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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
RESTON, VA. 22092

RESULTS OF AQUIFER TESTING IN THE BELCOURT AREA, ROLETTE COUNTY, NORTH DAKOTA

Open-File Report 75-396

Prepared in cooperation with the
U.S. Public Health Service

U.S. GOVERNMENT PRINTING OFFICE 589-917-b

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By P. G. Randich and G. E. Ghering

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Bismarck, North Dakota
August 1975

CONTENTS

ILLUSTRATIONS

TABLES

SELECTED FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

A dual system of measurements--English units and the International System (SI) of units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English units	By	To obtain SI units
Acres	0.4047	hectares (ha)
	.004047	square kilometres (km^2)
Acre-feet	1.233×10^{-6}	cubic kilometres (km^3)
Cubic feet per second (ft^3/s)	28.3162	litres per second (l/s)
Feet	.3048	metres (m)
Feet per day (ft/d)	.3048	metres per day (m/d)
Feet per mile	.1894	metres per kilometre (m/km)
Feet squared per day (ft^2/d)	.0929	metres squared per day (m^2/d)
Gallons	.003785	cubic metres (m^3)
Gallons per minute (gal/min)	.06309	litres per second (l/s)
Inches	25.4	millimetres (mm)
Miles	1.609	kilometres (km)
Square miles	2.590	square kilometres (km^2)

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ABSTRACT

The city of Belcourt, Agency headquarters for the Turtle Mountain Indian Reservation, is located in northeastern Rolette County, north-central North Dakota. At the request of the U.S. Public Health Service, the U.S. Geological Survey conducted a study in the vicinity of Belcourt to assist in location of a suitable water supply for the city.

The Shell Valley aquifer is located about 5 miles southwest of Belcourt. Test drilling and aquifer testing in the Shell Valley aquifer indicate an adequate quantity of suitable quality water is available for development as a municipal supply for the city of Belcourt. Transmissivities in the test area average 7,760 feet squared per day (721 metres squared per day). The aquifer, which is generally unconfined, contains about 5,000 acre-feet (0.006 cubic kilometres) of water per square mile of surface area. Wells developed at a depth of about 38 feet (12 metres) will yield as much as 125 gallons per minute (8 litres per second) individually, if spaced at least 700 feet (213 metres) apart.

The water is a calcium bicarbonate type and has a dissolved-solids concentration of 323 to 566 milligrams per litre. Trace elements did not exceed allowable limits as defined by the U.S. Public Health Service.

INTRODUCTION

Purpose and Scope

At the request of the U.S. Public Health Service, the U.S. Geological Survey conducted a two-phase ground-water study in the vicinity of Belcourt, N. Dak., Agency headquarters for the Turtle Mountain Indian Reservation, to locate a suitable water supply for the city.

Phase 1 consisted of a reconnaissance of the geology and hydrology of the area, test drilling, sample description, geophysical logging, observation-well installation, water sampling for chemical analyses, and preparation of a report (Randich, 1974) describing the major findings of this phase. Selection of the Shell Valley aquifer (Randich, 1974, p. 10) as a suitable ground-water source was based on the results of this phase.

Phase 2 consisted of aquifer delineation, selection of a test site for development, well construction, aquifer testing and analyses, and water sampling and analyses. The objectives of phase 2 were to determine well yields, proper well spacing, and long-term adequacy of the Shell Valley aquifer as a source of supply for the city of Belcourt. This report is the result of phase 2 of the study.

Location of Study Area

The study area (fig. 1) consisted of about 6 square miles ($16\ km^2$) near the Turtle Mountain Indian Reservation about 5 miles (8 km) southwest of the city of Belcourt in northeastern Rolette County, north-central North Dakota.

System of Numbering Data-Collection Sites

The system of numbering data sites used in this report is illustrated in figure 2 and is based upon the location of the well or test hole within the grid established by the U.S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of a base line; the second numeral denotes the range west of the fifth principal meridian; and the third numeral denotes the section in which the well or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre, or 4-ha, tracts). Consecutive terminal numerals are added if more than one well is located within a given 10-acre (4-ha) tract. Thus, well 162-069-15DAA is in the NE¼NE¼SE¼ sec. 15, T. 162 N., R. 69 W. Similarly, well 162-069-08CDD2 is the second well located in the SE¼SE¼SW¼ sec. 8, T. 162 N., R. 69 W.

