Ground-Water Conditions in the Proposed Waterfowl Refuge Area Near Chapman, Nebraska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1779-E

Prepared as part of the program of the Department of Interior for development of the Missouri River basin

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By C. F. KEECH

With a section on CHEMICAL QUALITY OF THE WATER

By P. G. ROSENE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GROUND-WATER CONDITIONS IN THE PROPOSED WATERFOWL REFUGE AREA NEAR CHAPMAN, NEBRASKA

By C. F. Keech

ABSTRACT

The Chapman area, as described in this report, includes about 10 square miles of Platte River bottom land which, for the most part, lies between the Platte River and the North Channel of the Platte River near their confluence. The Wood River discharges into the North Channel of the Platte River upstream from the area; thus, below the confluence, the stream is known by either name.

The study was made at the request of the U.S. Bureau of Sport Fisheries and Wildlife which proposes to develop the area for a waterfowl refuge. The refuge would consist of artificial ponds surrounded by a margin of uninhabited land about 0.5 mile wide to provide sanctuary for the waterfowl.

Two types of ponds are being considered for construction in the area: surface ponds and water-table ponds. Surface ponds constructed above the water table would be the more desirable from the standpoint of management of biota in the pond environment because they could be drained.

The establishment of ponds in the area, whether surface or water-table, would not seriously deplete the water supply because the area is one from which natural discharge of water is continuous. Evaporation from ponds would reduce the total amount of water naturally discharged by other means. Water-table ponds, however, could not be drained and may also be less desirable because their water level would fluctuate with the water table. Because the surficial deposits are very permeable, they will not sustain the installation of surface-water ponds without an artificial impermeable lining to prevent excessive seepage. On the other hand, water-table ponds could be developed by simply excavating the earth materials to a depth below the lowest position of the water table.

The ground water is very hard, and some of it contains iron and manganese much in excess and sulfate, fluoride, and nitrate slightly in excess of commonly accepted standards for drinking water. The ground water would be suitable for use in the proposed refuge, and it is unlikely that the development of a waterfowl refuge would significantly alter the chemical quality of the ground water.

INTRODUCTION

The U.S. Bureau of Sport Fisheries and Wildlife proposes to develop a waterfowl refuge of about 10 square miles in an area near Chapman, Nebr. At the request of the Bureau, the U.S. Geological Survey, in July 1958, began an investigation of ground-water conditions in an area of about 25 square miles adjacent to the Platte River near Chapman. The requirements of the Bureau were twofold: (1) to obtain data needed for the design of water impoundments, structures, and related works, and (2) to obtain data for estimating the probable effect of the proposed hydraulic works on future groundwater conditions in the vicinity of the proposed refuge.

The investigation was made as part of the program of the Department of Interior for development of the Missouri River basin.

GENERAL FEATURES OF THE AREA

The area studied is confined principally to the eastern end of a large island in the Platte River system. This island is called Grand Island (fig. 1), and it was from this island that the nearby city of Grand Island received its name. The highest elevation on the island is only about 5 feet above the Platte River surface. The island is virtually bottom land, although only part is subject to inundation during periods of exceptionally high water. The water table is normally less than 5 feet below the surface, and in rainy seasons it rises enough to produce extensive marshy areas. The surface of the almost flat island is modified by old stream channels, cutoffs, and shallow depressions.

The island is bordered on the south by the Platte River and on the north by the North Channel of the Platte River. The Platte River normally becomes dry for short periods during the summer, but the North Channel has perennial flow in its lower reaches because the Wood River, which is a perennial stream, discharges into it.

The principal soil of the area is classified as loamy sand, but the upper subsoil contains some silt and clay. The lower subsoil, beginning at an average depth of about 20 inches, is composed of medium to coarse sand and some gravel. Locally, the loamy sand rests on coarse sand and gravel. Some of the less stable soils have been deposited by the wind; these form small low ridges and knolls, creating a billowy topography.

Field crops are grown on the well-drained land. Most of the land, however, is not suitable for cultivation although it supports a luxuriant growth of native grasses that are cut for hay or used for pasture.

PREVIOUS INVESTIGATIONS

Several reports dealing specifically with the geology or groundwater resources, or both, describe areas that extend into the Platte River valley in the vicinity of Chapman, Nebr. The earliest of these was written by Darton (1898), who described both the bedrock and mantling deposits and discussed the occurrence of ground water. Lugn and Wenzel (1938) described in greater detail the deposits of

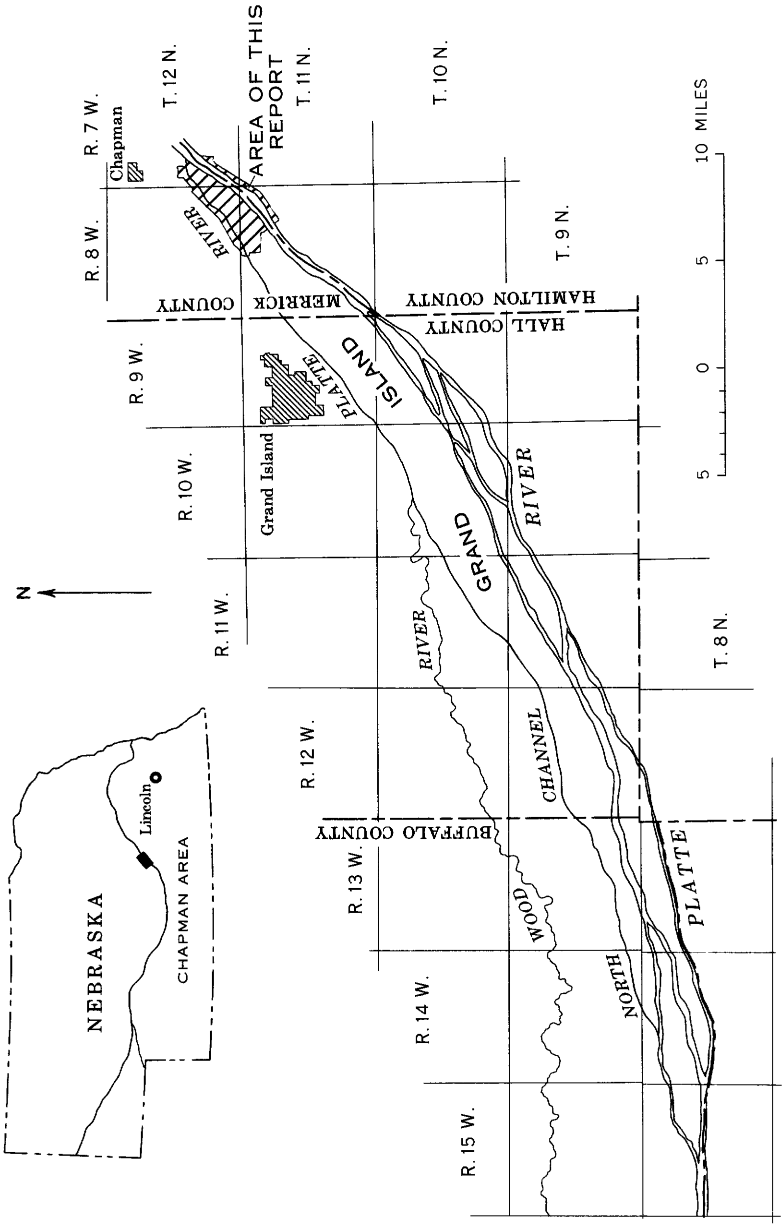


FIGURE 1.—Map showing the location and extent of the Chapman area with respect to the Grand Island in the Platte River.

Quaternary age and presented maps showing the depth to and the configuration of the water table.

As part of geologic and ground-water studies made in Nebraska by the Conservation and Survey Division of the University of Nebraska in cooperation with the U.S. Geological Survey, some test holes that completely penetrated the unconsolidated deposits have been drilled at points within a few miles of the Chapman area. Also, as part of the State-Federal program, periodic water-level measurements in selected wells have been made during the past 14 years. (See table 6.) These records of water-table fluctuations are an index to the magnitude of changes in ground-water storage.

METHODS OF INVESTIGATION

A review of data collected during previous investigations indicated that additional information was needed for the present investigation. All irrigation wells were inventoried, and information concerning well casings, pumps, and power supplies was collected. Water samples from representative wells were analyzed in the U.S. Geological Survey laboratory at Lincoln, Nebr., to determine the chemical properties of the ground water.

A total of 45 water-level observation wells of small diameter were installed by jetting. Measurements of the water levels in these and three additional wells were made monthly. One well of 8-inch diameter was installed and equipped with a recording gage to continuously record fluctuations of the water level in the well.

Two deep test holes were drilled to bedrock to determine the physical characteristics of the water-bearing deposits. Samples of sediments obtained from the two test holes were analyzed in the U.S. Geological Survey laboratory at Denver, Colo.

In addition to the samples of sediment obtained from the test holes, 48 samples of the surficial materials in the proposed area of the refuge were obtained. The disturbed samples were collected by use of an "Orchard" or bucket-type hand auger, and the undisturbed samples were collected by means of a "Pomona" core barrel. (See fig. 2.) The latter instrument consists of a 2-inch inside diameter by 4-inch long open-drive core barrel with extension tubes 1 inch in diameter and 5 feet long for sampling at depth. Brass cylinder liners, 2 inches long, were used to retain the undisturbed core samples. The filled liners were removed from the core barrel by pushing an attached plunger. They then were capped, taped, and paraffined on each end prior to shipment to the laboratory. There the samples, still in their liners, were installed directly in the permeability apparatus and analyzed in their undisturbed condition.

FIGURE 2.—Pomona core barrel.

PERSONNEL AND ACKNOWLEDGMENTS

Special credit is due the following employees of the U.S. Geological Survey: James W. Nelson who installed the observation wells and made most of the depth-to-water measurements, John A. Eisenmenger who compiled the data for the geologic sections, and D. A. Morris who collected the soil samples. The physical properties of the samples were determined by C. R. Jones, M. L. Millgate, R. A. Speirer, N. N. Yabe, R. P. Moston, and J. D. Tiff, under the supervision of A. I. Johnson, chief, U.S. Geological Survey Hydrologic Laboratory.

Many persons supplied data that otherwise could not have been readily obtained, if at all. E. C. Reed and V. H. Dreeszen of the Conservation and Survey Division of the University of Nebraska made available their files of pertinent geologic and hydrologic data and assisted in the interpretation of the data. They also made available the State-owned test drilling equipment to drill two test holes through the water-bearing deposits in the Chapman area. J. A. Elder, soil

scientist, Conservation and Survey Division, furnished the information concerning soils in the area. D. S. Jones, Jr., of the Nebraska Water Resources Division, furnished data on the location and ownership of irrigation wells in the area. Farmers permitted the measurement of the water levels in their wells and supplied data concerning the wells.

SYSTEM USED IN NUMBERING WELLS AND TEST HOLES

All wells and test holes referred to in this report have been assigned numbers indicating their location within the land subdivisions surveyed by the U.S. Bureau of Land Management. The first numeral within the number indicates the township, the second the range, and the third the section in which the well or test hole is located. The lowercase letters a, b, c, and d following the section number designate the quarter section and the quarter-quarter section. The letters are assigned in a counterclockwise direction beginning with "a" in the northeast quadrant. If two or more wells or test holes within the same quarter-quarter section are listed, they are distinguished by adding consecutive numerals after the lowercase letters. The system used in numbering is illustrated in figure 3.

GEOGRAPHY

CLIMATE

The climate in the Chapman area is subhumid, and the average annual precipitation is about 24 inches. About 80 percent of the precipitation falls in the period of April through September, more than half of which falls during thundershowers. The spring and early summer rain storms are usually well distributed, although drought periods are not uncommon. The distribution of the precipitation normally is less uniform in late summer and early fall than it is in spring and early summer. The average annual snowfall is about 25 inches, and the snowfall usually is greatest during February and March.

Precipitation records have been maintained continuously at Grand Island since 1895. (See fig. 4.)

Prevailing winds are from the south during the summer and from the northwest during the winter; however, winds frequently blow from other directions. The winds are usually moderate to strong during the summer and are often accompanied by high temperature and low humidity, both of which cause rapid loss of soil moisture and a high rate of evapotranspiration. Winds—sometimes accompanied by hail and strong enough to damage property, trees, and crops—occasionally occur during thunderstorms.

The average annual temperature at Grand Island is 51°F. Temperatures of more than 100° are common in midsummer, and in winter

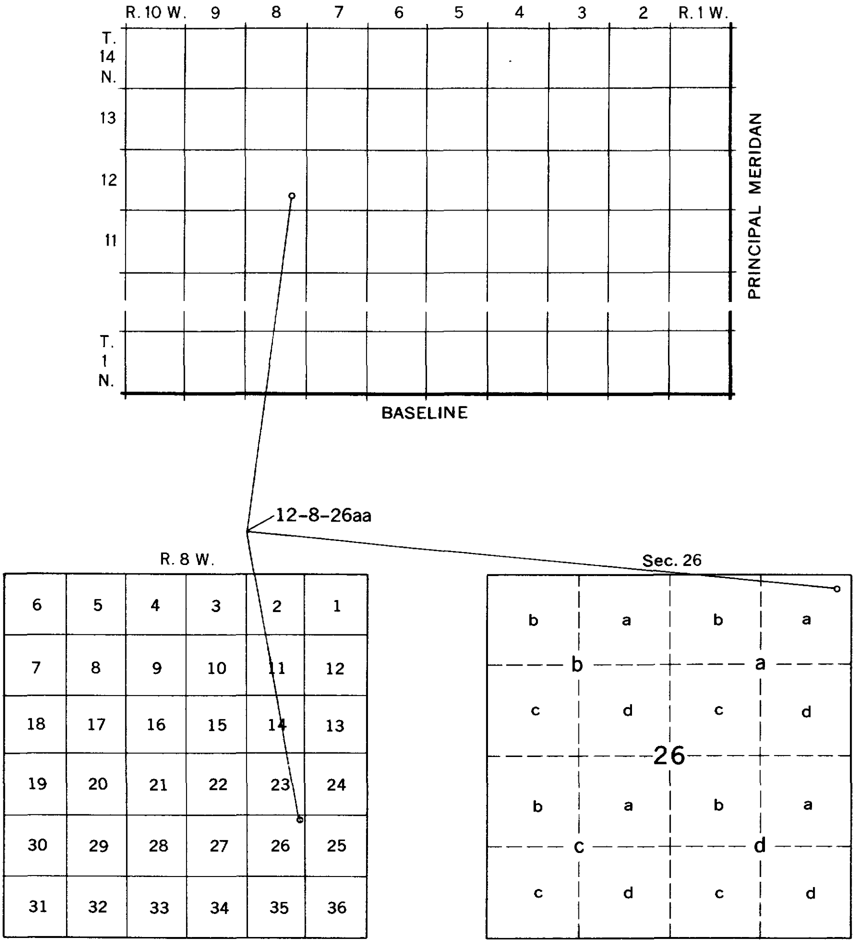


FIGURE 3.—Sketch showing well-numbering system.

they often drop below zero; lows of −25°F have been recorded. The last killing frost in the spring generally occurs about April 28, and the first in the fall occurs about October 3. This range allows a growing season of about 158 days. There is a high percentage of clear, sunshiny days. The rate of evaporation from a free water surface is about 60 inches per year.

SOILS

The soils of the bottom lands of the Platte River valley southwest of Chapman have been developed from parent materials of alluvial origin. The parent materials, consisting principally of fine to medium sand and containing different amounts of clay, silt, and coarse sand and gravel, were deposited in braided, partly blocked channels that

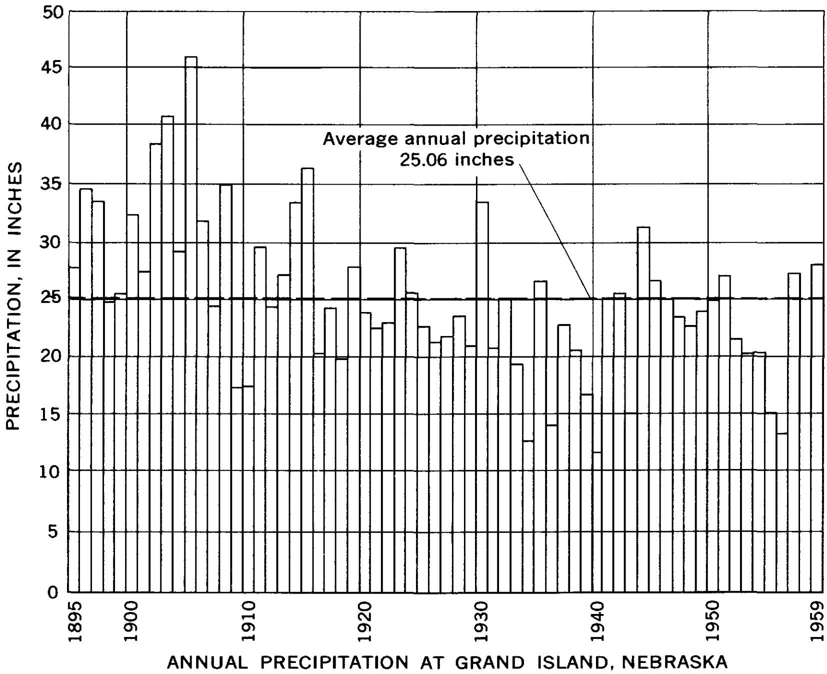


FIGURE 4.—Precipitation at Grand Island, Nebr., 1895-1959. (From records of the U.S. Weather Bur.)

carried water only when the rivers were at flood stage. In general, the texture of the parent materials is finer than that of the deposits they overlie. When the channels became filled with sediment, the flood water from the river spread over most of the area depositing a layer of organically enriched fine-grained sediments. The soils that developed on this mantle contain loamy materials to a depth ranging from less than 1 inch to as much as 3 feet. Although the parent materials differ widely within short distances, there are few, if any, surface characteristics that indicate the character of the subsoil. To determine the intricate distribution pattern of the subsoil would require a pattern of soil test holes spaced as closely as 100 feet.

