STATE OF SOUTH DAKOTA
Frank Farrar, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 50

WATER SUPPLY FOR THE CITY OF COLUMBIA, SOUTH DAKOTA

by

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and

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University of South Dakota
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CONTENTS

ILLUSTRATIONS

Page

FIGURES

TABLES

APPENDICES

INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota Geological Survey from August 6, 1968, to September 6, 1968, in and around the city of Columbia, Brown County, South Dakota (fig. 1). The purpose of the investigation was to assist the city in locating a future municipal water supply. At the present time, the city does not have a central water supply.

A survey of the ground-water supplies was conducted in the Columbia area. Included in this survey were: (1) mapping the geology of 90 square miles, (2) drilling 59 auger and two rotary test holes, (3) collecting 25 water samples for analysis, (4) obtaining electric logs from the two rotary test holes, and (5) a well inventory.

The cooperation of the residents of Columbia, especially Mayor Vern Seiber, City Policeman Gustaze Newbauer, and Martin Weismantel of the First State Bank of Columbia, is greatly appreciated. Special thanks are due to Independent Drilling Company of Aberdeen for making well records available.

Location and Extent of Area

The Columbia area, as used in this report, includes a region that measures nine miles north-south and ten miles east-west. The area is located in north-central South Dakota, in Brown County, and is in the Lake Dakota Plain of the James Basin of the Central Lowlands Physiographic Province (fig. 1). The city of Columbia is located in the center of the study area. The altitude at Columbia is approximately 1,300 feet, and the population is 278 (1960 census).

Topography and Drainage

The topography of the Columbia area ranges from a gently-sloping to flat-lying surface underlain by Lake Dakota sediments, to slightly undulating glacial deposits along the west edge of the Columbia area (fig. 2).

All streams in the area form an integrated drainage system that drains into the James River.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Columbia area include alluvium along present drainages and Pleistocene glacial deposits (fig. 2).

Alluvium consists of a grayish-brown fine, silty sand with some clay. The maximum thickness penetrated was 13 feet (App. A, test hole 18, and fig. 3).

The glacial deposits are collectively called drift, and can be divided into till and outwash deposits and glacial lake sediments.

Lake sediments were deposited in Lake Dakota, a Pleistocene lake of glacial origin. The sediments are composed of dark- to light-gray very fine sand with silt and clay. The thickness of the sediment varies from zero in the western part of the study area to 92 feet in the eastern part of the study area (App. A, test hole 21, and fig. 3).

Till consists of clay and silt mixed with boulders, pebbles, and sand; all were carried and deposited by the ice itself. Outwash material was deposited by meltwater streams issuing from the ice; such material is more sorted, consisting mostly of gravel and sand, with minor amounts of silt and clay.

Glacial till underlies the lake sediments in most of the area and is present on the surface in the western part of the study area. There is a buried outwash in the northwestern part of the study area (fig. 4). This outwash deposit consists of sand and gravel and some clay.

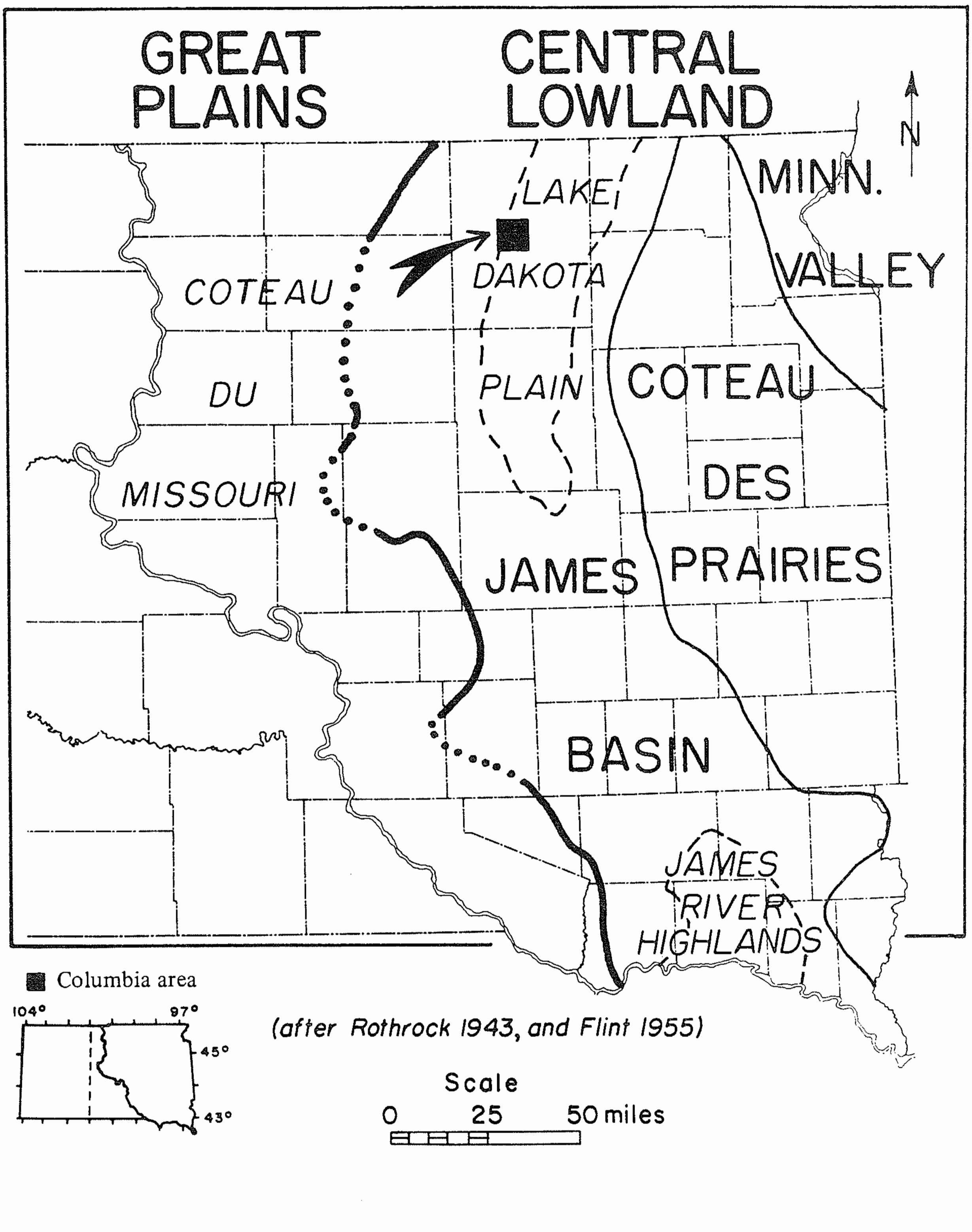

Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Columbia area.

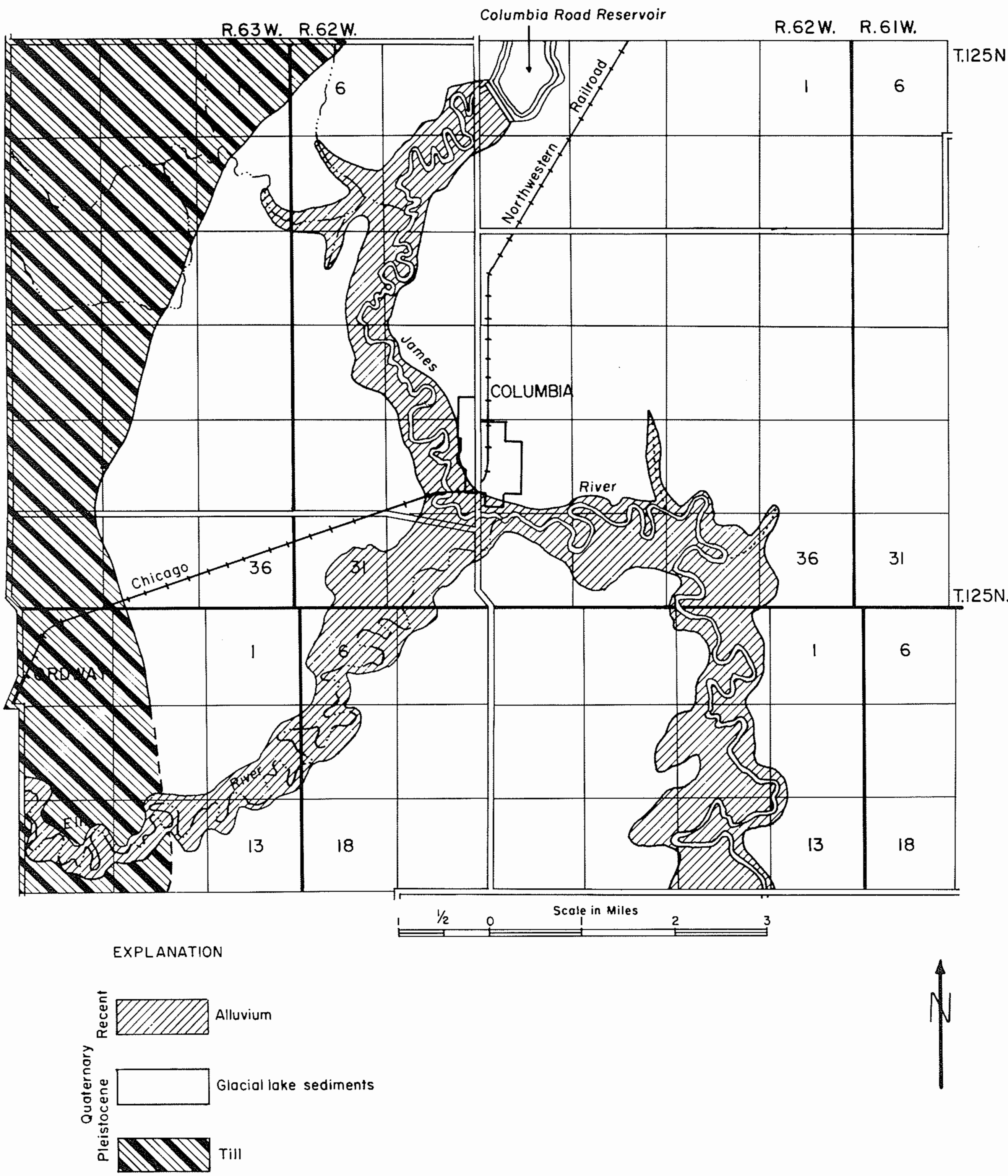

Figure 2. Generalized Geologic map of the Columbia area.