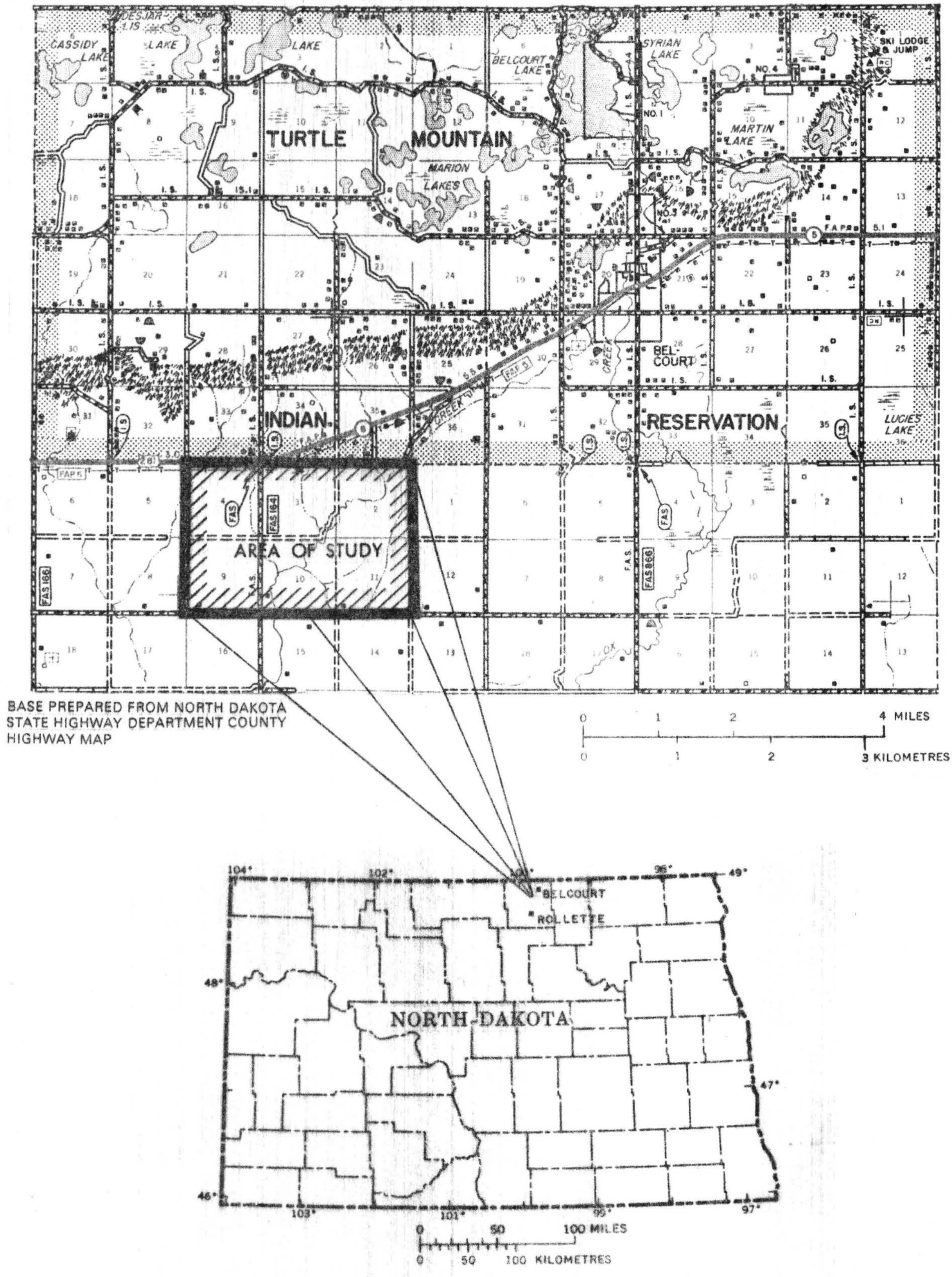

FIGURE 1.--Map showing location of study area.