Laboratory analyses of samples obtained from shallow test holes at 29 sites indicate that in about 40 percent of the area the soil profile contains one or more layers that are silty or clayey, or both. The particle-size determinations of samples within 3 feet of the surface at the 29 sites indicate that these layers are either 30–50 percent silt and 7–27 percent clay or are more than 50 percent silt and less than 27 percent clay. The soil in about 40 percent of the area consists wholly of loamy sand (70–85 percent sand) or sand (85 percent or more sand); in a few places, however, the soil contains one or more clayey layers within 3 feet of the surface. Plate 1 shows the soil types in the area.

NATURAL VEGETATION

Except where cultivated crops are grown, native grass is the dominant vegetation. The grasses are predominantly those that depend on ground water for their water supply. Several kinds of trees and shrubs that also depend on ground water grow in the uncultivated areas; the most prevalent of these are species of willow and cottonwood.

GEOLOGY

The Platte River valley in the vicinity of Chapman is underlain by unconsolidated deposits that range in thickness from about 90 feet to more than 300 feet. (See pl. 2.) These deposits overlie chalk, shale, and limestone, of Cretaceous age, which are not sufficiently permeable to serve as aquifers. The formations that compose the platform on which the water-bearing deposits rest are the Pierre Shale and Niobrara Formation, both of Late Cretaceous age.

The sand and gravel deposits exposed along the Platte River appear at first glance to be alluvium transported and deposited by the river. Examination of the deposits by means of test drilling in both the valley and the adjacent uplands, however, has shown that except for the uppermost sediments the unconsolidated deposits were not deposited by the Platte River but were in place prior to the existence of the river. These deposits are broad, more or less continuous sheets that extend under both the Platte River valley and the adjacent uplands.

The glacial ice sheets that advanced out of the centers of snow accumulation in Canada and northern United States probably were an indirect cause of the sheetlike widespread deposition of the unconsolidated deposits.

When the first of the continental glaciers, the Nebraskan ice sheet, advanced, it dammed the eastward-draining valleys and caused them to fill with water and eventually to overflow. The overflow followed the ice margin until the water reached a valley draining to the Gulf of Mexico. Meanwhile, the blocked valleys were being filled with sediment that the streams dropped when they entered the body of ponded water. As the glacier melted, the older deposits were mantled by fine-grained materials that were partly wind deposited and partly stream deposited. During the interglaciation that followed, the streams again entrenched and broadened their valleys; thus, they removed much of the material that had been deposited during the Nebraskan Glaciation. When the second continental glacier, the Kansan ice sheet, advanced into eastern Nebraska, ice again blocked the valleys and caused them to be filled with coarse sediments. These coarse sediments also were mantled with fine-grained deposits during the waning phase of Kansan Glaciation.

There were four major glaciations—Nebraskan, Kansan, Illinoian, and Wisconsin—and a similar cycle of erosion and deposition occurred in each stage.

Figure 5 is a correlation chart after Condra, Reed, and Gordon (1950), showing the stratigraphic units of the Pleistocene as used by

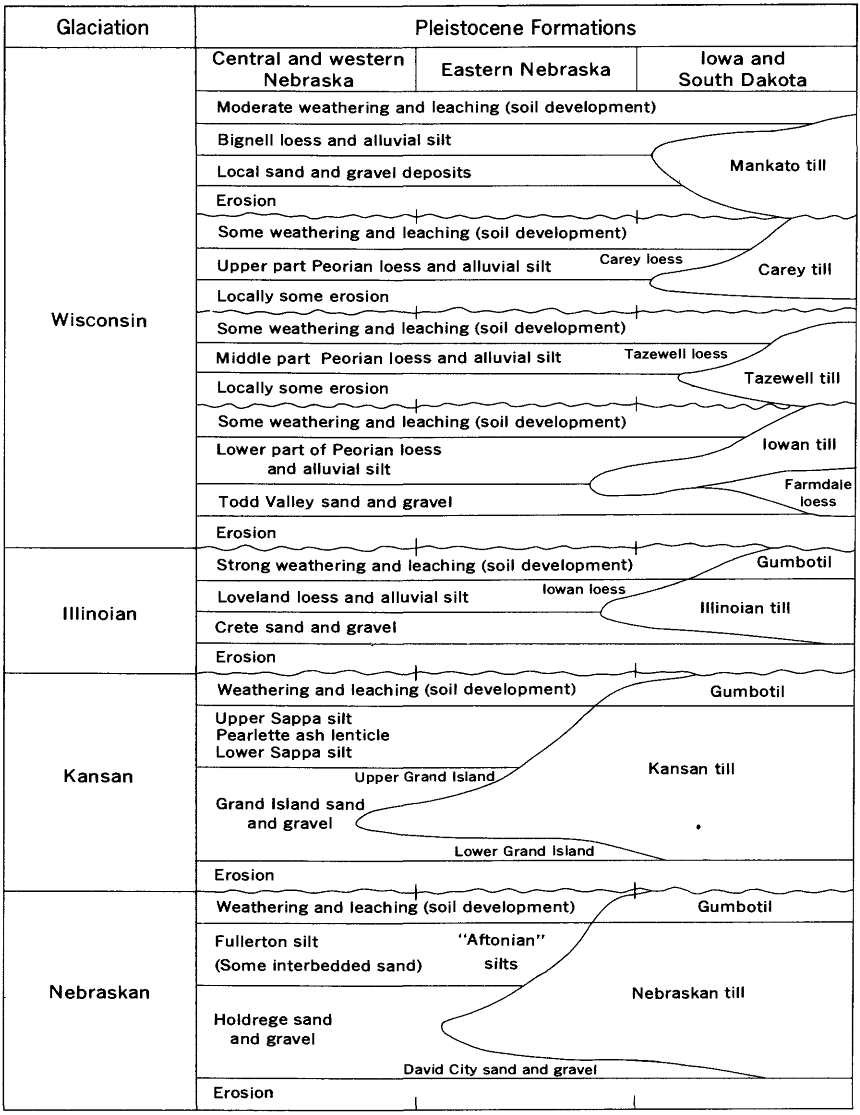


FIGURE 5.—Correlation chart showing the Pleistocene formations in relation to continental glaciation in Nebraska. (After Condra and others, 1950.)

the Nebraska Geological Survey. The deposits of Pleistocene age have not been differentiated in this report but are considered as a single stratigraphic unit.

The segment of the Platte River in the vicinity of Chapman did not occupy the area of its present valley until rather late in Pleistocene time; thus, the older ice-age deposits beneath the Platte River valley were in place long before the river carved its present channel. The later deposits of Pleistocene age, however, were reworked by the river as it meandered across its valley. Because much of the finer grained material was washed away by the action of the river, the upper sand and gravel deposit in the Platte River valley now consists of the coarser sand and gravel. This upper sand and gravel alluvium ranges in thickness from a few feet to as much as 40 feet.

The topsoil, surficial wind-blown loess, stream- and slope-washed clay, silt, sand, and gravel constitute the deposits of Recent age.

Throughout most of south-central Nebraska, the fluviatile deposits of Pleistocene age are overlain by thick deposits of loess. In the Platte River valley, however, much of the loess has been removed by erosion and, at the Platte River, it is entirely absent and sand and gravel are exposed in the river bed.

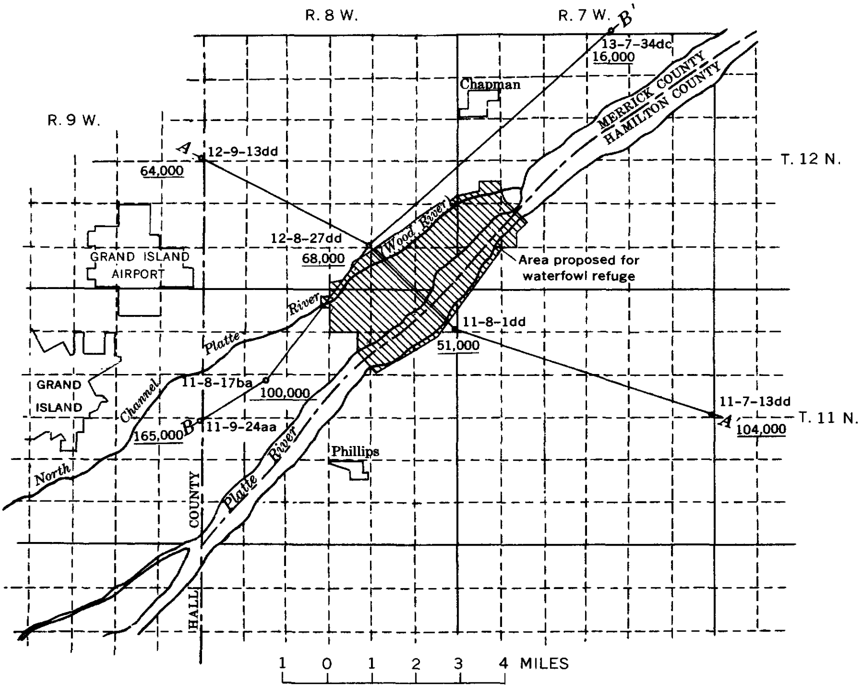
The thickness of the unconsolidated deposits varies considerably, reflecting irregularities in the bedrock platform on which they were deposited and in the present surface topography. The logs of test holes drilled in the vicinity of the Chapman area are given in table 7. The locations of the test holes are shown in figure 6. The thickness of the unconsolidated deposits drilled in these holes ranged from 92 to 305 feet. Geologic sections based on the logs of the test holes are shown in plate 2.

PHYSICAL AND HYDROLOGIC PROPERTIES OF THE ROCK MATERIALS

LABORATORY METHODS OF ANALYSIS

The samples obtained by use of hand auger and core barrel were analyzed for particle-size distribution and coefficient of permeability. The samples obtained by use of the drilling rig were analyzed for coefficient of permeability only.

From the hydrometer analysis and the sieve analysis, the percentage of the particles smaller than a given size were calculated and plotted as an accumulative distribution curve. The particle sizes, in millimeters, were plotted as abscissas on a logarithmic scale and the accumulative percentages of particles smaller than the size shown, by weight, as ordinates on an arithmetic scale. (See pl. 3.) The percentage in each of several size ranges was then determined from this curve.



EXPLANATION

11-8-17ba
o

Test hole and identification number

104,000

Coefficient of transmissibility of the saturated deposits, in gallons per day per foot

FIGURE 6.—Map of the vicinity of the Chapman area, Nebraska, showing the locations of the geologic sections based on test holes, and the estimated coefficients of transmissibility of the saturated deposits at the test-hole sites.

The analyses were divided into the following groups according to their particle sizes:

Description	*Diameter (mm)*
Gravel	>2. 0
Very coarse sand	1. 0–2. 0
Coarse sand	0. 5–1. 0
Medium sand	0. 25–0. 5
Fine sand	0. 125-0. 25
Very fine sand	0. 0625–0. 125
Silt	0. 004–0. 0625
Clay	<0. 004

This classification system is that used officially by the Ground Water Branch, U.S. Geological Survey, and is virtually the same as that proposed by the Sedimentation Subcommittee of the American Geophysical Union.

PERMEABILITY

Permeability is the capacity of rock or soil materials to transmit water under pressure. Permeability is usually expressed as a coefficient of permeability, defined as the number of gallons per day (gpd) that is conducted laterally through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60°F (Wenzel, 1942, p. 7). The field coefficient of permeability is the same except that it is not corrected for temperature.

Permeability may be determined in the laboratory by observing the rate of percolation through a sample of known length and cross-sectional area.

Coefficients of permeability ranging from 0.0001 to 30,000 gpd per sq ft have been determined in the laboratory. The value depends in general upon the degree of sorting and upon the arrangement and size of the particles. Generally, it is low for clay and other fine-grained or tightly cemented materials, and high for coarse, clean gravel.

Constant-head and variable-head methods are used in the laboratory for determining coefficients of permeability. Ordinarily, the constant-head method is used for samples of medium to high permeability and the variable-head method for samples of low permeability.

CHARACTERISTICS OF THE SURFICIAL SEDIMENTS

The surficial sediments sampled during this investigation represent the alluvium deposited along the Platte River and the Wood River—the Wood River is known locally as the North Channel of the Platte (fig. 1). Table 8 and the particle-size graphs (pl. 3) show that sediments of the shallow (less than 3 ft deep) alluvium consist principally of very fine to medium sand with varying amounts of clay, silt, coarse sand, and gravel. The sediments of the deep alluvium are principally medium to very coarse gravel with varying amounts of medium to very coarse sand and interbedded silt and clay.

The shallow alluvium becomes coarser both with depth and with distance down the valley. The permeability of sediments to 1 foot in depth is usually about 5 gpd per sq ft and that of sediments from a depth of 1–3 feet is about 300 gpd per sq ft. The average permeability of the upper 3 feet of sediments tends to increase downvalley, ranging from about 100 to 300 gpd per sq ft from west to east along the Platte River. The average permeability of the upper 3 feet of sediments along the North Channel of the Platte River tends to be greater than that of the sediments near the main channel of the Platte and in places is as much as 500 gpd per sq ft. The lowest average permeabilities (usually less than 30 gpd per sq ft) for the shallow sediments characterize a narrow band between the two channels, extending southwest to northeast through the approximate center of sec. 3, 25, and 35 of the area under study.

Laboratory analyses were run on samples from all but three auger holes. Those from which samples were not obtained were 12–7–30ac, 12–8–25ad, and 12–8–25bc. The results of the laboratory analyses are presented in table 9 and by means of the particle-size distribution graphs. (See pl. 3.)

The median particle diameter was determined from the particle-size distribution curves for all samples on which both particle-size and permeability analyses were completed. Median particle diameter and the corresponding coefficients of permeability of these samples were plotted on logarithmic graph paper to produce figure 7. The trend line shows that the permeability increases from 1 to 1,000 gpd per sq ft with an increase in median particle size from approximately 0.02–0.5 mm.

Figure 10 was then used to estimate the permeability of the various lithologic units logged for each shallow test hole in the study area. Table 8 presents the logs for each of these shallow test holes. The estimated permeability was then multiplied by the thickness of each lithologic unit to determine a "weighted permeability" for the unit. For each shallow test hole, the weighted permeabilities for all lithologic units to a depth of 3 feet were determined, added, and then divided by three. This procedure provided the data on the average permeability for the upper 3 feet of sediments as presented in table 9. The data in table 9 were then used to prepare a map of the study area

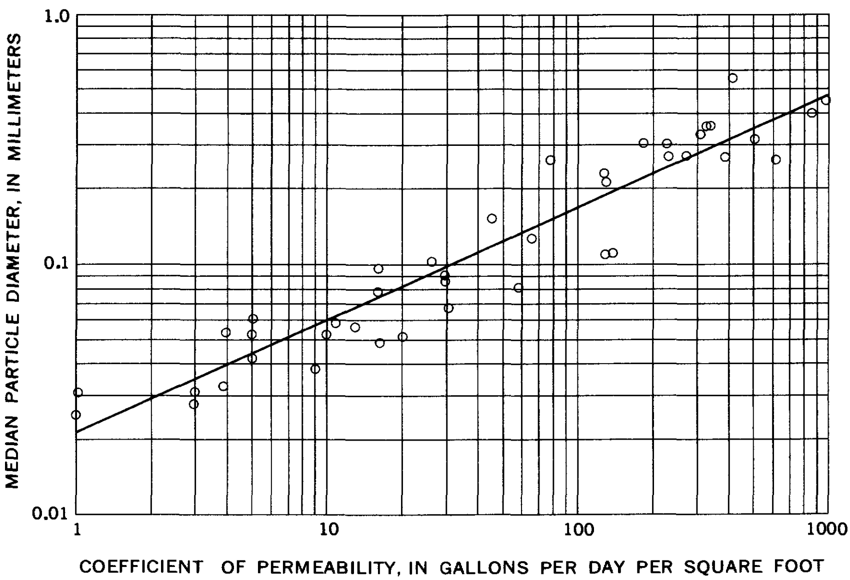


FIGURE 7.—Relation of permeability to median particle size of surficial sediments in the Chapman area, Nebraska.

(fig. 8) showing the range in permeability of the shallow alluvial sediments.

