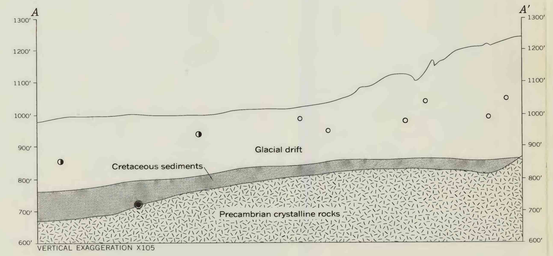
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS, AND MINERALS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-272 (SHEET 4 OF 4)



EXPLANATION

Area of predominantly calcium magnesium sulfate type
Water in glacial drift

Area of predominantly calcium sodium bicarbonate type
Water in glacial drift

Eastern limit of Cretaceous sediments

LOCATION OF WATER SAMPLE FROM GLACIAL DRIFT

180 c, △ s
Calcium magnesium sulfate type
Circle is ground water analysis, triangle is surface water analysis

116
Mixed type

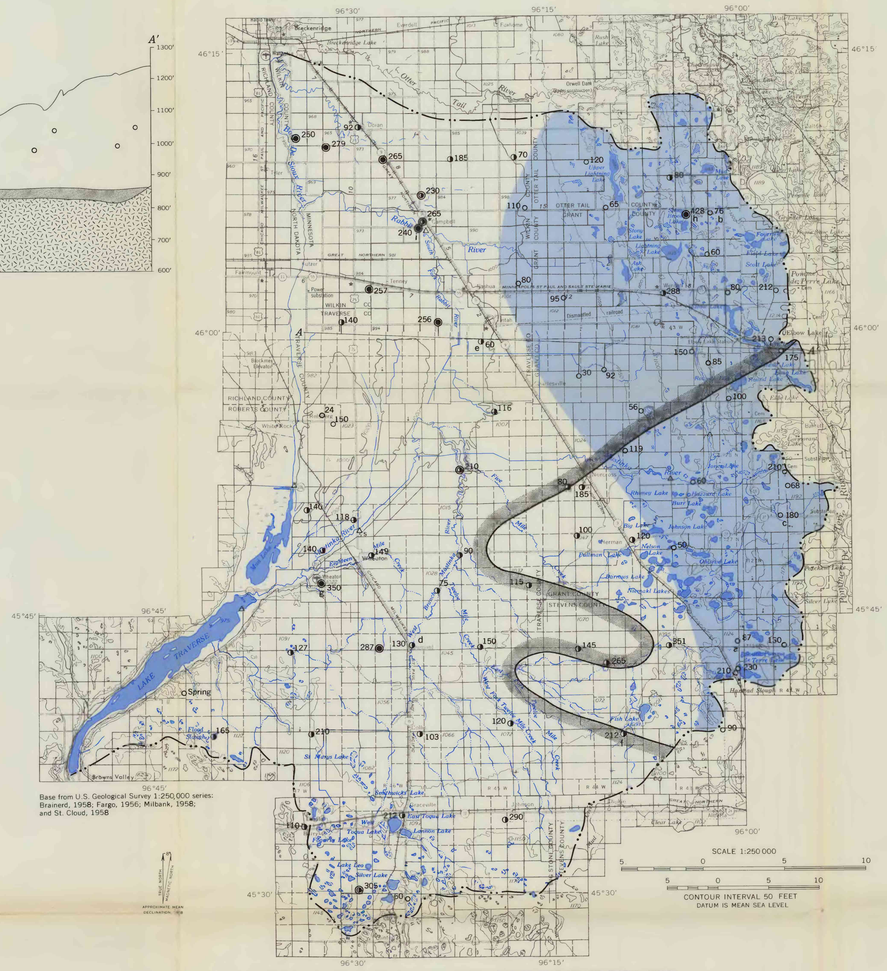
LOCATION OF WATER SAMPLE FROM CRETACEOUS SEDIMENTS

230
Mixed type

350 g
Sodium chloride bicarbonate type
Numbers are depths of wells from which samples were taken. Letters by selected locations are keyed to logarithmic graphs to right of map

A — A'
Line of geologic section
Holes projected to line of section are shown by connecting line

