STATE OF SOUTH DAKOTA
Nils Boe, Governor

SOUTH DAKOTA STATE GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 34

GROUND-WATER INVESTIGATION FOR THE CITY OF LAKE NORDEN, SOUTH DAKOTA

by
Donald Jorgensen

Science Center
University of South Dakota
Vermillion, South Dakota
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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota Geological Survey for the city of Lake Norden from June 15 to July 26, 1964. The purpose of the investigation was to assist the city in locating future ground-water supplies.

Lake Norden receives water from two wells located half a mile north of the city. City Well 1 is 24 feet deep and produces about 40 gallons per minute and City Well 2 is 40 feet deep and produces about 140 gallons per minute. Although water from City Well 1 is of better quality than water from City Well 2, both are high enough in iron and manganese concentrations to cause serious pipe incrustation problems to water mains and plumbing fixtures. Although the combined pumpage of water from both wells is sufficient for much of the year, increased annual consumption and peak demands are increasingly insufficient to meet the water demand.

A survey of the shallow ground-water aquifers was conducted in an area of 64 square miles around the city. This survey consisted of preparing a generalized geologic map, drilling 40 test holes, and collecting 21 water samples for analyses. A complete interview of the existing wells in and around the city of Lake Norden was also conducted. As a result of the survey, four areas were found which may be further tested for future water supplies.

The field work and preparation of this report were performed under the supervision of Merlin J. Tipton, Assistant State Geologist and Lynn Hedges, Ground-Water Geologist. Robert Schoon, Geologist, and Lloyd Helseth, Driller, installed the deep test hole in the city of Lake Norden. The field work for the survey was conducted with the assistance of Steve Pottratz, Ronald Little and other members of the field survey party. Special acknowledgment is given to Mayor Leroy Koistenen, Auditor Vaino Bajuniemi and the City Council for their aid and cooperation. The survey was also aided by the personnel of the State Chemical Laboratory who analyzed several water samples.

Location and Extent of Area

The city of Lake Norden (population 390, 1960 census) is located in south-central Hamlin County which is in east-central South Dakota and is near the center of the Coteau des Prairies section of the Central Lowland physiographic province (fig. 1). This study covers an area of 64 square miles in and around Lake Norden including 8 square miles in northeastern Kingsbury County.

Climate

The climate is continental temperate with large daily and seasonal temperature fluctuations. At the U. S. Weather Bureau Station at

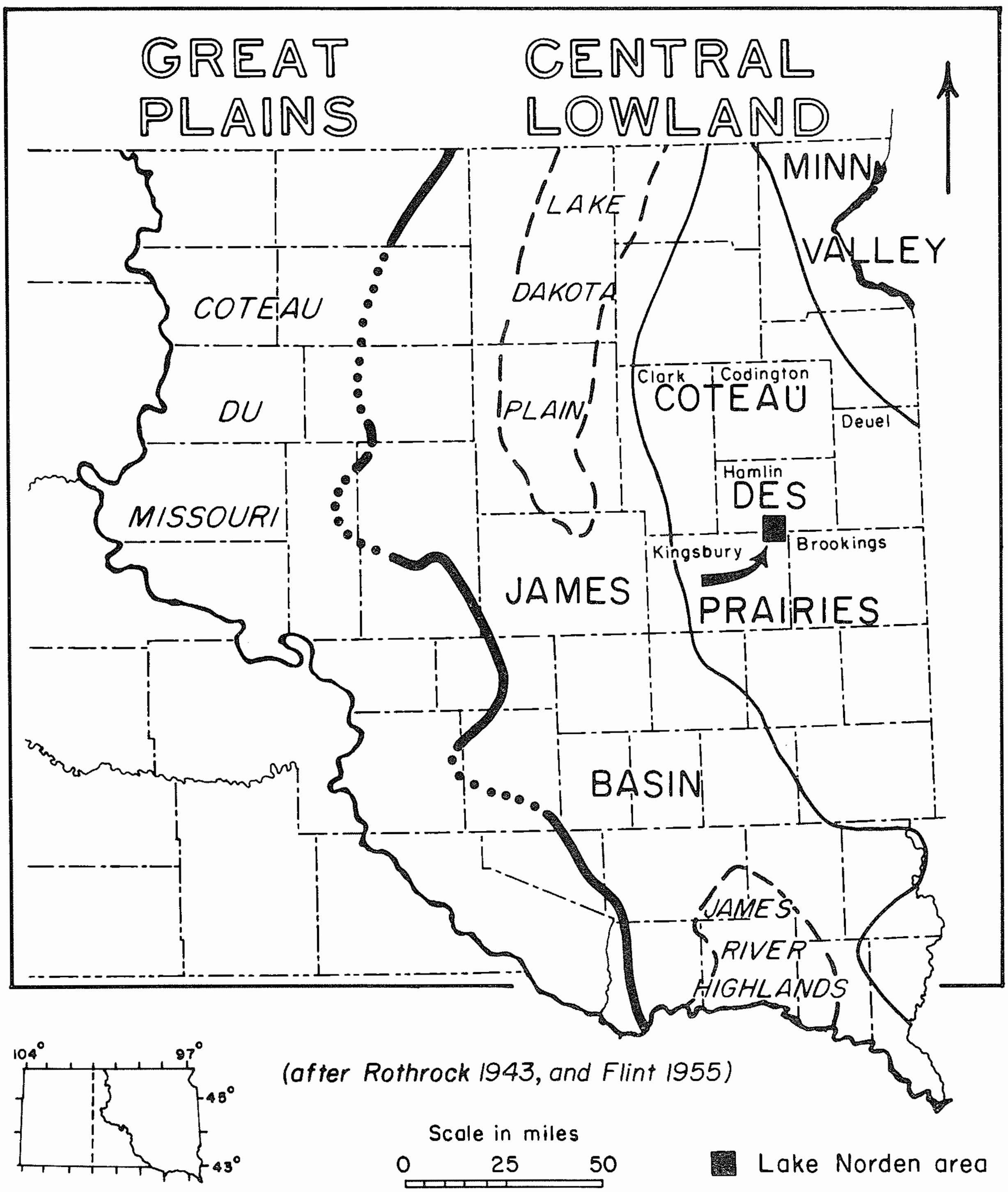


Figure I. Map of eastern South Dakota showing the major physiographic divisions and location of the Lake Norden area.

Castlewood, 13 miles northeast of Lake Norden, the average daily temperature is 43.5 degrees F., and the average annual precipitation is 20.80 inches. Precipitation occurs mainly as rain during spring and early summer, although heavy rains in late summer and fall are not uncommon.

Topography and Drainage

The topography of the Lake Norden area is characterized by a gently undulating surface typical of late Pleistocene glacial terrain with hills and closed depressions. The smaller closed depressions contain sloughs and the larger ones contain lakes.

Data Point Numbering System

Data points in this report are numbered in accordance with the U. S. Bureau of Land Management's system of land subdivision. The first numeral of a point designation indicates the township, the second the range, and the third the section in which the well is situated. Lower case letters after the section number indicate the position of the data point within the section. The letters a, b, c, d are assigned in a counter-clockwise direction, beginning in the northeast corner of each tract. The first letter denotes the 160-acre tract, the second the 40-acre tract, the third the 10-acre tract, and the fourth the $2\frac{1}{2}$-acre tract. Test Hole 48, 113-53-19bccc is located in the $SW\frac{1}{4}SW\frac{1}{4}SW\frac{1}{4}NW\frac{1}{4}$ sec. 19, T. 113 N., R. 53 W.; the method of designation is shown in Figure 2.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Lake Norden area are the result of late Pleistocene glaciation and post-glacial stream deposition. The glacial deposits, collectively called drift, have a thickness of approximately 400 feet in the mapped area and can be divided into till and outwash.

Till consists of a compact unsorted mixture of clay, silt, sand, and gravel deposited by the ice. Till is the surficial deposit in approximately 70 percent of the study area (fig. 3). Till also comprises a great percentage of the 400 feet of glacial drift in the Lake Norden area (Test Hole 51, fig. 4 and App. A).