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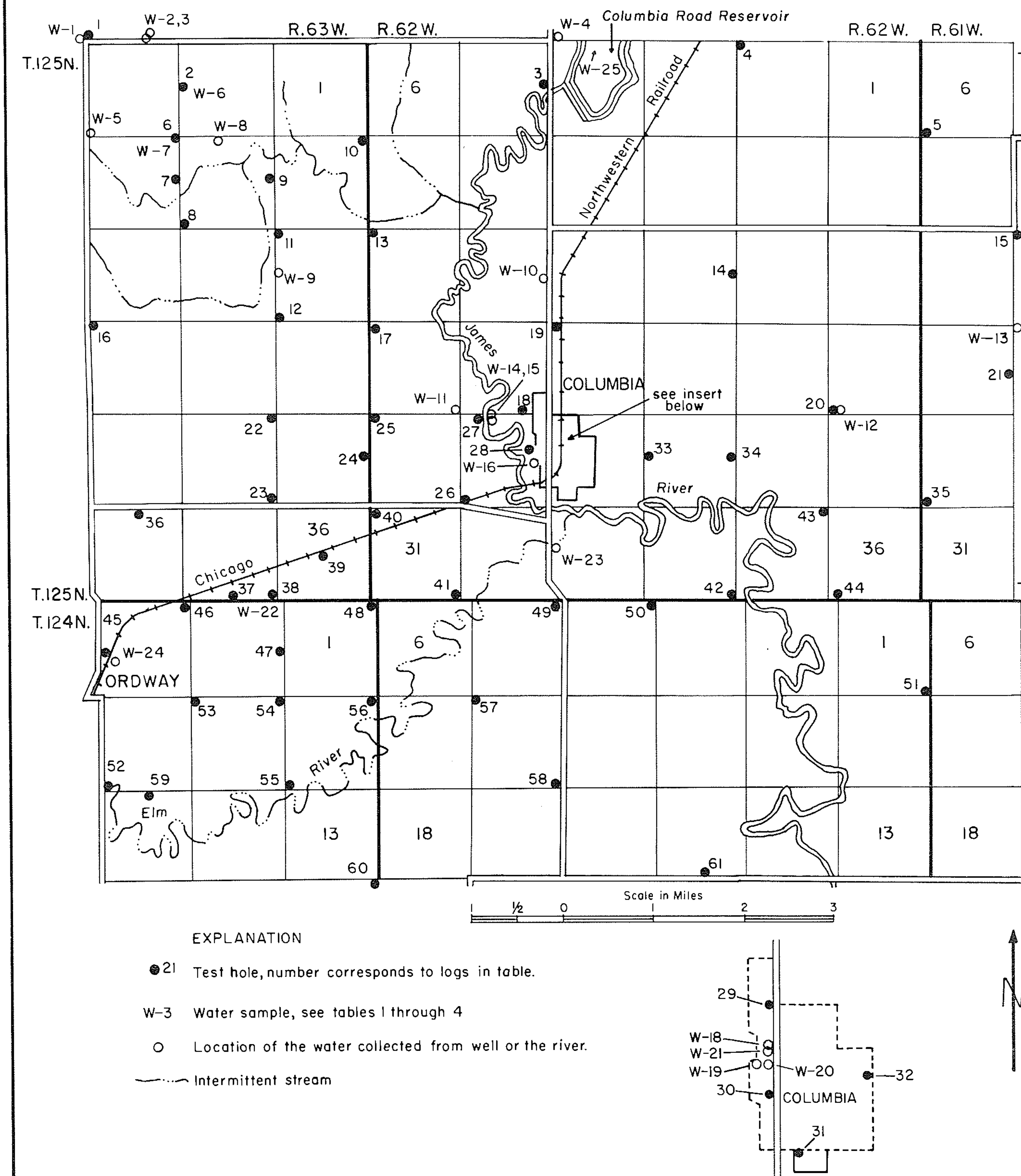

Figure 3. Data map of the Columbia area.

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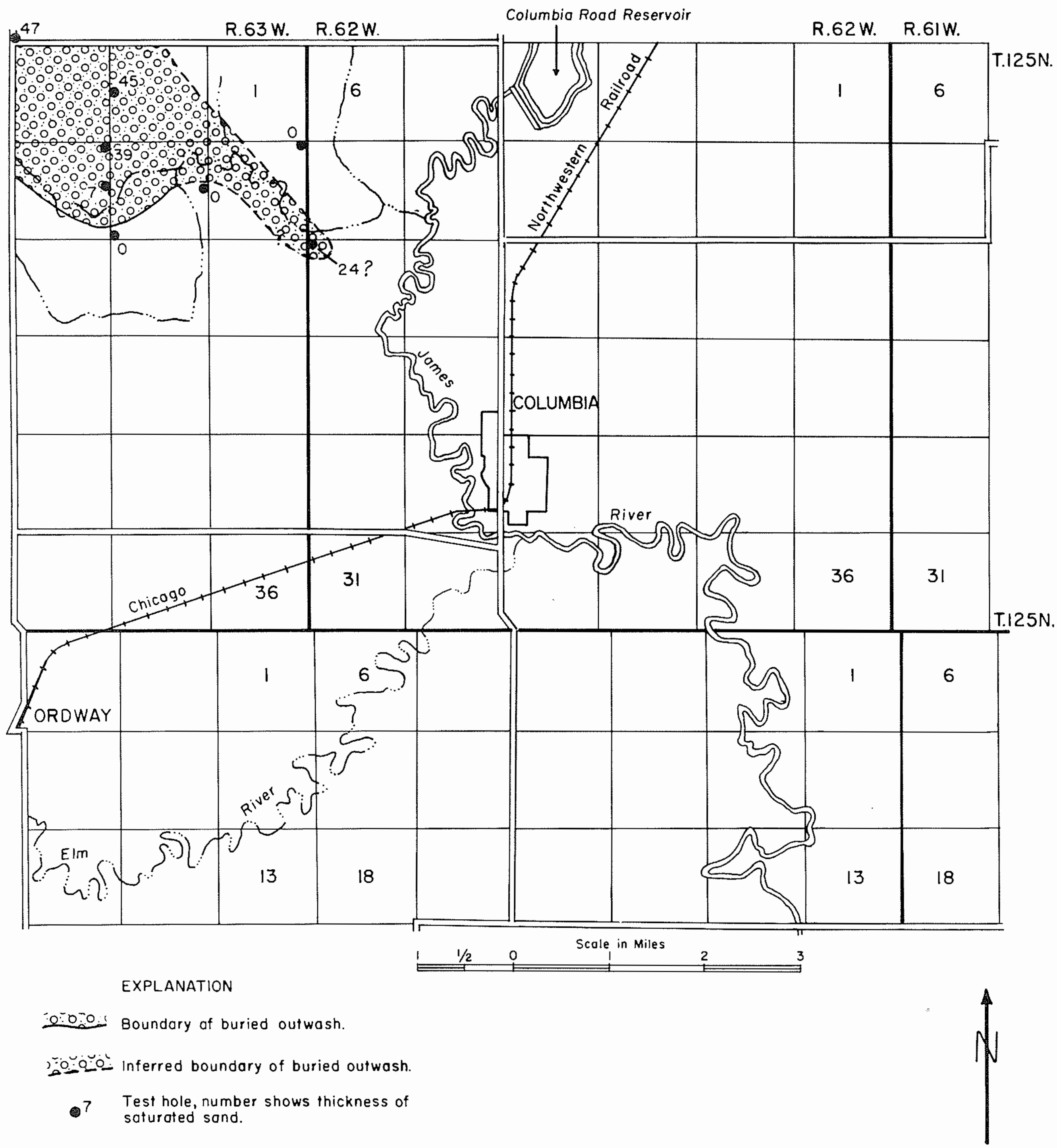

Figure 4. Map showing buried outwash in northwestern part of the Columbia area.

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There are also other outwash deposits and sand lenses, but they do not cover a large area and are not shown on figure 4.

Subsurface Bedrock

Stratified sedimentary rocks of Cretaceous age are present beneath the glacial drift. These deposits in descending order are the Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, Dakota Formation, Skull Creek Shale, and Fall River Formation.

The Pierre Shale consists of light- to dark-gray clayey shale, and is approximately 65 to 80 feet thick in the eastern part of the study area, thinning to zero feet thick in the west part of the study area. Beneath the Pierre Shale is approximately 175 feet of Niobrara Marl. The marl contains many shaly layers.

The Carlile Shale underlies the Niobrara Marl, and consists of light-gray to black shale interbedded with silt and sand. Its thickness is approximately 100 feet.

The Greenhorn Limestone is predominantly a hard, light-colored limestone, with some shale and siltstone. It is about 45 to 50 feet thick.

The Graneros Shale underlies the Greenhorn Limestone, and is a dark gray clayey shale approximately 245 feet thick.

The Dakota Formation is a sequence of alternating sand, sandstone and shale beds. In the Columbia area it is approximately 265 feet thick.

The Skull Creek Shale is approximately 50 feet thick and is a medium- to dark-gray shale that has a silt horizon near its center which is partly glauconitic.

The Fall River Formation underlies the Skull Creek Shale. It is a white to light-gray, fine to medium-grained sand, ranging from 60 to 200 feet in thickness.

Below the Cretaceous bedrock there may be Paleozoic rocks from Pennsylvanian or Ordovician age. If Paleozoic rocks are present in the study area they are probably not over 30 feet thick.