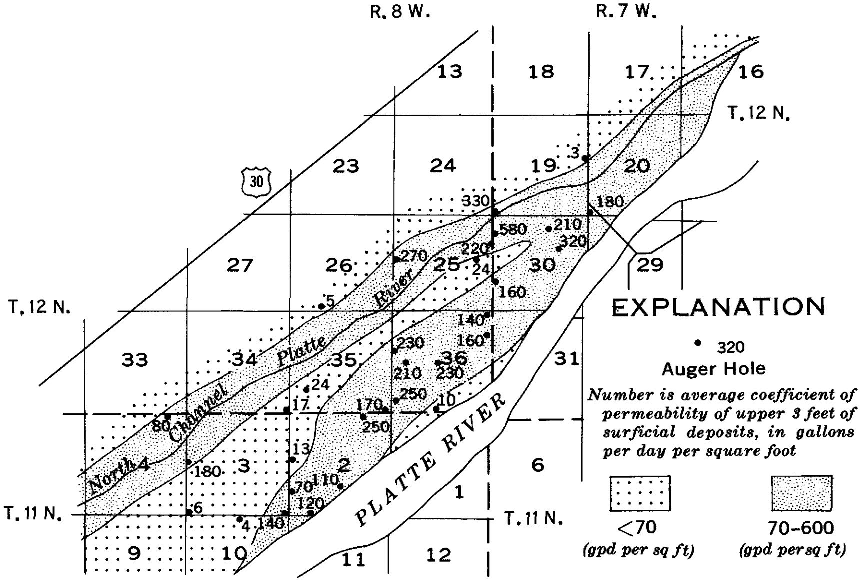


FIGURE 8.—Map of the Chapman area, Nebraska, showing the average coefficient of permeability of the upper 3 feet of alluvial sediments.

Analysis of the data indicates that the surface materials are so permeable that permanent ponds could not be maintained unless the bottoms were lined with impervious material or sealed with material which would greatly reduce the permeability. Some reduction in permeability could be expected if silt or sediment partly sealed the pond bottoms.

An estimated average inflow of more than 2,000 gpm (gallons per minute) would be required to maintain each square mile of pond area to balance the evaporation loss, which according to U.S. Weather Bureau records, averages about 64 inches. (See fig. 11.) A greater inflow would be required if vegetation was allowed to grow along the margin or in the ponds.

Evaporation losses would be greatest during the hot summer and, therefore, more inflow of water to the ponds would be required during the hot, dry periods.

CHARACTERISTICS OF THE WATER-BEARING MATERIALS

TRANSMISSIBILITY

Perhaps the most important hydrologic property of an aquifer is its ability to transmit water. The deposits of Pleistocene age which make up the aquifer are heterogeneous, the strata of clay, silt, sand, gravel, and combinations of these differing considerably in physical properties. All the saturated unconsolidated deposits beneath the Chapman area are considered to constitute a single aquifer. This aquifer is capable of transmitting a large volume of water. The coefficient of transmissibility, which is defined as the number of gallons per day transmitted through a strip of aquifer 1 mile wide and extending the height of the aquifer under a hydraulic gradient of 1 foot per mile, is a measure of the capacity of the aquifer to transmit water. The coefficient of transmissibility divided by the saturated thickness is the average permeability, in Meinzer unit, of the aquifer at the site of the test.

By means of an aquifer performance test, Wenzel (Lugn and Wenzel, 1938, p. 101–103) determined the transmissibility of the aquifer at testhole site 11–8–17ba to be about 100,000 gpd per ft. Nineteen samples of the aquifer at this site were obtained by means of test drilling. Testing in the laboratory of the Geological Survey indicated that their coefficients of permeability ranged from 2 to 4,350 gpd per sq ft and averaged 1,200. The average, however, as determined from the pumping test was 997.

As part of this study, two test holes were drilled to bedrock, and representative samples of the unconsolidated sediments were tested for permeability in the hydrologic laboratory at Denver, Colo. Test hole 12–8–27dd was drilled in the Platte River valley at the north edge of the proposed refuge area in Merrick County, and test hole 11–8–1dd was drilled in the upland just south of the area in Hamilton County. (See fig. 6.)

The 15 representative samples obtained from the zone of saturation penetrated in the drilling of test hole 12–8–27dd ranged in permeability from 380 to 2,400 gpd per sq ft, and the weighted average of the sample was 1,066 gpd per sq ft. (See table 1.) The saturated thickness is about 63.5 feet; thus, the coefficient of transmissibility is computed to be about 68,000 gpd per ft.

TABLE 1.—*Coefficient of permeability of water-bearing materials from test hole 12–8–27dd, Merrick County*

Depth (feet)		Coefficient of permeability (gpd per sq ft)	Depth (feet)		Coefficient of permeability (gpd per sq ft)
From	To		From	To	
3	3. 4	380	35	40	690
3. 4	5	1, 900	40	45	740
5	10	1, 200	45	50	880
10	15	890	50	55	1, 000
15	20	2, 400	55	60	890
20	25	1, 700	60	65	930
25	30	620	65	68. 5	720
30	35	1, 100			

Thirty-three samples were obtained from the saturated zone in test hole 11–8–1dd, and permeability tests were made in the laboratory. (See table 2.) These tests indicate that the transmissibility of the aquifer at this site is about 51,000 gpd per ft.

TABLE 2.—*Coefficient of permeability of water-bearing materials from test hole 11–8–1dd, Hamilton County*

Depth (feet)		Coefficient of permeability (gpd per sq ft)	Depth (feet)		Coefficient of permeability (gpd per sq ft)
From	To		From	To	
91	94	0. 5	150	155	220
94	95	. 2	155	160	1, 000
95	96. 5	. 8	160	165	560
96. 5	98. 5	. 1	165	170	550
98. 5	100	. 09	170	175	580
100	102. 8	. 2	175	180	420
102. 8	105	310	180	185	410
105	110	170	185	189	220
110	115	1, 800	189	191. 5	. 9
115	120	400	191. 5	194	2
120	125	920	194	197. 5	2
125	129. 5	320	197. 5	200	60
129. 5	131. 5	. 07	200	205	160
131. 5	135	130	205	210	140
135	140	200	210	213	480
140	145	640	213	215	. 04
145	150	950			

In previous studies of the Platte River valley sediments, four other test holes had been drilled to bedrock in the vicinity of the Chapman area. Visual examination of the samples from these tests was made by E. C. Reed, State Geologist of Nebraska, in the following manner—each lens or layer of material in a test hole was examined, classified, and assigned a coefficient of permeability within a range as follows:

Material	*Gallons per day per square foot*	*Material*	*Gallons per day per square foot*
Clay and silt	0–100	Sand, coarse	800–900
Sand, very fine, silty	100–300	Sand, very coarse	900–1, 000
Sand, fine to medium	300–400	Sand and gravel	1, 000–2, 000
Sand, medium	400–600	Gravel	2, 000–5, 000
Sand, medium to coarse	600–800		

After each lens or bed of material of similar texture was assigned a coefficient of permeability, each coefficient was multiplied by the thickness, in feet, of that material. This number was an estimate of the coefficient of transmissibility for that unit of material. Then the rounded sum of the coefficients of all saturated beds was considered to be the coefficient of transmissibility of the aquifer.

The estimated coefficients of transmissibility at the test holes are shown in figure 6.

The saturated deposits in the Chapman area decrease in transmissibility from southwest to northeast. The average coefficient of transmissibility of the aquifer in the area of the proposed refuge is probably about 65,000 gpd per ft and is sufficient to supply water to wells which, if properly constructed, would yield as much as 1,000 gpm.

SPECIFIC YIELD

The amount of water that can be stored in an aquifer depends on the porosity of the water-bearing rock material, and the proportion of the stored water in the saturated rock that will drain by gravity is expressed as its "specific yield." The specific yield of an aquifer is defined by Meinzer (1923, p. 28) as the ratio of the volume of water which the aquifer, after being saturated, will yield by gravity to its own volume. The average specific yield for the aquifer was determined at the site of test hole 11–8–17ba (Wenzel, 1942, p. 125) to be 20.1 percent; thus, under natural conditions, recharge of about 0.20 foot, or 2.4 inches, produces a rise in the water table of about 1 foot, conversely, a decline of the water table of 1 foot represents a loss of water equal to 2.4 inches.

GROUND WATER

PRINCIPLES OF OCCURRENCE

All water beneath the surface of the earth is termed "subsurface water." In most regions there is a zone, called the "zone of saturation," below the surface of the earth where the pores in the rocks are filled with water under hydrostatic pressure. The water in the zone of saturation is called "ground water," and the pressure surface, or that level at which water will stand in a well, is called the "water table."

On the north side of the Platte River in the Chapman area, the water table is near the land surface and ranges in depth from less than 1 foot to less than 10 feet. In general, the depth to water increases with the distance from the river. South of the Platte River in Hamilton County, the depth to water increases greatly as the valley limit is approached, and at some points, which are less than 1 mile from the river, the depth to water in wells is greater than 90 feet.

FLUCTUATIONS OF THE WATER TABLE

The water table beneath the Chapman area fluctuates in about the same way as does any surface-water impoundment; during some periods, the ground-water reservoir is replenished more rapidly than it is discharged and the water table rises; during other periods, withdrawals exceed the available recharge and the water table declines. The changes in water level in wells indicate the changes in storage to the ground-water reservoir, or the net differences in inflow and outflow.

Precipitation that filters through the soil to the water table, seepage from the Platte when the stage of the river is higher than the adjacent water table, and underflow from the southwest cause the water table to rise when the total amount of recharge from these sources exceeds the discharge from the aquifer.

Discharge of water from the ground-water reservoir by evaporation, transpiration by growing vegetation, pumping from wells, outflow into the Platte River, and underflow into adjacent areas depletes the ground-water storage and causes a decline of the water table when it exceeds the total recharge. The rate and magnitude of the fluctuations of the water table are governed by the rate and magnitude at which the ground-water reservoir is replenished or depleted.

Hydrographs of the observed fluctuations of water levels in the wells are shown in plate 3 and figures 7 and 8. Where the water table is deep, southeast of the proposed refuge area, it does not respond to precipitation, evaporation, and stage of the Platte River nearly so sharply as it does in the shallow-water area; however, the water table beneath the upland does fluctuate in response to pumping from irrigation wells. Figure 9 shows, for the period of record, the range of fluctuation of the water table along a section drawn approximately normal to the river.

In the proposed wildlife refuge area, except for a few irrigation wells, the wells are generally of small yield, and the total amount of water withdrawn by them is not enough to affect the regional water table significantly; thus, the fluctuations of the water table generally correlate with variations in the climatic factors of precipitation, temperature, and evaporation and with changes in the stage of the water in the Platte River and the North Channel of the Platte River.

As part of this investigation, 47 wells were visited periodically to observe water-level fluctuations; most of the wells were visited once each month. One well was equipped with a recording gage which continuously recorded the water-level fluctuations. The locations of the observation wells are shown in plate 5, and pertinent information concerning them is given in table 10.

FLUCTUATIONS CAUSED BY PRECIPITATION

The water table in the Chapman area is shallow, and the soils are so permeable that rainfall easily seeps down through them to the zone of saturation; thus, the water table rapidly responds to recharge from precipitation.

Evidence that water levels rise sharply after a heavy rain is indicated by the hydrographs of water levels of wells in the shallow-water

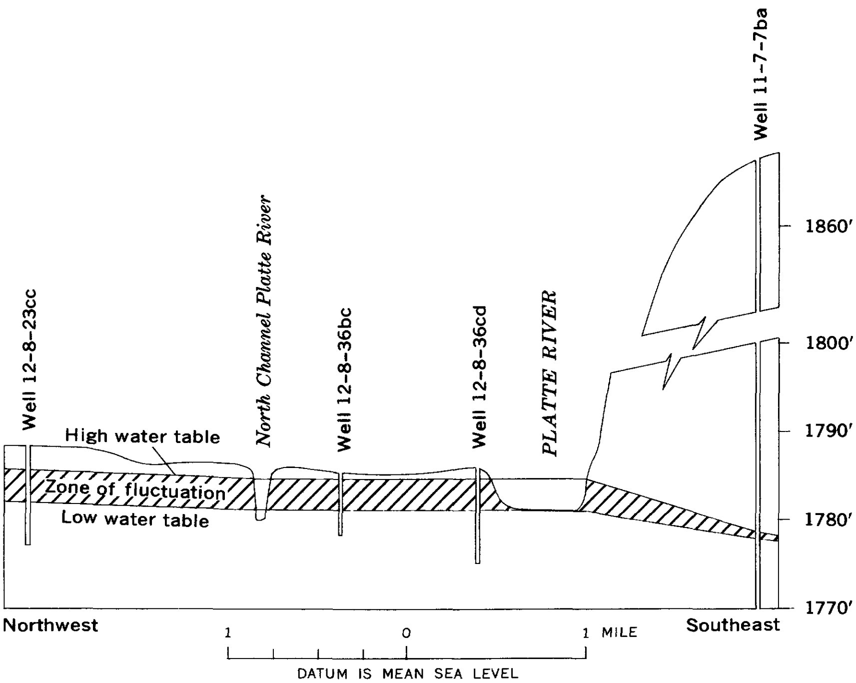


FIGURE 9.—Profiles of the water table across the Chapman area, Nebraska, showing the range of fluctuation during the period of August 1958 to June 1960.

area (pl. 4). Water levels in the wells were observed July 23, 1958, prior to a 1.5-inch rainfall that occurred July 24. Immediately following the rain on July 24, water levels in the wells were observed to have risen from a few inches in some to more than 1½ feet in others. On August 1, the wells were revisited and water levels were noted to be at about the level they were prior to the heavy rainfall.

FLUCTUATIONS CAUSED BY EVAPOTRANSPIRATION

The water table also fluctuates as the result of the discharge of ground water by evapotranspiration. Growing plants may absorb large quantities of water directly from the zone of saturation or from the capillary fringe and discharge it into the atmopshere by transpiration. The amount of water transpired at any given time depends primarily on the temperature and relative humidity. During hot, dry summer days much water is used; but at night or during cloudy days when the relative humidity is high, only a very small amount of water is transpired.

FLUCTUATIONS CAUSED BY THE PLATTE RIVER

The water table tends to fluctuate in response to the rise or fall of the stage of the river because the aquifer beneath the proposed refuge area has excellent hydraulic connection with the river. When the stage of the Platte River rises above the ground-water level at its banks, water percolates out of the river and into the ground until the adjacent water table is raised to a level corresponding approximately to the level of the stream. Conversely, when the stage of the river is lower than the adjacent water table, water percolates back to the river and the water table declines.

RELATION OF FLUCTUATIONS TO RECHARGE AND DISCHARGE

Under natural conditions, there is a long-term balance between recharge and discharge. If the factors of recharge and discharge were to act continuously on the aquifer at their average intensity, the amount of water in storage would not change and the water table would remain constant. Actually, however, the rates of recharge and discharge vary with changes in the weather. Because the position of the water table is regulated by the amount of water stored in the aquifer, which changes with effects related to the weather, a single-line curve expressing the combined effects of those changes in the weather should be similar to a graph of concurrent water-table fluctuations.

The principal climatic factors that affect the recharge-discharge relationships are precipitation and evapotranspiration. In the Chapman area, recharge is closely related to the amount of infiltration, and discharge is governed principally by the rate of evapotranspiration.

The total annual precipitation in the Chapman area is about 40 percent of the total annual potential evaporation, based on 15 years of precipitation records by the U.S. Weather Bureau at Grand Island and evaporation records from the nearest class A pan at Rosemont, Nebr. During the winter, when the pan was not in operation, evaporation was estimated.

If the evaporation were 100 percent effective, all precipitation would be evaporated; but because during periods of precipitation the evaporation rate is low, some of the precipitation is available for recharge to the ground-water reservoir. It was found that a graph (fig. 10) of the cumulative precipitation minus the apparent effective evaporation (40 percent of the actual) would show fluctuations that are similar to those of a shallow water table. In order to make a comparison with the average fluctuating water table, as observed in 43 wells, the precipitation received during the period between well measurements was totaled; from this total, 40 percent of the recorded evaporation was subtracted. These totals for each period were cumulated and plotted to obtain points on the graph. If the shallow water-table fluctuation deviates significantly from this graph, the

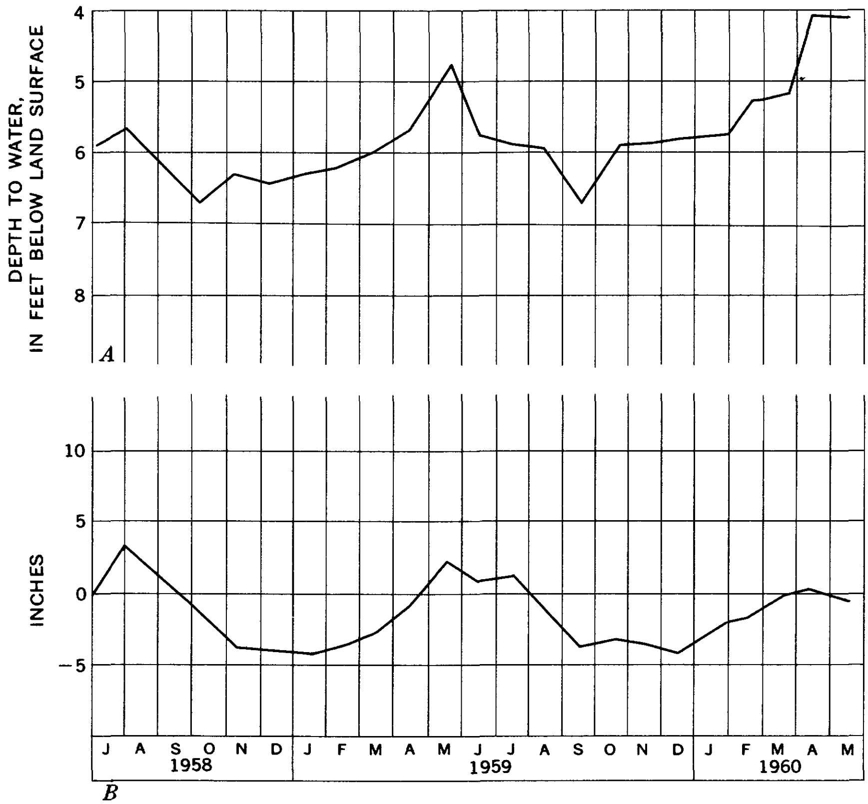


FIGURE 10.—*A*, Graph showing average water levels in 43 wells in the Chapman area; *B*, Graph showing cumulative precipitation at Grand Island minus 40 percent of the evaporation from the class A pan at Rosemont.

deviation is probably caused by recharge to or discharge and (or) withdrawal from the ground-water reservoir by other than climatic factors—such as discharge from heavy pumping during the irrigation season.