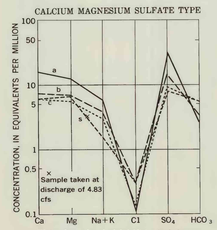
Watershed boundary



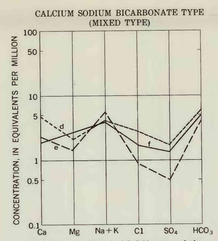
Base from U.S. Geological Survey 1:250,000 series: Brainerd, 1958; Fargo, 1956; Milbank, 1958; and St. Cloud, 1958

CHANGES IN CHEMICAL CHARACTER OF GROUND WATER INDICATE THAT GROUND WATER MOVES FROM THE MORAINAL AREA TO THE LAKE PLAIN WHERE IT MIXES WITH WATER MOVING UPWARD FROM THE CRETACEOUS SEDIMENTS

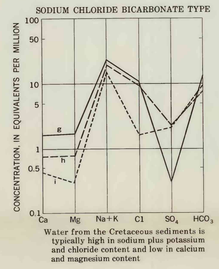
The waters are classified into the calcium magnesium sulfate, the calcium sodium bicarbonate and the sodium chloride bicarbonate types on the basis of the dominant ions in solution. Surface water and all ground waters sampled within the drift in the predominantly morainal area shown in blue on the map are the calcium magnesium sulfate type and is generally found in the clay till at depths generally greater than 50 feet below land surface. Water from the Cretaceous deposits is a sodium chloride bicarbonate type. Chemical quality of ground water in the glacial drift of the lake plain is more variable than that in the morainal area. Most ground waters from the lake plain are classified as a calcium sodium bicarbonate type, which is interpreted as a mixture of sodium chloride bicarbonate water from the Cretaceous deposits and calcium magnesium sulfate water from the drift.



Water from the glacial drift in shaded area shown on the map is very low in chloride content and high in calcium, magnesium, and sulfate content

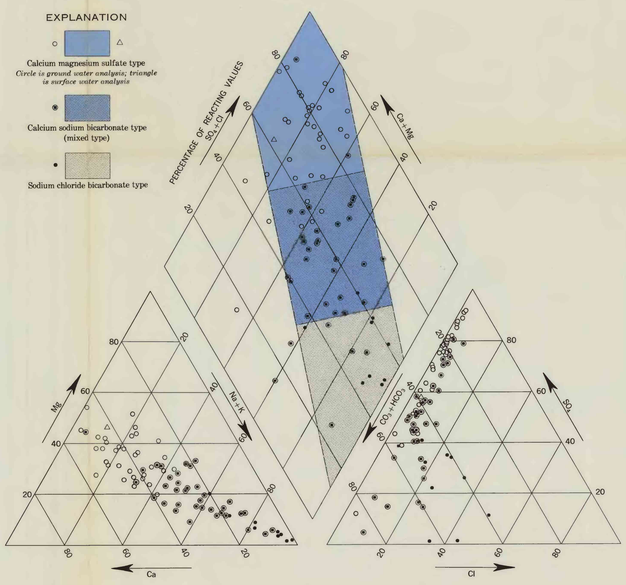


Water from the glacial drift west of the shaded area shown on map is higher in chloride content and lower in calcium and magnesium content which indicates a mixing of waters from the drift and Cretaceous sediments



Water from the Cretaceous sediments is typically high in sodium plus potassium and chloride content and low in calcium and magnesium content.

QUALITY OF WATER

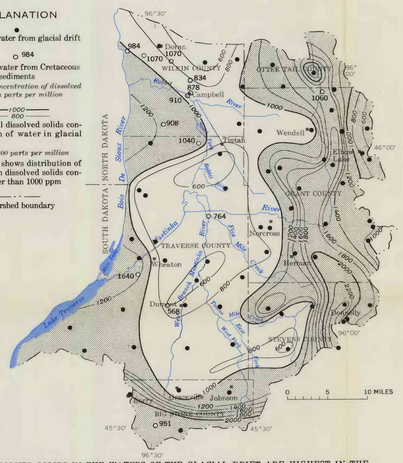


PLOTS OF THE PERCENTAGE DISTRIBUTION OF THE SIX MAJOR IONS IN SOLUTION FOR GROUND WATER IN THE WATERSHED INDICATE THAT THE SODIUM CHLORIDE BICARBONATE TYPE MIXES WITH THE CALCIUM MAGNESIUM SULFATE TYPE TO FORM THE CALCIUM SODIUM BICARBONATE TYPE