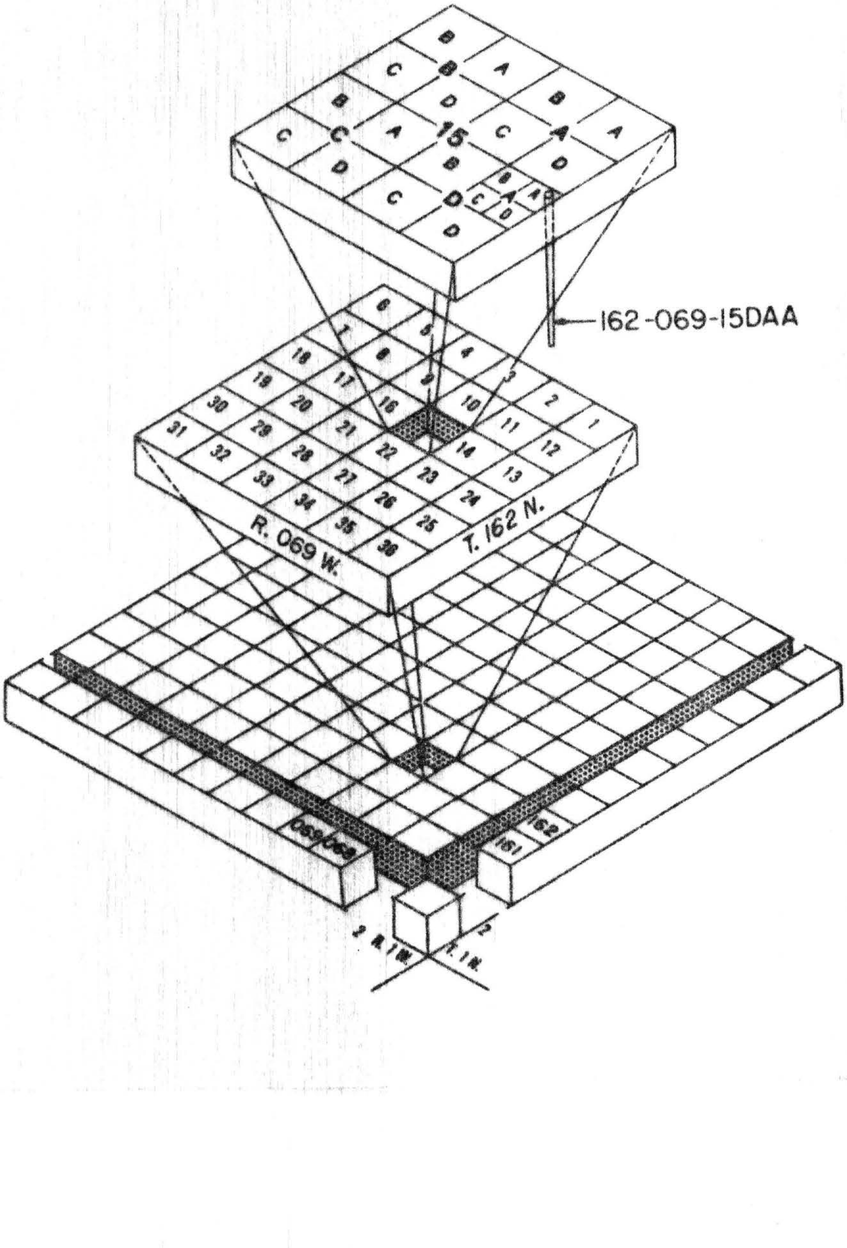

FIGURE 2.--System of numbering data-collection sites.

GEOHYDROLOGY OF THE TEST SITE

The Shell Valley aquifer is located about 5 miles (8 km) southwest of Belcourt, Rolette County, N. Dak. The section of the aquifer investigated during this phase is located in T. 161 N., R. 71 W. and is 1 to 2 miles (1.6 to 3.1 km) wide, about 4 miles (6.4 km) long, and generally is parallel to and west of Wolf Creek (fig. 3).