Pre-Cambrian rocks underlie the Paleozoic rocks.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water is defined as that water contained in the voids or openings within rocks or sediments below the water table. The water table is the upper surface of the zone of saturation. Practically all open spaces in the rocks that lie below the water table are filled with water. Rocks (including the soil) that lie above the water table are in the zone of aeration. Some of the interstices in this zone are also filled with water, but the water is either held in them by molecular attraction, or is moving downward toward the zone of saturation. Water within the ground above the saturated zone moves downward under the action of gravity, whereas in the saturated zone, it moves in a direction determined by the hydraulic head.

Contrary to popular belief, ground water does not occur in "veins" that crisscross the land at random. Instead it can be shown that water is found nearly everywhere beneath the surface, but at varying depths.

Nearly all ground water is derived from precipitation in the form of rain, melting snow, or ice. This water either evaporates, percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward into the rocks.

Recharge is the addition of water to an aquifer (a formation having structures that permit appreciable water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral underflow of water in transient storage, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge of ground water from an aquifer is accomplished in four main ways: (1) by evaporation and transpiration of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping from wells, which constitutes the major artificial discharge of ground water.

The porosity of a rock or soil is a measure of the contained open pore spaces, and it is expressed as the percentage of void spaces to the total volume of the rock. The porosity of a sedimentary deposit depends chiefly on (1) the shape and arrangement of its constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Thus, the size of the material has little or no effect on porosity if all other factors are equal.

The permeability of a rock is its capacity for transmitting a fluid. Water will pass through a material with interconnected pores, but will not pass through material with unconnected pores, even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms.

Ground Water in Alluvium

Alluvium is present along the streams in the Columbia area (fig. 2). Clay in alluvium decreases the permeability of these sediments. Because of the low permeability, these sediments should not be considered as a city water supply.

Ground Water in Lake Deposits

The main portion of the study area is covered by glacial lake deposits (fig. 2). The saturated thickness of these materials varies from zero to a maximum of 76 feet in test hole 21 (App. A). Within the city of Columbia, the saturated thickness of the lake deposits varies between 47 feet in test hole 29 to 72 feet in test hole 30 (App. A). There are few wells within the city limits that obtain water from the lake sediments. These sediments have a low permeability; therefore, it is not expected to produce large quantities of water. A well drilled in the James River valley, near a recharge source (river), is expected to produce more water than a well within the city limits.

Ground Water in Glacial Deposits

It was stated earlier that glacial deposits are divided into till and outwash. Till does not yield water readily because of its highly unsorted nature and low permeability. Locally there are some lenses of sand and gravel within the till which provide an adequate water supply for farm wells but are not important as a possible water supply for the city of Columbia.

The shallow buried outwash deposit northwest of Columbia (fig. 4) consists mainly of sand and gravel with some clay. It has a maximum saturated thickness of 45 feet in test hole 2 (App. A). This aquifer probably could provide adequate water for the city, but additional testing is required to define the extent of these sediments.

Ground Water in Bedrock

The Dakota Formation and the Fall River Formation are the two major bedrock aquifers in the Columbia area. The Dakota Formation is at a depth of approximately 835 feet and, as mentioned earlier, is composed of alternating layers of sand, sandstone, and shale beds that are approximately 265 feet thick. The water in this formation is under pressure and flows from wells drilled into it in the Columbia area. Wells two inches in diameter yield a flow of two to 30 gallons per minute (gpm) in this area.

The Fall River Formation as previously described is approximately 60 to 200 feet thick and is a white to light-gray, fine- to medium-grained sand. This formation is approximately 1200 feet below the surface in the study area. The water in this formation is also under pressure and yields about the same flow from wells drilled into it as the Dakota Formation.

Quality of Ground Water

Ground water always contains dissolved chemical substances in various amounts. Contained chemicals are derived from: (1) the atmosphere as water condenses and falls, (2) the soil and underlying deposits as the water moves downward to the water table, and (3) rock deposits below the water table where the water is circulating. In general, the more chemical substances that a water contains, the poorer its quality.

Tables 1, 2, 3, and 4 show the quality of water from the various aquifers in the Columbia area as compared with the limits recommended by the U. S. Department of Public Health. Table 5 shows the significance of some chemical and physical properties of drinking water.

Table 1 shows the quality of water from the buried outwash in the study area. Samples w-1, w-2, w-6, and w-7 were taken from the buried outwash in the northwest of the study area (figs. 3 and 4). Comparison of these samples with the State Health Standards shows that except for iron in sample w-1 these samples are high in iron and manganese and low in fluoride. The rest of the chemicals in these samples are within the State Health standards. Sample w-7 was collected from the northwest part of the study area, near an abandoned artesian well. This well is not flowing at the present time, but high chemicals in sample w-7 probably indicate the well is recharging the shallow aquifer in this location. Sample w-9 was collected from a farm well and probably obtained water from a sand lense. Samples w-22 and w-24 were collected from small buried outwash or sand lenses in the southwest part of the study area. Sample w-22 is high in sulfate and iron. Sample w-24 is high in nitrate and low in fluoride.

Table 2 shows the results of water analyses from the Lake Dakota sediments. Samples w-12, w-16, w-17, and w-18 were collected from wells which possibly are getting some or all water from a buried sand lense at the top of till. Except for sample w-13 all samples are high in chloride, iron, and total solids. Sample w-13 is high in sulfate, and samples w-4, w-13, w-16, and w-17 are high in manganese. Except for low fluoride in all samples, the rest of the chemicals are within the limits set by the South Dakota Department of Health.

Table 3 shows the results of water analyses of flowing wells in the study area. Sample w-5 is from the Fall River Formation and the rest of the samples are from the Dakota Formation. Sample w-5 is higher in sulfate and lower in chloride than the samples from the Dakota Formation. Except for chloride in sample w-5 all samples are high in chloride and fluoride, and total solids. Iron is high in samples w-5, w-8, w-11, w-19, and w-23. Except for w-10, w-19, w-20, and w-21, all samples are high in sulfate. The remaining chemicals are within the limits set by the South Dakota Department of Health.

Table 4 shows the results of water analyses from the Columbia Road Reservoir, approximately three miles north of the city, and the James River next to the city. Samples w-14 and w-15 were taken from the same location at different times. Comparing these two samples shows a variation in their chemical contents. Samples w-14 and w-15 are high in iron and all the samples have less fluoride than the recommended limits, but otherwise the rest of the chemicals are within the limits of the South Dakota Department of Health.

Table 5 shows the significance of some chemical and physical properties of drinking water.

CONCLUSIONS AND RECOMMENDATIONS

There are four potential sources of water for the city of Columbia. The cost, quality of water, and the engineering problems involved in obtaining water should dictate the order of preference of the sources. These sources without considering the order of preference are:

1. The Dakota Formation and the Fall River Formation which underlie the study area have water under pressure and provide water for the flowing wells in this area. The water from the Fall River Formation has higher sulfate and lower chloride than the water from the Dakota Formation. Water from both sources has lower calcium than any other source in this area. The water from these formations has higher fluoride and total solids content than the recommended limits set by the South Dakota Department of Health (table 3). The Dakota Formation or the Fall River Formation will provide adequate water for the city, but the flow probably will decrease due to decline of head in these formations.

Table 1.--Chemical analyses of water samples from buried outwash in the study area

Sample	Parts Per Million											
	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Hardness $CaCO_3$	pH	Total Solids
A1	—	—	—	250	500[1]	0.3	0.005[1]	10.0	0.9[2] 1.7	—	--	1000[1]
w-1	127	80	25	35	220	0	0.3	0.4	0.2	418		888
w-2	119	100	96	131	210	4.3	0.6	0	0.8	423		886
w-6	85	80	36	30	226	39	4.7	0.2	0.6	360		776
w-7	170	310	163	52	1038	20.5	1.5	8.8	0.6	1095		2256
w-9	108	170	32	58	302	0.9	0.2	0	0.6	400		924
w-22	284		187	1000	975	58		0	1.0	1480	7.6	3540
w-24	260		41	175	410	0.03		15.7	0.58	820	7.3	1330

All the samples in Table 1 were analyzed by the South Dakota Chemical Laboratory except for samples w-22 and w-24 which were done by the Water Quality Laboratory of the South Dakota Geological Survey.

[1] Modified for South Dakota by the State Department of Health (written communication, Water Sanitation Section, March 20, 1968).
[2] 1.2 is optimum for South Dakota.

Location of Water Samples

(for map location, see figure 3)

A1. Drinking Water Standards, U. S. Public Health Service (1968).
w-1. SE¼SE¼SE¼SE¼ sec. 33, T. 126 N., R. 63 W., P. Dennert, 65 feet deep.
w-2. SW¼SE¼SW¼SE¼ sec. 34, T. 126 N., R. 63 W., T. Bell, 40 feet deep.
w-6. SW¼SW¼SW¼NW¼ sec. 2, T. 125 N., R. 63 W., collected by South Dakota Geological Survey from test hole number 2.
w-7. NE¼NE¼NE¼NE¼ sec. 10, T. 125 N., R. 63 W., collected by South Dakota Geological Survey from test hole number 6.
w-9. SW¼SW¼SW¼NW¼ sec. 13, T. 125 N., R. 63 W., J. Frerichs, 40 feet deep, water table 14 feet.
w-22. SE¼SE¼SE¼SE¼ sec. 35, T. 125 N., R. 63 W., collected by South Dakota Geological Survey from test hole number 38.
w-24. SE¼NW¼NW¼SW¼ sec. 3, T. 124 N., R. 63 W., R. Askew, 20 feet deep, water table 13 feet.