Outwash deposits generally consist of stratified sand and gravel with minor amounts of silt and clay and generally exhibit a nearly-level surface. The outwash deposits in the mapped area (fig. 3) are a special type and have been identified as "collapsed" outwash by Flint (1955), and were later mapped in detail by Steece (1958). Collapsed outwash is an ice-contact deposit, having been deposited on or against the ice. If the

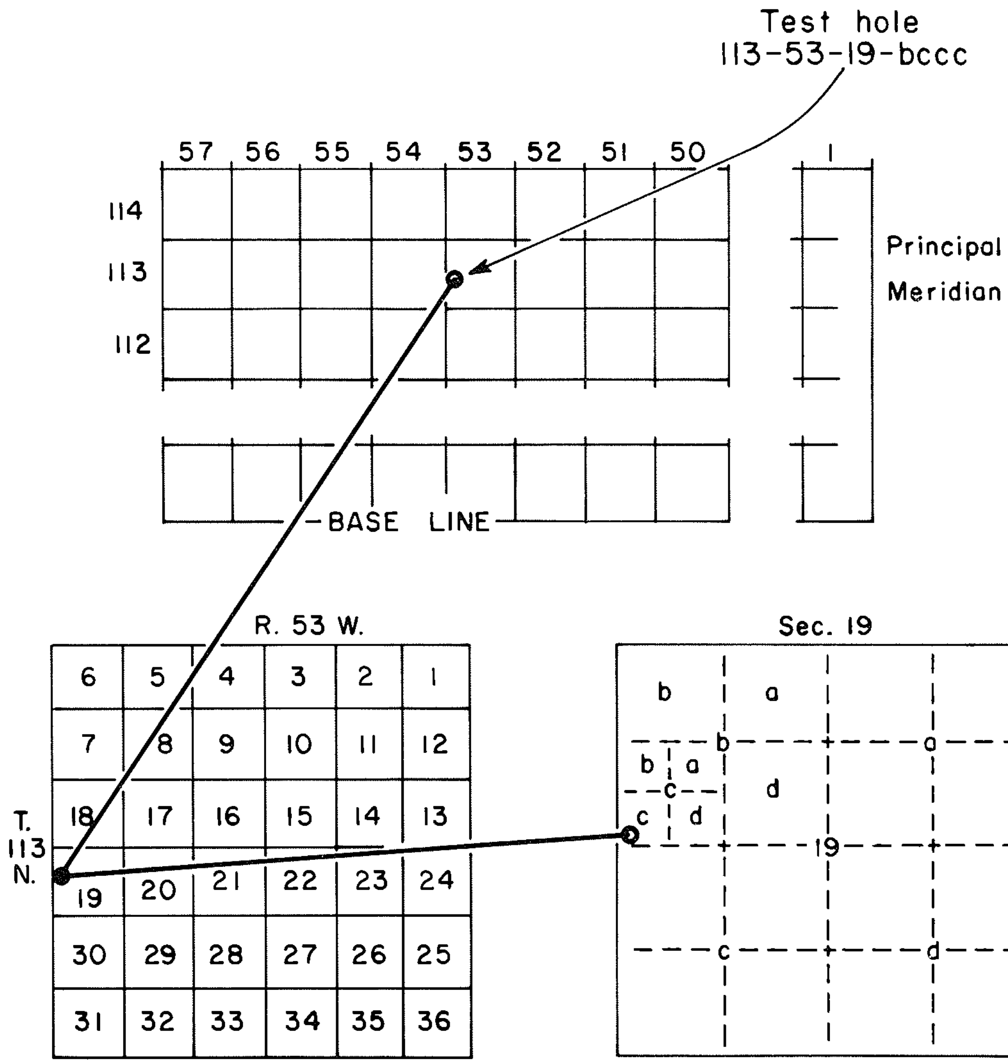


Figure 2. Data point numbering system.

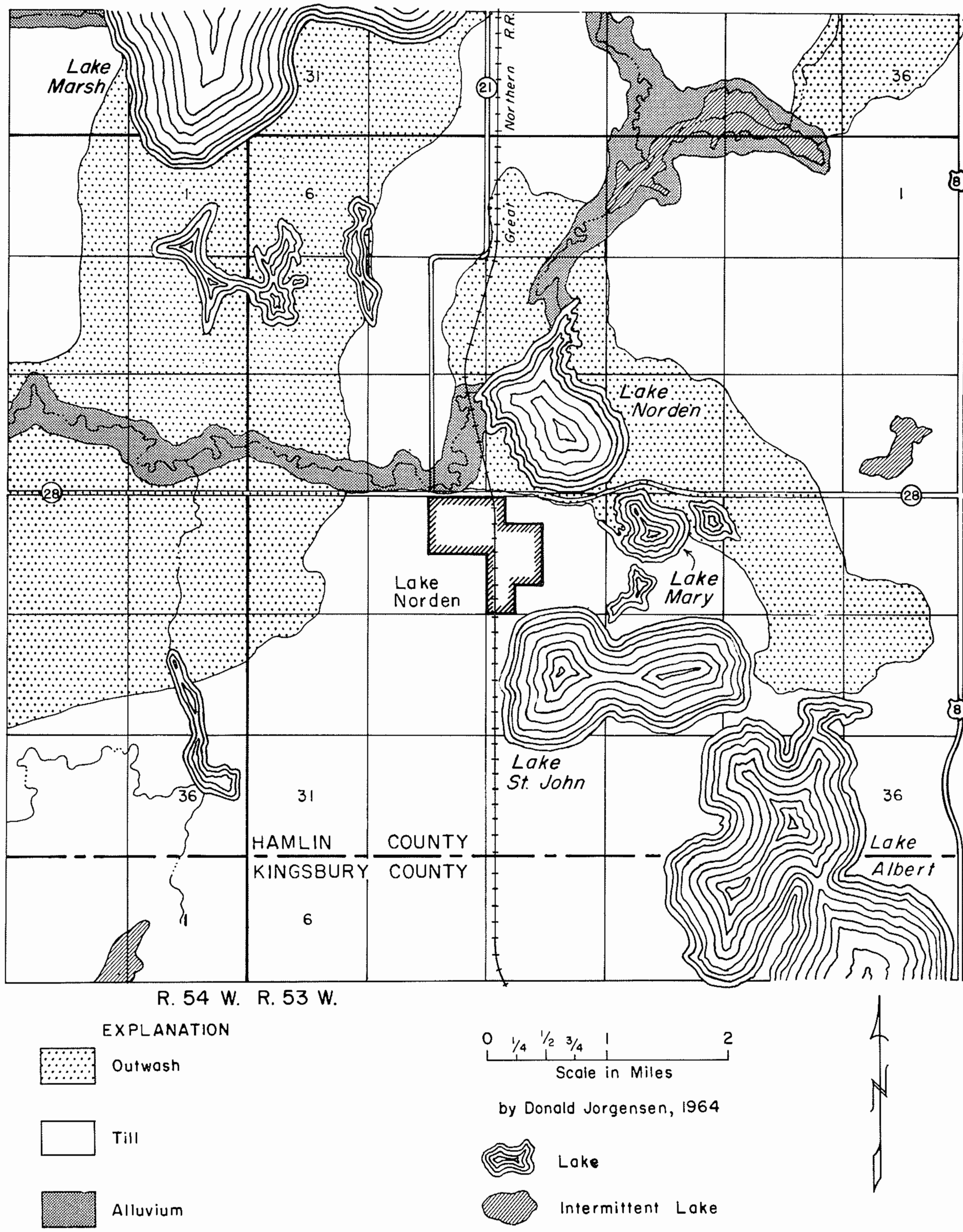
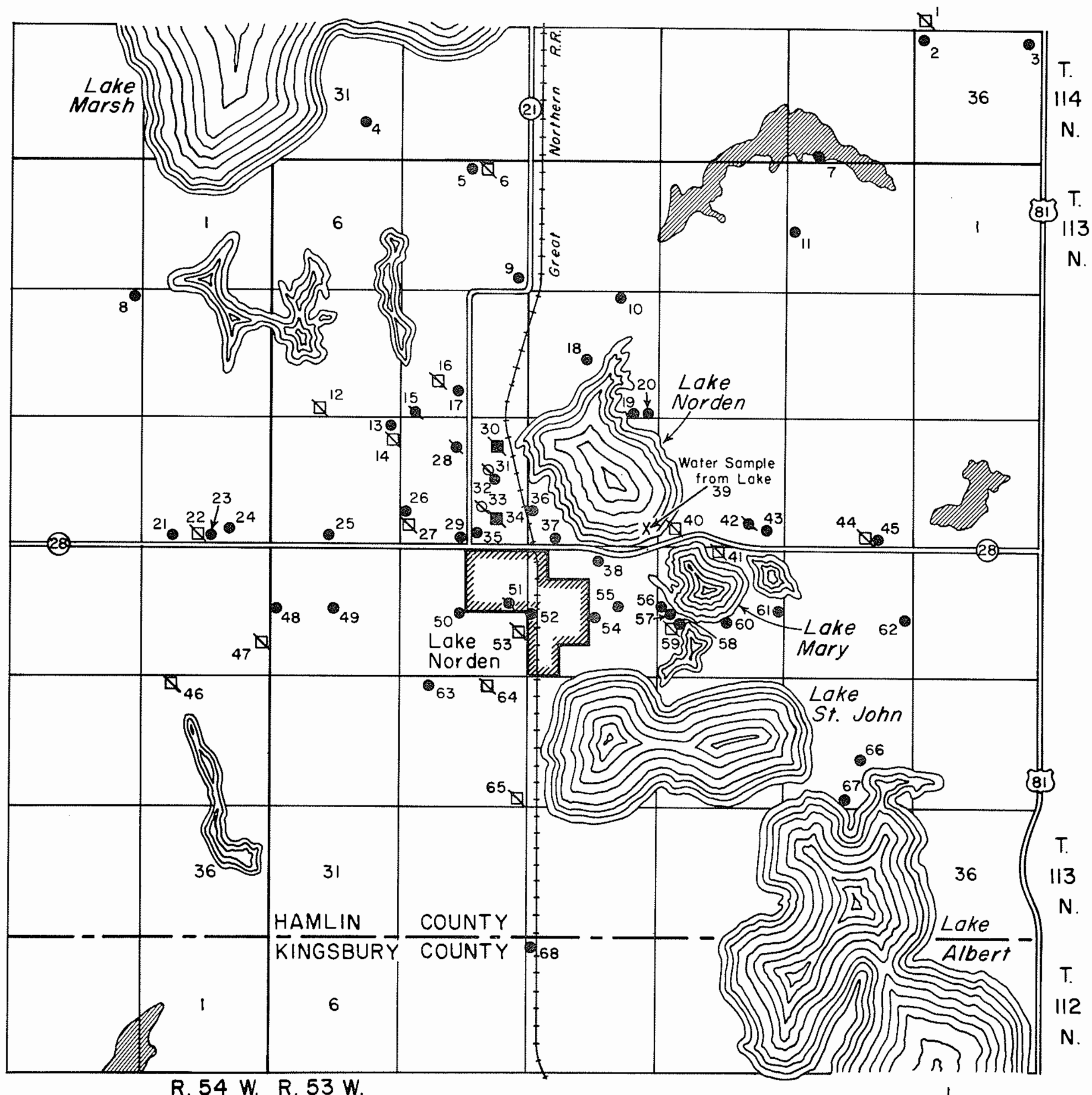