Thus, by comparing the two graphs, the effect of artificial withdrawals of ground water on the ground-water reservoir can be seen. The close conformity of the two graphs indicates that in the Chapman area the present withdrawals of ground water for irrigation have very little influence on the position of the water table.

The water-level hydrograph showed a rise that was considerably more than the corresponding rise in the precipitation evaporation graph for the period February to May 1960. This recharge was probably caused by the melting of the heavy accumulation of snow that covered the area during the winter of 1959–60.

RATE AND DIRECTION OF MOVEMENT OF GROUND WATER

The rate of movement of ground water depends on two factors—the permeability of the water-bearing medium and the slope, or gradient, of the water table. In saturated sand and gravel, the water is contained in the voids between the grains of rock. Obviously, if water is to move through sand and gravel, the voids must be interconnected and there must be a different hydrostatic pressure from one void to the next to cause the water to move. The water table in the Chapman area has a gradient of only 7 feet per mile, or about 1.6 inches per 100 feet; therefore, the pressure differential that causes the water to move is small and therefore, the ground water moves very slowly. Lugn and Wenzel (1938, p. 136) computed the velocity of the ground-water movement to be 0.63 foot per day, or about 230 feet per year.

The configuration of the water table is shown in plate 5. Two sets of contours based on altitudes of water levels in 48 wells are shown. One set shows the highest stage of the water table and the other shows the lowest stage for the period July 1958 to June 1960. The water table was lowest during the fall of 1959 and highest in April 1960. North of the Platte River, the direction of movement of the ground water and the rate of slope of the water table were virtually the same at both stages. South of the river, however, the direction and slope differed with the two stages. The slope was greater and the angle of direction away from the river was greatest at the high stage of the water table.

The water table north of the Platte River slopes rather uniformly, northeastward, as does the gradient of the river, at about 6.7 feet per mile, a fact indicating that the ground water in the valley is virtually in equilibrium with the river and therefore is not receiving an appreciable amount of recharge from the river. South of the river, the water table slopes southward rather abruptly, a fact indicating that some ground-water percolation probably occurs under the uplands of Hamilton County from the Platte River valley. This underflow must originate from the Platte River. Figure 9, which shows profiles of the water table across the Chapman area, portrays how the water table slopes from the river to the southeast at both high and low stages of the water table.

DEPTH TO WATER

The depth to water in the Chapman area is generally less than 5 feet when the water table is at high stages and is not greater than 10 feet at low stages. The depth to water increases abruptly on the south side of the river as the valley limit is approached, however. The depth to water in the area does not seem to have been increased as the result of pumping of ground water or irrigation, even though ground water has been used for irrigation in the Chapman vicinity for more than 30 years.

GROUND-WATER DISCHARGE

Ground water is discharged from the Chapman area by wells, plants, evaporation, streams, and underflow. The rate at which it is withdrawn from the zone of saturation varies with many factors, but especially with the stage of the water table and with the season of the year. Water is discharged from irrigation wells only during periods of prolonged dry weather. Transpiration by plants, which is the principal discharging agent, occurs throughout the growing season but is greatest during hot, dry weather. Evaporation of water directly from the zone of saturation probably occurs from the dry bed of the Platte River and in the areas where the water table is within a few inches of the land surface. Discharge by seepage into the river probably occurs during and after periods of precipitation, and ground water moves as underflow out of and into the area at about the same rate.

WELLS

DOMESTIC SUPPLIES

All the residents of the area obtain their domestic water supplies from small wells. Most of these wells yield only a few gallons per minute at intervals when the water is needed, and the total amount of water pumped for rural use is small.

IRRIGATION SUPPLIES

Most farmers in the Chapman area pump water from one or more irrigation wells. Only seven wells, however, are inside the boundaries of the proposed wildlife refuge because in most of this area the water table is so close to the surface that irrigation is not required. A canvass was made in the spring of 1960 of the irrigation wells that were within about a mile of the proposed refuge. The locations of the wells are shown on plate 6, and pertinent data about them is given in the table of well records (table 10). Wells at a greater distance than 1 mile from the proposed refuge area would probably not in any event be affected by the proposed development.

The annual pumpage for irrigation in the vicinity of the Chapman area varies with the effective precipitation. Because the water table is generally close to the surface and crops are subirrigated, pumps are idle except during extremely dry summer weather. No doubt much of the water spread on the land seeps back to the water table because the soils are very porous. Evidence of much seepage loss is apparent because several days of pumping are required to spread water over a moderately large field.

TRANSPIRATION AND EVAPORATION

The water table is very close to the surface in the area proposed for the wildlife refuge. Its average depth below the land surface is only about 5 feet, and the maximum depth is about 10 feet. Most plants growing in the area receive part or all their water requirement from the ground-water supply. Much of the land is not cultivated but supports a luxuriant growth of native plants that are used for pasture or are harvested for hay. Many of these plants obtain their water supply from the zone of saturation, and throughout the growing season they transpire ground water into the atmosphere. The quantity transpired varies with many factors, some of which are the species of plants, the density of growth, the amount of sunlight, heat, wind, humidity, rainfall, and depth to water. The amount of water transpired in the area of the proposed refuge may be almost as much as that which would be evaporated from a free water surface of equal size.

As part of an investigation of phreatophytes in Western United States, Robinson (1948a, p. 59) found that a comparison of evapotranspiration and evaporation rates, as determined from U.S. Weather Bureau class A pans, showed that evaporation was always greater. For example, the water table at a depth of 1 foot lost water at a rate of 68–75 percent of pan evaporation, and for depths greater than 1 foot the loss decreased correspondingly. Robinson concluded, however, that more study was required to define the ratio of transpiration to evaporation.

The Weather Bureau reports observations of the evaporation rate during the growing season for several points in Nebraska. The nearest pan to the Chapman area is about 40 miles south and is maintained by the U.S. Department of Agriculture in the upland at Rosemont, Nebr. Figure 11 shows by bargraphs the amount of precipitation received at the station and the amount of evaporation from a class A pan.

The graphs show that in years of least precipitation the evaporation is greatest and that the evaporation in the years of average precipitation is greatest in summer, when the average temperature is highest and the precipitation normally declines. Thus, in a shallow-water area, water loss by evapotranspiration is greatest when the evaporation rate is high.

The total evaporation from the pan during the period of April to October 1959 was 63.30 inches.

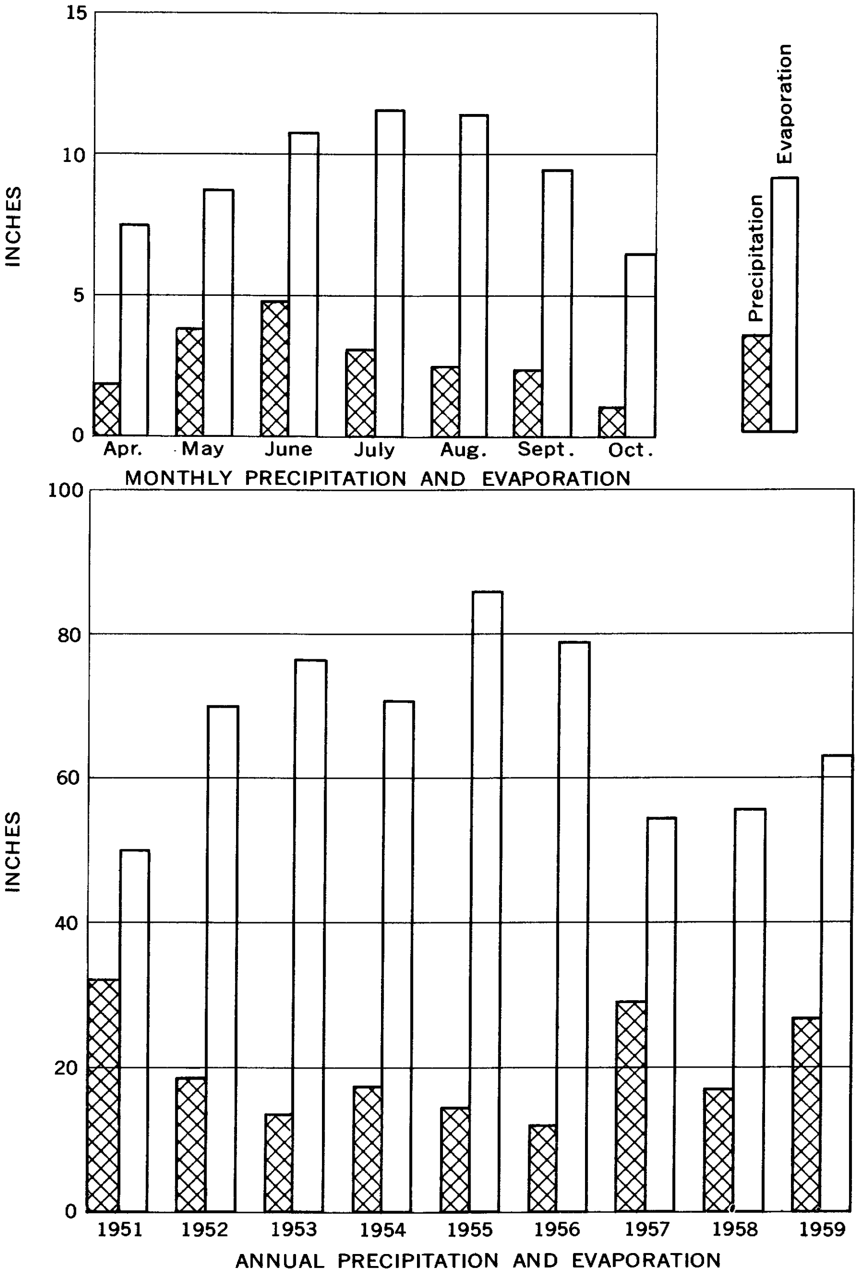


FIGURE 11.—Average monthly precipitation and evaporation for the period 1945–59 and annual precipitation and evaporation for the period 1951–59. (From records of the U.S. Department of Agriculture at Rosemont, Nebr.).

The rate of evaporation for a natural free water surface is generally slower than the rate indicated by a class A pan. Kohler (1952), as part of water-loss investigations at Lake Hefner, Okla., investigated the reliability of pan coefficients for estimating lake evaporation. He listed a summary of coefficients for class A pans derived in 44 past tests. These coefficients range from 0.60 to 0.97, and the studies at Lake Hefner indicated an annual coefficient of 0.69 between the class A pan and the lake.

If it is assumed that this holds true in the Chapman area, then the amount of water evaporated from pond or reservoir probably would be only slightly greater than the amount transpired from a dense growth of phreatophytes growing in a shallow-water area of equal size.

In addition to the loss of water by transpiration, a considerable amount of moisture is lost in the Chapman area by direct evaporation. Because the slope of the water table in the valley is virtually parallel

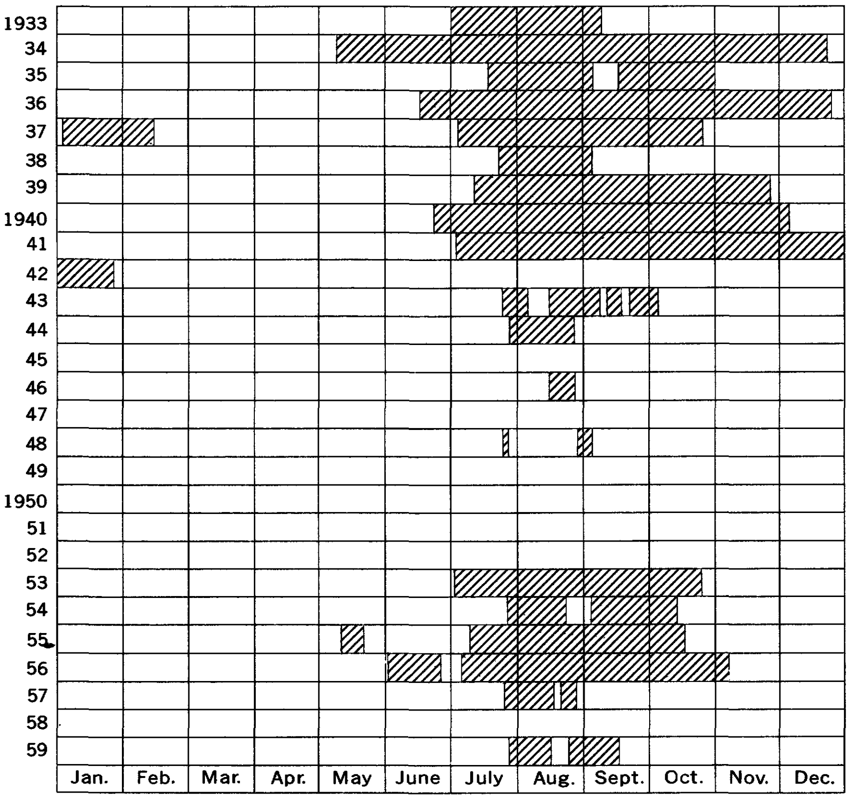


FIGURE 12.—Chart showing the periods of zero flow in the Platte River at Grand Island, Nebr., 1933–59.

to the gradient of the Platte River, fluctuations of the water table or changes in river stage cause the Platte River to become either a losing or gaining stream. When the Platte River is dry, as it is much of the time (fig. 12), the rate of evaporation from its bed is not as rapid as from the free water surface when the river is flowing; however, Wenzel (Lugn and Wenzel, 1938, p. 153) found that the amount of evaporation may be considerable. He computed, by analysis of the fluctuation of the water level in a well in the dry bed of the Platte River, that the evaporation from the riverbed amounted to about 26 percent of the rate of evaporation from a free water surface. Wenzel also pointed out that the high evapotranspiration loss near the Platte River is indicated by the action of the river during summer. On cloudy days the stream, if it has been dry, will sometimes start to flow or, if flowing, will increase its discharge, owing to the difference in rate of evapotranspiration

In the Chapman area, the net loss or gain in ground-water storage is controlled principally by the factors of precipitation and evaporation. Because the soil is highly permeable, recharge from precipitation occurs readily and effectively; however, because the water table is so near the surface, the rate of discharge of ground water is determined to a large extent by the effective evaporation.

Pumping of water for spreading on the land, either for irrigation or for ponds, would probably not materially change the aforementioned relations. However, if water-table ponds were developed a larger area of free water surface would be exposed to the atmosphere, and the amount of evaporation would probably be slightly greater than from areas of equal size supporting phreatophytes.

The water that seeps into the river from the adjacent ground-water reservoirs, however, represents part of the discharge that leaves the area naturally; thus, whether this water evaporates as soon as it becomes part of the river or discharges downstream is not of importance to the area. If water is to be conserved for use in the area, it must be withheld or withdrawn to the degree that the natural discharge is reduced. This balance can only be accomplished if the water table is lowered to below the reach of phreatophytes or if the gradient toward points of natural discharge is reduced.

CHEMICAL QUALITY OF THE WATER

By P. G. Rosene

Water from 13 observation wells, ranging in depth from 9.4 to 17.8 feet, was sampled in April 1960; and water from 3 irrigation wells, ranging in depth from 63 to 72 feet, was sampled in June 1961. The water was analyzed in the U.S. Geological Survey Laboratory at Lincoln, Nebr., according to methods described by Rainwater and Thatcher (1960), and results of the analyses are given in table 3.

CHEMICAL COMPOSITION OF THE WATER

The concentrations of dissolved solids in water from the observation wells were relatively diverse and ranged from 225 to 913 ppm (parts per million); however, those in water from irrigation wells were relatively uniform and ranged from 339 to 447 ppm. Generally, the water north of the Wood River had less than 500 ppm of dissolved solids, and the water south of the Wood River had more than 500 ppm.