Table 2.--Chemical analyses of water samples from
Lake Dakota sediments

	Parts Per Million											
Sample	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Hardness $CaCO_3$	pH	Total Solids
A1	—	—	—	250	500[1]	0.3	0.005[1]	10.0	0.9[2] 1.7	—	–	1000[1]
w-4	108		24	550	159	1.13	0.3	0	.57	370	7.3	1795
w-12[3]	88		12	430	146	7.5	0	0	.50	270	7.3	1982
w-13	140		17	30	600	0.07	0.3	3.0	.38	420	7.6	569
w-16[3]	90		13	530	165	1.01	0.3	0	.65	280	7.4	1810
w-17[3]	156		22	305	159	1.43	0.5	0	0.5	480	7.2	1335
w-18	93	340	35	500	80	2.7	0	0	0.8	260		1254

Sample w-18 was analyzed by the South Dakota Chemical Laboratory. All other samples in table 2 were analyzed by the Water Quality Laboratory of the South Dakota Geological Survey.

[1] Modified for South Dakota by the State Department of Health (written communication, Water Sanitation Section, March 20, 1968).

[2] 1.2 is optimum for South Dakota.

[3] Some of the water is possibly coming from sand lenses at the top of till beneath the lake deposit. This conclusion was reached by considering the depth of the well and the thickness of the lake deposits as found from the test holes.

Location of Water Samples

(For map location see figure 3)

A1. Drinking Water Standards, U. S. Public Health Service (1968).
w-4. SW¼SW¼SW¼SW¼ sec. 33, T. 126 N., R. 62 W., G. Wilke, water table 12 feet.
w-12. SE¼SW¼SW¼SW¼ sec. 24, T. 125 N., R. 62 W., J. Daly, 100 feet deep, water table 20 feet.
w-13. NW¼NW¼NW¼NW¼ sec. 20, T. 125 N., R. 61 W., E. Daly, 32 feet deep, water table 20 feet.
w-16. NW¼NE¼NE¼SE¼ sec. 29, T. 125 N., R. 62 W., V. Sieber, 103 feet deep.
w-17. NW¼NW¼NW¼SW¼ sec. 28, T. 125 N., R. 62 W., Co-op well, 97 feet deep.
w-18. SE¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W., M. Weismantel, 92 feet deep.

Table 3.–Chemical analyses of water samples from flowing wells

Sample	Parts Per Million											
	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Hardness $CaCO_3$	pH	Total Solids
A1	—	—	—	250	500[1]	0.3	0.005[1]	10.0	0.9[2] 1.7	—	--	1000[1]
w-3	4	920	9	431	786	0.3	0	0	4.7	46	–	2348
w-5	7	760	11	108	1292	0.6	0	0	3.3	62	--	2278
w-8	0	860	9	631	534	0.5	0	0	4.7	—	--	2298
w-10	12	—	0	710	500	0.08	0	0	4.9	30	8.0	2920
w-11	10	—	0	530	565	0.58	0	0	4.4	25	8.1	2450
w-19	0	1130	9	893	362	0.5	0	1	3.3	36	–	2796
w-20	1	1060	9	690	494	0	0	0	4.7	38	--	2630
w-21	4	1400	11	1333	72	0	0	0	2.0	54	--	3302
w-23	5	800	7	347	740	0.46	0	0	4.7	30	8.2	2040

Sample w-5 is from the Fall River Fromation, the rest of the samples are from the Dakota Formation.
Samples w-10 and w-11 were analyzed by the Water Quality Laboratory of the South Dakota Geological Survey. The rest of the samples were analyzed by the South Dakota Chemical Laboratory except for the pH of sample w-23.

[1] Modified for South Dakota by the State Department of Health (written communication, Water Sanitation Section, March 20, 1968).
[2] 1.2 is optimum for South Dakota.

Location of Water Samples

(For map location see figure 3)

A1. Drinking Water Standards, U. S. Public Health Service (1968).
w-3. SW¼SE¼SW¼SE¼ sec. 34, T. 126 N., R. 63 W., T. Bell.
w-5. SW¼SW¼SW¼SW¼ sec. 3, T. 125 N., R. 63 W., C. Olson, 1400 feet deep.
w-8. NW¼NE¼NE¼NW¼ sec. 11, T. 125 N., R. 63 W., 1086 feet deep.
w-10. NE¼NE¼NE¼SE¼ sec. 17, T. 125 N., R. 62 W., G. P. Roettele, 1285 feet deep.
w-11. SE¼SE¼SE¼SE¼ sec. 19, T. 125 N., R. 62 W., A. Zastrow, 1100 feet deep.
w-19. In the City of Columbia, one block west of the Public School House, 900 feet deep.
w-20. In the City of Columbia, Public School House flowing well, 1100 feet deep.
w-21. SE¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W., M. Weismantel, 1100 feet deep.
w-23. SW¼SW¼SW¼NW¼ sec. 33, T. 125 N., R. 62 W., R. Jackson, 1120 feet deep.

Table 4.–Chemical analyses of water samples from Columbia Road Reservoir and the James River

Sample	Parts Per Million											
	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Hardness $CaCO_3$	pH	Total Solids
A1	—	—	--	250	500[1]	0.3	0.005[1]	10.0	0.9[2] 1.7	—	--	1000[1]
w-14	46	—	33	60	248	0.13	0.8	0	0.70	235	7.6	686
w-15	61	180	64	67	286	0.8	0	0	0.60	416	--	890
w-25	84	—	39	50	258	0	0	0	0.62	370	7.6	855

Samples w-14 and w-25 were analyzed by the Water Quality Laboratory of the South Dakota Geological Survey. Sample w-15 was analyzed by the South Dakota Chemical Laboratory.

[1] Modified for South Dakota by the State Department of Health (written communication, Water Sanitation Section, March 20, 1968).
[2] 1.2 is optimum for South Dakota.

Locations of Water Samples

(For map location see figure 3)

A1. Drinking Water Standards, U. S. Public Health Service (1968).
w-14. NE¼NE¼NW¼NW¼ sec. 29, T. 125 N., R. 62 W., James River.
w-15. NE¼NE¼NW¼NW¼ sec. 29, T. 125 N., R. 62 W., James River (Sample w-14 was collected on August 19, 1968, and sample w-15 was collected on November 9, 1968.).
w-25. NW¼NW¼NE¼NW¼ sec. 33, T. 126 N., R. 62 W., Columbia Road Reservoir.

Table 5.--Significance of some chemical and physical properties of drinking water.

Chemical Constituents	Significance	Recommended Limits (ppm)[1]
Calcium (Ca) and Magnesium (Mg)	Cause most of the carbonate hardness and scale-forming properties of water by combining with carbonate and bicarbonate present in the water. Seldom can be tasted except in extreme concentrations.	Ca–None Mg–None
Sodium (Na)	Large amounts in combination with chloride will give water a salty taste. Large amounts will limit water for irrigation and industrial use.	None
Chloride (Cl)	Large amounts in combination with sodium give water a salty taste. Large quantities will also increase corrosiveness of water.	250
Sulfate (SO_4)	Large amounts of sulfate in combination with other ions give a bitter taste to water and may act as a laxative to those not used to drinking it. Sulfates of calcium and magnesium will form hard scale. U. S. Public Health Service recommends 250 ppm maximum concentration.	500[2]
Iron (Fe) and Manganese (Mn)	In excess will stain fabrics, utensils, and fixtures and produce objectionable coloration in the water. Both constituents in excess are particularly objectionable.	Fe–0.3 Mn–0.005[2]
Nitrogen (N)	In excess may be injurious when used in infant feeding. The U. S. Public Health Service regards 45 ppm as the safe limit of nitrate (NO_3) or 10 ppm nitrogen (N).	10
Fluoride (F)	Reduces incidence of tooth decay when optimum fluoride content is present in water consumed by children during period of tooth calcification. Excessive fluoride in water may cause mottling of enamel.	0.9-1.7[3]
pH	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values lower than 7.0 indicate acidity, pH values higher than 7.0 indicate alkalinity. Alkalinity tends to aid encrustation and acidity tends to aid corrosion.	None
Hardness	Hardness equivalent to carbonate and bicarbonate is called carbonate hardness. Hardness in excess of this amount is noncarbonate hardness. Hardness in water consumes soap and forms soap curd. Will also cause scale in boilers, water heaters and pipes. Water containing 0-60 ppm hardness considered soft; 61-120 ppm moderately hard; 121-180 ppm hard and more than 180 ppm very hard. Good drinking water can be very hard.	None
Total Solids	Total of all dissolved constituents. U. S. Public Health Department recommends 500 ppm maximum concentration. Water containing more than 1000 ppm dissolved solids may have a noticeable taste; it may also be unsuitable for irrigation and certain industrial uses.	1000[2]

Modified from Jorgensen (1966) error

[1] (ppm) parts per million

[2] Modified for South Dakota by the South Dakota Department of Health (written communication, Water Sanitation Section, March 20, 1968).

[3] 1.2 is optimum for South Dakota

2. The Columbia Road Reservoir, a shallow body of water approximately eight miles long and one-half mile wide, could probably provide enough water for the city of Columbia. This source would require, in addition to approximately three and one-half miles of pipeline, a filtration plant if used for municipal water supply. Sample w-25 (table 4) shows the chemical analyses of water from this source. Except for low fluoride, it is within the South Dakota Department of Health Standards. Seasonal change of water quality is expected from this source.

3. The James River Valley is located near the town. Lake Dakota sediments which consist of very fine silty sand underlie the alluvial deposits in this valley. The alluvial deposits and the lake sediments do not have a high permeability, but the short distance to the river and the small quantity of water required for a city of this size suggests the possibility of obtaining sufficient quantity of water by a collector well or an infiltration gallery in this valley. The quality of water should be similar to w-14 and w-15 which were both collected from the river. Except for low fluoride content these samples are within the South Dakota Department of Health limits. Development of this type of water supply system would have to be preceeded by additional testing and would involve special engineering considerations before constructing a permanent city well.

4. The buried outwash deposits northwest of the city (fig. 4) would probably provide a sufficient quantity of water for a city supply. Water from this area is high in iron and manganese and low in fluoride content. Additional testing would be required to define the areal extent of this aquifer and the quality of water.

