A PRELIMINARY REPORT OF A RECENTLY DISCOVERED AQUIFER AT SIOUX FALLS, SOUTH DAKOTA

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ABSTRACT

A hydrologic study of the Big Sioux aquifer system was begun July 1, 1966, by the U. S. Geological Survey, in cooperation with the City of Sioux Falls and the East Dakota Conservancy Sub-District.

Test drilling being done in the search for a southern outlet to the Big Sioux aquifer has led to the discovery of the outlet and of a deeper aquifer than was previously known to exist in this area. This aquifer, herein called the Sioux Falls aquifer, was first recognized as a very clean gravel in test hole USGS #1 between the depths of 60 to 83 feet.

Subsequent test drilling and aquifer testing has shown the Sioux Falls aquifer to be capable of producing several hundred gallons of water per minute. The chemical quality of this water surpasses that currently being used for the city supply.

Further investigation of the aquifer is planned as a part of the continuing expansion of the water-supply facilities for Sioux Falls.

This publication has been authorized by the Director of the U. S. Geological Survey and Earl McCart, Commissioner, City of Sioux Falls, South Dakota.

INTRODUCTION

A hydrologic study of the Big Sioux aquifer was begun July 1, 1966, by the U. S. Geological Survey, in cooperation with the City of Sioux Falls and the East Dakota Conservancy Sub-District.

Sioux Falls, with an estimated population in 1968 of 73,500, is located in southeastern South Dakota. It is situated in a loop of the Big Sioux River and derives its name from a picturesque falls where the river tumbles about 100 feet over exposed Sioux Quartzite bedrock.

The city originally obtained its water supply from the river; however, in 1890, engineers of the South Dakota Water Company, predecessor to the City Water Department, discovered the Big Sioux aquifer. This aquifer, which is of the water-table type, occupies the valley of the Big Sioux River and extends from the north edge of Sioux Falls to Dell Rapids, a distance of about 20 miles. The width varies from 1 to 3 miles and the thickness averages 27 feet at depths

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from 6 to 42 feet below the land surface. It is from this extensive aquifer that the city currently withdraws its water at an average daily rate of 10.2 million gallons. Twenty-six wells are used, ranging in age from 2 to 55 years, with diameters of 2 to 50 feet. The large diameter wells are of either pit or collector type.

The topography and surficial deposits of eastern South Dakota are the result of the continental glaciation described in detail by Flint, 1955. Generally, the sand and gravel deposits are scattered, poorly sorted, and discontinuous. An exception to this is the outwash in the valley of the Big Sioux River between Sioux Falls and Dell Rapids. Flint says "These exceptional accumulations of outwash sand and gravel were localized by pre-existing basins, created apparently by blockades of till across valleys in the underlying Sioux Quartzite."

The chemical nature of the water found in the Big Sioux Valley is largely determined by the glacial drift. The subsoil of the surrounding terrane is basically clayey gray drift. The water is usually "very hard" with the hardness ranging from 400 to 800 mg/1 (milligrams per liter) as $CaCO_3$. Mineralization varies with location in a range of total solids of 700 to 1,500 mg/1. The water from the Big Sioux aquifer is of better quality than that obtained from other aquifers in the area also of glacial origin. Bedrock water from the underlying Sioux Quartzite is little used and its chemical nature is not well known at the present time (1968).

TEST DRILLING

In analyzing the movement of water in the Big Sioux River and the Big Sioux aquifer (see Rothrock, 1947, p. 11) it was postulated that a southern outlet through the quartzite permitted ground water to move out of the area (Ackroyd, 1968). This outlet was located by test drilling and is centered near the corner of Minnesota Avenue and State Highway 38.

A zone of sand and gravel occurs in this outlet at depths from 60 to 83 feet (see Table 1). The clay overlying this zone is relatively impermeable and acts as a confining bed resulting in the artesian nature of the water contained therein. The Sioux Quartzite immediately underlies the gravel. The lower 23 feet of water-bearing material is the Sioux Falls aquifer.

Several additional test holes have been drilled by the City in adjacent areas, however, at this time, the aquifer boundaries and recharge sources have not been determined. (See Figure 1.)

AQUIFER TESTING

Test hole City TW-5, drilled near the entrance to the airport, was chosen for testing because the Sioux Falls aquifer could be readily developed at this point and the water discharge could be readily directed into a storm sewer. A log of this hole is shown in table 2.