Figure 3. Generalized Geologic Map of the Lake Norden Area.



EXPLANATION

- ● S. Dak. Geol. Survey Test Hole
- ○ Layne Test Hole
- ■ City Well
- □ Private Well

A hachure (\) through data collection point indicates a water analysis.
Number after data collection point corresponds to test hole numbers (App. A).
and/or water quality analyses (Table 2).
Note: Data collection point 69 not shown on map.

0 1/4 1/2 3/4 1 2
Scale in Miles

by Donald Jorgensen, 1964

Figure 4. Data Map of the Lake Norden Area.

outwash material is deposited on the surface of the ice, the sediments will generally be thickest in low areas and thinnest in high areas. Subsequent melting of the supporting ice allows the sediments to "collapse" and to conform more or less to the pre-existing topography. Both unequal distribution of debris on the ice and its later collapse tend to create a deposit variable in thickness. Its surface form is characterized by an undulating topography similar to that developed in till.

Commonly, collapsed outwash deposits may contain large blocks of till or silty, clayey material somewhat gradational between till and outwash. Furthermore, in areas of collapsed outwash the distribution of the sand and gravel and the silty, clayey material in relation to each other may be quite erratic. Thus mapping of the deposits is quite difficult without extremely detailed information.

The geologic mapping done for this report was aided by the detailed drilling program. The resultant generalized geologic map (fig. 3) delineates the collapsed outwash deposits on the basis of their water-bearing characteristics rather than mode of origin. Thus, relatively impermeable glacial outwash may be included with till.

The outwash mapped in 114-53-35 and 36 (fig. 3) has been mapped as outwash valley train deposits by Steece (1958). These deposits consist of stratified sand and gravel deposited in a valley beyond the margin of a glacier. These deposits exhibit a level topography and generally are of more uniform thickness than the collapsed outwash.

Alluvium is material deposited by streams since the ice retreated. Alluvium is composed mainly of silt and clay and may contain minor amounts of sand and gravel. Small amounts of alluvium occur in the streams entering Lake Norden from the north and west (fig. 3).

Subsurface Bedrock

Beneath the glacial deposits in the Lake Norden area are stratified sedimentary rocks of Cretaceous age. In descending order they are the Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Group.

The Pierre Shale consists of light- to dark-gray clayey bentonitic shale and sandy shale with ironstone concretions. The contact between the glacial deposits and the Pierre is an uneven erosional surface; therefore, the thickness of the Pierre Shale is variable but may be as much as 400 feet thick in this area.

The Niobrara Marl is composed of a light- to medium-gray calcareous shale or marl, which contains numerous microscopic white specks. In this area it is approximately 140 feet thick.

The Carlile Shale consists of medium- to dark-gray bentonitic shale with pyrite concretions, and thin sandstone layers. The Carlile is approximately 180 feet thick in the mapped area.

The Greenhorn Limestone is made up of a layer of hard, gray to brown limestone containing numerous fossil shell fragments. The limestone layer is often overlain and underlain by calcareous gray shale with white specks. The thickness of the limestone is approximately 30 feet.

The Graneros Shale is gray to dark-gray clayey shale, often containing thin layers of cemented sandstone. The thickness of this formation is approximately 160 feet.

The Dakota Group consists of a series of alternating sandstones and shales. The Dakota Group is of variable thickness and is probably over 100 feet thick in the Lake Norden area.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water may be defined as water contained in the voids or openings of rocks or sediments below the water table. The water table marks the upper surface of the zone of saturation of the water-bearing formation, called an aquifer.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates downward to the water table or drains off as surface water. Surface water evaporates, escapes to the ocean or percolates downward to the ground-water table. In general, the precipitated water that percolates downward to the ground-water table flows laterally down the hydraulic gradient of the water table. When the water is moving down the hydraulic gradient of the water table, it is said to be in transient storage.

If an aquifer is confined by impervious stratum and the confining pressure is greater than atmospheric pressure, water table conditions no longer exist. The aquifer is then said to be an artesian aquifer. Water from a well in an artesian aquifer will rise above the base of the upper confining bed coinciding with the hydrostatic pressure level of the water in the aquifer, disregarding frictional losses. This hydrostatic pressure level is an imaginary line called the piezometric surface. When a well penetrates a piezometric surface which lies above ground level, a flowing artesian well results. If the piezometric surface lies below ground level, a non-flowing artesian well results.

Recharge, the addition of water to an aquifer is accomplished in three main ways: (1) direct downward percolation derived from rain or melting snow, (2) downward percolation from surface bodies of water, and (3) underflow of water in transient storage into the aquifer.

Discharge or removal of ground water is accomplished in four main ways: (1) transpiration by plants, and evaporation, (2) seepage upward or laterally into surface bodies of water such as streams, lakes, and springs, (3) underflow of water in transient storage from the aquifer, and (4) pumping water from wells completed in the aquifer.

The volume of water capable of being stored in a material is equal to the volume of voids or pore space in the material. Porosity is the ratio of the volume of voids in the material to the rock volume (which includes pore space). The shape and arrangement of grains in a material affects the porosity greatly, but the size has no effect. Therefore, a rock would hold the same amount of water if it consisted of well-sorted sand or if it consisted of well-sorted gravel, provided the particles of sand and gravel had the same packing and shape. Sands and gravels usually have porosities of 15 to 40 percent; whereas sandstones normally have porosities of 10 to 25 percent. The lower porosity of sandstone is due to close packing of the grains, and often to the presence of cementing material between the grains.

The rate at which water under pressure will drain or pass through a material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores even if the latter material has a greater porosity. Therefore, permeability and porosity are not synonymous terms. As an example, glacial till may have a high porosity but yield little water because of low permeability.

An idealized aquifer is one that is large, consists of well-sorted sand or gravel, possesses high permeability and has recharge equal to or exceeding the discharge. Small water-bearing sand and gravel lenses often occur in the glacial drift at many locations, both at the surface and at depth. These should not be considered as "veins". Generally the small stratified lenses will not yield enough water to supply a city's needs.

Ground Water in Alluvium

Small amounts of alluvium occur in the intermittent stream valleys flowing into Lake Norden (fig. 3). Because of the high clay and silt content, the alluvium has low permeability and therefore does not readily yield large volumes of water to wells.

Ground Water in Glacial Deposits

Till does not yield water readily because of its highly unsorted nature and resulting low permeability.

Outwash deposits, because they are better sorted and contain less clay and silt-size particles, yield water much more readily than till.

Two distinct outwash deposits are known to exist in the mapped area. The first outwash includes all the mapped outwash on Figure 3 except for that portion located in the northeast corner (114-53-35 and 36) of the study area.

Most of the outwash occurs at the surface of the ground except for a narrow band about one mile wide which trends northward from the northwest corner of the town of Lake Norden (fig. 3). In this area, till and silty-clayey material of unknown origin is at the surface and overlies the outwash. Although mapped as a continuous covering, sand and gravel may locally occur at the surface as in Test Hole 31 (App. A).

In Test Hole 15 (App. A) 24 feet of till and silty-clay material was penetrated before encountering sand and gravel; however, 3 to 10 feet is the normal thickness encountered. The outwash occurring at the surface is thought to be hydraulically connected to the outwash underlying the till and silty-clayey material, thereby making a continuous aquifer.

The thickness of saturated sand and gravel has been plotted for each test hole (fig. 5). The four areas outlined on Figure 5, (A, B, C, and D) may have an adequate thickness of saturated sand and gravel to warrant further investigation.

