W, wind; H, hand; G, gasoline or diesel; E, electric.

7 D, domestic; I, irrigation; In, industrial; N, not being used; O, observation; P public supply; S, stock.

8 Altitude of land surface taken from USBR topographic maps are given in feet; altitudes determined by instrumental leveling given in feet, tenths, and hundredths.

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

10 May not be static water level.