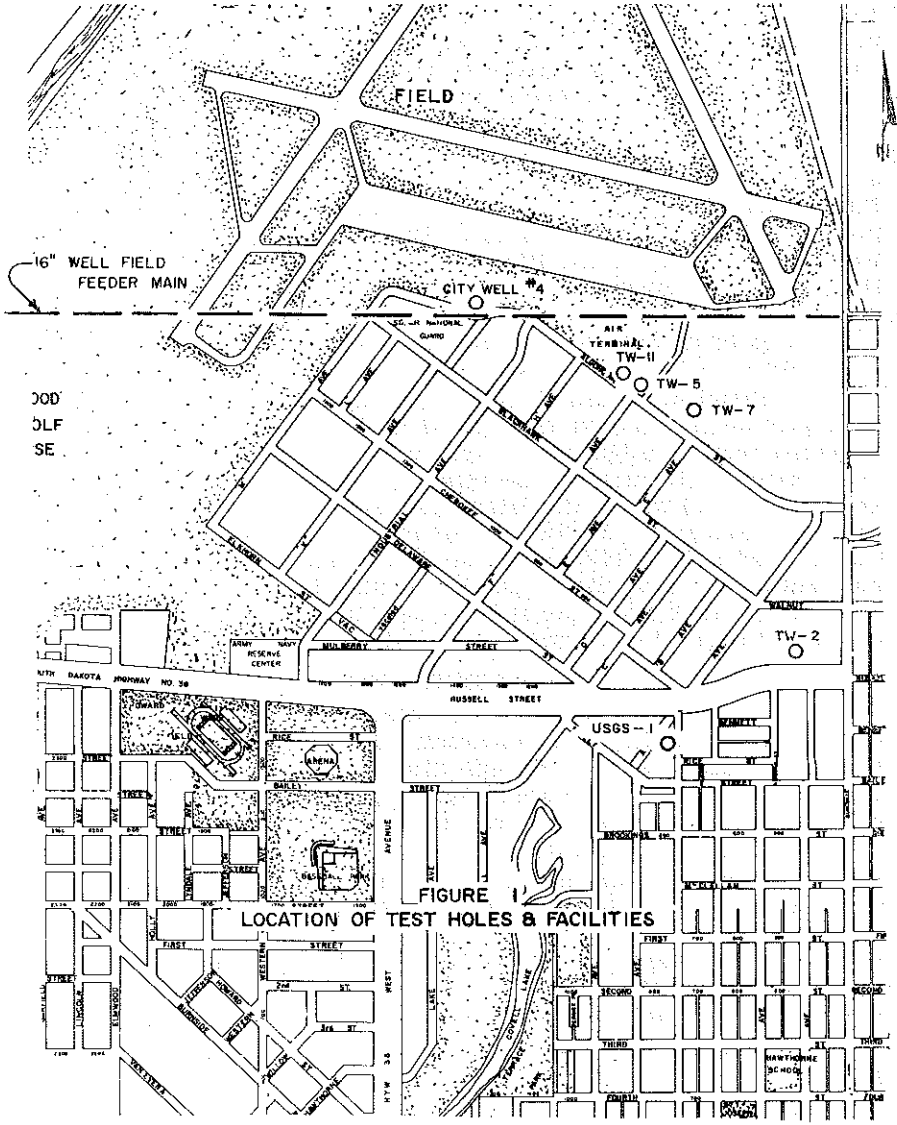

Figure 1.

FIGURE 1
LOCATION OF TEST HOLES & FACILITIES

TABLE I

Log of Test Hole USGS #1

Depth (feet)	Description
0 - 6	Topsoil, fill, clay
6 - 17	Sand, gravel, few pebbles
17 - 19	Good gravel
19 - 23	Sand and gravel
23 - 27	Dirty sand, clay
27 - 60	Tight clay
60 - 83	Good gravel
- 83	Quartzite

TABLE 2

Log of Test Hole City TW-5

Depth (feet)	Description
1 - 6	Black topsoil
6 - 11	Gray and brown clay
11 - 37	Fine to very coarse sand and gravel
37 - 52	Gray clay
52 - 82	Brown clay
82 - 98	Gray clay with sand streaks
98 - 103	Fine sand (cemented)
103 - 127	Fine to coarse sand
- 127	Quartzite

Sand from the lower aquifer was mechanically analyzed to determine the particle sizes and gradation. The results of the analysis are shown in table 3. Test wells TW-2, TW-7, TW-11 were cased with 3-inch pipe and sand points to monitor water levels.

Test well TW-5 was reamed to a 15-inch diameter. Thirty feet of 10-inch diameter, slotted screen with a gravel pack was set with the entire formation screened. A 6-inch turbine pump was installed with the suction 10 feet from the bottom of the casing. A diesel engine was used to provide power for the pump.