Mixtures of the two waters in all proportions, if all dissolved substances remain in solution, plot in the trilinear fields on straight lines. Water in the Cretaceous sediments is characteristically softer (lower in calcium and magnesium ion concentrations) and higher in chloride ion concentration than water in the drift. However, where the drift is underlain by Cretaceous sediments the water in the drift shows some softening. No softening is indicated where the drift is not underlain by Cretaceous sediments, therefore, it is interpreted that the relatively softer water is due to upward movement of water from the Cretaceous sediments.

EXPLANATION

Analysis of water from glacial drift
984
Analysis of water from Cretaceous sediments
Number is concentration of dissolved solids, in parts per million
1000
800
Lines of equal dissolved solids concentration of water in glacial drift
Interval, 200 parts per million
Shaded area shows distribution of water with dissolved solids content greater than 1000 ppm
Watershed boundary



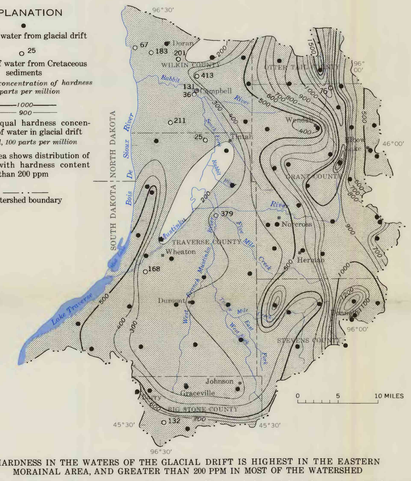
DISSOLVED SOLIDS IN THE WATERS OF THE GLACIAL DRIFT ARE HIGHEST IN THE MORAINAL AREA AND LOWEST IN THE LAKE PLAIN

The highest dissolved solids content occurs in areas of low altitude within the moraine. The dissolved solids content in the Cretaceous sediments generally is less than in the glacial drift and the relatively lower mineralization of water in the Lake Plain area may be due to dilution by the water from the Cretaceous sediments.

Water containing dissolved solids of less than 1,000 ppm is suitable for domestic and stock uses. Some water containing 1,000 or more ppm dissolved solids contains certain constituents which produce a noticeable taste

EXPLANATION

Analysis of water from glacial drift
25
Analysis of water from Cretaceous sediments
Number is concentration of hardness in parts per million
1000
900
Lines of equal hardness concentration of water in glacial drift
Interval, 100 parts per million
Shaded area shows distribution of water with hardness content greater than 200 ppm
Watershed boundary



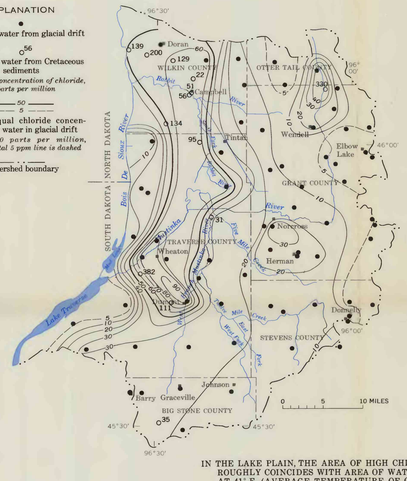
HARDNESS IN THE WATERS OF THE GLACIAL DRIFT IS HIGHEST IN THE EASTERN MORAINAL AREA, AND GREATER THAN 200 PPM IN MOST OF THE WATERSHED

Water in the Cretaceous sediments ranges from soft to very hard but is generally softer than water in the glacial drift. As shown in the trilinear diagram, water in glacial drift that overlies Cretaceous sediments in the Lake Plain is softer than that in the morainal areas due to mixing with the soft water from the Cretaceous sediments. Northwest of Wheaton the hardness of ground water in the glacial drift is relatively high because no mixing occurs in the local recharge area.

Hardness is due mainly to the presence of calcium and magnesium ions which react with soap to form insoluble products. Mineral salts of calcium and magnesium cause hardness and can form incrustation on well screens. Where hardness exceeds 500 ppm, incrustation of well screens may be rapid for small-diameter wells that are heavily pumped.