Area A includes the area in which the city's present wells are located plus an additional adjoining three-quarter square mile area to the west and north. The thickness of saturated sand and gravel in this area varies from 15 feet in Test Hole 29 to 47 feet in Test Hole 17. The city's present wells are located in an area where the saturated thickness is generally between 20 and 25 feet. Twenty feet of saturation is usually considered about the minimum thickness which will sustain any long-term high capacity wells such as may be used for city wells. Therefore, those marginal areas which have less than 20 feet of saturated material should not be considered unless thorough testing shows that an adequate supply of water is available. From a quantity aspect the northern half of Area A, including Test Holes 15, 17, and 28 (fig. 4) would probably provide enough water for a city supply.

Area B is located two miles east of Lake Norden and north of State Highway 28, and covers an area of about one-quarter square mile. Test Holes 42 and 43 penetrated 32 and 40 feet, respectively, of aquifer in this area. In Test Hole 43 the main aquifer occurred at a depth of 35 to 66 feet, whereas in Test Hole 42 the aquifer occurred from 10 to 42 feet. More test drilling would probably be required to determine whether the aquifers in these two holes are hydraulically connected.

Area C is located about three miles west of Lake Norden and occupies about one-quarter square mile. Test Holes 21 and 48 penetrated 37 and 18 feet, respectively, of aquifer in this area. Although the area outlined includes both test holes, it is not known whether the aquifer maintains the thickness indicated by the two test holes in that area. Two other nearby test holes (Test Holes 23 and 24) show 0 to 8 feet of aquifer, suggesting that the aquifer may thin rapidly.

Area D is located 6 miles northeast of Lake Norden and as shown by Steece (1958) continues eastward for more than five miles. Test Hole 3 penetrated 45 feet of aquifer; however, Test Hole 2 contained no saturated sand and gravel. According to Steece, the eastward extension of this aquifer may have a greater thickness than indicated in Test Hole 3.

Test Holes 10 and 18 just north of Lake Norden showed 19 to 30 feet of aquifer. This area could be considered an extension of Area A; however, lack of information concerning aquifer thickness and water quality was not obtained in sufficient detail to determine whether the two areas should be considered in a single unit.

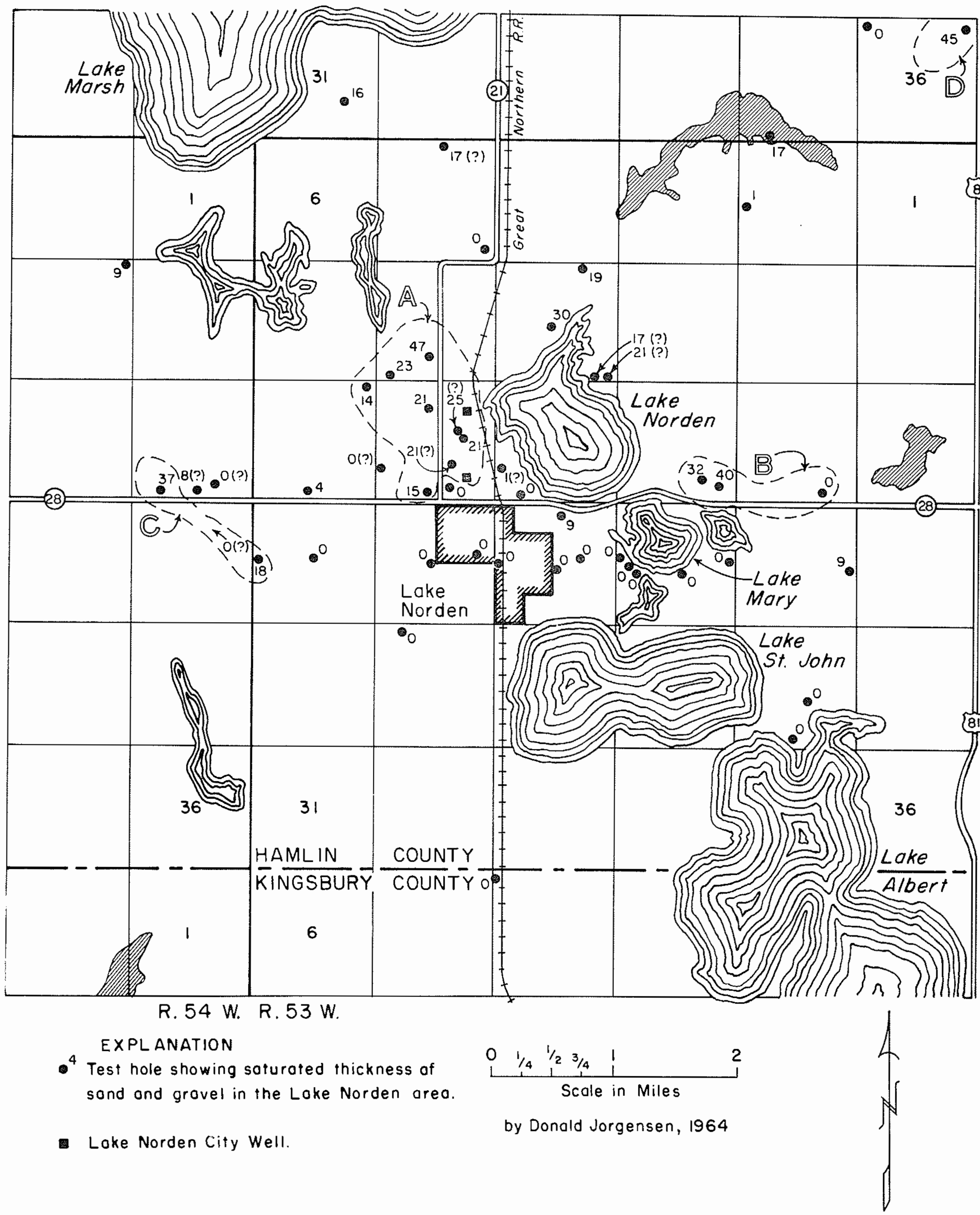


Figure 5. Map showing areas of greatest thickness of saturated sand and gravel deposits in the Lake Norden Area.

Ground Water in the Subsurface Bedrock

The thick glacial deposits in the study area are the source of water for all wells investigated in the study area. Therefore, information on ground water from the subsurface bedrock must be extrapolated from nearby city and domestic wells.

The Pierre, Niobrara, Carlile, Greenhorn and Graneros Formations are seldom used as a source of water in Hamlin and surrounding counties. The sandstones of the Dakota Group, however, furnish water for many community and farm wells outside the study area and may yield water up to 100 gallons per minute. The quality of this water in most cases is of much poorer quality than Lake Norden's present supply.

The water from the Dakota Group is under artesian pressure. It is believed that the recharge of the Dakota Group comes from the Sioux Ridge area to the south and from the Black Hills area to the west, and by leekage from other bedrock formations.

QUALITY OF GROUND WATER

Precipitated water is nearly pure before it reaches the ground. After reaching the ground it comes in contact with many minerals. In general, surface water picks up minerals in solution as it moves to the ocean or other surface water bodies. The water percolating downward through the soil towards the water table dissolves soil minerals and mineral residues left by plant transpiration and by evaporation. This leaching process is beneficial for future plant growth, but it does cause deterioration of water quality. After the percolating water reaches the water table, the water comes in contact with minerals in the aquifer and more mineral content is added to the water. Therefore, the mineral content of ground water is dependent upon the minerals the water comes in contact with and the length of time of the contact.

General standards have been adopted to aid in evaluating the mineral content of the water for suitability as a drinking water supply. Table 1 lists the various mineral constituents determined in this study and briefly discusses their significance and recommended limits as defined by the U. S. Department of Public Health. It should be pointed out, however, that if the recommended limits are exceeded this does not necessarily indicate that the water is unfit for human consumption.

Table 2 compares water from various aquifers in the Lake Norden area with the U. S. Public Health Standards recommended for drinking water.

An appraisal of the ground-water quality in the Lake Norden area shows that general statements can be made concerning several of the chemical constituents. By most standards every water sample tested in the Lake Norden area can be classed as very hard water. The range in concentration of calcium carbonate hardness is from 220 ppm to 2400 ppm; more than half of the samples fall in the 500-800 ppm range.

Table 1.--Significance of some chemical and physical properties of 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 - 125
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 -0.05
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[2,3]
pH	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values lower than 7.0 indicates acidity, pH values higher than 7.0 indicate alkalinity. Alkalinity tends to aid encrustation and acidity tends to aid corrosion.	None
Hardness $CaCO_3$	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.	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]

1 (ppm) parts per million
2 Modified for South Dakota by the State Department of Health (written communication, February 5, 1962)
3 Optimum

Table 2.--Chemical analyses of water samples from the Lake Norden area.