The aquifer is a glacial-outwash deposit composed of interbedded and mixed sand and gravel from 1 to 45 feet (0.30 to 14 m) below land surface, and generally very fine to medium silty sand from 45 to 54 feet (14 to 16.5 m) below land surface. The material was deposited during glaciation of the Turtle Mountain area. The aquifer ranges in thickness from 15 to 54 feet (4.6 to 16.5 m), and averages about 38 feet (12 m), based on data from 25 test holes (table 1). The average saturated thickness is about 26 feet (8 m). The aquifer is underlain by glacial till.

Water levels in 22 observation wells range from 2 to 15 feet (0.6 to 5 m) below land surface. The shallowest levels are in the Wolf Creek valley. The water levels fluctuate about 3 feet (1 m) annually in response to precipitation, evapotranspiration, and discharge to Wolf Creek and its tributaries.

The hydraulic gradient is about 3 feet per mile (0.6 m/km), generally toward the southwest, with some local deviations.

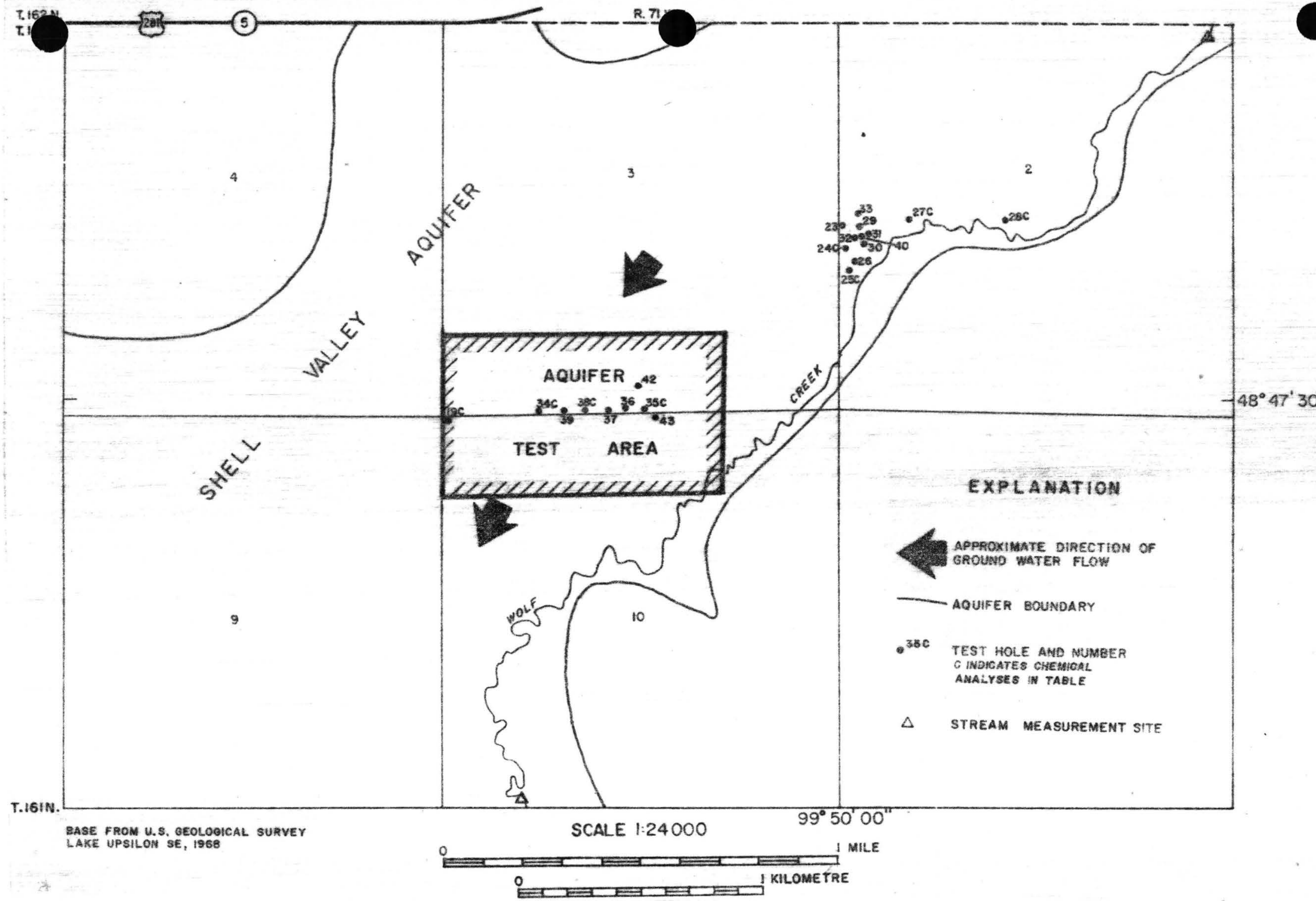

FIGURE 3.--Locations of test sites in the Shell Valley aquifer near Belcourt.

Discharge in Wolf Creek was measured in April 1974 at sites 161-071-02AAA and 161-071-10CCC (fig. 3). At that time 60 ft^3/s (2 m^3/s) was flowing through Wolf Creek in sec. 2, and only 35 ft^3/s (1 m^3/s) in sec. 10, 2 miles (3 km) downstream. The loss was attributed to infiltration to the Shell Valley aquifer. Late-fall observations indicated that springs and seeps discharged into Wolf Creek, but only in sufficient quantities to cause swampy areas adjacent to the stream. These data indicate there is a hydraulic connection between the Shell Valley aquifer and Wolf Creek and its tributaries. A dam constructed on Wolf Creek near the test site would make more of the streamflow available as recharge to the Shell Valley aquifer.

The Shell Valley aquifer contains approximately 5,000 acre-feet (0.006 km^3) of water in storage per square mile (2.6 km^2) of aquifer surface area. About 50 percent of this amount may be available to properly constructed wells.

Aquifer Tests

