SOUTH DAKOTA GEOLOGICAL SURVEY
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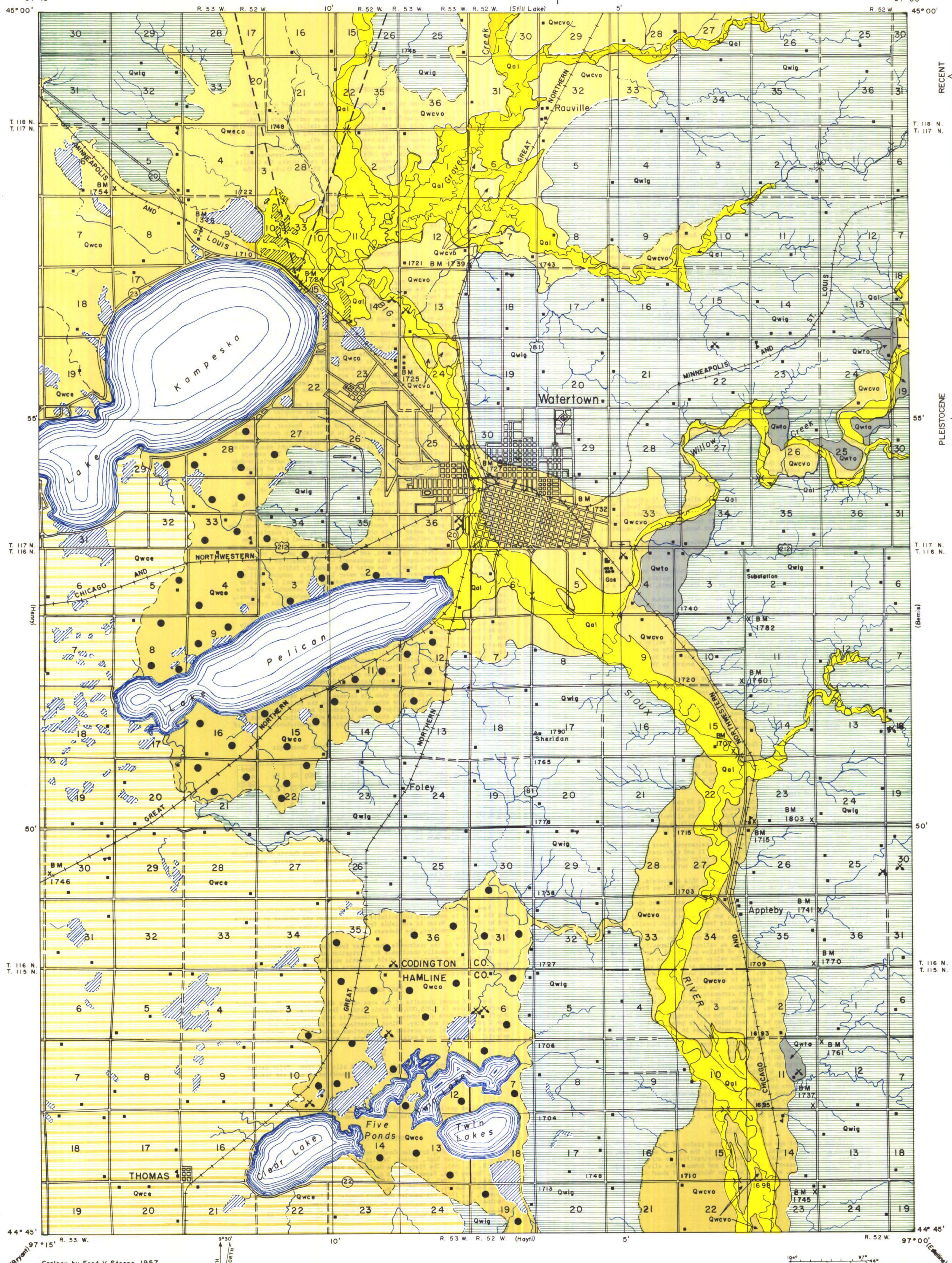
STATE OF SOUTH DAKOTA
JOE FOSS, GOVERNOR

# GEOLOGY of the WATERTOWN QUADRANGLE SOUTH DAKOTA




## EXPLANATION

QUATERNARY

RECENT

**Qal** — Alluvium
(Semistratified deposits of gravel, sand and silt, humic; brown to black; 0-20 feet thick; in stream flood plains and lakebeds.)