The water having the lowest dissolved solids contained mostly

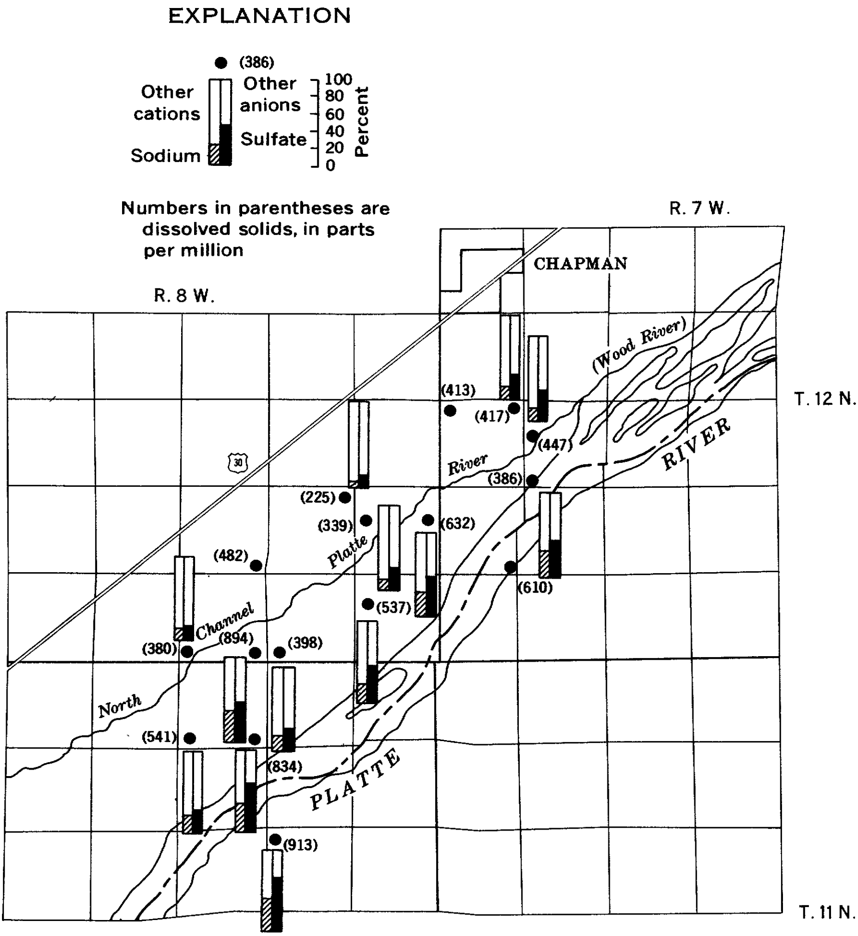


FIGURE 13.—Sodium and sulfate contents in relation to distance from the Platte River.

TABLE 3.—*Chemical analyses of ground water*

[Use: O, observation; Irr., irrigation. Results in parts per million except as indicated]

Location	Date of collection	Well depth (feet)	Use	Temperature (° F.)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
	1960											
11-8-3ccl	Apr. 13	10.6	O	---	18	0.03	0.00	110	27	36	6.9	376
3dd	do	9.4	O	42	18	.13	.09	112	27	108	7.9	254
14bb	Apr. 12	10.5	O	51	23	6.3	.36	113	27	131	7.2	236
12-7-19aal	do	17.0	O	49	22	.03	.01	74	23	22	14	260
19bb	do	10.5	O	45	---	.03	.01	67	20	28	---	215
	1961											
20bc	June 28 [1]	65	Irr.	52	25	.04	.00	85	19	27	5.3	240
	1960											
20cc	Apr. 12	10.6	O	39	18	.04	.00	56	15	43	6.4	178
30dd	do	17.8	O	53	---	.14	1.3	82	22	76	---	226
12-8-25ad	do [2]	10.5	O	47	21	.03	3.8	104	25	62	5.8	275
	1961											
25bc	June 28 [3]	63	Irr.	53	29	.03	.00	69	13	19	5.0	222
	1960											
26aa	Apr. 12	10.5	O	41	13	.03	.01	49	16	6.4	2.3	196
27ddl	Apr. 13	16.0	O	49	---	.02	.01	72	40	30	---	296
34cc	do	10.5	O	45	25	.03	.00	75	15	18	11	244
34ddl	do [4]	10.5	O	45	21	.03	.00	123	33	120	12	398
	1961											
35cc	June 28 [5]	72	Irr.	52	23	.03	.00	79	15	29	4.8	255
	1960											
36bc2	Apr. 13	10.5	O	46	19	1.2	.45	89	19	57	4.1	254

Location	Date of collection	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos per cm at 25° C)	pH
	1960												
11-8-3ccl	Apr. 13	109	13	1.6	36	0.08	541	386	78	17	0.8	839	7.2
3dd	do	365	37	.8	1.3	.05	834	390	182	37	2.4	1,170	7.2
14bb	Apr. 12	423	39	.8	.2	.10	913	395	201	41	2.9	1,260	6.8
12-7-19aal	do	79	7.3	1.6	42	.08	417	278	65	14	.6	642	7.1
19bb	do						413	250	74	20	.8	614	7.2
	1961												
20bc	June 28[1]	123	4.0	.9	27	.06	[1] 447	292	95	16	.7	658	7.1
	1960												
20cc	Apr. 12	132	14	.6	.2	.09	386	201	55	31	1.3	583	7.3
30dd	do						[2] 610	296	111	36	1.9	890	7.2
12-8-25ad	do[2]	239	21	.4	.5	.04	632	364	138	27	1.4	916	7.1
	1961												
25bc	June 28[3]	67	7.9	.4	13	.05	[3] 339	227	45	15	.6	518	7.1
	1960												
26aa	Apr. 12	27	.3	1.3	8.8	.05	225	187	26	7	.2	380	7.2
27ddl	Apr. 13						482	342	99	16	.7	748	7.0
34cc	do	45	16	.5	40	.08	380	250	50	13	.5	579	7.0
34ddl	do[4]	300	17	.7	63	.07	[4] 894	444	118	36	2.5	1,270	7.0
	1961												
35cc	June 28[5]	81	12	.3	20	.05	[5] 398	260	51	19	.8	613	7.4
	1960												
36bc2	Apr. 13	191	17	.4	.1	.05	537	302	94	29	1.4	794	7.1

[1] Zinc (Zn), 1.5 ppm.
[2] Copper (Cu), 0.01 ppm; zinc (Zn), 0.14 ppm.
[3] Zinc (Zn), 0.09 ppm.
[4] Copper (Cu), 0.01 ppm; zinc (Zn), 0.11 ppm.
[5] Zinc (Zn), 0.02 ppm.

calcium and bicarbonate, and the water having the highest dissolved solids contained mostly sodium and sulfate. The percentages of sodium and sulfate, computed from concentrations in equivalents per million, seem to correlate with distance to the Platte River; the highest percentages are in water near the river. (See fig. 13.)

Why the water from the shallow wells differs as it does in dissolved solids and in percentages of sodium and sulfate is uncertain. Part of the variation in dissolved-solids content may be due to local differences in rock types and soils through which the water has percolated or with which the water was in contact and part may be due to local differences in rate of evapotranspiration caused by differences in soil texture and in type and density of vegetation; higher rates of evapotranspiration may cause the dissolved solids that remain in the water to increase in concentration more in some places than in others.

Perhaps the most significant influence on the chemical composition of the ground water is exerted by the surface water of the area. When the surface of the water in the stream is low, ground water moves toward the river and feeds the streams. Conversely, when the surface of the water in the stream is high, water from the river moves into the ground-water reservoir. Consequently, if the chemical quality of streamflow differs significantly from that of the ground water, the chemical quality of the ground water is affected.

The chemical quality of water from the Wood and Platte Rivers is indicated in table 4. Water from the Wood River has a low dissolved-solids content consisting principally of calcium and bicarbonate at all rates of flow. It is similar in chemical quality to the ground water nearby; therefore, the effects of water from the Wood River on the quality of ground water are not significant. Water from the Platte River, however, is relatively high in dissolved solids, which most of the time consist predominantly of sodium and sulfate. Movement of water from the Platte River into the ground-water reservoir increases the dissolved solids and the percentages of sodium and sulfate in the ground water.

Data from two adjacent wells indicate poor vertical mixing in some places between the waters supplying the deep and the shallow wells; the water from shallow well 12–8–34dd1 contained 894 ppm of dissolved solids, which consisted approximately of equal concentrations, in equivalents per million, of calcium, sodium, bicarbonate, and sulfate, whereas the water from deep well 12–8–35cc contained 398 ppm of dissolved solids, which consisted mostly of calcium and bicarbonate. Residents of the area indicated that a "blue clay" layer lies between the two sand and gravel aquifers which supply the deep and shallow wells; this layer may prevent or retard vertical mixing of the waters. The layer evidently is not uniform throughout the report area according to data from wells 12-7-19aa1, 12-7-20bc, and 12-7-20cc; although two of the wells are shallow and one is deep, the water from all three wells contains nearly the same amount of dissolved solids.

WATER QUALITY IN RELATION TO USE

At present the ground water is used for domestic and stock supply and for irrigation. The chemical quality of water for domestic use commonly is evaluated by reference to the drinking-water standards of the U.S. Public Health Service (1962) given, in part, as follows:

Constituent	*Maximum concentration (ppm)*	*Constituent*	*Maximum concentration (ppm)*
Copper (Cu)	1.0	Chloride (Cl)	250
Iron (Fe)	.3	Fluoride (F)	[1] 1.3
Manganese (Mn)	.05	Nitrate (NO_3)	45
Zinc (Zn)	5.0	Dissolved solids	500
Sulfate (SO_4)	250		

[1] Varies for different parts of the United States.

Water from several wells had much more iron, manganese, or dissolved solids than allowed by the standards and slightly more sulfate, fluoride, and nitrate. Of the constituents in excess of the standards, nitrate is probably the most significant because in high concentrations it indicates the possibility of pollution in the water. Also, it may cause a form of "blue-baby" disease known as methemoglobinemia in some infants to whom the water is fed. The water from all wells is very hard.

The water is of good quality for irrigation. Evaluation of the water according to the criteria of the U.S. Salinity Laboratory Staff (1954, p. 69-82) indicates that the water has a medium to high salinity hazard, a low sodium hazard, little or no residual sodium carbonate, and low concentrations of boron. However, much of the report area has such a high water table that irrigation is unnecessary.

The relatively high concentrations of nitrate, which adversely affect the quality of the water for drinking, enhance the quality of the water for irrigation. Because the nitrogen in the nitrate is readily available for plant use, less nitrogen needs to be applied as fertilizers in crop production. Much of the nitrate in the ground water and in the surface water is probably due to nitrogen fertilizers applied in previous years to cultivated soils. Because nitrate salts are generally very soluble and because the water table is near the land surface, the nitrate could easily be transferred to the ground water.

Much of the water for the proposed waterfowl refuge would probably be from the Wood River. The chemical quality of water from the Wood River is generally good. (See table 4.) The river however, carries sewage from Grand Island that has undergone secondary treatment and, at times, untreated sugar-beet wastes. Thus, problems of

TABLE 4.—*Chemical analyses of surface waters*

[Results in parts per million except as indicated]

Date of collection	Discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation at 180 °C)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos per cm at 25 °C)	pH
Platte River near Grand Island																						
Nov. 5, 1945	------	------	18	0.09	------	67	23	78	11	216	220	25	0.5	0.6	0.06	560	262	84	38	------	836	7.7
Dec. 11, 1950	1,350	------	26	.04	------	79	22	99		262	235	28	.5	2.0	.10	622	286	71	43	------	916	7.8
Mar. 12, 1951	1,000	------	28	.02	------	91	22	100		275	254	28	.5	2.5	.15	684	316	90	41	------	967	8.0
June 11	2,130	------	26	.02	------	70	19	77		242	180	22	.4	2.1	.17	534	253	55	40	------	776	7.6
Nov. 13	1,720	------	------	------	------	------	------	------	------	234	190	23	------	------	------	------	252	60	40	2.2	795	7.9
Feb. 11, 1952	4,790	------	25	------	------	65	18	73		221	175	21	------	------	------	500	234	53	40	2.1	745	7.7
June 20	[1] 600	------	------	------	------	------	------	------	------	226	235	------	------	------	.16	------	260	75	------	------	888	8.1
Aug. 27	[1] 250	86	------	------	------	------	------	------	------	[2] 194	251	------	------	------	.14	------	240	81	------	------	885	8.4
Mar. 30, 1957	985	46	23	------	------	------	------	69		214	160	20	.6	.1	------	------	222	47	40	2.0	707	7.8
Oct. 25, 1959	------	------	22	.00	------	61	19	75	12	223	181	22	.5	.4	.18	513	231	48	40	2.1	772	7.6

Wood River near Chapman

Sept. 20, 1957	12.2	---	25	0.01	---	51	9.5	26	13	186	59	17	0.4	4.5	0.07	296	166	13	24	0.9	474	7.4
Dec. 17	18	52	31	.17	---	75	13	36	41	388	58	2.7	.4	.2	.13	441	240	0	21	1.0	806	7.6
Mar. 19, 1958	10	57	27	.01	---	58	13	32	11	190	58	20	.5	36	.12	363	196	40	25	1.0	548	7.0
June 10	[3] 17	76	28	.02	---	62	13	33	12	212	75	20	.5	11	.14	373	210	36	24	1.0	591	7.3
July 23	452	79	17	.05	---	17	3.3	3.0	12	69	12	.4	.4	4.0	.09	102	56	0	8	.2	158	6.8
Nov. 10	21	51	29	.15	---	70	12	28	22	308	41	19	.4	.2	.10	370	225	0	19	.8	647	7.2
June 26, 1959	[3] 2	82	---	---	---	---	---	30	---	220	79	---	---	---	---	---	230	50	22	.9	594	7.3
Sept. 22	13	73	28	.02	---	77	13	41	14	226	93	30	.4	30	.15	458	244	59	25	1.1	688	7.1
Nov. 12	18	50	31	.36	---	69	13	31	25	227	76	20	.4	31	.12	405	226	40	21	.9	654	7.7
Mar. 1, 1960	12	42	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	628	---
Mar. 30	580	51	12	.96	---	19	2.1	3.3	13	72	13	.1	.2	1.7	.06	131	56	0	9	.2	167	6.5
Apr. 13	50	58	25	.58	0.03	77	16	32	11	224	114	19	.4	16	.07	432	258	74	20	.9	649	7.0
June 14	760	68	20	.52	---	38	7.8	11	13	116	58	4.5	.3	5.6	.06	239	127	32	14	.4	339	7.0
Sept. 14	10	---	31	.08	---	71	13	34	10	208	88	24	.4	30	.23	450	232	61	23	1.0	621	7.1
Dec. 14 [4]	---	---	30	.15	.00	81	12	44	82	327	71	33	.5	87	.14	612	251	0	21	1.2	915	7.1
Mar. 21, 1961 [5]	---	---	29	.03	.08	65	15	37	13	234	75	24	.5	35	.17	412	223	31	25	1.1	642	7.0
June 28 [6]	[3] 22	89	28	.01	.01	70	14	28	10	220	84	16	.5	14	.09	387	232	52	20	.8	577	7.4
June 29 [7]	[3] 21	78	28	.01	.01	70	13	28	10	212	84	16	.5	16	.09	383	226	52	20	.8	576	7.1

[1] Daily mean discharge.
[2] Incl·des equivalent of 6 ppm carbonate (CO_3).
[3] Estimated.
[4] Copper (Cu), 0.06 ppm; zinc (Zn), 0.96 ppm.
[5] Copper (Cu), 0.10 ppm; zinc (Zn), 0.06 ppm.
[6] Zinc (Zn), 0.04; dissolved oxygen, 4.4 ppm.
[7] Zinc (Zn), 0.03 ppm; dissolved oxygen, 4.0 ppm.

water quality that might arise in the proposed refuge are more likely to be associated with the organic content than with the inorganic content of the water.

Little information could be found how the water quality relates directly to the propagation and growth of waterfowl. Probably, highly saline water can cause physiological effects of varying degrees of severity from mild gastrointestinal disturbances to death. Such effects however, are not likely to occur in the Chapman area because the dissolved-solids content of the water is too low. According to standards in use in Australia, poultry can safely consume water having less than about 3,000 ppm of dissolved solids (California Institute of Technology, 1957, p. 154).

Water quality may be indirectly important in the proposed waterfowl refuge. The growth and development of plants and animals on which some of the fowl will depend for shelter or food may be influenced by the chemical quality of the water.

In other areas, untreated sugar-beet wastes like those present at times in the Wood River, have caused mass killing of fish, inhibited growth of diatoms, stimulated growth of sewage fungus, and destroyed normal benthonic organisms (California Institute of Technology, 1957, p. 189). The lethal effect was attributed to a combination of the deoxygenating effect of the BOD (biochemical oxygen demand) and the toxicity of beet saponin, which is a group of glucosides characterized by their property of producing a soapy lather. The beet-processing season is in the fall and lasts from 30 to 90 days. The hazard from the beet wastes could be greatly reduced or eliminated if diversion from the river could be reduced or stopped during this period.