Before additional testing is undertaken, the city should hire a consulting engineer licensed in South Dakota. If, based on the recommendation of the engineering report, the city should decide to obtain water from the James River valley or the buried outwash northwest of the city, it is recommended that the city hire a commercial drilling company to construct an aquifer (pump) test well. The aquifer test should be conducted by a qualified hydrologist or engineer and run for 72 hours. An aquifer test is recommended for the following reasons: (1) to determine the expected yield from well(s); (2) to determine the proper spacing of wells; (3) to obtain data for final design of the well or well system; and (4) to obtain water samples during the aquifer test for chemical analyses.

Before constructing a permanent city well, the city officials should consult with the South Dakota Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the South Dakota Department of Health with regard to the biological and chemical suitability of the water.

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Rothrock, E. P., 1943, A geology of South Dakota, part I: The Surface: S. Dak. Geol. Survey Bull. 13, 88 p., 30 pl., 3 maps.

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APPENDIX A

Logs of test holes in the Columbia area

(for location see figure 3)

Test Hole No. 1
Location: SW¼SW¼SW¼SW¼ sec. 34, T. 126 N., R. 63 W.
Surface Elevation: 1350 feet
Depth to Water: 28 feet

0- 1	Topsoil
1-22	Clay, dark-brown, with sand (till)
22-28	Clay, dark-gray, pebbly (till)
28-38	Sand and gravel, with clay
38-75	Sand, light-gray, medium to coarse
75-99	Clay, dark-gray, pebbly (till)

* * *

Test Hole No. 2
Location: SW¼SW¼SW¼NW¼ sec. 2, T. 125 N., R. 63 W.
Surface elevation: 1300 feet
Depth to water: 13 feet

0- 1	Topsoil
1-12	Clay, yellow, pebbly (till)
12-25	Clay, gray, with sand (till)
25-50	Gravel, medium
50-70	Sand, gray, fine to medium
70-90	Clay, gray, pebbly (till)

* * *

Test Hole No. 3
Location: SE¼SE¼SE¼NE¼ sec. 5, T. 125 N., R. 62 W.
Surface elevation: 1295 feet
Depth to water: 10 feet

0- 1	Topsoil
1-20	Clay, tan, with fine sand
20-41	Clay, grayish-brown
41-62	Clay, dark-gray, pebbly (till)

* * *

Test Hole No. 4
Location: NW¼NW¼NW¼NW¼ sec. 2, T. 125 N., R. 62 W.
Surface elevation: 1288 feet
Depth to water: 8 feet

0- 1	Topsoil
1- 13	Clay, yellowish-brown
13- 64	Clay, gray, with fine sand
64-114	Clay, gray, pebbly (till)
114-119	Clay, bluish-black (shale)

* * *

Test Hole No. 5
Location: SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 6, T. 125 N., R. 61 W.
Surface elevation: 1293 feet
Depth to water: 7 feet

0- 1	Topsoil
1-11	Clay, grayish-brown
11-30	Clay, tannish-gray, with fine sand
30-73	Clay, gray
73-82	Clay, gray, pebbly (till)

* * *

Test Hole No. 6
Location: NE$\frac{1}{4}$NE$\frac{1}{4}$NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 10, T. 125 N., R. 63 W.
Surface elevation: 1325 feet
Depth to water: 19 feet

0- 1	Topsoil
1- 12	Clay, brown, pebbly (till)
12- 23	Clay, gray, with sand
23- 47	Clay, gray, pebbly (till)
47- 86	Sand, light-gray, medium to coarse
86-110	Clay, gray, pebbly (till)

* * *

Test Hole No. 7 (Rotary test)
Location: SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 10, T. 125 N., R. 63 W.
Surface elevation: 1315 feet
Depth to water: 18 feet

0- 2	Topsoil
2- 4	Clay, yellow, silty
4- 18	Clay, brown, with fine sand and gravel
18- 25	Clay, gray, pebbly (till)
25- 33	Sand, gray, coarse, with gravel
33- 43	Clay, gray
43- 50	Sand, gray
50- 75	Clay, gray, with sand and gravel
75- 97	Clay, gray, with sand
97-158	Clay, gray, pebbly (till)
158-168	Sand and gravel
168-200	Clay, dark-gray, pebbly (till)
200-215	Clay, gray
215-230	Sand and gravel
230-247	Clay, gray, pebbly (till)
247-354	Clay, light-gray, (chalk)
354-410	Clay, bluish-black, (shale)

* * *

Test Hole No. 8
Location: SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 11, T. 125 N., R. 63 W.
Surface elevation: 1319 feet
Depth to water: 32 feet

Test Hole No. 8 (continued)

0- 1	Topsoil
1- 38	Clay, brown, pebbly
38- 67	Clay, gray, with fine sand
67- 90	Clay, gray
90-111	Clay, gray, pebbly
111-119	Clay, dark-gray, pebbly (till)

* * *

Test Hole No. 9
Location: SE¼SE¼SE¼NE¼ sec. 11, T. 125 N., R. 63 W.
Surface elevation: 1307 feet
Depth to water: 33 feet (?)

0- 2	Topsoil
2- 6	Clay, yellowish-brown, silty
6- 9	Sand, yellowish-brown
9-35	Clay, yellowish-brown, silty (till)
35-56	Clay, gray, with sand
56-60	Clay, gray

* * *

Test Hole No. 10
Location: NE¼NE¼NE¼NE¼ sec. 12, T. 125 N., R. 63 W.
Surface elevation: 1305 feet
Depth to water: Dry

0- 1	Topsoil
1-13	Clay, tannish-brown, with fine sand
13-47	Clay, brownish-gray, pebbly
47-67	Clay, gray
67-89	Clay, gray, pebbly (till)

* * *

Test Hole No. 11
Location: NW¼NW¼NW¼NW¼ sec. 13, T. 125 N., R. 63 W.
Surface elevation: 1303 feet
Depth to water: 12 feet

0- 1	Topsoil
1-22	Clay, yellowish-brown, silty
22-33	Clay, yellowish-brown, with sand
33-88	Clay, gray, with sand (till)

* * *

Test Hole No. 12
Location: SW¼SW¼SW¼SW¼ sec. 13, T. 125 N., R. 63 W.
Surface elevation: 1305 feet
Depth to water: 7 feet

0- 1	Topsoil
1- 13	Clay, yellowish-brown, with sand

Test Hole No. 12 (continued)

13- 26	Clay, gray, with sand and gravel
26- 36	Sand and gravel
36- 60	Clay, gray
60- 88	Clay, gray, pebbly
88-101	Sand and gravel, dark-brown, medium to coarse, with clay
101-109	Clay, grayish-black, with sand
109-129	Clay, bluish-black, compact, (shale?)

* * *

Test Hole No. 13
Location: NW¼NW¼NW¼NW¼ sec. 18, T. 125 N., R. 62 W.
Surface elevation: 1293 feet
Depth to water: 38 feet?

0- 1	Topsoil
1- 6	Sand, yellow, fine
6-12	Sand, gray, silty
12-15	Sand, coarse
15-38	Clay, gray, with sand and pebbles
38-62	Sand, medium (?)
62-70	Clay, gray, pebbly (till)

* * *

Test Hole No. 14
Location: SE¼SE¼SE¼NE¼ sec. 15, T. 125 N., R. 62 W.
Surface elevation: 1295 feet
Depth to water: 12 feet

0- 1	Topsoil
1-12	Clay, brown, with fine sand
12-71	Clay, gray
72-83	Clay, gray, pebbly (till)

* * *

Test Hole No. 15
Location: NW¼NW¼NW¼NW¼ sec. 17, T. 125 N., R. 61 W.
Surface elevation: 1300 feet
Depth to water: 20 feet

0- 1	Topsoil
1- 20	Sand, yellowish-brown, fine, silty
20- 62	Clay, gray, with fine sand
62-102	Clay, dark gray, pebbly (till)
102-109	Clay, bluish-gray, compact (shale)

* * *

Test Hole No. 16
Location: NW¼NW¼NW¼NW¼ sec. 22, T. 125 N., R. 63 W.
Surface elevation: 1320 feet
Depth to water: 7 feet

Test Hole No. 16 (continued)

0- 6	Clay, brown, with sand
6- 13	Clay, dark-brown, pebbly
13- 62	Clay, dark-gray, pebbly
62-129	Clay, dark-gray, boulders, pebbly (till)

* * *

Test Hole No. 17
Location: SW¼NW¼NW¼NW¼ sec. 19, T. 125 N., R. 62 W.
Surface elevation: 1290 feet
Depth to water: 7 feet

0- 1	Topsoil
1-13	Clay, light-brown, silty
13-22	Clay, gray, with fine sand
22-26	Sand, gray, medium to coarse, with clay
26-74	Clay, bluish-black, pebbly (till)

* * *

Test Hole No. 18
Location: SE¼SE¼SW¼SE¼ sec. 20, T. 125 N., R. 62 W.
Surface elevation: 1282 feet
Depth to water: 8 feet

0-13	Sand, grayish-brown, very fine with clay
13-25	Clay, brown, with sand
25-48	Clay, gray
48-67	Sand, gray, medium to coarse, with clay
67-74	Clay, gray, pebbly (till)

* * *

Test Hole No. 19
Location: NW¼NW¼NW¼NW¼ sec. 21, T. 125 N., R. 62 W.
Surface elevation: 1290 feet
Depth to water: 14 feet

0- 16	Clay, light-brown, silty
16- 53	Clay, light- to dark-gray, with fine sand
53-106	Clay, dark-gray, pebbly (till)
106-119	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 20
Location: SW¼SW¼SW¼SW¼ sec. 24, T. 125 N., R. 62 W.
Surface elevation: 1290 feet
Depth to water: 8 feet

0- 1	Topsoil
1- 19	Clay, yellowish-brown, with fine sand
19- 30	Clay, brownish-gray, with fine sand
30- 82	Clay, gray, with silt

Test Hole No. 20 (continued)

82- 93	Clay, dark-gray, pebbly
93-110	Clay, bluish-black, compact (shale?)