The aquifer test began at 10:30 A.M., January 25, 1968 and continued for 72 hours. Water-level recorders were placed on two test

TABLE 3

Mechanical Analysis of Test Hole City TW-5 (124'-127')

Passing No.	Opening inches	Percent
4	0.187	100
10	.0187	99
20	.0331	78
40	.0165	30
80	.0070	5.5
200	.0029	3.9

wells, TW-11 and TW-7, located 200 feet and 900 feet respectively from the pumping site. Steel-tape measurements were taken at two other test wells in the Sioux Falls aquifer and at several test wells in the Big Sioux aquifer. The pump was operated to produce a constant flow of 328 gallons per minute throughout the test. An attempt to obtain recovery curves was made; however, sleet and icing conditions kept the recorders from operating properly. Data from hand measurements during recovery were insufficient for analysis; however, the water returned to the original level in 72 hours of recovery.

The data from the pumping test were analyzed using Jacob method (Todd, 1964, p. 94).

Examination of the water-level measurements taken at the start of the aquifer test revealed the water level in the well tapping the Sioux Falls aquifer to be 40 feet below the water level in the Big Sioux aquifer. The Sioux Falls aquifer had an initial piezometric head of 38 feet. This decreased 16 feet in city well TW-11 leaving an artesian head of 22 feet at the end of the pumping test.

The lower Sioux Falls aquifer is artesian with 40 feet head differential between water levels in the upper Big Sioux aquifer and the lower one. The transmissibility of the lower aquifer was computed to be 14,400 gallons per day per foot; the storage coefficient of the lower aquifer was computed to be 2.8×10^{-4}. This is approximately 10 percent of the transmissibilities recorded for the upper aquifer. The transmissibility is very low because of the fineness of grain size; nevertheless, production capability far exceeds the characteristic yield from an aquifer of such low transmissibility.

QUALITY CONSIDERATIONS

Twenty water samples were collected during the test and analyzed by the authors in the City Water Purification Plant Laboratory in accordance with "Standard Methods for the Examination of Water and Waste Water," 12th edition. The composite results of the twenty analyzes and composite results of analyses of water from the Big Sioux aquifer are shown on table 4.

TABLE 4

Average Chemical Composition of Water, in Milligrams Per Liter, From Sioux Falls and Big Sioux Aquifers

	Sioux Falls[1] aquifer	Big Sioux[2] aquifer
Iron (Fe)	0.5	3.8
Manganese (Mn)	.4	3.0
Calcium (Ca)	117	146
Magnesium (Mg)	20	35
Bicarbonate (HCO_3)	306	295
Dissolved solids (residue at 180° C)	502	780
Hardness as $CaCO_3$	375	510
Specific conductance (micromhos at 25° C)	600	1,100
pH	7.4	7.2
Temperature (°F)	46	48

[1] Average of 20 water samples.
[2] Average of 25 water samples.

The chemical quality of the water from the Sioux Falls aquifer is better than that from the Big Sioux aquifer. Comparison shows the Sioux Falls aquifer water to be of higher pH; slightly higher alkalinity, calcium, and magnesium content; and much lower iron, manganese, conductivity, and total solids content than the water from the Big Sioux aquifer. Of considerable importance is the lower total solids content of 230 mg/1, the lower hardness of 135 mg/1, and the much lower conductivity reading of 335 micromhos in the Sioux Falls aquifer.

CONCLUSIONS

1. An aquifer extensive enough to provide an additional water supply for the city was discovered in the Sioux Falls area (Sioux Falls aquifer).
2. The water in the Sioux Falls aquifer was found to be under artesian pressure (rises in a well to a level above the top of the aquifer).
3. In the area tested, the upper Big Sioux aquifer is apparently not directly connected to the Sioux Falls aquifer by permeable zones.

4. The Sioux Falls aquifer is capable of producing 328 gallons per minute continuously for 72 hours without causing undue drawdown in the producing well.
5. The water contained in the Sioux Falls aquifer is of excellent quality compared to other water in the area. In addition, it is relatively "soft" in comparison with other water from this general area.
6. At this time, the origin of the producing interval is not established as being glacial.
7. The source of recharge to this aquifer is not known.

RECOMMENDATIONS

The recently discovered Sioux Falls aquifer is considered to have a high potential to supplement the Sioux Falls water supply. The improved water quality and proximity of existing well-field collector mains to the aquifer has caused the city to plan further investigation of the aquifer as a part of the continuing program of expansion of the water-supply facilities for Sioux Falls.

ACKNOWLEDGMENT

Acknowledgment is given to Mr. Vern Butler, Manager-Engineer, East Dakota Conservancy Sub-District for his assistance with this paper.

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