As part of this investigation, two aquifer tests were made during November and December 1974 in that part of the Shell Valley aquifer selected for development. The test well was installed at 161-071-03CDD4 (No. 41) using 8-inch (200-mm) steel casing, a 6-inch (150-mm) stainless steel No. 40-slot screen set from 28 to 38 feet (8 to 12 m) below land surface, and gravel packed. The well was equipped with a 6-inch (150-mm) turbine pump powered by an industrial engine using propane fuel. Water was discharged 800 feet (244 m) east of the well near Wolf Creek. The discharge was maintained constant within 2 percent by a valve at the pump, monitored by a cumulative inline flow meter, and measured by an orifice and a manometer at the point of discharge. The water discharged during the test did not infiltrate the ground and affect test results because freezing temperatures caused the water to pond and freeze on the surface near the point of discharge.

The first test was run for 27 hours at a pumping rate of 150 gal/min (9.5 l/s). Water samples were collected at the well for standard chemical analyses after 4, 12, and 24 hours of pumping and for trace-element analyses after 26 hours of pumping. This test was used to establish a maximum pumping rate and to calibrate the instrumentation.

The second test was run for 71 hours at a pumping rate of 120 gal/min (7.6 l/s). Water samples were collected for standard chemical analyses after 48 hours of pumping and for trace-element analyses after 71 hours.

Data from the aquifer test were analyzed using methods described by Ferris and others (1962); the results are summarized in table 2. The transmissivity of the aquifer in the vicinity of the test site ranges from 6,350 to 8,650 ft^2/d (721 m^2/d) and averages 7,760 ft^2/d (721 m^2/d). The storage coefficient ranges from 0.051 to 0.16, indicating water-table conditions that trend toward leaky artesian conditions in some parts of the aquifer (table 2).

The areal extent of the cone of depression and the amount of drawdown measured during the 71-hour test are shown in figure 4. Recharge boundaries, attributed to vertical drainage of upper materials in the aquifer, were detected in the early parts of the test. The effect of a confining boundary, probably the edge of the aquifer about 1,200 feet (365 m) east of the pumped well, was detected after 800 minutes of pumping. The water level in the test well recovered to the original level about 70 hours after the test.