* * *

Test Hole No. 21
Location: NE¼NE¼NE¼SE¼ sec. 19, T. 125 N., R. 61 W.
Surface elevation: 1297 feet
Depth to water: 16 feet

0- 2	Topsoil
2- 13	Clay, light-brown
13- 33	Clay, tannish-brown, with fine sand
33- 42	Sand, gray, fine, with some clay
42- 92	Clay, gray, sandy
92-102	Clay, grayish-black, pebbly (till)
102-109	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 22
Location: NE¼NE¼NE¼NE¼ sec. 26, T. 125 N., R. 63 W.
Surface elevation: 1298 feet
Depth to water: 7 feet

0- 1	Topsoil
1-18	Clay, light-brownish-tan, with fine sand
18-39	Clay, gray, gravelly (till)
39-74	Clay, gray, pebbly (till)

* * *

Test Hole No. 23
Location: SE¼SE¼SE¼SE¼ sec. 26, T. 125 N., R. 63 W.
Surface elevation: 1300 feet
Depth to water: 7 feet

0- 1	Topsoil
1-10	Clay, yellowish-brown, with fine sand
10-26	Sand, brown-to-gray, very fine, with some clay
26-41	Clay, gray, gravelly (till)
41-74	Clay, gray, pebbly (till)

* * *

Test Hole No. 24
Location: SE¼SE¼SE¼NE¼ sec. 25, T. 125 N., R. 63 W.
Surface elevation: 1298 feet
Depth to water: 24 feet

0- 1	Topsoil
1- 14	Clay, light- to dark-brown, silty
14- 31	Sand, brown to gray, with some clay
31- 70	Clay, dark-gray, pebbly (till)
70-134	Clay, dark-gray, pebbly (more compact) (till)

* * *

Test Hole No. 25
Location: NW¼NW¼NW¼NW¼ sec. 30, T. 125 N., R. 62 W.
Surface elevation: 1298 feet
Depth to water: 19 feet

0- 1	Topsoil
1-19	Clay, brown, with fine sand
19-26	Clay, light-gray, with fine sand and silt
26-61	Clay, dark-gray, pebbly (till)
61-84	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 26
Location: SW¼SW¼SW¼SW¼ sec. 29, T. 125 N., R. 62 W.
Surface elevation: 1304 feet
Depth to water: 17 feet

0- 1	Topsoil
1-35	Sand, tannish-brown, very fine, with some clay
35-53	Sand, brown, very fine, with clay
53-66	Clay, grayish-brown, sandy
66-74	Clay, dark-gray, pebbly (till)

* * *

Test Hole No. 27
Location: NE¼NE¼NW¼NW¼ sec. 29, T. 125 N., R. 62 W.
Surface elevation: 1280 feet
Depth to water: 4 feet

0- 1	Topsoil
1- 4	Sand, brown, very fine
4- 42	Sand, grayish-brown, very fine to fine, clay
42-122	Clay, gray, pebbly (till)

* * *

Test Hole No. 28
Location: SW¼NW¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.
Surface elevation: 1282 feet
Depth to water: 10 feet

0-10	Clay, grayish-brown, sandy
10-38	Clay, gray
38-55	Clay, gray, with fine to coarse sand and some gravel
55-69	Clay, gray, pebbly (till)

* * *

Test Hole No. 29
Location: NE¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.
Surface elevation: 1293 feet
Depth to water: 6 feet

0- 1	Topsoil
1- 6	Sand, brown, medium with clay

Test Hole No. 29 (continued)

6- 35	Sand, brown to gray, fine, with clay
35- 53	Clay, gray, with some sand
53- 63	Sand and gravel, gray, with clay
63- 76	Clay, gray, gravelly (till)
76-120	Clay, dark-gray, gravelly, compact (till)

* * *

Test Hole No. 30
Location: SE¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.
Surface elevation: 1304 feet
Depth to water: 20 feet

0- 1	Topsoil
1- 20	Clay, tannish-brown, with fine sand
20- 34	Sand, grayish-brown, very fine, with clay
34- 66	Clay, gray, with fine sand
66- 92	Clay, dark-gray, with fine sand
92-104	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 31
Location: NE¼NW¼SW¼SW¼ sec. 28, T. 125 N., R. 62 W.
Surface elevation: 1287 feet
Depth to water: 13 feet

0- 1	Topsoil
1- 7	Clay, brown
7-13	Clay, grayish-brown, with some sand
13-61	Clay, gray, with very fine sand
61-74	Clay, grayish-brown, pebbly (till)

* * *

Test Hole No. 32
Location: SE¼SE¼SE¼NW¼ sec. 28, T. 125 N., R. 62 W.
Surface elevation: 1304 feet
Depth to water: 21 feet

0- 1	Topsoil
1-21	Sand, tan, very fine, silty
21-38	Sand, gray, very fine, with clay
38-76	Clay, gray, with fine sand
76-89	Clay, grayish-black, pebbly (till)

* * *

Test Hole No. 33
Location: SW¼SW¼SW¼NW¼ sec. 27, T. 125 N., R. 62 W.
Surface elevation: 1303 feet
Depth to water: 22 feet

0- 1	Topsoil
1- 22	Clay, yellowish-brown, with some sand

Test Hole No. 33 (continued)

22- 30	Sand, brownish-gray, fine, with clay
30- 86	Clay, brownish-gray
86- 93	Clay, gray, pebbly, (till)
93-103	Clay, gray, with sand and gravel
103-129	Clay, gray, compact, pebbly (till)

* * *

Test Hole No. 34
Location: SE¼SE¼SE¼NE¼ sec. 27, T. 125 N., R. 62 W.
Surface elevation: 1303 feet
Depth to water: 10 feet

0- 1	Topsoil
1- 19	Clay, brown, with fine sand
19- 29	Sand, brown, very fine
29- 86	Clay, gray, with very fine sand
86- 93	Clay, dark-gray, pebbly (till)
93-110	Clay, bluish-gray, pebbly, compact (till)

* * *

Test Hole No. 35
Location: SW¼SW¼SW¼SW¼ sec. 30, T. 125 N., R. 61 W.
Surface elevation: 1296 feet
Depth to water: 14 feet

0- 14	Clay, light-brown, with very fine sand
14- 83	Clay, gray, with fine sand
83-108	Clay, dark-gray, pebbly (till)
108-120	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 36
Location: NW¼NW¼NW¼NE¼ sec. 34, T. 125 N., R. 63 W.
Surface elevation: 1307 feet
Depth to water: 14 feet

0- 1	Topsoil
1- 14	Clay, brown, pebbly
14-102	Clay, gray, pebbly (till)
102-129	Clay, dark-gray, gravelly (till)

* * *

Test Hole No. 37
Location: SW¼SW¼SW¼SE¼ sec. 35, T. 125 N., R. 63 W.
Surface elevation: 1301 feet
Depth to water: 12 feet

0- 1	Topsoil
1-12	Sand, dark-brown, with clay
12-47	Clay, light- to dark-gray, pebbly (till)
47-83	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 38
Location: SE¼SE¼SE¼SE¼ sec. 35, T. 125 N., R. 63 W.
Surface elevation: 1300 feet
Depth to water: 13 feet

0-17	Silt, brown
17-27	Sand, brownish-gray, medium to coarse
27-37	Clay, gray, with sand (till)
37-72	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 39
Location: NE¼NE¼NE¼SW¼ sec. 36, T. 125 N., R. 63 W.
Surface elevation: 1295 feet
Depth to water: 8 feet

0- 1	Topsoil
1- 8	Clay, yellowish-brown, silty
8-12	Sand, dark-brown, medium to coarse
12-17	Sand, gray, very fine, with clay
17-29	Clay, dark-gray, pebbly (till)

* * *

Test Hole No. 40 (Rotary test)
Location: NW¼NW¼NW¼NW¼ sec. 31, T. 125 N., R. 62 W.
Surface elevation: 1302 feet
Depth to water: 17 feet

0- 10	Clay, yellow
10- 20	Sand, light-brown, fine to medium
20- 24	Sand, dark-brown, medium to coarse
24- 45	Clay, gray, with fine sand
45-104	Clay, gray, pebbly (till)
104-113	Coarse gravel
113-153	Clay, dark-gray, pebbly (till)
153-184	Clay, dark-gray, gravelly (till)
184-215	Clay, light-gray, calcareous (chalk)

* * *

Test Hole No. 41
Location: SE¼SE¼SE¼SE¼ sec. 31, T. 125 N., R. 62 W.
Surface elevation: 1290 feet
Depth to water: 12 feet

0- 3	Topsoil
3- 12	Clay, brownish-yellow, silty
12- 32	Sand, brown, fine
32- 63	Clay, gray, with sand
63- 75	Clay, gray, pebbly (till)
75-115	Clay, gray, pebbly, compact (till)

* * *

Test Hole No. 42
Location: SE¼SE¼SE¼SE¼ sec. 34, T. 125 N., R. 62 W.
Surface elevation: 1286 feet
Depth to water: 7 feet

0- 1	Topsoil
1- 24	Clay, brown, with sand
24- 93	Clay, gray, with fine sand
93-103	Clay, gray, pebbly, compact (till)
103-123	Clay, gray, compact (shale)

* * *

Test Hole No. 43
Location: NE¼NE¼NE¼NE¼ sec. 35, T. 125 N., R. 62 W.
Surface elevation: 1292 feet
Depth to water: 7 feet

0- 2	Topsoil
2- 13	Sand, brown, fine, with clay
13- 72	Clay, brown to gray, with some sand
72- 95	Clay, grayish-black, pebbly (till)
95-102	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 44
Location: SE¼SW¼SW¼SW¼ sec. 36, T. 125 N., R. 62 W.
Surface elevation: 1301 feet
Depth to water: 26 feet

0- 1	Topsoil
1- 26	Clay, tannish-brown, with fine sand
26- 93	Clay, gray, with fine sand
93-108	Clay, gray, pebbly, compact (till)

* * *

Test Hole No. 45
Location: NW¼NW¼NW¼SW¼ sec. 3, T. 124 N., R. 63 W.
Surface elevation: 1307 feet
Depth to water: 7 feet

0- 7	Sand and gravel, coarse
7-11	Sand and gravel, light-brown
11-22	Clay, gray, pebbly (till)