EXPLANATION

Analysis of water from glacial drift
56
Analysis of water from Cretaceous sediments
Number is concentration of chloride, in parts per million
50
5
Lines of equal chloride concentration of water in glacial drift
Interval, 10 parts per million, supplemental 5 ppm line is dashed
Watershed boundary



IN THE LAKE PLAIN, THE AREA OF HIGH CHLORIDE CONCENTRATION IN THE DRIFT WATERS ROUGHLY COINCIDES WITH AREA OF WATER THAT IS UNSATURATED WITH RESPECT TO CALCITE AT 41° F. (AVERAGE TEMPERATURE OF GROUND WATER)

The water in the underlying Cretaceous sediments is unsaturated with respect to calcite and relatively high in chloride. This suggests that the area of high chloride concentration marks a discharge zone for aquifers in the Cretaceous sediments. The magnesium to calcium ratio shows no significant differences between areas of calcite unsaturation and supersaturation, which suggests that no precipitation of calcium carbonate occurs in the areas of supersaturation.

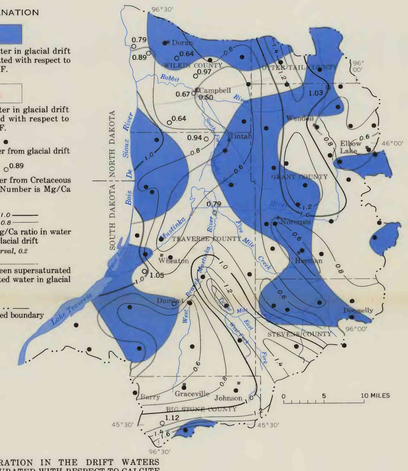
Chloride content in the drift is within the 250 ppm recommended as a maximum for potable water by the U.S. Public Health Service.

EXPLANATION

Area where water in glacial drift is supersaturated with respect to calcite at 41° F.

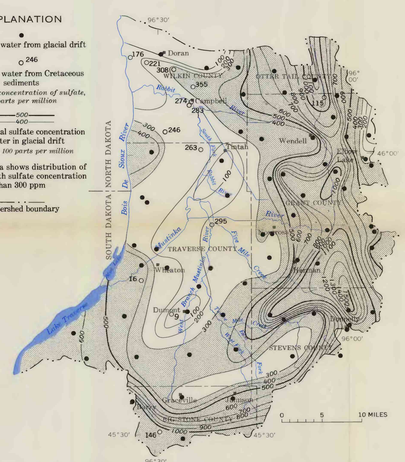
Area where water in glacial drift is unsaturated with respect to calcite at 41° F.

Analysis of water from glacial drift
0.89
Analysis of water from Cretaceous sediments. Number is Mg/Ca ratio
1.0
0.8
Lines of equal Mg/Ca ratio in water from glacial drift
Interval, 0.2
Boundary between supersaturated and unsaturated water in glacial drift
Watershed boundary



EXPLANATION

Analysis of water from glacial drift
246
Analysis of water from Cretaceous sediments
Number is concentration of sulfate, in parts per million
500
400
Lines of equal sulfate concentration of water in glacial drift
Interval, 100 parts per million
Shaded area shows distribution of water with sulfate concentration greater than 300 ppm
Watershed boundary



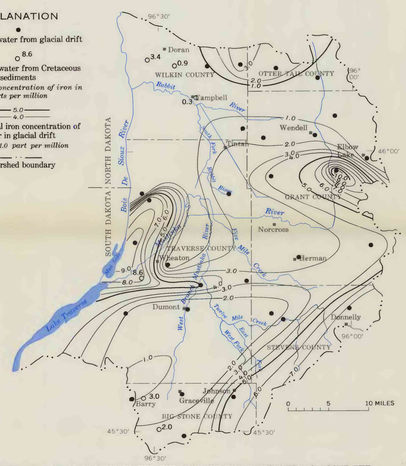
SULFATE CONCENTRATION IN THE WATERS OF THE GLACIAL DRIFT IS HIGHEST IN THE MORAINAL AREA AND LOWEST IN THE LAKE PLAIN

Lower sulfate concentration in the glacial drift probably is due to dilution of glacial drift water by low sulfate water from the Cretaceous sediments.