If a varied fish population is to be maintained in good condition, the dissolved-oxygen concentration of water should be 5.0 ppm or more. The minimum concentration at which fish can survive varies with the species, length of time the shortage of oxygen occurs, temperature of the water, and other factors; but, under average conditions, 3.0 ppm or less should be considered hazardous or lethal (California Institute of Technology, 1957, p. 244). The concentrations of dissolved oxygen in Wood River near Chapman are given in table 5. Most of the time dissolved oxygen is about 5 ppm or more, and thus the BOD caused by sewage in the water is not excessive. However, during October, November, and December, which is the sugar-beet season, the dissolved oxygen is at times entirely depleted.

According to the California Institute of Technology (1957, p. 230, 407), zinc and copper are particularly toxic to fish and other forms of aquatic life. Calcium, however, seems to counteract the toxicity of zinc; reportedly, the lethal dose for some mature fish is 2.0 ppm in

TABLE 5.—*Chemical and physical data for Wood River near Chapman*

[Data compiled by Bureau of Sport Fisheries and Wildlife]

Date of collection	Discharge (cfs)	Temperature (°F)	Dissolved oxygen (ppm)	pH
1957				
Aug. 8	------	75	7.1	7.8
Sept. 25	------	73	5.3	7.5
Oct. 9	11	55	.5	7.5
Oct. 16	------	------	.0	7.5
Nov. 12	------	54	.0	7.5
Dec. 19	12.6	52	1.2	7.3
1958				
Jan. 3	5.25	36	9.5	8.5
Feb. 3	5.40	39	12.8	8.3
Mar. 6	6.95	46	14.0	7.8
Apr. 2	83.0	48	11.1	7.8
Apr. 24	17.5	57	9.3	7.7
May 5	11.4	72	12.7	8.2
May 22	12.6	73	10.2	7.8
June 5	21.5	66	5.5	7.8
June 19	53.0	75	7.3	7.8
July 2	11.1	83	7.4	7.8
Aug. 8	17.5	82	9.3	7.8
Sept. 9	9.2	81	8.4	8.0
Oct. 2	4.5	54	12.2	8.3
Oct. 8	7.0	72	8.2	------
Oct. 9	10	57	6.7	------
Oct. 10	11	59	3.1	------
Oct. 13	11	------	.0	------
Nov. 6	13.1	57	1.8	7.0
Nov. 25	15	48	1.3	------
Dec. 10	14	48	2.6	7.3
Dec. 16	11	48	4.8	------
1959				
Jan. 12	8	50	9.0	7.8
Feb. 12	7	50	9.3	7.5
Mar. 18	9	59	8.0	7.5
Apr. 17	65	56	6.2	7.5
May 20	32	70	4.1	7.5
July 22	40	72	4.3	----
Oct. 6	9	66	8.3	7.5
Oct. 12	9	61	9.4	7.5
Oct. 13	14	59	8.2	7.5
Oct. 14	14	59	4.8	8.5
Oct. 20	17	64	1.3	7.3

water having 50 ppm of calcium, whereas it is only 0.3 ppm in water having 1 ppm of calcium. Copper, in concentrations ranging from 0.015 to 3.0 ppm, has been reported to be toxic, particularly in soft water, to many kinds of fish, crustacea, mollusks, insects, and plankton. Copper seems to have a synergistic effect on the toxicity of zinc to fish. As little as 0.25 ppm of copper has greatly increased the toxicity of zinc to fish. The limited amount of data for zinc and copper in tables 3 and 4 indicate that some species of fish and other aquatic forms could be adversely affected by zinc and copper in the water.

Nitrate can be as injurious to ducks as it is to other animals if large amounts are ingested. Feeding mixtures of salts containing about 220 milligrams of nitrate has resulted in duck poisoning (Shaw, 1929, p. 120, 275). Conceivably, ducks that feed on the lakebeds might ingest sufficient nitrate at times to be harmed, but this situation seems unlikely in the proposed refuge.

Probably the nitrate in the ground and surface waters of the area would be beneficial. It would stimulate the growth of plankton and other aquatic plants (California Institute of Technology, 1957, p. 302). Plankton growth would aid the development of fish and other organisms that are food for some species of waterfowl. Better plant growth in and near the ponds would provide better shelter and concealment, and the tubers and seeds of some of the plants would augment the food supply for some waterfowl.

It is unlikely that development of the proposed waterfowl refuge would alter significantly the quality of the ground water in the vicinity of the refuge. Although a free lake surface might cause an increase in the dissolved solids of the water, such an increase probably would be small. Studies by Kohler (1952) suggest that the amount of water that would evaporate from the free lake surface would be only slightly greater than the amount now being evaporated and transpired. If water is diverted from the Wood River into the proposed refuge only during periods of relatively high flow when the dissolved-solids content of the water is low, some improvement in the quality of the ground water downgradient could be expected.

CONCLUSIONS

The saturated unconsolidated deposits that underlie the proposed waterfowl refuge area are capable of yielding large amounts of water to wells. The amount of ground water available would be adequate to supply water for ponds.

A partial emptying of the ground-water reservoir by pumping would make storage space available during periods of surplus water, which occur during prolonged periods of precipitation and at times when the Platte River is at flood stage. Lowering of the water table by pumping would tend to reduce natural discharge if the water table were lowered enough to prevent the roots of phreatophytes from reaching it.

Investigation of the surficial deposits in the Chapman area indicates that they are so permeable that surface ponds above the level of the water table could not be constructed successfully without the installation of impervious liners to seal their beds. If impervious liners were provided, it is estimated that an average of about 5 cubic feet per second (2,200 gallons per minute) of water would be required for each square mile of pond surface to supply the evaporation losses. The rate would be much larger during periods of high evaporation and much smaller during periods of low evaporation. If the pond bottoms were only partly sealed, additional water, equal to the seepage loss, would be required to maintain ponds.

An alternative to the construction of surface-water ponds would be to dredge water-table ponds, although the transport and disposal of the excavated sediments might pose a problem if the volume was large. If a large number of small ponds would serve as well as a small number of large ponds, the excavated materials could then be piled between the ponds. The water table is generally within 3–6 feet of the land surface; however, ponds would require additional depth to accommodate water-table fluctuation of as much as 4 feet if it is desirable that water be maintained in the ponds the year around. Ponds excavated to slightly below the lowest level of the water table would not be as difficult to maintain as ponds above the water table. Water-table ponds are common in the lower Platte River valley as a result of mining sand and gravel. Many are stocked with fish and are used for recreation without maintenance.

Ample water supplies are available in the area for maintenance of ponds regardless of whether they are surface or water-table ponds. Use of the water for ponds would not deplete the supply sufficiently to be detrimental to other uses in the area.

The proposed waterfowl refuge area is in an area of natural ground-water discharge, and ponds—whether constructed above the water table and filled with water pumped from wells or excavated below the water table to form ground-water ponds—would probably not significantly reduce the available supply.

The dissolved solids in the ground water range from 225 to 913 ppm; those in water from the irrigation wells are relatively uniform in concentration, and those in water from shallow observation wells are relatively diverse. The water having the lowest concentration of dissolved solids contains mostly calcium and bicarbonate, whereas the water having the highest concentration of dissolved solids contains mostly sodium and sulfate. The percentages of sodium and sulfate seem to vary with distance to the Platte River; the highest percentages are in the water near the river. Data from adjacent wells indicate poor vertical mixing in some places between waters supplying the shallow observation wells and the deeper irrigation wells.

The ground water is very hard; some of it contains iron and manganese much in excess and sulfate, fluoride, and nitrate slightly in excess of commonly accepted standards for drinking water. It is suitable for irrigation. The water in the area would be of suitable quality for use in the proposed refuge provided diversions to the ponds from the Wood River are not made in late fall when the BOD of the streamflow is high. It is unlikely that development of the proposed waterfowl refuge would alter significantly the chemical quality of the ground water in the vicinity of the refuge.

TABLE 6.—*Periodic water-level measurements in selected wells in the Chapman area, Nebraska*

[Measurements are given in feet below land-surface datum]

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			11-8-3dd				
Apr. 16, 1946	2.30	Sept. 6, 1949	1.82	Oct. 4, 1955	4.85	Oct. 19, 1959	2.22
May 7	2.31	Nov. 1	2.10	May 25, 1956	[1] 3.08	Nov. 17	2.22
June 4	2.10	Jan. 3, 1950	1.45	Nov. 7	[1] 5.47	Dec. 15	2.04
July 9	2.90	Feb. 27	1.17	May 29, 1957	[1] 2.70	Feb. 17, 1960	1.01
Aug. 6	3.09	May 1	1.82	Sept. 18	[1] 2.51	Mar. 22	.59
Sept. 4	3.22	July 3	2.41	May 1, 1958	[1] 1.74	Apr. 11	1.69
Oct. 3	2.29	Sept. 13	2.37	June 3	2.06	13	1.50
Nov. 5	1.04	Oct. 12	2.14	Aug. 1	2.40	May 2	[1] 1.93
Dec. 2	1.88	Nov. 6	2.02	Oct. 7	2.99	16	1.76
Jan. 6, 1947	1.95	Jan. 8, 1951	1.42	28	[1] 2.60	June 29	2.26
Mar. 7	1.54	Mar. 26	1.55	Nov. 6	2.49	Aug. 23	3.83
May 8	2.34	May 1	1.39	Dec. 9	2.26	Sept. 28	[1] 3.45
July 10	1.85	Nov. 6	1.66	Jan. 14, 1959	1.40	Oct. 18	2.75
Sept. 5	3.32	Jan. 25, 1952	1.58	Feb. 12	1.52	Nov. 18	2.32
Nov. 3	2.27	May 27	.94	Mar. 2	[1] 1.10	Dec. 27	1.87
Jan. 5, 1948	1.58	Oct. 30	2.28	12	1.38	Jan. 13, 1961	1.68
Mar. 17	.55	Sept. 14, 1953	4.28	Apr. 14	1.83	June 12	2.47
May 3	1.30	Oct. 20	4.60	May 20	1.58	July 24	3.39
July 5	2.41	Nov. 9	2.84	26	[1] 2.00	Sept. 1	3.32
Sept. 2	3.25	Feb. 25, 1954	1.43	June 16	3.09	25	3.00
Nov. 2	2.29	Apr. 12	2.27	July 16	2.93	Oct. 18	2.57
Jan. 5, 1949	1.89	Sept. 15	3.70	Aug. 14	2.97	Nov. 27	2.03
Apr. 12	1.37	May 9, 1955	2.90	Sept. 15	4.06		
July 5	1.80	June 17	1.67	Oct. 13	[1] 2.25		
			12-7-7aa				
Dec. 11, 1945	6.35	Nov. 2, 1948	7.16	Nov. 9, 1953	8.42	Oct. 19, 1959	6.82
Jan. 4, 1946	6.36	Jan. 5, 1949	6.82	Apr. 12, 1954	8.16	Nov. 17	6.99
Feb. 13	6.37	Mar. 9	6.19	Nov. 19	8.42	Dec. 15	7.14
Mar. 12	6.20	Apr. 13	4.72	June 15, 1955	[1] 8.41	Feb. 17, 1960	6.57
Apr. 9	6.11	July 5	5.13	Oct. 4	[1] 9.15	Mar. 22	6.46
May 7	6.46	Sept. 1	6.44	Nov. 22	9.36	Apr. 11	4.20
June 4	6.37	Nov. 1	6.74	Apr. 18, 1956	9.48	May 2	[1] 4.62
July 9	6.62	Jan. 3, 1950	7.01	May 22	[1] 9.30	16	4.35
Aug. 6	6.98	Feb. 27	6.94	Nov. 5	[1] 10.26	June 29	4.75
Sept. 4	7.32	May 1	6.79	May 27, 1957	[1] 9.86	Oct. 3	[1] 6.75
Oct. 3	7.26	July 3	6.69	Sept. 18	[1] 9.45	18	6.96
Nov. 6	6.64	Sept. 13	6.48	May 1, 1958	[1] 8.87	Nov. 18	7.14
Dec. 2	6.00	Oct. 12	6.53	Oct. 7	8.68	Dec. 29	7.27
Jan. 6, 1947	6.24	Nov. 6	6.79	28	[1] 8.83	Jan. 13, 1961	7.33
Mar. 6	6.25	Jan. 8, 1951	6.91	Jan. 14, 1959	8.87	June 10	[1] 5.76
May 8	5.62	Mar. 26	6.56	Feb. 12	9.02	12	5.95
July 10	4.34	May 1	5.93	Mar. 12	8.93	July 24	6.12
Sept. 5	6.55	July 24	5.15	Apr. 14	8.10	Sept. 1	7.28
Nov. 3	7.12	Nov. 6	6.00	May 27	[1] 6.58	25	7.48
Jan. 5, 1948	7.10	Jan. 22, 1952	6.04	June 16	6.82	28	[1] 7.58
Mar. 17	6.69	25	6.14	July 16	6.54	Oct. 18	7.65
May 3	6.72	Mar. 27	5.20	Aug. 14	6.40	Nov. 27	7.66
July 5	6.19	May 6, 1953	6.89	Sept. 15	7.18		
Sept. 2	6.47	Sept. 14	8.06	Oct. 13	[1] 6.73		

See footnote at end of table.

TABLE 6.—*Periodic water-level measurements in selected wells in the Chapman area, Nebraska*—Continued

[Measurements are given in feet below land-surface datum]

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			12-8-28dc				
Dec. 11, 1945	2.3	Mar. 9, 1949	1.34	Apr. 12, 1954	2.23	Oct. 13, 1959	[1]2.74
Jan. 4, 1946	1.95	Apr. 13	+.11	Sept. 15	[1]3.23	19	2.71
Feb. 13	1.80	July 5	1.80	Nov. 19	3.18	Nov. 17	2.47
Apr. 9	1.59	Sept. 6	1.75	June 17, 1955	[1]2.52	Dec. 15	2.21
May 7	1.96	Nov. 1	2.42	Oct. 6	[1]4.59	Jan. 30, 1960	2.64
June 4	1.55	Jan. 3, 1950	2.35	Nov. 22	4.38	Feb. 17	1.67
July 9	2.15	Feb. 27	2.05	Apr. 18, 1956	3.57	Mar. 22	1.28
Aug. 6	2.87	May 1	1.86	May 22	[1]3.20	Apr. 11	+.53
Sept. 4	3.40	July 3	1.80	Nov. 7	[1]5.12	May 2	[1].39
Oct. 3	3.32	Sept. 13	1.61	May 28, 1957	[1]3.19	16	.15
Nov. 6	2.20	Oct. 12	1.70	Sept. 18	[1]3.74	June 29	.42
Dec. 2	1.24	Nov. 6	1.96	May 1, 1958	[1]1.92	Sept. 28	[1]2.86
Jan. 6, 1947	1.52	Jan. 8, 1951	1.94	June 3	2.11	Oct. 18	2.98
Mar. 7	1.52	Mar. 26	1.19	Oct. 28	[1]3.27	Nov. 18	2.93
May 8	1.00	May 1	+.17	Dec. 9	[1]3.24	Jan. 4, 1961	2.69
July 10	.59	July 24	+.91	Feb. 12, 1959	3.02	13	2.68
Sept. 5	3.02	Nov. 6	1.84	Mar. 2	[1]2.92	June 10	[1]+.63
Nov. 3	3.30	Jan. 25, 1952	1.70	12	2.80	12	+.10
Jan. 5, 1948	2.77	Mar. 27	.54	Apr. 14	1.60	July 24	2.09
Mar. 17	1.88	May 27	+.58	May 20	+.36	Sept. 1	2.98
May 3	1.90	May 6, 1953	1.20	27	[1]+.15	25	[1]3.20
July 5	1.94	Sept. 14	3.33	June 16	1.11	25	3.22
Sept. 2	2.60	Oct. 20	[1]3.50	July 16	1.43	Oct. 18	3.30
Nov. 2	3.12	Nov. 9	3.40	Aug. 14	2.42	Nov. 27	3.11
Jan. 5, 1949	3.42	Feb. 25, 1954	[1]2.52	Sept. 15	2.91		

[1] Indicates measurements made by Midstate Irrigation District.