* * *

Test Hole No. 46
Location: NE¼NE¼NE¼NE¼ sec. 3, T. 124 N., R. 63 W.
Surface elevation: 1301 feet
Depth to water: 5 feet

0- 1	Topsoil
1- 5	Clay, brown, sandy
5-16	Sand, grayish-brown, fine to coarse

Test Hole No. 46 (continued)

16-24	Sand, grayish-brown, with clay
24-46	Clay, gray
46-54	Clay, gray, with sand and gravel
54-89	Clay, gray, pebbly, compact (till)

* * *

Test Hole No. 47
Location: NE¼NE¼NE¼SE¼ sec. 2, T. 124 N., R. 63 W.
Surface elevation: 1303 feet
Depth to water: 13 feet

0- 1	Topsoil
1-13	Sand, yellowish-brown, silty
13-21	Sand, dark-brown, medium to coarse, with clay
21-41	Clay, gray, with sand
41-70	Clay, dark-gray, gravelly (till)
70-74	Clay, dark-gray, with sand
74-92	Clay, gray, pebbly, compact (till)

* * *

Test Hole No. 48
Location: NE¼NE¼NE¼NE¼ sec. 1, T. 124 N., R. 63 W.
Surface elevation: 1300 feet
Depth to water: 16 feet

0- 1	Topsoil
1- 16	Sand, brownish-yellow, with clay
16- 50	Sand, grayish-brown, very fine to fine, with clay
50- 71	Clay, gray, gravelly (till)
71-100	Clay, dark-gray, gravelly (till)

* * *

Test Hole No. 49
Location: NE¼NE¼NE¼NE¼ sec. 5, T. 124 N., R. 62 W.
Surface elevation: 1300 feet
Depth to water: 19 feet

0- 1	Topsoil
1- 19	Clay, light-brown, with very fine sand
19- 33	Sand, light-brown, fine, with clay
33- 88	Clay, gray, with very fine to fine sand
88-106	Clay, dark-gray, pebbly, compact (till)
106-109	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 50
Location: NE¼NE¼NE¼NE¼ sec. 4, T. 124 N., R. 62 W.
Surface elevation: 1301 feet
Depth to water: 23 feet

0- 1	Topsoil

Test Hole No. 50 (continued)

1- 23	Clay, yellowish-brown, with fine sand
23- 50	Sand, brown, fine, with clay
50- 85	Clay, gray, with sand
85-122	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 51
Location: SE¼SE¼SE¼SE¼ sec. 1, T. 124 N., R. 62 W.
Surface elevation: 1300 feet
Depth to water: 23 feet

0- 3	Topsoil
3- 23	Clay, yellowish-brown
23- 93	Clay, gray
93-100	Clay, dark-gray, pebbly (till)
100-114	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 52
Location: SW¼SW¼SW¼SW¼ sec. 10, T. 124 N., R. 63 W.
Surface elevation: 1305 feet
Depth to water: 15 feet

0- 1	Topsoil
1-15	Clay, dark-brown, pebbly (till)
15-28	Clay, gray, with medium to coarse sand
28-33	Sand and gravel, coarse, with clay
33-39	Clay, gray, pebbly, compact (till)

* * *

Test Hole No. 53
Location: NW¼NW¼NW¼NW¼ sec. 11, T. 124 N., R. 63 W.
Surface elevation: 1298 feet
Depth to water: 6 feet

0- 1	Topsoil
1- 8	Clay, light-brown, with very fine sand
8-22	Sand, brown, coarse, with clay
22-73	Clay, grayish-black
73-89	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 54
Location: NE¼NE¼NE¼NE¼ sec. 11, T. 124 N., R. 63 W.
Surface elevation: 1301 feet
Depth to water: 9 feet

0- 1	Topsoil
1- 9	Clay, brown, with very fine sand
9-45	Sand, brownish-gray, fine to medium, with clay
45-79	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 55
Location: SW¼SW¼SW¼SW¼ sec. 12, T. 124 N., R. 63 W.
Surface elevation: 1299 feet
Depth to water: 17 feet

0- 1	Topsoil
1- 17	Clay, brown, pebbly
17- 30	Sand, gray, fine to medium, with clay
30- 47	Clay, gray
47- 82	Clay, dark-gray, pebbly, compact (till)
82-129	Clay, dark-gray, gravelly, compact (till)

* * *

Test Hole 56
Location: NE¼NE¼NE¼NE¼ sec. 12, T. 124 N., R. 63 W.
Surface elevation: 1292 feet
Depth to water: 7 feet

0- 1	Topsoil
1- 7	Clay, brown, with sand
7-31	Clay, light-brown, with fine sand
31-58	Clay, dark-gray, gravelly (till)
58-79	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 57
Location: NW¼NW¼NW¼NW¼ sec. 8, T. 124 N., R. 62 W.
Surface elevation: 1297 feet
Depth to water: 12 feet

0- 1	Topsoil
1- 7	Clay, brownish-black, with sand
7-12	Sand, dark-brown, fine to medium
12-38	Sand, gray, fine to coarse
38-68	Clay, gray, with some sand
68-84	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 58
Location: SE¼SE¼SE¼SE¼ sec. 8, T. 124 N., R. 62 W.
Surface elevation: 1300 feet
Depth to water: 11 feet

0- 1	Topsoil
1- 11	Clay, light-brown, silty
11- 50	Clay, brown, silty
50- 92	Clay, gray, with some sand
92-107	Clay, gray, pebbly (till)
107-124	Clay, dark-gray, pebbly, compact (till)
124-129	Clay, bluish-black, compact (shale)

* * *

Test Hole No. 59
Location: NW¼NW¼NW¼NE¼ sec. 15, T. 124 N., R. 63 W.
Surface elevation: 1300 feet
Depth to water: 13 feet

0- 1	Topsoil
1-13	Clay, brown, pebbly (till)
13-23	Clay, dark-brown, with sand
23-79	Clay, dark-gray, pebbly, compact (till)

* * *

Test Hole No. 60
Location: NE¼NE¼NE¼NE¼ sec. 24, T. 124 N., R. 63 W.
Surface elevation: 1303 feet
Depth to water: 17 feet

0- 1	Topsoil
1- 9	Sand, light-brown, very fine, with clay
9- 17	Clay, dark-brown, pebbly
17- 23	Clay, dark-brown, sandy
23- 68	Clay, gray, with sand
68-108	Clay, dark-gray, pebbly, compact (till)
108-129	Clay, bluish-black, some pebbles (shale?)

* * *

Test Hole No. 61
Location: SW¼SW¼SW¼SE¼ sec. 15, T. 124 N., R. 62 W.
Surface elevation: 1299 feet
Depth to water: 22 feet

0- 1	Topsoil
1- 10	Clay, light-brown, silty
10- 42	Clay, light-brown, with fine sand
42- 87	Clay, gray, with some fine sand
87-105	Clay, dark-gray, pebbly (till)
105-107	Clay, bluish-black, compact (shale)

APPENDIX B

Well records in the Columbia area

Source: GO, glacial outwash; LD, Lake Dakota; DF, Dakota Formation or Fall River Formation; Ob, buried sand lenses in till.
Use: D, domestic; S, stock

Name	Location	Depth of well (feet)	Depth to water (feet)	Source	Use
Dennert, P.	NE¼NE¼NE¼SE¼ sec. 4, T. 125 N., R. 63 W.	60	—	GO	D,S
Bell, T.	SW¼SE¼SW¼SE¼ sec. 34, T. 126 N., R. 63 W.	— 40	— —	DF GO	D S
Olson, C.	SW¼SW¼SW¼SW¼ sec. 3, T. 125 N., R. 63 W.	1400	Flowing	DF	D,S
Ringgenberg, H.	NE¼NE¼NE¼NW¼ sec. 6, T. 125 N., R. 62 W.	1100	Flowing	DF	D,S
Wilke, G.	SW¼SW¼SW¼SW¼ sec. 33, T. 126 N., R. 62 W.	58	15	Ob	D,S
Albrecht, F.	SW¼SW¼SW¼SW¼ sec. 1, T. 125 N., R. 62 W.	1098	Flowing	DF	D,S
Kemnitz, H.	SE¼SE¼SE¼SE¼ sec. 1, T. 125 N., R. 62 W.	900+ 40+	Flowing —	DF LD	D,S D
Mitchell, M.	SE¼NE¼NE¼NE¼ sec. 6, T. 125 N., R. 61 W.	827	Flowing	DF	D,S
Tunbuy, E.	SW¼SE¼SE¼SE¼ sec. 6, T. 125 N., R. 61 W.	865 97	Flowing 18	DF LD	D,S D,S
Oschmann, M.	NW¼NW¼NW¼NW¼ sec. 10, T. 125 N., R. 63 W.	1300	Flowing	DF	D,S
Ringgenberg, A.	SE¼SE¼NW¼NW¼ sec. 12, T. 125 N., R. 63 W.	990+	Flowing	DF	D,S
Karlen, R.	SE¼SE¼NE¼SE¼ sec. 9, T. 125 N., R. 62 W.	90	—	LD	D,S
Sieber, W.	SW¼SW¼SW¼NW¼ sec. 10, T. 125 N., R. 62 W.	1000	Flowing	DF	D,S
Gilchrist, J.	NE¼NE¼NE¼NE¼ sec. 10, T. 125 N., R. 62 W.	900+ 46	Flowing —	DF LD	D,S D,S
Arvidson, D.	SW¼SW¼SW¼SW¼ sec. 11, T. 125 N., R. 62 W.	2200?	Flowing	DF	D,S