Data Collection Point Number	Location Number	Well or Test Hole Number	Depth (feet)	Source (1)	Parts Per Million: Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrogen	Fluoride	pH	Hardness $CaCO_3$	Total Solids
0	U. S. Public Health Department recommended limits for drinking water.				---	---	125	250	(2) 500	0.3	0.05	10.0	(3)0.9-1.7	---	---	(2)1000
1	114-53-25ccc	A. Appel	24	so	70	14	38	0	134	0.3	0.00	4.6	0.70	7.4	330	516
6	113-53-5abb	Q. Olson	16	so	88		90	44	88	0.00				8.0	580	893
12	113-53-7cdc	G. Skoglund	30	so	79		83	4	170	0.00				8.0	530	737
14	113-53-18aad	G. Hoglund	38	so	104		30	18	42	Trace				7.5	388	580
15	113-53-8cccd	SDGS 15	(4) 24-47	so	121	20	57	0	473	0.05	0.22	0.10	0.60	7.9	536	968
16	113-53-8cacc	E. Kangas	60	so	182		55	2	457	0.36				7.8	680	995
22	113-54-13cdd	A. Lehtola	12	so	42		61	4	107	0.00				8.2	350	529
27	113-53-17ccb	H. Hoglund	43	so	204	25	56	3	450	0.09					780	
28	113-53-17badd	SDGS 28	(4) 30	so	90		18	8	69	0.15				7.7	300	440
(5)30a	113-53-17abdd	Lake Norden City Well 2	40	so	192	55	89	6	614	2.3	1.5	0.6	0.4		851	1332
(5)30b	113-53-17abdd	Lake Norden City Well 2	40	so	172	52	85	10	620	1.80		0.00			780	
31	113-53-17acd	Layne-Minn. Test Hole	30(?)	so	360	100	112	5	1250	0.03		0.00			1360	
33	113-53-17dbc	Layne-Minn. Test Hole	29(?)	so	176	34	70	10	525	0.26		0.00			730	
(5)34	113-53-17dcaa	Lake Norden City Well 1	24	so	145	32	56	6	358	0.40	0.30	0.20	0.30		595	874
(6)39	SE portion of Lake Norden		----	lake	129	200	86	13	659	0.30	0.10	0.00	0.70	7.9	677	1284
40	113-53-15cc	A. Palm	35	so	245		96	18	227	0.05				7.7	910	1295
41	113-53-22abb	L. Pearson	33	so	70		131	6	281	1.04				7.1	700	1019
42	113-53-15dca	SDGS 42	(4) 35-42	so	129	40	75	3	554	0.01	0.00	1.4	0.80	7.3	632	1148
44	113-53-14dcd	E. Isaacson	65	so(?)	82		106	4	170	Trace				7.9	620	820
46	113-54-25bba	R. Tuohino	20	so	119		15	4	83	0.00				8.3	350	465
47	113-54-24dad	J. Spilde	28	so	65		89	6	88	0.00				8.1	520	632
51	113-53-20adca	SDGS 51	440-460	bs	64		27	24	166	2.50				7.9	270	842
53	113-53-20da	J. Johnson	170	ssl	234	100	83	18	781	10.60	0.52	1.8	0.70	7.7	925	1650
59	113-53-22cba	J. Stoner	18	ssl	35		141	15	365	Trace				7.7	650	1036
64	113-53-29ab	C. Tormanen	32	ssl	232		49	68	292	0.22				7.1	780	1130
65	113-53-29ddd	C. Thue		ssl(?)	282		449	204	1212	0.12				6.8	2400	3250
69	112-53-17dd	J. Anderson	400	bs	60		17	44	244	4.00				7.9	220	1156

[1]Source: so, surface outwash; bs, basal sand; ssl, stratified sand lens.
[2]Modified for South Dakota by the State Department of Health (written communication, February 5, 1962).
[3]Optimum
[4]Approximate depth or interval from which water sample obtained.
[5]Sample 30a and 34 analyzed in 1961 and sample 30b analyzed in 1964.
[6]Water sample collected approximately July 7, 1964.

Water samples 30a, 30b, and 34 were analyzed by the South Dakota Department of Health, Pierre.
Water samples 31 and 33 were analyzed by Layne-Minnesota, Sioux Falls.
Water sample 27 was analyzed by the South Dakota Biochemical Station, Brookings.
Water samples 1, 15, 39, 42, and 53 were analyzed by the South Dakota Chemical Laboratory, Vermillion.
The remaining water samples were analyzed by the South Dakota State Geological Survey, Vermillion.

The sulfate content ranges from 42 to 1250 ppm with 6 samples showing an excess of 600 ppm and 8 samples above 500 ppm.

The total solids content ranges from 440 to 3250 ppm and about 70% of the samples fall between 500 and 1200 ppm. In general, the water having a higher total solids content is also the water with high sulfate and/or hardness content.

The iron and manganese content varies greatly and seems to be a reflection of very local influences. In spite of this erratic concentration of iron and manganese, three areas (western part of Area A, Area B and C, fig. 6) have been located which may have water containing less iron than the present city supply. Not enough data is present to draw any conclusions about the manganese content.

Quality of the ground water found in the alluvial deposits was not determined because no areas were found where the alluvium might yield enough water to be considered for a city water supply.

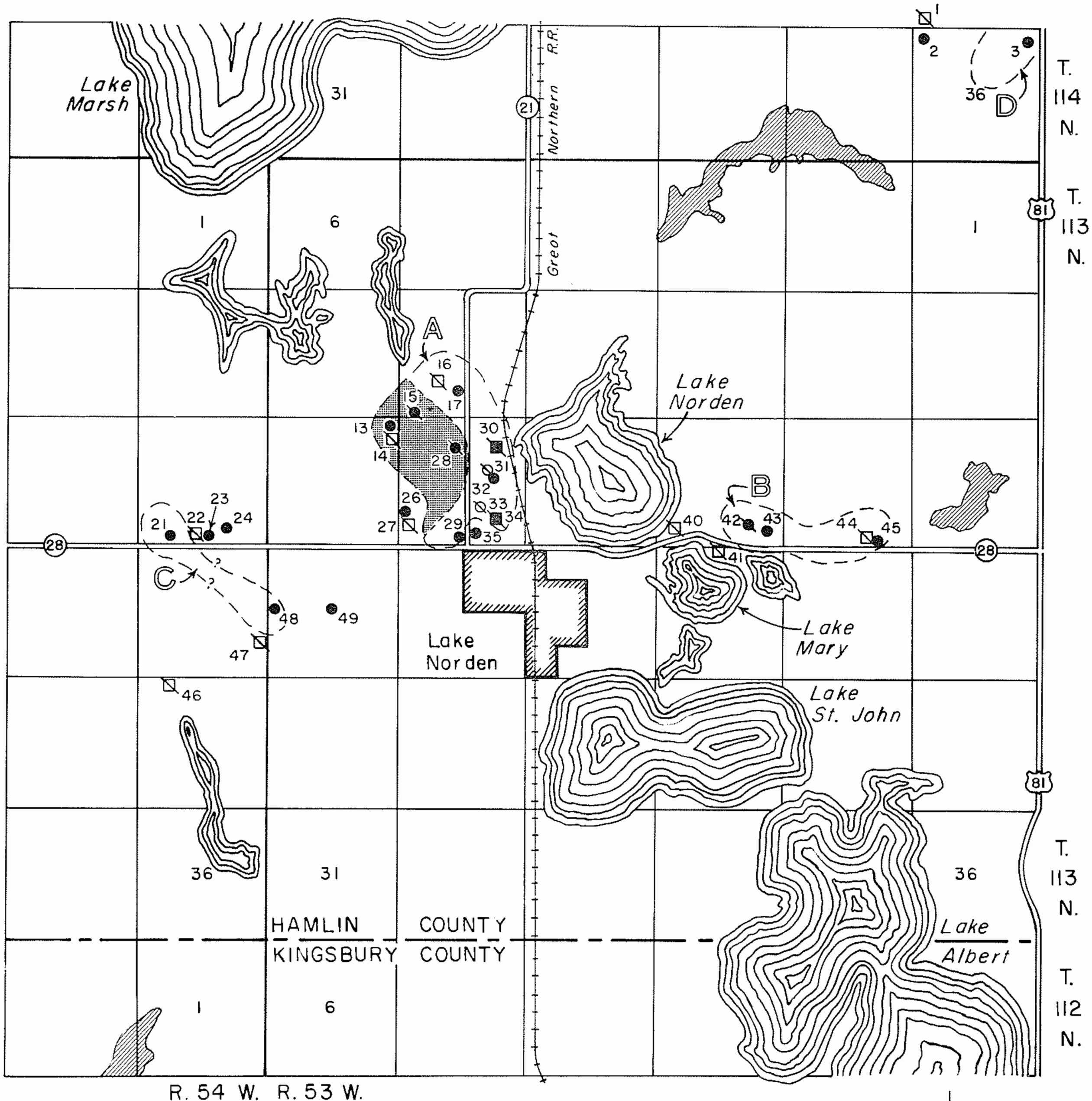
Ground water occurring in sand lenses in the till varies greatly in quality as shown in samples 53, 64 and 65.

Figure 6 shows those general areas for potential ground-water development near Lake Norden in relation to the water analyses.

Area A (fig. 6) has been divided into two sections on the basis of water quality. The eastern section (unhachured) includes the present well field and contains water generally poorer in quality than the water from the western section (hachured). In order to better visualize this, the following table was compiled using data directly from Table 2.