TABLE 7.—*Logs of test holes*

[Altitude of land surface in feet above mean sea level was determined by altimeter (a), spirit leveling (i), estimated from topographic map (t). All test holes were drilled by the Conservation and Survey Division, University of Nebraska, in cooperation with the U.S. Geol. Survey. Depth to water given in feet below land surface]

	Thickness (feet)	Depth (feet)
11-7-13dd [Hamilton County. Alt (a) 1,826. Depth to water, 85.5 ft (8-13-49)]		
Soil: Silt, slightly clayey, dark brownish-gray	1.5	1.5
Silt, slightly clayey, granular structure, medium brownish-gray; below 2.5 ft, buff-gray	2.5	4
Silt, slightly calcareous, light buff-gray with yellowish tint; below 5 ft, slightly sandy; below 12.5 ft, contains a few gastropod shells	21	25
Soil: Silt, slightly sandy, dark brownish-gray with tan tint	3.5	28.5
Silt, moderately clayey to slightly sandy, brownish-tan; sand is very fine to fine; below 30 ft, tannish-gray	9	37.5
Silt, sandy, tannish-gray with buff tint; sand is very fine to fine, some medium; from 45 to 46.5 ft, brownish-tan	12.5	50
Sand, silty, tannish-gray; sand is very fine to medium	12	62
Sand, light tannish-gray; sand is very fine to coarse, some very coarse	3	65
Silt, sandy, to silty sand, tannish-gray; sand is very fine to medium; below 75 ft, contains some medium sand	19	84
Silt, moderately sandy, slightly clayey, tannish-gray with pink tint; sand is very fine to fine, some medium	6	90
Sand, silty, light-gray; contains some limonitic stain	25	115

TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
11-7-13dd—Continued		
Sand and gravel, brownish-gray to pink; fine sand to medium gravel; from 120 to 125 ft, contains much limonitic stain	15	130
Sand, medium tannish-gray; sand is fine to very coarse; below 145 ft, contains some fine gravel	20	150
Sand, in part silty, light yellowish-tan and gray; sand is very fine	5	155
Sand, gray to tannish-gray; sand is very fine to coarse, some very coarse	12.5	167.5
Sand in part silty, tannish-buff; sand is fine to coarse, some very coarse	2.5	170
Sand and gravel, brownish-gray; fine sand to fine gravel, some medium gravel	44	214
Silt, very sandy, light-gray; sand is very fine to medium	1.5	215.5
Sand, light brownish-gray; sand is very fine to medium	2	217.5
Silt, slightly clayey to sandy, light-gray with slight bluish-green tint; sand is very fine to fine; below 225 ft, brownish-gray, slightly calcareous	33.5	251
Silt, sandy, to siltstone, moderately calcareous, brownish-gray; sand is very fine; contains a few rootlets	25	276
Silt, sandy to slightly clayey, moderately calcareous, brownish-gray; sand is very fine; below 280 ft, contains many calcareous nodules	24	300
Sand and gravel, greenish-gray; medium sand to fine gravel	5.5	305.5
Clay shale, very calcareous, very light yellowish-gray; below 308 ft, light-gray with slight bluish tint	14.5	320
11-8-1dd		
[Hamilton County. Alt (i) 1,873. Depth to water unknown; test hole caved at 91 ft (6-5-59)]		
Roadfill	1.5	1.5
Silt, slightly clayey, slightly calcareous, light yellow-gray; contains some limy rootlets; below 10 ft, slightly more clayey, noncalcareous	9	10.5
Silt, slightly clayey, light-brown	2	12.5
Silt, slightly clayey, dark brownish-gray; below 13 ft, slightly sandy, sand is very fine to fine	2	14.5
Silt, moderately clayey, slightly sandy, medium-brown; sand is very fine to fine; below 16.5 ft, slightly clayey, slightly lighter in color; below 18 ft, slightly more sandy	4.5	19
Sand, slightly clayey, very silty; sand is very fine to medium; below 20 ft, contains no clay; from 20 to 23 ft, moderately silty; below 23 ft, slightly silty	13	32
Sand, moderately silty; sand is very fine to medium, some coarse; from 34 to 37 ft, very silty; from 34 to 35 ft, slightly clayey; below 37 ft, slightly silty	13.6	45.6
Silt, slightly clayey, moderately sandy, medium-brown with some brownish-yellow; sand is very fine to fine, some medium	.4	46
Soil, moderately clayey, moderately sandy, medium brownish-gray; sand is very fine to medium	2	48
Silt, slightly clayey, very sandy, light-brown; and is very fine to medium	2	50
Sand, very silty; sand is very fine to medium; below 52.5 ft, moderately silty, contains some coarse sand	4.5	54.5
Silt, slightly clayey, very sandy, light yellow-gray; sand is very fine to fine, some medium	2	56.5

TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
11-8-1dd—Continued		
Sand, very silty; sand is very fine to medium	5	61.5
Sand, very fine to medium, some coarse; from 73.2 to 73.5 ft, contains a light-gray, very sandy, silt lens	16	77.5
Sand, very silty; sand is very fine, some fine; from 80 to 84 ft, sand is very fine to fine, some medium; below 84 ft, sand is very fine to medium, some coarse	7.5	85
Sand, slightly silty; sand is very fine to medium; contains some thin silty sand lenses; below 91 ft, very silty, contains less medium sand	9	94
Silt, moderately clayey, light brownish-gray; from 96.5 to 98.5 ft, slightly sandy, sand is fine to coarse; below 98.5 ft, slightly calcareous, contains a few sand grains, shell fragments, and limy nodules	8.8	102.8
Sand, gravelly; fine sand to fine gravel; contains about 10 percent gravel to 105 ft; from 105 to 110 ft, contains about 15 percent gravel; from 110 to 120 ft, contains about 25 percent gravel; from 115 to 120 ft, contains mostly fine to medium sand; below 120 ft, contains about 30 percent gravel; from 120 to 125 ft, contains much coarse to very coarse sand	26.7	129.5
Silt, slightly clayey, very sandy, light olive-gray; sand is very fine to fine	2	131.5
Sand, fine to coarse, some very coarse; below 135 ft, contains about 5 percent very coarse sand to fine gravel	8.5	140
Sand, gravelly; medium sand to fine gravel, some medium gravel (about 25 percent gravel); from 145 to 150 ft, contains some fine sand, contains about 30 percent gravel; below 150 ft, contains about 20 percent gravel	15	155
Sand, gravelly; medium sand to fine gravel, some medium gravel (about 30 percent gravel); from 155 to 160 ft, contains about 30 percent gravel; below 160 ft, contains much coarse to very coarse sand; from 160 to 170 ft, contains about 20 percent gravel; from 170 to 185 ft, contains about 15 percent gravel; below 185 ft, contains about 25 percent gravel	34	189
Silt, slightly clayey, granular structure, light brownish-yellow; from 190 to 191.5 ft, coarse textured, light brownish-gray; below 191.5 ft, light-gray	5	194
Silt, sandy, granular structure, light yellow-gray; sand is very fine, some fine	3.5	197.5
Sand, fine to coarse, some very coarse; below 205 ft, contains some fine gravel	12.5	210
Sand, gravelly; fine sand to fine gravel (about 15 percent gravel)	3	213
Silt, moderately clayey, light-gray to light brownish-yellow; below 215 ft, in part slightly calcareous, light-gray; from 217.3 to 217.5 ft, contains limy nodules	5.5	218.5
Silt, moderately clayey, slightly calcareous, medium brownish-gray	1.5	220
Silt, slightly clayey, slightly calcareous, light yellow-gray; contains a few limy layers to 223 ft; below 223 ft, contains some limy nodules	8.5	228.5
Silt, moderately clayey, slightly calcareous, medium-brown	1.5	230
Silt, slightly clayey, slightly calcareous, light yellow-gray with brownish tint; from 232.5 to 237 ft, contains some limy nodules; from 235 to 241.5 ft, in part granular structure	20	250

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TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
11-8-1dd—Continued		
Silt, moderately clayey, slightly calcareous, light yellow-gray with brownish tint; from 250 to 255 ft, contains some limy lenses and nodules; below 255 ft, slightly more clayey, contains some chalk fragments	6.5	256.5
Silt, moderately clayey, light brownish-gray; in part marly to 260 ft; below 260 ft, contains some limy nodules and chalk fragments; below 265 ft, moderately sandy to gravelly, consisting principally of chalk fragments	10.5	267
Gravel, fine to medium; consisting principally of chalk fragments	1	268
Sand, gravelly; medium sand to medium gravel (about 20 percent gravel); contains some chalk fragments; below 275 ft, contains about 35 percent gravel	12	280
Sand and gravel, medium sand to medium gravel (about 50 percent gravel); contains some chalk fragments	3	283
Shale, chalky, light gray-yellow	4.5	287.5
Shale, chalky, medium brownish-gray; below 288 ft, medium-gray	22.5	310
11-8-17ba [Merrick County. Alt (i) 1,820. Depth to water, 4.5 ft (7-17-31)]		
Soil: Silt, sandy, black	0.5	0.5
Sand, buff; sand is fine	.5	1
Sand and gravel; from 34 to 37 ft, contains some clay	40	41
Clay and silt, gray; contains some sand	20	61
Sand, gravel, and clay	4	65
Silt and clay, light buff-gray	5	70
Sand and gravel, light-green to light-buff; below 85 ft, finer textured	29	99
Sand, buff; sand is fine to medium	1	100
Gravel; from 104 to 105 ft, contains gray silty clay	10	110
Sand, buff-gray with some green grains; sand is fine to medium	1.5	111.5
Clay, green-gray; from 115.5 to 116 ft, contains sand and gravel	5.5	117
Gravel and sand	9	126
Shale, clayey, yellow-brown	1	127
Shale, clayey, blue-gray	16	143
11-9-24aa [Hall County. Alt (a) 1,826. Depth to water, 5 ft (7-15-54)]		
Roadfill: slightly calcareous, dark-gray	2	2
Sand and gravel, light-brown; medium sand to medium gravel (about 20 to 40 percent gravel)	13	15
Gravel, sandy, light-brown; medium sand to medium gravel (about 75 to 80 percent gravel)	10	25
Sand and gravel, light brown-gray; medium sand to fine gravel (about 40 to 60 percent gravel)	65	90
Sand, gravelly, light brown-gray; medium sand to fine gravel (about 20 to 35 percent gravel)	30	120
Sand, fine to very coarse, some fine gravel (about 10 percent gravel)	9	129

TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
11-9-24aa—Continued		
Silt, moderately clayey, light olive-gray	3.7	132.7
Silt, slightly clayey, moderately sandy, medium-gray	2.3	135
Silt, sandy silt, and sand, interbedded, slightly clayey, light-gray	5	140
Sand, light-gray; sand is very fine to medium, some coarse to very coarse	25	165
Sand, medium-gray; sand is medium to very coarse, some fine gravel	13.6	178.6
Silt, slightly clayey, slightly calcareous, light-gray; below 187.5 ft, moderately clayey; below 190 ft, contains white limy areas	16.9	195.5
Silt, slightly clayey, slightly sandy, moderately calcareous, light-gray; sand is very fine; from 205 to 210 ft, moderately clayey, contains a few limy nodules	19.5	215
Silt to siltstone, moderately calcareous, light-gray	9	224
Silt, slightly clayey, moderately calcareous, light-gray; moderately clayey to 226.5 ft	7	231
Silt, very clayey, moderately calcareous, light yellow-gray to light brown-gray; contains slightly less clay to 235 ft; from 235 to 238 ft, contains some limy nodules and embedded sand; below 238 ft, in part marly	9	240
Chalk to chalky shale, very calcareous, very light-yellow	5	245
Limestone, chalky, very calcareous, very light-yellow; highly speckled with white	4	249
Shale, chalky, very calcareous, light-yellow to light yellow-brown	28.5	277.5
Shale, chalky, very calcareous, light blue-gray	2.5	280
12-8-27dd [Merrick County. Alt (t) 1,794. Depth to water, 4 ft (5-28-59)]		
Roadfill	1	1
Silt, moderately clayey, slightly sandy, moderately calcareous, dark brownish-gray; sand is very fine	1	2
Silt, moderately clayey, sandy, light brownish-gray; sand is very fine to fine	1	3
Sand and gravel, very fine sand to coarse gravel (about 50 percent gravel); below 3.4 ft, contains about 40 percent gravel	7	10
Sand, gravelly; fine sand to medium gravel (about 30 percent gravel)	5	15
Sand and gravel, medium sand to medium gravel (about 40 percent gravel)	5	20
Sand, gravelly; fine sand to fine gravel (about 25 percent gravel)	5	25
Sand and gravel, fine sand to fine gravel (about 60 percent gravel); contains a thin silt lens at 28 ft	5	30
Sand, gravelly; fine sand to fine gravel (about 15 percent gravel); below 40 ft, contains about 30 percent gravel	38.5	68.5
Silt, slightly clayey, coarse-textured, granular structure, light-brown	6.5	75
Silt, very clayey, light-brown; from 80 to 85 ft and from 90 to 95 ft, moderately clayey; from 80 to 85 ft, 90 to 93 ft, and below 95 ft, contains some limy grains	21.5	96.5

TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
12-8-27dd—Continued		
Silt, moderately clayey, moderately sandy, light-brown; contains coarse silt to very fine sand; below 100 ft, slightly calcareous; from 100 to 105 ft, slightly clayey; below 109.5 ft, contains some limy grains	20. 5	117
Silt, very clayey, moderately calcareous, light-brown to light-gray; below 120 ft, contains limy grains; from 120 to 126.5 ft, moderately clayey; below 126.5 ft, slightly clayey	11. 5	128. 5
Clay, silty, very calcareous, light-gray with some yellow-brown; contains some limy grains	1. 5	130
Limestone, chalky, interbedded with chalky shale, light-gray to light yellow-brown	3. 1	133. 1
Shale, chalky, light-gray to light yellow-brown; from 134.2 to 135 ft and from 135 to 145 ft, contains some limestone lenses; below 145 ft, light-gray to light yellow-gray	26. 9	160
12-9-13dd		
[Hall County. Alt (a) 1,827. Depth to water, 7.7 ft (7-20-54)]		
Roadfill: dark-gray	1. 5	1. 5
Soil: Silt, slightly clayey, medium-gray to dark-gray; below 2.5 ft, contains some sand	1. 5	3
Silt, slightly clayey, very sandy, medium-gray	1	4
Silt, moderately clayey, slightly sandy, light-gray	. 5	4. 5
Sand, medium brown-gray; sand, fine to coarse, some fine gravel	5. 5	10
Sand, gravelly; medium sand to fine gravel, some medium to coarse gravel (about 15–25 percent gravel)	22	32
Gravel, fine to medium; contains about 20 percent coarse sand; below 45 ft, contains rounded clay grains	19. 7	51. 7
Silt, moderately clayey, light-gray to light brown-gray; from 52.5 to 56 ft, contains limy nodules	8. 3	60
Silt, very marly, light-gray	2	62
Silt, slightly clayey, slightly sandy, slightly calcareous, granular structure, light-gray; below 66.8 ft, moderately clayey	5. 5	67. 5
Silt, slightly to moderately clayey, slightly sandy, light-gray; from 69.5 to 72 ft, moderately to very clayey; below 73.5 ft, moderately to very sandy, slightly calcareous	12. 5	80
Sand, fine to very coarse	3. 3	83. 3
Silt, moderately clayey, moderately sandy, light-gray	1. 7	85
Sand, slightly clayey, very silty, light-gray; sand is very fine to medium	4. 5	89. 5
Silt, moderately clayey, very sandy, light-gray	1	90. 5
Sand, slightly silty, light-gray	1. 4	91. 9
Shale, clayey, slightly to moderately calcareous, light yellow-gray	5. 6	97. 5
Shale, clayey, slightly to moderately calcareous, medium-gray; from 111.3 to 114 ft, at 139.2 ft, and from 148.3 to 148.6 ft, contains thin layers of bentonite	61. 4	158. 9
Shale, chalky, very calcareous, light-gray	11. 1	170

TABLE 7.—*Logs of test holes*—Continued

	Thickness (feet)	Depth (feet)
13-7-34dc		
[Merrick County. Alt (i) 1,744. Depth to water, 5 ft (7-12-32)]		
Silt and sand, gray; sand is fine	8	8
Sand and gravel, pink	27	35
Sand and silt; sand is very fine	1	36
Silt, sandy, to silty sand, in part clayey, light-brown to light-gray; contains some hard limy layers	79	115
Shale, chalky, light-yellow to white	61	176

TABLE 8.—*Logs of auger holes*

	Thickness (feet)	Depth (feet)
11-8-2ab		
Silt, clayey, black (topsoil)	0. 4	0. 4
Sand, very fine, brown	. 7	1. 1
Sand, medium to very coarse, oxidized; contains fine to coarse gravel	2. 0	3. 1
11-8-2bc		
Silt, clayey, black (topsoil)	2. 6	2. 6
Sand, medium to very coarse; contains fine to coarse gravel	. 8	3. 4
11-8-2cb		
Silt, clayey, black (topsoil)	1. 0	1. 0
Sand, very fine, brown	1. 1	2. 1
Sand, fine to medium, brown	1. 1	3. 2
Sand, medium to very coarse; contains fine to medium gravel	. 3	3. 5
11-8-2cc		
Silt, sandy, black (topsoil)	0. 9	0. 9
Sand, very fine, brown	1. 1	2. 0
Sand, medium to very coarse, oxidized; contains fine gravel	1. 4	3. 4
11-8-2cd		
Sand, very fine to fine, brown	1. 0	1. 0
Sand, medium, brown	1. 9	2. 9
Sand, medium to very coarse; contains fine gravel	. 3	3. 2
11-8-3cb		
Sand, silty, black (topsoil)	1. 0	1. 0
Sand, fine to medium, light-brown	. 8	1. 8
Sand, medium to very coarse; contains fine gravel	. 2	2. 0
11-8-3cc		
Silt, sandy, black (topsoil)	1. 3	1. 3
Silt, sandy, light-brown	2. 1	3. 4
Sand, medium to very coarse; contains fine gravel	--------	3. 4+