PLEISTOCENE — WISCONSIN

**Qwcvo** — Middle? Cary Valley Train Outwash
(Stratified deposits of brownish-gray to bluish-gray poorly-sorted fine sand to coarse gravel; unoxidized; level topography; sandy loam soil; ranges from 15-95 feet in thickness.)

**Qwco** — Middle? Cary Plain Outwash
(Semistratified to stratified poorly-sorted fine sand to coarse gravel and till inclusions; rugged "pitted" topography; ranges from 15-92 feet in thickness. Stippled where collapsed.)

**Qweco** — Early Cary Outwash
(Stratified brown fine sand to coarse gravel; weathered; contains abundant iron-oxide; these terrace remnants stand about 25 feet above valley floor; exposed thickness 25 feet.)

**Qwce** — Cary End Moraine
(Boulder-clay till consisting of olive-gray to olive-brown calcareous silt and clay with rock fragments friable; ranges up to 100 feet in thickness; rugged undrained knob and kettle topography.)

**Qwto** — Tazewell Outwash
(Stratified poorly-sorted sand and gravel; terrace remnants; oxidized; ranges from 10-30 feet thick.)

**Qwig** — Iowan? Ground Moraine
(Boulder-clay till consisting of olive-gray to olive-brown calcareous friable to compact silt and clay with rock fragments; mostly unoxidized; ranges up to 150 feet in thickness, level and well-drained topography; calcareous loess cover up to four feet thick.)

Contact
(dashed where approximately located)

Gravel Pit

X BM 1737
Bench Mark
(monument showing exact altitude above sea level)

△ Sheridan
Triangulation Station
(monument marking exact geographic location)

House, school, and church

Cemetery

Geology by Fred V. Steece, 1957
Assisted by R.C. Wilson, D.G. Jorgenson, R. VonHoldt
Vertical and horizontal control surveyed from triangulation and level lines of Federal surveys
Drafted by L.C. Zamow, R.H. Benson

Scale 1:62 500
1 ½ 0 1 2 3 4 Miles

Vermillion, South Dakota
1958

Quadrangle Location

Watertown Quadrangle

## INTRODUCTION

The Watertown quadrangle is in parts of Codington and Hamlin Counties in northeastern South Dakota (fig. 1) (see Index Map reverse side); it occupies about 214 square miles. The quadrangle lies in the north-central part of the Coteau des Prairies upland (Rothrock, 1943, map). The drainage of the area is controlled by the Big Sioux River, and its major tributaries Gravel and Willow Creeks. Natural lakes in the area include Lake Kampeska, Lake Pelican and Five Ponds. The topography ranges from nearly flat and gently undulating to rugged knob and kettle. The average relief is 30 to 40 feet, and the maximum relief is about 80 to 90 feet.

The center of population in the quadrangle is the city of Watertown, population 12,699 (1950 census). Thomas, Rauville, and Appleby are unincorporated communities in the quadrangle.

The quadrangle is crossed by U. S. Highways 81 and 212, which intersect in Watertown. State Routes 20, 22, and 23 supplement the Federal roads. In addition, nearly every section line is marked by an improved gravel road. The Great Northern, the Chicago and North Western, and the Minneapolis and St. Louis railroads serve the area and the city of Watertown. Commercial air service to the city of Watertown is provided by Braniff and North Central airlines.

The climate of the area is characterized by rapid and extreme fluctuations in temperature with long cold winters and short hot summers. The average annual temperature is 43° F., and the average annual precipitation is about 21 inches. Agriculture is the chief industry in the area, the major crops being corn, wheat, barley, oats, alfalfa, soybeans, sorghum, flax, and potatoes. Meat-packing, potato-distributing, tree-farming, livestock-raising, flax-straw processing, and resorts are industries important to the city of Watertown.

Geologic mapping was done on air photos in the summer of 1957. Outcrop information was supplemented by hand-auger borings, and the thickness of outwash deposits was determined by 52 holes drilled by jeep-mounted augers.

Thanks is due Dr. A. F. Agnew under whose supervision this work was accomplished, to Dr. M. M. Leighton whose comments were helpful, and to Dr. K. Y. Lee and M. J. Tipton for their help in field conferences. The writer wishes to thank the residents of the Watertown quadrangle for their cooperation and aid during the course of the work.

## SURFICIAL DEPOSITS

The surficial deposits of the Watertown quadrangle are Pleistocene glacial drift and Recent alluvium.