	Sample No.	Total Solids	Hardness	Sulfates	Iron	Manganese
Western	14	580	388	42	Trace	----
	15	968	536	473	0.05	0.22
	28	440	300	69	0.15	----
Eastern	16	995	680	457	0.36	----
	30	1332	851	614	1.80	1.5
	31	----	1360	1250	0.03	----
	33	----	730	525	0.26	----
	34	874	595	358	0.40	0.30

The chemical constituents, total solids, hardness, sulfate, iron and manganese were used because it is felt that in most cases the range in



EXPLANATION

- ● S. Dak. Geol. Survey Test Hole
- ○ Layne Test Hole
- ■ City Well
- □ Private Well
- (shaded) Area near present well field containing water of better quality than the present supply.

A hachure (\) through data collection point indicates a water analysis.
Number after data collection point corresponds to test hole numbers (App. A) and/or water quality analyses (Table 2).

Figure 6. Map showing general areas for potential ground water development near Lake Norden.

quantity of the other chemical constituents is too small to be used for comparative purposes. The water of poorest quality from the western section (sample 15) is still generally of better quality than the present city supply. The manganese content is high, according to U. S. Public Health Standards, but is still less than the present city supply (samples 30 and 34).

Total solids figures were unavailable for samples 31 and 33 from the eastern section; however, the sulfate and hardness content of both samples indicate they would exceed the recommended limits in total solids. As mentioned previously, not enough data is available to make comparisons on the manganese content of water in the Lake Norden area.

Area B is represented by water sample 42 (Table 2). It is just over the recommended limits in sulfates and total solids but contains practically no iron and has no manganese. Sample 40 about half a mile to the west indicates similar water quality. However, sample 41 about one-third mile southwest indicates water high in iron.

Area C has no water samples obtained from it. Nearby water samples (22 and 47, Table 2) indicate water with no iron and relatively low in total solids, sulfates, and hardness.

No water analyses are available for Area D. Water sample 1 (Table 2) is from a shallow well in the same outwash valley, but it cannot be considered typical of Area D.

CONCLUSIONS AND RECOMMENDATIONS

Four locations which the city may investigate for future ground-water supplies are located within the glacial outwash deposits occurring at or near the surface in the Lake Norden area. The first area (Area A, fig. 5) includes the present well field and about an additional square mile to the north and west.

Test Hole 17 (App. A) penetrated 47 feet of saturated sand and gravel and would probably produce high-capacity wells (200-500 gallons per minute). The rest of Area A has only about 20-25 feet of aquifer and probably would produce only medium-capacity wells (100-200 gallons per minute) on a long-term basis. Unfortunately, the water quality in the area of Test Hole 17 (eastern section) is of poorer quality than the water in the western section (fig. 6).

In the western section, Test Hole 15 penetrated up to 23 feet of aquifer. The water in this section is generally of better quality than the present city supply. It is suggested that the city further test the triangular-shaped area enclosed by Test Holes 15, 17, and 28 to try and locate an area which will suit the city for both quality and quantity.

Areas B, C, and D (figs. 5 and 6) are small areas with a limited amount of information which indicates that at least moderate-capacity wells could be developed. In addition, the data indicates the water in these areas to be of better quality than the present city supply.

Additional testing would be warranted in Areas B, C, or D if further investigations in Area A fail to produce the desired results.

It should be pointed out that in the development of a water supply from the outwash deposits it may be necessary to sacrifice quantity of water from individual wells in order to locate them in an area where good quality water can be obtained.

It should also be pointed out that in the outwash material, the quality of water may change quite abruptly. This factor may result in a change in water quality after a well is pumped for a considerable time.

If the city decides to develop more wells in the outwash in any of the areas recommended, a reputable well-drilling firm should be contracted to drill test holes to determine the thickness and extent of the aquifer. In addition, water samples should be collected and analyzed to determine the quality of the water. On the basis of this information, a test site can be selected and a test well with observation wells can be installed. Licensed engineers should conduct a pump test for a minimum of 72 hours and periodically sample the water during the test. From this data accurate predictions can be made on quantity and quality of water, rate of recharge, and what the expected sustained yield will be.

The sandstones of the Dakota Group may also be considered a potential ground-water supply, although the quality would probably be poorer than the city's present supply. Wells in the Dakota Group would probably be similar in quantity and quality to the city wells in nearby towns, such as Bryant, which produce water from this aquifer.

If the city decides to drill a new city well, the city officials should consult the State Water Resources Commission, Pierre, to obtain a permit to drill a well and establish water rights, and the State Department of Health with regard to biological and chemical acceptability of the water.

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APPENDIX A

Logs of Test Holes in the Lake Norden Area

(for locations see Figure 4)

Test Hole No. 2
Location: 114-53-36bbbb
Depth to water: 23 feet

0- 2	topsoil, black
2- 4	sand, medium; with clay
4-13	sand, medium, brown
13-23	clay and gray sand
23-44	clay and brown sand

* * * * *

Test Hole No. 3
Location: 114-53-36aaaa
Depth to water: 20 feet
Elevation: 1697 feet

0- 5	topsoil, black, sticky
5-20	silty layers; alternately black and light brown
20-40	clay, sand, and some fine gravel; less clay 30-40 feet
40-50	silt, sand and some fine gravel
50-52	gravel, coarse
52-65	sand, medium to coarse; occasional gravels

* * * * *

Test Hole No. 4
Location: 114-53-31dbda
Depth to water: 24 feet
Elevation: 1688 feet

0- 5	topsoil, black
5- 6	sand, coarse and fine gravel
6- 7	gravel, fine
7-25	sand, fine to medium
25-28	as above, some clay
28-40	sand, fine

* * * * *

Test Hole No. 5
Location: 113-53-5abbb
Depth to water: not recorded

0- 1	topsoil, black
1- 8	clay, dark, with pebbles
8-11	gravel, coarse
11-13	clay, brown
13-30	sand and medium gravel, with clay
30-49	clay, blue

* * * * *

Test Hole No. 7
Location: 114-53-35ccdd
Depth to water: not recorded
Static water level: 6 feet

0- 2	topsoil, black
2-13	clay, brown, and pebbles
13-18	clay, brown, and medium sand
18-35	sand, medium
35-36	clay

* * * * *

Test Hole No. 8
Location: 113-54-11aaaa
Depth to water: not recorded
Static water level: 10 feet

0- 3	clay, brown; with silt
3- 6	sand, fine, and silt
6- 8	gravel, fine
8- 9	clay and fine sand
9-10	clay and coarse sand
10-19	sand, coarse; with clay
19-23	clay; with fine to medium sand
23-39	clay, bluish-gray

* * * * *

Test Hole No. 9
Location: 113-53-5dddd
Depth to water: 42 feet
Elevation: 1685 feet
(continued on next page)

Test Hole No. 9--continued

0- 8	topsoil and fill
8-10	clay, yellow brown, and pebbles
10-15	sand and gravel, coarse
15-30	sand, coarse and some fine gravel, brown; silty 20-30 feet
30-35	sand, coarse; and fine gravel; silty
35-40	gravel; coarse
40-60	till

* * * * *

Test Hole No. 10
Location: 113-53-9abaa
Depth to water: 8 feet

0- 5	topsoil, dark brown
5-11	sand, coarse and fine gravel
11-13	sand, medium coarse; with clay
13-21	sand, medium and oxidized clay
21-27	sand, medium and unoxidized clay
27-39	clay, gray; with sand

* * * * *

Test Hole No. 11
Location: 113-53-2cbbb
Depth to water: 12 feet

0- 3	sand and gravel
3-12	sand, coarse
12-13	sand and gravel
13-71	clay, gray

* * * * *

Test Hole No. 13
Location: 113-53-18aaaa
Depth to water: not recorded
Static water level: 26 feet

0- 2	topsoil, black
2- 4	clay, dark brown
4- 7	clay, light brown
7-17	clay, brown; with sand and gravel
17-40	sand, fine to medium
40-59	clay, gray

* * * * *

Test Hole No. 15
Location: 113-53-8cccd
Depth to water: 19 feet
Static water level: 12 feet

0- 4	topsoil, black; with silt
4- 9	clay, brown
9-12	clay, red-brown
12-17	clay, light brown
17-19	clay, gray
19-24	clay, gray; with sand
24-39	sand, medium, and gray clay
39-47	gravel, fine; with sand
47-79	clay, dark brown

* * * * *

Test Hole No. 17
Location: 113-53-8cdaa
Depth to water: 3 feet

0- 2	topsoil, black
2- 3	clay, brown
3-21	sand, coarse; with clay
21-26	sand, very coarse, brown; with clay
26-50	sand, coarse
50-58	clay, bluish-gray

* * * * *

Test Hole No. 18
Location: 113-53-9caaa
Depth to water: 19 feet

0- 1	topsoil, black
1-13	sand, very fine and brown silt
13-19	sand, fine, brown
19-26	sand, medium, brown
26-49	sand, medium; with clay