Name	Location	Depth of well (feet)	Depth to water (feet)	Source	Use
Hanson, J.	SE¼SE¼SW¼SE¼ sec. 11, T. 125 N., R. 62 W.	1000	Flowing	DF	D,S
Hanson, J.	SW¼SW¼NW¼NW¼ sec. 12, T. 125 N., R. 62 W.	900	Flowing	DF	D,S
Daly, D.	SE¼SE¼SE¼SE¼ sec. 7, T. 125 N., R. 61 W.	1000+ 80	Flowing —	DF LD	D,S D,S
Daly, A.	SW¼SW¼SW¼SW¼ sec. 8, T. 125 N., R. 61 W.	38	—	LD	D,S
Frerichs, J.	NE¼NE¼NW¼NW¼ sec. 14, T. 125 N., R. 63 W.	948	Flowing	DF	S
Huettl, J.	SE¼SW¼SW¼SW¼ sec. 14, T. 125 N., R. 63 W.	1100?	Flowing	DF	D,S
Frerichs, J.	NW¼NW¼NW¼SW¼ sec. 13, T. 125 N., R. 63 W.	40	14	GO	D,S
Hansen, D.	SE¼NW¼NW¼SE¼ sec. 18, T. 125 N., R. 62 W.	1050	Flowing	DF	D,S
Roettele, G. P.	NE¼NE¼NE¼SE¼ sec. 17, T. 125 N., R. 62 W.	1285	Flowing	DF	D,S
Miller, L.	SW¼SW¼SW¼SW¼ sec. 15, T. 125 N., R. 62 W.	1000+	Flowing	DF	D,S
Spencer, E.	NW¼NW¼SW¼SW¼ sec. 17, T. 125 N., R. 61 W.	55	25	LD	D,S
Olsen, M.	SW¼SW¼SW¼NW¼ sec. 23, T. 125 N., R. 63 W.	1100?	Flowing	DF	D,S
Kruse, L.	NE¼NE¼NE¼NW¼ sec. 19, T. 125 N., R. 62 W.	1000	Flowing	DF	D,S
Roettele, R.	SE¼SE¼SE¼SW¼ sec. 19, T. 125 N., R. 62 W.	985	Flowing	DF	D,S
Zastrow, A.	SE¼SE¼SE¼SE¼ sec. 19, T. 125 N., R. 62 W.	1100	Flowing	DF	D,S
Meints, F.	NE¼NE¼NE¼SE¼ sec. 20, T. 125 N., R. 62 W.	1096	Flowing	DF	D,S
Daly, J.	SW¼SW¼SW¼SW¼ sec. 24, T. 125 N., R. 62 W.	100	20	Ob	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Daly, E.	NW¼NW¼NW¼NW¼ sec. 20, T. 125 N., R. 61 W.	32	20	LD	D,S
Hansen, J.	NW¼NW¼NW¼SW¼ sec. 20, T. 125 N., R. 61 W.	1200 40	Flowing 20	DF LD	S D
Kemnitz, W.	SW¼NW¼NW¼NW¼ sec. 26, T. 125 N., R. 63 W.	875	Flowing	DF	D,S
Ringgenberg, K.	NW¼NW¼NW¼NW¼ sec. 25, T. 125 N., R. 63 W.	900 1100	Flowing Flowing	DF DF	D,S D,S
Bohling, W.	NE¼NE¼NE¼NE¼ sec. 25, T. 125 N., R. 63 W.	1200	Flowing	DF	D,S
Zastrow, B.	NE¼NE¼NE¼SE¼ sec. 30, T. 125 N., R. 62 W.	90	—	LD?	D,S
Wockemfuss, C.	NE¼SW¼NE¼SW¼ sec. 29, T. 125 N., R. 62 W.	68	10?	LD	D,S
Stanley, C.	SE¼SE¼NW¼NW¼ sec. 28, T. 125 N., R. 62 W.	42	—	LD	D,S
Sieber, V.	NW¼SE¼SE¼SE¼ sec. 29, T. 125 N., R. 62 W.	103	—	LD	D
Weismantel, M.	SW¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.	92	—	LD	D
Karlen, E.	NW¼SE¼SE¼SE¼ sec. 29, T. 125 N., R. 62 W.	82	—	LD	D
Krage, E.	NW¼SE¼SE¼SE¼ sec. 29, T. 125 N., R. 62 W.	83	—	LD	D
Karlen, J.	NW¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.	85	—	LD	D
Farmers Union	NW¼NW¼NW¼SW¼ sec. 28, T. 125 N., R. 62 W.	97	—	LD	D
St. Johns Lutheran School	SW¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.	90	—	LD	D
Becker, R.	NW¼NW¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	102	—	LD	D
Pool Hall	SE¼NE¼NE¼SE¼ sec. 29, T. 125 N., R. 62 W.	90	—	LD	D
Olson, L.	SW¼NE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	82	—	LD	D

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Henther	NW¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	80	—	LD	D
Karlen, J.	NW¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.	—	Flowing	DF	D
Elliot, D.	NW¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	900	Flowing	DF	D
Weismantel, M.	SE¼NE¼NE¼NE¼ sec. 29, T. 125 N., R. 62 W.	1100	Flowing	DF	D
Karlen, E.	SE¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	945	Flowing	DF	D
Karlen, E.	SW¼SE¼NE¼SE¼ sec. 29, T. 125 N., R. 62 W.	952	Flowing	DF	D
Public School	NW¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	1100	Flowing	DF	D
Karlen, E.	SW¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	900?	Flowing	DF	D
St. Johns Lutheran Church	SW¼SE¼SE¼NE¼ sec. 29, T. 125 N., R. 62 W.	1000?	Flowing	DF	D
Larson, A.	NW¼NW¼NW¼SE¼ sec. 28, T. 125 N., R. 62 W.	997 82	Flowing —	DF LD	D S
Dean, C.	SE¼SE¼NE¼SW¼ sec. 27, T. 125 N., R. 62 W.	900+?	Flowing	DF	D,S
Buntrock, E.	NW¼NW¼SW¼SW¼ sec. 26, T. 125 N., R. 62 W.	1000 93	Flowing 20	DF LD	S D
Bohling, H.	SW¼SW¼SW¼SW¼ sec. 25, T. 125 N., R. 62 W.	80	12	LD	D,S
Gabert, L.	SW¼SW¼SW¼NE¼ sec. 30, T. 125 N., R. 61 W.	800? 47	Flowing 14	DF LD	D S
VanWinkle, W.	NW¼NW¼SW¼NW¼ sec. 34, T. 125 N., R. 63 W.	700?	Flowing	DF	D,S
Buntrock, W.	NE¼NE¼NE¼SE¼ sec. 35, T. 125 N., R. 63 W.	1100	Flowing	DF	D,S
Wockenfuss, C.	NE¼SE¼NE¼NE¼ sec. 31, T. 125 N., R. 62 W.	1000?	Flowing	DF	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Jackson, R.	SW¼SW¼SW¼NW¼ sec. 33, T. 125 N., R. 62 W.	1120	Flowing	DF	D,S
Larson, C.	NW¼NW¼NW¼SE¼ sec. 33, T. 125 N., R. 62 W.	52	17	LD	D,S
Bohling, H.	SE¼NE¼NE¼NW¼ sec. 35, T. 125 N., R. 62 W.	1200	Flowing	DF	D,S
Gilchrist, L.	SW¼SW¼SW¼SW¼ sec. 36, T. 125 N., R. 62 W.	105	—	LD	D,S
Smilloff, J.	NE¼NW¼NW¼NE¼ sec. 36, T. 125 N., R. 62 W.	104	—	LD	D,S
Askew, R.	SE¼NW¼NW¼SW¼ sec. 3, T. 124 N., R. 63 W.	20	13	GO	D,S
Bohn, A.	SE¼NW¼NW¼SW¼ sec. 3, T. 124 N., R. 63 W.	30	20	GO	D,S
Rathert, F.	SW¼SW¼SW¼NW¼ sec. 6, T. 124 N., R. 62 W.	965	Flowing	DF	D,S
Weismantel, K.	NE¼NE¼NE¼SE¼ sec. 6, T. 124 N., R. 62 W.	1000+ 90	Flowing —	DF LD	D,S S
Weismantel, W.	SW¼SW¼NW¼NW¼ sec. 4, T. 124 N., R. 62 W.	1100?	Flowing	DF	D,S
Fetherhuff, R.	SE¼SE¼SW¼SE¼ sec. 2, T. 124 N., R. 62 W.	1100	Flowing	DF	D,S
Howell, J.	NW¼NW¼NW¼NE¼ sec. 10, T. 124 N., R. 63 W.	1050 12	Flowing 8	DF GO	D,S D
Davis, K.	SE¼SE¼SE¼SW¼ sec. 7, T. 124 N., R. 62 W.	1200	Flowing	DF	D,S
Nilsson, C.	NE¼NE¼SE¼NE¼ sec. 7, T. 124 N., R. 62 W.	26	13?	LD	D,S
Mertz, D.	SW¼SW¼SW¼SW¼ sec. 9, T. 124 N., R. 62 W.	1200?	Flowing	DF	D,S
Buntrock, O.	NW¼NW¼NE¼NE¼ sec. 9, T. 124 N., R. 62 W.	1100	Flowing	DF	D,S
Mertz, D.	NE¼NE¼NE¼SE¼ sec. 9, T. 124 N., R. 62 W.	1100	Flowing	DF	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Schliebe, J.	NW¼NW¼NW¼NE¼ sec. 10, T. 124 N., R. 62 W.	887	Flowing	DF	D,S
Bohling, A.	SE¼SE¼SW¼SW¼ sec. 11, T. 124 N., R. 62 W.	1100	Flowing	DF	D,S
Stucke, B.	SW¼NW¼NW¼NW¼ sec. 22, T. 124 N., R. 63 W.	20	11	GO	D,S
Zick, D.	NE¼NE¼NW¼NW¼ sec. 14, T. 124 N., R. 63 W.	30	—	GO	D
James, D.	SE¼SE¼SE¼SE¼ sec. 17, T. 124 N., R. 62 W.	1180	Flowing	DF	D,S
Gilchrist, J.	NE¼NE¼SE¼NE¼ sec. 14, T. 124 N., R. 62 W.	1200	Flowing	DF	D,S
McCormick, H.	NW¼NW¼NW¼NW¼ sec. 13, T. 124 N., R. 62 W.	1100?	Flowing	DF	D,S