### Glacial Drift

Glacial drift comprises all the material transported and deposited by glacial ice of the Nebraskan, Kansan, Illinoian, and Wisconsin glacial stages of the Pleistocene Epoch. Drift includes till, outwash, and loess. Till is nonsorted, nonstratified boulder clay. Outwash is stratified sand and gravel deposits, usually unsorted. Loess is wind-blown silt and clay derived from the ablation of outwash.

The glacial drift in the Watertown quadrangle represents the Iowan (?), Tazewell, and Cary substages of the Wisconsin glacial stage.

#### Iowan (?) Substage

Iowan (?) till is dark olive-gray to dark olive-brown in color; it normally is calcareous, but may be leached locally to a depth of several feet. The generally dark color of the fresh till is due to the lack of oxidation. Where the till is compact, however, it does exhibit iron-oxide staining on joint faces; where the till is friable, on the other hand, little or no oxidation is present except after long exposure.

The average composition of the 4-8 mm. pebbles of the Iowan (?) till is 52 percent carbonate rocks, 8 percent igneous and metamorphic rocks, and 40 percent other rocks. The thickness of the Iowan (?) till ranges up to 146 feet.

The Iowan till is characterized by level topography with well integrated dendritic drainage and only a few lakes. The till is overlain by a variable thickness of discontinuous brownish-yellow calcareous loess, which has a maximum thickness of four feet.

A silt or clay loam, brownish-black soil, with a maximum thickness of 3 feet, is developed on the surface of the Iowan (?) till and the loess. The soil is normally leached to a depth of about 8 to 10 inches.

#### Tazewell Substage

Tazewell deposits in the quadrangle are remnants of valley outwash preserved as terraces along Willow Creek, and at one locality on the Sioux River. The Tazewell age of the deposits is based on the fact that they can be traced northeastward along Willow Creek nearly to their source in the Bemis (Tazewell) moraine.

The Tazewell remnants are small, averaging no more than a quarter to one-half square mile. They are composed of sand and gravel ranging in texture up to very coarse boulders. The material is ordinarily well weathered, and contains abundant iron-oxide. In composition it differs but slightly from Cary gravel with carbonate rocks and igneous and metamorphic rocks predominating over minor percentages of other rocks. These remnants range from 10 to 30 feet in exposed thickness, and average about 20 feet. They stand 10 to 20 feet above the lower valley outwash and have a level surface.

#### Cary Substage

The Cary drift in this quadrangle consists of till and outwash, deposited by the first two of three possible advances of the Cary ice of the James lobe which followed the James River lowland in South Dakota.

The Cary till is characterized by rugged knob and kettle end moraine topography. Undeveloped drainage is shown by the abundance of natural lakes and the absence of streams.

The average composition of the Cary till is 39 percent carbonate rocks, 10 percent igneous and metamorphic rocks, and 51 percent other rocks. The till is light and dark olive-gray to light and dark olive-brown, and weathers light-buff. It is calcareous throughout and normally is not oxidized except after prolonged exposure. The Cary till ranges from 20 to 100 feet in thickness, and averages about 45-50 feet.

Very thin discontinuous brownish-yellow calcareous loess overlies the till. The till has a variable thickness of silt and clay-loam soil on its surface. The soil is dark brown or black in color and is usually leached near the top; it ranges up to 1$\frac{1}{2}$ feet in thickness but averages about six inches.

Two ages of Cary outwash are recognized in this quadrangle. Early Cary outwash is preserved as a terrace remnant along the Big Sioux River in the northwestern corner of the quadrangle. This outwash is composed chiefly of poorly-stratified sand and medium to coarse gravel, containing minor amounts of silt and clay. Average percentages of 4-8 mm. constituents are 50 percent carbonate rocks, 30 percent other rocks, and 20 percent clastic and precipitate rocks. The material has considerable iron-oxide which locally serves as cement. The soil developed on this terrace is sandy loam about 8-12 inches thick. The terrace stands about 25 feet above the valley outwash.

The Middle (?) Cary outwash occurs as valley-train deposits in the Big Sioux River valley and in the valleys of Willow and Gravel Creeks, and as collapsed or pitted plain-outwash. The valley train outwash is more predominant and more important. This material consists of sand and gravel with lesser amounts of silt and clay. It is normally unoxidized and is gray to brown in color. The material occurs in alternating coarse and fine layers which are often coarser near the source. The average composition of the Middle (?) Cary outwash is 45 percent carbonate, 43 percent igneous and metamorphic, and 12 percent other rocks. The topography of the valley train is level to gently undulating. This outwash is mantled by a variable thickness of sandy loam and silty loam soil. The soil normally is less than a foot thick, but locally may be 2$\frac{1}{2}$ feet thick; it is generally leached in the upper few inches. The valley train outwash ranges in thickness from 15-95 feet and averages about 55 feet.