* * * * *

Test Hole No. 19
Location: 113-53-9ddcc
Depth to water: not recorded
(continued on next page)

Test Hole No. 19--continued

0- 2	topsoil, black
2- 9	sand, coarse, and fine gravel with clay
9-14	clay; with sand
14-31	sand, medium and fine; with clay
31-34	(no sample) clay?
34-39	clay and medium sand
39-44	clay, bluish and medium sand

* * * * *

Test Hole No. 20
Location: 113-53-9dddc
Depth to water: not recorded

0- 2	topsoil, black
2- 5	sand, very coarse and fine- to medium-sand
5- 7	sand, very coarse; with clay
7-10	clay; with medium sand
10-31	sand, fine to medium; with clay
31-37	clay; with gray-brown sand
37-44	clay, gray and brown; with sand

* * * * *

Test Hole No. 21
Location: 113-54-13ccdd
Depth to water: 12 feet

0- 3	topsoil, black
3- 9	gravel and sand
9-12	sand and gravel; with clay lenses
12-18	sand, medium; with clay
18-19	sand and gravel; with clay
19-23	gravel, fine
23-49	sand, coarse

* * * * *

Test Hole No. 23
Location: 113-54-13dccc
Depth to water: 16 feet

0- 3	topsoil, dark gray
3- 7	gravel, fine, about $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter, and sand
7-16	clay, dark gray; with gravel
16-24	silt, sand; gravel

* * * * *

Test Hole No. 24
Location: 113-54-13dcdb
Depth to water: not recorded

0- 4	sand and gravel
4- 9	sand and gravel; with thin clay lenses
9-14	sand and gravel; with clay
14-19	sand; with clay
19-24	clay, bluish-gray

* * * * *

Test Hole No. 25
Location: 113-53-18cddd
Depth to water: 23 feet

0- 2	topsoil, dark brown
2- 5	clay, brown
5- 7	gravel, fine, about $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter; clay, brown
7- 8	gravel, fine; sand, coarse
8-20	sand, medium and fine
20-27	sand, fine; clay
27-29	clay, brown
29-39	clay, gray

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Test Hole No. 26
Location: 113-53-17cbcc
Depth to water: not recorded

0- 2	topsoil, black
2- 7	silt, brown; with brown clay
7-10	gravel, fine, about $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter
10-11	sand, medium
11-44	clay, gray

* * * * *

Test Hole No. 28
Location: 113-53-17badd
Depth to water: not recorded
Static water level: 9 feet

0- 2	topsoil, black
2- 7	clay, brown
7-30	sand, medium, brown; clayey
30-39	clay, bluish-gray

* * * * *

Test Hole No. 29
Location: 113-53-17cdda
Depth to water: 5 feet
Elevation: 1655 feet

0- 5	topsoil
5-20	sand, dark gray-brown; silty
20-30	clay, blue, sandy and silty
30-45	till, blue-gray

* * * * *

Test Hole No. 31
Data from: Layne-Minnesota Co.
Location: 113-53-17acd
Depth to water: not recorded

0- 5	gravel
5-30	gravel, coarse
30-38	clay, blue

* * * * *

Test Hole No. 32
Location: 113-53-17acdd
Depth to water: not recorded
Static water level: 8 feet

0- 1	topsoil, black
1- 4	clay, brown
4- 5	sand, medium, oxidized
5- 8	sand, very coarse, brown; with clay
8-29	sand, medium, brown; with clay
29-39	clay, bluish-gray

* * * * *

Test Hole No. 33
Data from: Layne-Minnesota Co.
Location: 113-53-17dbc
Depth to water: not recorded

0- 2	topsoil
2- 6	clay
6- 8	silt
8-29	gravel and water
29-32	clay

* * * * *

Test Hole No. 35
Location: 113-53-17dccb
Depth to water: 6 feet

0- 3	topsoil, black
3-16	clay, brown; with sand and gravel
16-33	clay, gray with fine sand

* * * * *

Test Hole No. 36
Location: 113-53-16cbcc
Depth to water: not recorded

0- 2	topsoil, black
2- 4	clay, brown; with coarse sand
4- 7	sand, coarse; with clay
7-10	sand, fine to medium
10-15	clay; with medium sand
15-16	sand, fine, dark brown; with clay
16-18	clay, with dark brown sand
18-21	clay, brownish-black; with sand
21-26	clay, gray; with sand
26-44	clay, blue-gray; with sand

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Test Hole No. 37
Location: 113-53-16ccdd
Depth to water: 10 feet

0- 5	gravel, coarse; with sand and clay
5-10	gravel, fine
10-39	clay, blue

* * * * *

Test Hole No. 38
Location: 113-53-21abbb
Depth to water: 12 feet
Static water level: 6 feet

0- 2	topsoil, black
2- 6	clay, gray-brown
6- 9	clay, brown; with silt
9-12	clay, brown; with fine sand
12-21	sand, fine; with brown clay
21-26	clay, gray; and fine sand
26-65	clay, gray; with medium sand

* * * * *

Test Hole No. 42
Location: 113-53-15dcaa
Depth to water: 10 feet

0- 3	topsoil, black
3- 5	gravel
5-42	sand, medium and coarse; fine; gravel, with clay
42-44	clay

* * * * *

Test Hole No. 43
Location: 113-53-15ddbd
Depth to water: 11 feet

0- 1	topsoil, black
1- 2	sand, fine, yellow
2- 3	sand, brown, fine; with silt
3- 4	clay, dark brown
4- 7	clay, dark gray
7-11	gravel, fine; with black clay
11-20	sand, fine; with silt and clay
20-35	clay, gray
35-66	sand, very coarse; gravel, fine to medium
66-68	clay

* * * * *

Test Hole No. 45
Location: 113-53-14dcdd
Depth to water: not recorded
Static water level: 24 feet

0-13	clay, light brown; with pebbles
13-17	clay, dark brown
17-44	clay, gray

* * * * *

Test Hole No. 48
Location: 113-53-19bccc
Depth to water: 9 feet
Static water level: 9 feet

0- 2	topsoil, black
2- 6	silts, gray; with pebbles
6-27	sand, brown; with brown gravel
27-44	clay

* * * * *

Test Hole No. 49
Location: 113-53-19bddd
Depth to water: not recorded

0- 2	topsoil, black
2- 5	silt, brown; and brown clay
5- 8	gravel
8-16	clay, brown
16-20	clay, unoxidized

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Test Hole No. 50
Location: 113-53-20bddd
Depth to water: 9 feet

0- 2	topsoil, black
2- 9	clay, reddish-brown
9-21	clay, reddish-brown; with silty clay
21-64	clay, bluish-gray

* * * * *

Test Hole No. 51
Location: 113-53-20acda
Depth to water: not recorded
(Drilled by SDGS rotary drill)

0- 5	clay, sandy, buff
5- 15	clay, very sandy, buff
15-120	silt and sand; with many thin gravel layers
120-135	clay, sandy, buff, tough
135-195	clay, sandy, gray
195-305	clay, fissile, dark olive-gray; with sand
305-440	silt, very clayey, dry
440-460	sand, fine
460-485	shale (Pierre Shale)

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Test Hole No. 52
Location: 113-53-21bccc
Depth to water: 16 feet

0- 1	topsoil
1- 4	clay, silty, brown
4-16	clay, brown; with pebbles
16-21	clay, brown; with very fine sand
21-26	clay, dark brown
26-31	clay, gray, very tight

* * * * *

Test Hole No. 54
Location: 113-53-21caaa
Depth to water: 24 feet

0- 3	topsoil, black
3- 5	clay, brown
5- 7	gravel, fine; and dark brown clay
7-13	clay, brown; with gravel
13-34	clay, dark gray

* * * * *

Test Hole No. 55
Location: 113-53-21acdd
Depth to water: 21 feet

0- 3	topsoil
3-40	clay, silty, light brown
40-69	clay, gray

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Test Hole No. 56
Location: 113-53-22bccc
Depth to water: 20 feet
Elevation: 1649 feet

0- 2	topsoil, black
2-20	clay, silty, pebbly; light to dark brown
20-30	clay, light brown
30-45	clay, blue
45-60	sand, blue, fine; silty
60-90	sand with fine gravel; silty and clayey; blue-gray

* * * * *

Test Hole No. 57
Location: 113-53-22bcdc
Depth to water: (dry)

0- 1	topsoil, black
1- 3	gravel
3- 5	clay, brown
5- 8	gravel
8-20	clay, brown; with silt
20-39	clay, gray

* * * * *

Test Hole No. 58
Location: 113-53-22cbaa
Depth to water: 6 feet
Static water level: 6 feet

0- 2	topsoil, black
2-12	clay, brown
12-26	clay, dark brown; with medium sand
26-64	clay, gray; with fine sand

* * * * *

Test Hole No. 60
Location: 113-53-22dbbb
Depth to water: not recorded

0- 2	topsoil, black
2- 4	gravel, fine to medium
4-23	clay, brown
23-49	clay, gray