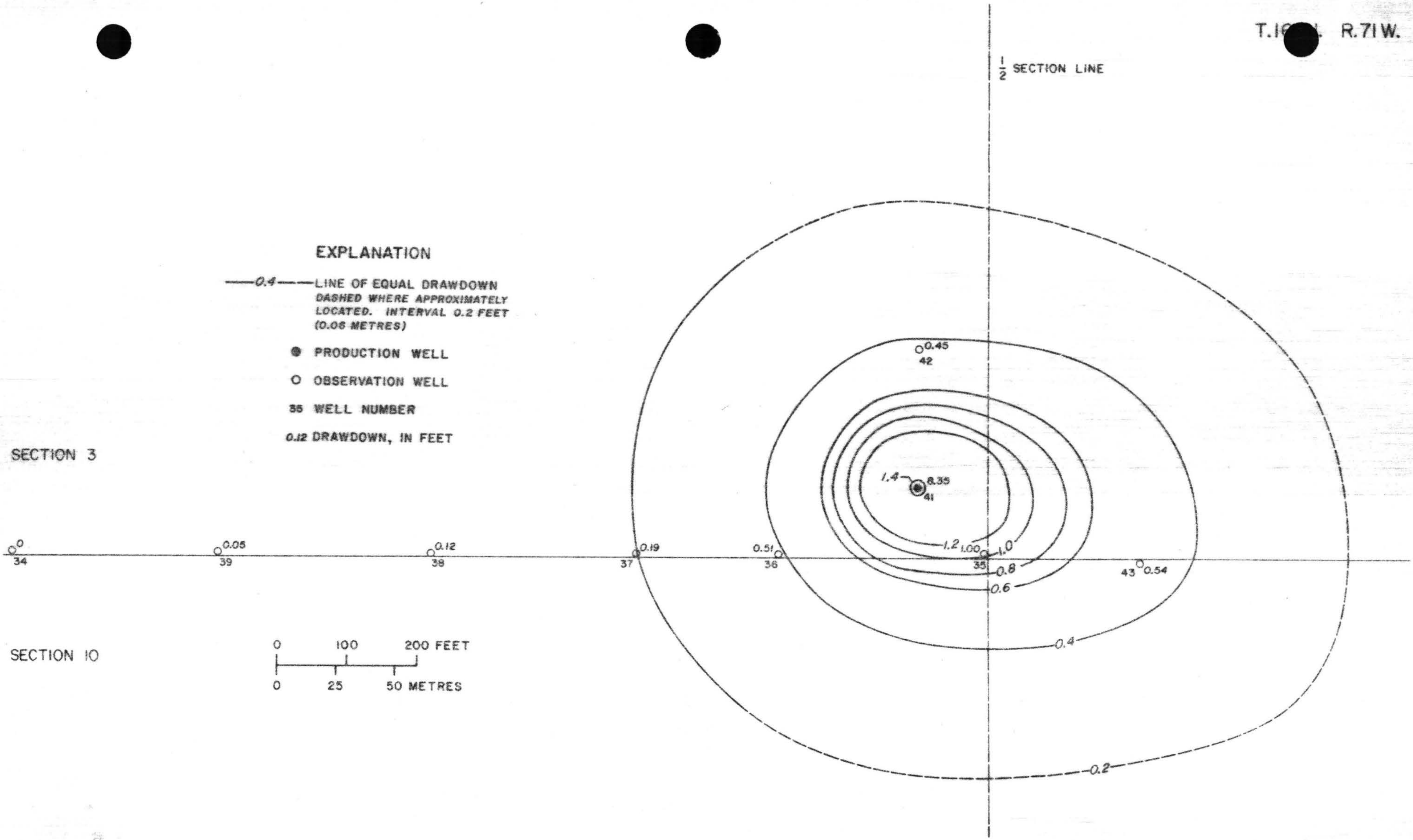

FIGURE 4.--Locations of wells used during aquifer tests and area of influence resulting from pumping 71 hours at 120 gallons per minute (7.6 litres per second).