The collapsed plain-outwash deposits occupy positions immediately adjacent to the Cary end moraine. The collapsed topography is rough and uneven, exhibiting as much as 50-60 feet of local relief. In places its topography is difficult to distinguish from end moraine. The collapsed material differs from end moraine, however, in being composed chiefly of sand and gravel with some inclusions of till. The material is commonly unstratified to poorly stratified fine to coarse gravel, sand, silt, and clay. The material is usually unoxidized and thus is light-gray to bluish-gray in color. A sandy silt-loam discontinuously mantles the surface of the collapsed outwash. The outwash ranges widely in thickness as depths of 15 to 92 feet have been penetrated; the average thickness is about 50 feet.

### Recent Alluvium

Alluvium of recent age occupies the flood plains of the Big Sioux River, and Gravel and Willow Creeks; it also occurs in the beds of modern lakes in the area. The alluvium consists of dark semistratified to stratified gravel, sand, and silt with lesser amounts of clay and humus. The alluvium ranges up to 20 feet in thickness, and has an average thickness of about 3 feet.

## SUBSURFACE ROCKS

No bedrock is exposed in the quadrangle. On the basis of data obtained from well logs in and around the area, however, Precambrian rocks form the basement and are unconformably overlain by Cretaceous sedimentary rocks.

The Precambrian rocks are red biotite granite similar to the Ortonville granite at Milbank; the pink quartzitic Sioux Formation; and metamorphic rock composed chiefly of serpentine (Erickson, 1954, p. 49).

The Cretaceous rocks are in ascending order, the Dakota Group (A. F. Agnew, personal communication, May 1958) 150 feet thick; the Graneros Formation, 155 feet thick; the Greenhorn Formation, 31 feet thick; the Carlile Formation, 196 feet thick; the Niobrara Formation, 93 feet thick; and the Pierre Formation, 243 feet thick.

## STRUCTURE

The structure of the subsurface rocks of the Watertown quadrangle is relatively simple. The surface of the Precambrian is uneven, probably erosional, and has a gentle slope to the northwest (Steece, 1953). The Cretaceous strata are relatively flat-lying and, as mentioned previously, unconformably lie on the basement. In places, Cretaceous rocks overlap the Precambrian.

## ECONOMIC GEOLOGY

### Shallow Ground Water

All the unconsolidated Pleistocene deposits in the quadrangle contain interstitial waters. The quantity and quality of water contained in the outwash exceeds that found in any of the other materials. The level at which the water is maintained in the outwash materials is the water table. This normally conforms to the topography and thus in this quadrangle it slopes generally southward with a resulting slow movement of water through the porous material from north to south.

The occurrence of ground water in the outwash is dependent on several factors, including permeability, porosity, and extent. Permeability is the ability of a material to transmit water through its interstices. In general, coarse-grained material is more permeable than fine-grained material, with similar grain arrangement. Porosity is the amount of pore space in a given material. Porosity is dependent on grain shape rather than size; thus a material may have a high degree of porosity and yet have a low permeability if the pores are not interconnected or if the openings between pores are very small. An ideal water reservoir material would have spherical grains one to two inches in diameter.

An equally important factor determining quantity of water is the extent of the deposit in which it is contained. The total area occupied by outwash deposits in the quadrangle is 68.4 square miles. Of this, 93 percent can be considered as potential source of shallow ground water. However, because 37 percent is collapsed plain-outwash and as it is so variable in character and thickness, it is not recommended as a consistent source for irrigation water; it is, nevertheless, included in the calculations. Thirty-eight square miles of normal valley train outwash averages 51 feet in thickness. The average depth to water is 16 feet. Thus 35 feet of saturated outwash material underlies the surface of 24,320 acres. The 1,377,200,000 cubic yards of saturated sand and gravel therein, with an average porosity of 30 percent, contains approximately 255,000 acre-feet, or 84,317,000,000 gallons of water. The water reserve in the collapsed plain-outwash is 153,000 acre-feet, or 50,540,000,000 gallons.