TABLE 8.—*Logs of auger holes*—Continued

	Thickness (feet)	Depth (feet)
11-8-3dd		
Silt, sandy, black	0.7	0.7
Sand, very fine, brown	.6	1.3
Sand, medium to very coarse; contains fine gravel	1.0	2.3
11-8-4aa		
Silt, sandy, black (topsoil)	0.7	0.7
Sand, very fine, brown	1.6	2.3
Sand, fine to very coarse; contains fine gravel	.4	2.7
Sand, medium to very coarse; contains fine to very coarse gravel	.4	3.1
11-8-10ab		
Silt, clayey, black (topsoil)	1.3	1.3
Silt, sandy, gray	1.0	2.3
Silt, sandy, black	1.9	4.2
Sand, medium to very coarse	--------	4.2+
12-7-19ad		
Sand, silty (topsoil)	1.7	1.7
Silt, clayey, black	1.4	3.1
Sand, very fine	1.9	5.0
Sand, medium to very coarse	--------	5.0+
12-7-19cc		
Silt, clayey (topsoil)	0.9	0.9
Sand, very coarse, and fine to very coarse gravel	1.1	2.0
12-7-20cc		
Sand, silty	0.9	0.9
Sand, medium to coarse	1.4	2.3
Sand, medium to very coarse; contains fine to coarse gravel	.7	3.0
12-7-30ac		
Silt, sandy, black (topsoil)	0.6	0.6
Sand, medium to very coarse; contains fine to very coarse gravel	2.9	3.5
12-7-30ba		
Silt, sandy, black (topsoil)	0.9	0.9
Sand, very fine, brown	.5	1.4
Sand, fine to coarse	.9	2.3
Sand, medium to very coarse; contains fine to very coarse gravel	1.3	3.6

TABLE 8.—*Logs of auger holes*—Continued

	Thickness (feet)	Depth (feet)
12-7-30bb		
Silt, sandy, black (topsoil)	0.5	0.5
Sand, medium to very coarse; contains silt lenses and coarse to very coarse gravel	3.5	4.0
12-7-30cb		
Silt, sandy, black (topsoil)	1.2	1.2
Sand, fine to medium, brown, oxidized	.6	1.8
Sand, medium to very coarse; contains fine to coarse gravel	1.8	3.6
12-8-25ac		
Silt, sandy, black (topsoil)	0.8	0.8
Sand, very fine, light brown-gray	.5	1.3
Sand, very fine, light-brown	1.5	2.8
Sand, medium to very coarse; contains fine gravel	--------	2.8+
12-8-25ad		
Sand, silty	0.9	0.9
Sand, medium to very coarse; contains fine gravel	1.3	2.2
12-8-25bc		
Silt, sandy, black (topsoil)	1.0	1.0
Sand, medium to very coarse; contains fine to very coarse gravel	1.5	2.5
12-8-26cd		
Silt, sandy, black (topsoil)	1.7	1.7
Sand, very fine, light-brown; contains some gray clay	2.4	4.1
Sand, medium to very coarse; contains fine gravel	.4	4.5
12-8-34dd		
Silt, sandy, black (topsoil)	0.5	0.5
Sand, very fine, brown mottled with black	2.3	2.8
Sand, very fine, brown; contains lens of gray clayey silt	.4	3.2
Clay, silty, black	2.1	5.3
Silt, clayey, green	.7	6.0
Sand, medium to coarse	.3	6.3
12-8-35ab		
Sand, medium to very coarse, dirty	1.5	1.5
Sand, very silty, light-brown	2.5	4.0
Sand, medium to very coarse; contains fine to coarse gravel	--------	4.0+
12-8-35cb2		
Silt, sandy, black	0.5	0.5
Sand, very fine, brown	2.3	2.8
Sand, very fine to very coarse; contains fine gravel	.3	3.1

TABLE 8.—*Logs of auger holes*—Continued

	Thickness (feet)	Depth (feet)
12-8-35dd		
Silt, clayey, black (topsoil)	1. 2	1. 2
Sand, very fine, brown	. 3	1. 5
Sand, medium to very coarse; contains fine gravel	. 4	1. 9
12-8-36aa		
Silt, clayey, black (topsoil)	0. 5	0. 5
Sand, very fine, with lens of black clay	1. 2	1. 7
Sand, medium to coarse; contains pebbles		1. 7+
12-8-36ad		
Silt, clayey, dark-brown (topsoil)	1. 0	1. 0
Sand, very fine, brown; contains mica	. 8	1. 8
Sand, medium to coarse; contains some pebbles		1. 8+
12-8-36bc		
Sand, silty, gray	1. 0	1. 0
Sand, medium to very coarse; contains fine gravel	2. 0	3. 0
12-8-36ca		
Silt, clayey, black (topsoil)	0. 5	0. 5
Sand, very fine, brown	. 2	. 7
Sand, medium to very coarse, oxidized; contains fine to very coarse gravel	1. 8	2. 5
12-8-36cb		
Silt, clayey, dark-gray	1. 1	1. 1
Sand, medium to very coarse, oxidized; contains fine to very coarse gravel	1. 9	3. 0
12-8-36cc		
Silt, sandy, gray (topsoil)	0. 7	0. 7
Sand, very fine, brown	1. 2	1. 9
Sand, medium to very coarse; contains fine to coarse gravel	1. 0	2. 9

TABLE 9.—*Coefficient of permeability of water-bearing materials from auger holes in the Chapman area*

Auger hole	Depth (feet)		Coefficient of permeability (gpd per sq ft)
	From	To	
11–8–2ab	0.9	1.1	5
2bc	1.0	1.2	3
	3.0	3.2	78
2cb	1.4	1.6	26
	2.5	2.7	130
2cc	1.0	1.2	60
2cd	1.2	1.4	45
3cb	1.0	1.2	270
3cc	1.1	1.3	5
	2.5	2.7	6
3dd	1.5	1.7	230
4aa	.8	1.0	16
	2.5	2.7	180
10ab	1.5	1.7	1
	2.5	2.7	13
12–7–19ad	1.5	1.7	1
	2.9	3.1	4
19cc	1.1	1.3	410
20cc	2.1	2.3	130
	2.8	3.0	510
30ba	1.0	1.2	.6
	1.6	1.8	390
30bb	2.2	2.4	860
30cb	1.5	1.7	140
8–25ac	1.0	1.2	9
	2.6	2.8	4
26cd	1.2	1.4	5
	2.5	2.7	4
34dd	.8	1.0	16
	1.7	1.9	20
	3.0	3.2	16
	4.1	4.3	.02
35ab	1.1	1.3	1,000
	3.6	3.8	30
35cb2	1.0	1.2	4
35dd	1.0	1.2	30
	1.7	1.9	310
36aa	.7	.9	11
	1.5	1.7	31
36ad	.5	.7	3
	1.5	1.7	130
36bc	1.0	1.2	340
36ca	.8	1.0	230
36cb	1.1	1.3	330
12–8–36cc	.8	1.0	69
	2.7	2.9	620
36cd	1.5	1.7	10
	3.0	3.2	.7

TABLE 10.—*Records of wells*

Well: See p. E6 for description of well-numbering system.
Depth of well: Reported depths below land surface are given in feet; measured depths are given in feet and tenths.
Land-surface altitude: Altitudes determined by altimeter are given in feet and tenths; altitudes determined by spirit leveling are given in feet, tenths, and hundredths.
Depth to water: Reported depths are given in feet below land surface; measured depths are given in feet, tenths, and hundredths.
Water use: I, irrigation; N, none.
Remarks: Ca, chemical analysis made of water; O, observation of water-level fluctuations.

Well	Owner or user	Year drilled	Depth of well below land surface (feet)	Diameter of casing (inches)	Altitude above mean sea level (feet)	Static water level: Distance below land surface (feet)	Static water level: Date of measurement	Yield (gpm)	Water use	Remarks
Hamilton County										
11-7-5ab	J. R. Nelson	1957	201	18		82.22	8- 6-57	1,000	I	
5bb	Vaughn Lewis	1956	170	18	1,861.51	88.33	1-14-59	1,700	I	O
5db	Susan Jane Engler	1955	187	18		85	8-27-56	1,000	I	
6dd	Clyde Englund	1956	170	18	1,866.12	92.03	7-16-59	1,000	I	O
						90.37	5- 5-60			
7ba	Dr. Houtz and Dorothy Steenburg	1955	180	18	1,867.78	90.71	7-16-59	1,000	I	O
						89.44	5- 5-60			
8-12ac	John Rodabough	1954	188	18	1,870.4	84.60	6-20-58	900	I	O
12cb	Francis and Richard McDonald	1955	180	18		82.01	7-17-58	900	I	
14bb	U.S. Geol. Survey	1958	10.5	¾	1,802.36	3.71	12-15-59	1.2	N	Ca, O
15ad	do	1958	41.7	¾	1,819.05	17.48	4-11-60		N	O
12-7-21cd	do	1958	20.8	¾		12.90	4-11-60		N	O
29aa	do	1958	21.0	¾		11.32	4-11-60		N	O
29bd	do	1958	10.6	¾	1,775.48	7.66	4-11-60		N	O
29cc	W. H. McHargue	1956	97	18		24	8- 7-57	1,000	I	
29dc	do	1957	97	18		21.27	7-31-58	1,300	I	
30dd	U.S. Geol. Survey	1958	17.8	¾	1,783.09	9.81	4-11-60	1	N	Ca, O
32ad	I. E. Caldwell	1957	156	18	1,856.45	90	8- 7-57	1,000	I	
32ca	Dr. Steenburg	1954	185	18				1,000	I	
Merrick County										
11-8-2bb	D. E. Neidfelt	1944	71	18		5.18	5- 3-60	900	I	
2bc	U.S. Geol. Survey	1958	13.8	¾	1,795.46	2.69	4-11-60		N	O
2cd	do	1958	18.0	¾	1,797.46	5.21	4-11-60		N	O
3cb	do	1958	10.5	¾	1,802.13	3.13	4-11-60		N	O
3cc1	do	1958	10.6	¾	1,803.82	2.97	4-11-60	7.5	N	Ca, O
3cc2	Julius Daberkow	1934	78	22		6.46	5- 3-60	1,000	I	
3dd	U.S. Geol. Survey	1946	9.4	1¼	1,796.19	1.69	4-11-60		N	Ca, O
9aa	Wilber Meyer	1947	60			7	5- 3-60	1,000	I	

9ab	do	1949	60	18		6.65	5- 3-60	1,000	I	
9db	Betty Ehlers	1948	50	18		5	5- 3-60	1,200	I	
9dd	do	1954	67	18		3.95	5- 3-60	1,200	I	
10ab	U.S. Geol. Survey	1958	15.5	¾	1,800.18	2.88	4-11-60		N	O
10bb	Herbert Giger	1956	62	18		4.25	5- 3-60	800	I	
10bc	Roland Scherzberg	1955	70	18					I	
10cc	Herbert Giger	1954	66	18		4.67	5- 3-60	1,000	I	
12-7-7aa	U.S. Geol. Survey	1945	13	1¼	1,762.16	4.20	4-11-60		N	O
17aa	do	1958	14.2	¾	1,761.67	6.58	4-11-60		N	O
18aa1	Elmo Carnes	1954	25.0	8	1,767.25	5.36	4-11-60	75	I	O
18ab	U.S. Geol. Survey	1958	10.6	¾	1,765.79	1.43	4-11-60		N	O
18bb	do	1958	10.6	¾	1,767.65	2.63	3-22-60		N	O
19aa1	do	1958	17.0	¾	1,771.99	7.62	4-11-60	8.6	N	Ca, O
19ab1	do	1958	14.7	¾	1,772.32	4.61	4-11-60		N	O
19ad1	do	1958	10.6	¾	1,769.74	4.57	4-11-60		N	O
19ad2	Loyd Leamons	1945	54	18		4.57	7-30-58	1,000	I	
19bb	U.S. Geol. Survey	1958	10.5	¾	1,774.95	4.55	4-11-60	4.6	N	Ca, O
19bc	D. A. Kirchheck			18		6.34	7-31-58		I	
19bd	do	1940	37	18		10.78	12- 4-59	500	I	
19cb1	U.S. Geol. Survey	1958	10.5	¾	1,776.22	3.81	4-11-60		N	O
19cb2	Albert Nieman	1940	56	18		6.55	7-31-58	800	I	
19cc	U.S. Geol. Survey	1958	10.5	¾	1,775.59	3.82	4-11-60		N	O
19cd	Albert Nieman	1956	61	18		4.63	7-31-58	1,000	I	
20ba	U.S. Geol. Survey	1958	10.6	¾	1,763.66	2.90	4-11-60		N	O
20bc	Mrs. C. J. Cleary	1956	65	18		4.95	7-31-58	1,000	I	Ca
20cc	U.S. Geol. Survey	1958	10.6	¾	1,770.90	4.48	4-11-60	6	N	Ca, O
30bc	Emil R. Guendel	1957	63	18		4.26	12- 4-59	1,000	I	
8-13cc1	U.S. Geol. Survey	1958	10.3	¾	1,777.72	1.83	4-11-60		N	O
23ac	Alferd Bader		40	18		9.00	11-27-59	1,000	I	
23cc	U.S. Geol. Survey	1958	10.5	¾	1,788.27	1.62	4-11-60		N	O
23db	A. Bader		45	18		6.14	11-27-59	1,000	I	
24ac	Loral A. Haddix	1957	42	18		5	5- 3-60	925	I	
24ad	Arnold Klingenberg	1949	51	18		4.79	5- 3-60	1,000	I	
24cc	Ross estate		68	24		5.94	11-27-59	1,400	I	
24dc	U.S. Geol. Survey	1958	14.5	¾	1,780.50	4.97	4-11-60		N	O
25ad	do	1958	10.5	¾	1,776.35	2.08	4-11-60	5	N	Ca, O
25bb	L. E. Hoskins		64	24		7.44	11-27-59	1,000	I	
25bc	U.S. Geol. Survey	1958	10.5	¾	1,781.45	1.21	4-11-60		N	Ca, O
25cc	do	1958	13.8	¾	1,785.14	4.12	4-11-60		N	O
26aa	do	1958	10.5	¾	1,782.81	5.48	3-22-60	12	N	Ca, O
12-8-26ab	William Schumacher		59	18		5.53	11-27-59		I	
26ac	do		59	18		6.34	11-27-59		I	
26bc	do		59	18		5.59	11-27-59		I	
26cb	Alfred Kuhlman	1959				5.22	12- 4-59		I	
26cd	U.S. Geol. Survey	1958	10.6	¾	1,787.69	3.16	4-11-60		N	O
27da	Alfred Kuhlman	1953				6.43	12- 4-59	1,200	I	
27dd1	U.S. Geol. Survey	1958	16.0	¾	1,790.87	1.83	4-11-60	15	N	Ca, O
27dd2	Mr. Roesch	1957	70	18		7.22	12- 4-59	1,000	I	
28dc	U.S. Geol. Survey	1945	12.3	1¼	1,799.83	1.28	3-22-60		N	O
28dd	Jack Lewis	1956							I	
33dd	Daniel P. Jonak	1935	45	24		5.46	5- 3-60	550	I	
34ac1	Fred Meier		30			4.39	11-27-59		I	
34ac2	Frank J. Grosch	1955	72	18		4.97	12- 4-59	1,500	I	

TABLE 10.—*Records of wells*—Continued

Well	Owner or user	Year drilled	Depth of well below land surface (feet)	Diameter of casing (inches)	Altitude above mean sea level (feet)	Static water level		Yield (gpm)	Water use	Remarks
						Distance below land surface (feet)	Date of measurement			
				Merrick County—Continued						
34cc	U.S. Geol. Survey	1958	10.5	¾	1,799.99	3.70	4-11-60	6	N	Ca, O
34cd	Frank J. Grosch	1957	70	18		3.86	12- 4-59	1,500	I	
34dd1	U.S. Geol. Survey	1958	10.5	¾	1,795.27	4.23	4-11-60	7.5	N	Ca, O
34dd2	Fred Meier	1958	80	18		5.86	12- 4-59	1,000	I	
35cb	U.S. Geol. Survey	1958	10.5	¾	1,791.48	2.72	4-11-60		N	O
35cc	Ernest W. Schinkel	1947	70	18		5.64	12- 4-59		I	Ca
35cd	U.S. Geol. Survey	1958	16.0	¾	1,792.09	3.58	4-11-60		N	O
35dd	do	1958	10.6	¾	1,788.03	2.13	4-11-60		N	O
36aa	do	1958	10.3	¾	1,777.43	1.94	4-11-60		N	O
36ad	do	1958	10.5	¾	1,780.50	3.55	12-15-59		N	O
36bb	Charles Kuhlman	1954	66	18		5.04	5- 3-60	1,000	I	
36bc1	U.S. Geol. Survey	1958	7.8	6	1,785.38	3.17	7-29-58		N	O
36bc2	do	1958	10.5	¾	1,783.87	1.02	4-11-60	3.2	N	Ca, O
36cd	do	1958	10.5	¾	1,786.31	1.69	4-11-60		N	O

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