The sulfate content of water from the glacial drift generally exceeds 250 ppm, which is the recommended limit for potable water set by the U.S. Public Health Service. Where sulfate content exceeds 1,000 ppm, water may have laxative effects on human.

EXPLANATION

Analysis of water from glacial drift
8.6
Analysis of water from Cretaceous sediments
Number is concentration of iron in parts per million
5.0
4.0
Lines of equal iron concentration of water in glacial drift
Interval, 1.0 part per million
Watershed boundary

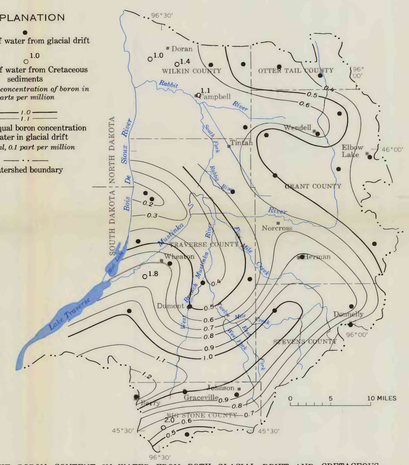


DISSOLVED IRON IN GROUND WATER THROUGHOUT THE WATERSHED IS ABOVE THE RECOMMENDED LIMIT OF 0.3 PPM SET BY THE U.S. PUBLIC HEALTH SERVICE AND GENERALLY IMPARTS A RUSTY COLOR TO WATER THAT STANDS OPEN TO THE AIR

Where iron concentration exceeds several parts per million, precipitation of iron and associated manganese minerals may substantially contribute to the incrustation of well screens.

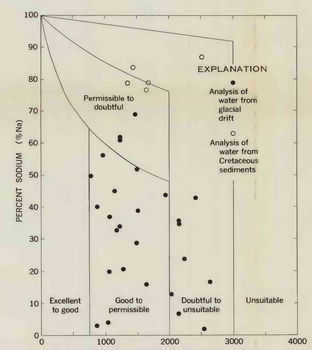
EXPLANATION

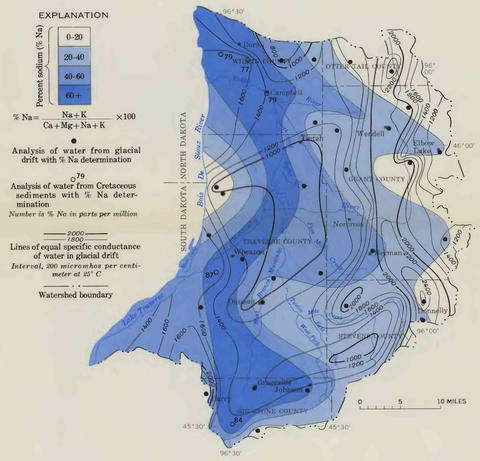
Analysis of water from glacial drift
1.0
Analysis of water from Cretaceous sediments
Number is concentration of boron in parts per million
1.0
1.1
Lines of equal boron concentration of water in glacial drift
Interval, 0.1 part per million
Watershed boundary



THE BORON CONTENT IN WATER FROM BOTH GLACIAL DRIFT AND CRETACEOUS SEDIMENTS IS WITHIN TOLERANCES (LESS THAN 2 PPM) OF MOST AGRICULTURAL CROPS GROWN IN THE WATERSHED

Boron is a necessary element for normal plant growth but is toxic to plants when in excess of 1 to 2 ppm. Beans are sensitive to excessive boron whereas wheat and alfalfa are semi-tolerant and tolerant, respectively.





WATER FROM THE GLACIAL DRIFT IS GENERALLY SUITABLE FOR IRRIGATION WHERE GOOD DRAINAGE IS PROVIDED WHILE WATER FROM THE CRETACEOUS SEDIMENTS IS GENERALLY HIGH IN SODIUM AND IS UNSUITABLE FOR IRRIGATION ON MOST SOILS IN THE WATERSHED

Suitability of ground water for irrigation depends upon the effects of the dissolved minerals on both the plants and soil structure.

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WATER RESOURCES OF THE MUSTINKA AND BOIS DE SIOUX RIVERS WATERSHED, WEST-CENTRAL MINNESOTA

By
R. W. Maclay, T. C. Winter, and L. E. Bidwell

1968