The average annual precipitation at Watertown is about 21 inches ( U. S. Weather Bureau ). Most of this water is absorbed directly by the porous soil on the outwash, to form the major part of the recharge for the materials. Recharge is also accomplished by runoff from surrounding uplands, by underflow or slow percolation of water in the gravels downstream, and by overflow of streams during flood periods. The main discharge or removal of water from the outwash material is through wells, underflow away from source areas, seeps and springs, transpiration by plants, and evaporation. In general the recharge exceeds the discharge in this quadrangle so that underflow accounts for any excess recharge, keeping the water table annually fairly constant.

Recovery is the process by which the water level in a pumping well or a well which is influenced by a pumping well resumes its normal level after pumping has ceased. The rate of recovery depends on the permeability of the material which the well penetrates, and on the rate of recharge. In general, the recovery in the outwash of this area is good and wells should return to normal in a short time if the recharge is normal.

The quality of water in the outwash deposits (table 1) is generally good for irrigation. Sample 2 is water from Iowan till and is considerably harder than the outwash water; till water is thus generally unsatisfactory for irrigation purposes. Excessive concentrations of sulfate, sodium, carbonate, chloride, and boron ions are considered harmful to plant development (see Steece, 1958, for further details).

The use of outwash water for irrigation in the Watertown quadrangle is recommended with several qualifications. First, periodic analyses of irrigation water should be carried out often during the pumping season owing to higher salt concentrations by re-circulation. Second, each well should be deep enough to completely penetrate the outwash, and should be located near the center of the outwash rather than its borders. Third, because of the porous nature of the soil on the outwash and because the valley outwash is relatively level, sprinkler irrigation would probably be more adaptable than ditch irrigation. Fourth, wells should be located with caution in areas of collapsed plain-outwash owing to the variability and unpredictable nature of the materials there.

Table 1. Analyses of Water Samples in Watertown Quadrangle

| Constituent ppm / No. | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | Cl | Fe | Hardness $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1* | 58 | 28 | 13 | 3 | 235 | 20 | 30 | 5 | 10 | 4.8 | 260 |
| 2* | 214 | 116 | 468 | 12 | 210 | 10 | 1650 | 3 | 43 | 0.2 | 1015 |
| 3* | 62 | 45 | 12 | 6 | 260 | 0 | 83 | 5 | 5 | 0.0 | 340 |
| 10** | 61 | 23 | 16 | | 218 | 0 | 64 | 0.2 | 11 | 0.1 | 243 |

1. W. R. Crapo, SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 9, T. 118 N., R. 53 W., Codington County.
2. J. E. Zerfas, NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 17, T. 116 N., R. 52 W., Codington County.
3. Roland Hyde, NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 115 N., R. 52 W., Hamlin County.
10. Watertown City Well No. 2.

*Analyzed by O. E. Olson, Station Biochemistry, South Dakota Agricultural Experiment Station, College Station, Brookings, South Dakota, 1957.

**Analyzed by Division of Sanitary Engineering, South Dakota State Department of Health, Pierre, South Dakota, 1956.

### Deep Ground Water

Some subsurface strata yield sufficient water for most domestic purposes, but the water is generally not suitable for irrigation use because of quality and/or quantity. Water is available from the Dakota Group, the Codell sand of the Carlile Formation, the Niobrara ("chalkstone") Formation, and the Sioux Formation.

Many wells in the quadrangle draw water from the till. As mentioned earlier, this is usually unsuitable for irrigation use.

Buried stream channels may yield domestic supplies of water. Flint (1955, map; Plate 7) has suggested the presence of several of these in the Watertown quadrangle.

### Sand and Gravel

Sand and gravel deposits of the area occupy 43,520 acres. The estimated reserve of these is 3,855,000,000 cubic yards. The material is composed chiefly of carbonate and igneous and metamorphic rock fragments with less than 2 percent silt and clay. Minor percentages of shale, chalk and clay-ironstone (limonite) are present as deleterious materials. In general, the material is good for road metal and concrete aggregate.

### Clay

The tills in the area contain 60 percent silt and clay. Brick-making and various ceramic industries could find an abundance of clay for their needs.

### Oil and Gas

No oil or gas has been found in eastern South Dakota. The pinchouts formed by the Cretaceous strata and the Precambrian basement may be sites of oil accumulation.

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__________, 1958, Geology and Ground Water Resources of the Watertown-Estelline Area, South Dakota, S. Dak. Geol. Survey Rept. Invest. 85.