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Test Hole No. 61
Location: 113-53-22addd
Depth to water: 16 feet
Elevation: 1669

0- 1	topsoil, black
1- 5	gravel, fine and coarse sand; some silt
5-20	silt, clayey, brown
20-90	clay, blue, very few pebbles and sand rare

* * * * *

Test Hole No. 62
Location: 113-53-23daaa
Depth to water: 11 feet
Elevation: 1657

0- 4	fill
4-10	sand, fine to medium; clayey, yellow
10-12	gravel, fine and coarse sand
12-15	clay, blue-gray
15-20	sand, medium to coarse; clayey; blue-gray
20-45	till

* * * * *

Test Hole No. 63
Location: 113-53-29bbaa
Depth to water: not recorded
Static water level: 35 feet

0- 2	topsoil, black
2-17	clay, dark brown
17-24	clay, grayish-brown
24-39	clay, gray

* * * * *

Test Hole No. 66
Location: 113-53-26dbbd
Depth to water: 26 feet

0- 2	silts, dark brown; and sand
2- 4	silts, light brown; and fine sand
4-19	gravel, fine to very coarse
19-21	clay, brown
21-29	clay, bluish-gray

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Test Hole No. 67
Location: 113-53-26cddd
Depth to water: 7 feet

0- 1	topsoil, black
1- 7	silt, black, and clay
7-15	clay, gray
15-18	rocks, large

* * * * *

Test Hole No. 68
Location: 112-53-4bbbb
Depth to water: 16 feet
Static water level: 16 feet

0- 2	clay, light brown
2- 5	sand, very fine; with clay
5-24	clay, brown

* * * * *

APPENDIX B

Records of wells in the Lake Norden area.

Use: S, stock; D, domestic; I, irrigation
Geologic source: stratified sand lens, ssl; outwash, o; alluvium, a; lacustrine, l; basal sand, bs

Name	Location	Depth of Well in ft.	Geologic Source	Use
Madisen, Andy	112-53-1a	280	ssl	D
Paulsen, Chirst	112-53-3c	200	ssl	S
Keiser, Floyd	112-53-4a	89	ssl	D&S
Holmgaard, Arnold	112-53-4b	180	ssl	S
Schultz, A. H.	112-53-5a	30	ssl	S
Odle, Woodroe	112-53-5a	375	ssl	S
Haufschild	112-53-6d	21	a	D
Peterson, Lawrence	112-53-9a	80	ssl	D&S
Anderson, Walt	112-53-17a	500	bs	D&S
Anderson, John	112-53-17d	400	bs	D&S
Cornelius Bros.	112-54-2b	48	ssl	D
Arnold	112-54-11b	285	ssl	S
Anderson, Geo. E.	112-54-12a	300	ssl	D
Cornelius Bros.	112-54-12b	360	ssl	D&S
Korstinen, Adrian	113-53-1b	120	ssl	D
Anderson, Rog.	113-53-1d	150	ssl	D
Ancons	113-53-2a	14	o	D
Clark, Loring	113-53-2c	65	ssl	D
Tzlaff, Earl	113-53-3a	76	ssl	D

Appendix B--Records of wells--continued

Name	Location	Depth of Well in ft.	Geologic Source	Use
Shelsta, Clayton	113-53-4a	70	ssl	D
Shelsta, Clayton	113-53-4b	100	ssl	S
Olson, Q.	113-53-5a	16	o	S
Meisel, Clyde	113-53-5d	196	ssl	S
Devine, Fritz	113-53-6a	25	o	D&S
Frederick, Wm.	113-53-6b	89	ssl?	S
Skoglund, Gordon	113-53-7c	30	o	S
Schultz, Henry	113-53-7d	26	o	D&S
Palm, Astrid	113-53-8b	44	ssl?	D
Kangas, Ernest	113-53-8c	60	o	I
Palm Bros.	113-53-9b	13	o	D
Lisentti, Aruid	113-53-10c	14	o	D
Lee, C.	113-53-11b	110	ssl	D
Jager, James	113-53-12a	170	ssl	D&S
Olson	113-53-12b	64	ssl	D&S
Suaruors, H. J.	113-53-12c	120	ssl	D
Jorgenson, R. M.	113-53-13a	25	ssl?	D&S
Suaruors, H. J.	113-53-13b	120	ssl?	D&S
Suaruors, E. J.	113-53-13c	32	ssl	D
Nelson, Lyle	113-53-13d	50	ssl	D&S
Lee, Ray	113-53-14b	80	ssl?	S
Isaacson, Arnold	113-53-14c	80	ssl?	D

Appendix B--Records of wells--continued

Name	Location	Depth of Well in ft.	Geologic Source	Use
Isaacson, Earl	113-53-14d	65	ssl?	D
Palm, A.	113-53-15c	35	o	D
Espland, Fran	113-53-16d	60	o	D
Hoglund, Harry	113-53-17c	43	o	D&S
Hoglund, Gene	113-53-18a	38	o	D&S
Skoglund, Alwood	113-53-18b	23	o	D
Fedt, Henry	113-53-18d	130	ssl	S
Koista, Mrs. H.	113-53-18d	130	ssl	S
Koistenen, Ester	113-53-19c	18	o	D&S
Johnson, Ole	113-53-19d	157	ssl	S
Roisum, A. R.	113-53-20a	256	ssl	S
Johnson, J. S.	113-53-20da	170	ssl	S
Juntunen, E. W.	113-53-21d	50	ssl	S
Pearson, Levi	113-53-22a	33	o	D
Lee, Wallace	113-53-22a	45±	o	D
Stoner, Jack	113-53-22c	18	l	D
Pearson, Harold	113-53-22d	145	ssl	D&S
Rust, Ernest	113-53-23a	30	o	D&S
Lukoen, Jock	113-53-23a	75	ssl	D
Mathieson, Hi	113-53-24a	20	ssl	S
Jacobson, Floyd	113-53-24d	58	ssl	D
Lee, Stanley	113-53-25c	40	o	D&S

Appendix B--Records of wells--continued

Name	Location	Depth of Well in ft.	Geologic Source	Use
Jacobson, Elmer	113-53-25d	45	o	S
Rust, Ernest	113-53-26c	16	l	D&S
Tormanen, Carl	113-53-29a	32	ssl	D
Tormanen, Marvin	113-53-29b	40	ssl	S
Oehinke, E. J.	113-53-29c	70	ssl?	S
Thue, Carl	113-53-29d	49	ssl	S
Thue, Carl	113-53-29d	170	ssl	D
Marklis	113-53-30a	100	ssl	S
Carlson, R.	113-53-30d	165	ssl	S
Aho, Einara	113-53-31b	200	ssl	D&S
Marttila, Geo.	113-53-31c	350	ssl	S
Olson, Ernest	113-53-33a	135	ssl	D
Koistinen, Verner	113-53-33b	160	ssl	D
Belkonen, Andrew	113-53-34b	125	ssl	D
Mackey, Ed	113-53-34b	129	ssl	S
Arneson, Ray	113-54-1c	12	o	D&S
Shelsta, Henry	113-54-2b	25	o	D&S
Popham, Jerald	113-54-2b	54	ssl	D&S
Dickinson, Andrew	113-54-11a	26	o	D&S
Hoika, Marvin	113-54-11d	12	o	D&S
Hilton, Sophie	113-54-12b	14	o	D&S
Seppanin, W.	113-54-12d	19	o	S

Appendix B--Records of wells--continued

Name	Location	Depth of Well in ft.	Geologic Source	Use
Lehtola, Abner	113-54-13c	12	o	D
Juntunen, Dave	113-54-13d	14	o	D&S
Thue, Neal	113-54-14a	35	o	D&S
Paro, George	113-54-23d	65	ssl	D
Lehtola, H.	113-54-24a	23	o	D
Spilde, John	113-54-24d	28	o	D
Tuohino, Reid	113-54-25b	20	o	D&S
Andrews, James	113-54-26d	25	o	D&S
Koistinen	113-54-34d	25	ssl	D
Anduwonke, Elmer	113-54-35a	50	ssl?	D&S
Koistinen, Alan	113-54-35c	22	o	D
Nelson, Claude	114-53-21d	60	ssl	S
Bunde, Porter	114-53-22c	100	ssl	D&S
Becker, Adolf	114-53-23d	120	ssl	D&S
Johnson	114-53-25a	33	o	D
Appel, Albert	114-53-25c	24	o	D
Olson, E. P.	114-53-26c	66	ssl	S
Wallenfels Bros.	114-53-27c	28	a	D
Person, Elmer	114-53-28d	140	ssl	D&S
Shesta, Jim	114-53-31c	29	o	D
Kastein, Harold	114-53-31d	25	o	D
Kaaz, Albert	114-53-33c	170	ssl	S

Appendix B--Records of wells--continued

Name	Location	Depth of Well in ft.	Geologic Source	Use
Koistinen, Fred	114-53-34b	290	ssl	S
Jorgenson	114-53-35b	70	ssl	D
Lee, Lloyd	114-53-36c	20	o	D
Jurgens, Harry	114-54-35a	25	o	D&S