Aquifer-test analyses indicate that maximum yields to adequately screened wells are about 125 gal/min (8 l/s) with a minimum spacing of 700 feet (213 m) between wells arranged in an east-west array across the aquifer in the proposed area for development (fig. 3). Present demands for the city of Belcourt could be met by pumping three wells in the vicinity of the test site.

WATER QUALITY

The chemical analyses of water samples collected from the Shell Valley aquifer during this phase of the study are listed in tables 3 and 4. The water in the Shell Valley aquifer is a calcium bicarbonate type. The dissolved-solids concentration ranges from 323 to 566 mg/l and averages 442 mg/l in 12 samples. A variation in concentration of dissolved solids of about 200 mg/l appears to be common in the Shell Valley aquifer.

As a means of judging the water quality in the Shell Valley aquifer, drinking water standards established for interstate carriers by the U.S. Public Health Service in 1946 and amended in 1962 are given as follow:

"Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumers. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

"The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the Reporting Agency and the Certifying Authority, other more suitable supplies are or can be made available.

Substance	Concentrations in mg/l
Alkyl Benzene Sulfonate (ABS	0.5
Arsenic (As)	0.01
Chloride (Cl)	250.
Copper (Cu)	1.
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	(See 5.23)
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate [1] (NO_3)	45.
Phenols	0.001
Sulfate (SO_4	250.
Total Dissolved Solids	500.
Zinc (Zn)	5.

[1] In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

"The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply:

Substance	*Concentration in mg/l*
Arsenic (As)	*0.05*
Barium (Ba)	*1.*
Cadmium (Cd)	*0.01*
Chromium (Hexavalent) (Cr^{+6})	*0.05*
Cyanide (CN)	*0.2*
Fluoride (F)	*(See 5.23)*
Lead (Pb)	*0.05*
Selenium (Se)	*0.01*
Silver (Ag)	*0.05*

"5.23 Fluoride.--When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit shown in the following table. Presence of fluoride in average concentrations greater than two times the optimum values listed shall constitute grounds for rejection of the supply.

"Where fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits listed below:

Annual average of maximum daily air temperatures[1]	*Recommended control limits--Fluoride concentrations in mg/l*		
	Lower	*Optimum*	*Upper*
50.0 - 53.7	*0.9*	*1.2*	*1.7*
53.8 - 58.3	*0.8*	*1.1*	*1.5*
58.4 - 63.8	*0.8*	*1.0*	*1.8*
63.9 - 70.6	*0.7*	*0.9*	*1.2*
70.7 - 79.2	*0.7*	*0.8*	*1.0*
79.3 - 90.5	*0.6*	*0.7*	*0.8*

[1] *Based on [Fahrenheit] temperature data obtained for a minimum of five years."*

Analyses of five water samples collected during the aquifer tests indicate a 40 to 50 percent decrease in dissolved manganese and iron and a slight decrease in chloride (table 3). These changes probably are due to well casing and artificial gravel pack used in constructing the test well.

DISCUSSION AND CONCLUSIONS

1. The Shell Valley aquifer consists of about 26 feet (8 m) of saturated sand and gravel deposits in the test area. The average transmissivity of the aquifer is 7,760 ft^2/d (721 m^2/d) and the storage coefficient ranges from 0.051 to 0.16. The ground-water gradient is about 3 ft/mi (0.6 m/km) toward the southwest. Static water levels range from 2 to 15 feet (0.6 to 5 m) below land surface datum with about 3 feet (1 m) of seasonal fluctuation. There is about 5,000 acre-feet (0.006 km^3) of water in storage per square mile of surface area of the aquifer, of which about 50 percent may be available to properly constructed wells.

2. Aquifer-test analyses indicate that the maximum individual well yield would be about 125 gal/min (8 l/s), and minimum spacing between wells arranged in an east-west array in the test area needs to be about 700 feet (213 m).

3. Test results indicate that present (1975) water demands for the city of Belcourt could be met by using three wells developed in the aquifer. Maximum well efficiency might be obtained by screening the wells from 28 to 40 feet (9 to 12 m) below land surface using 40-50-slot screen with a

gravel pack. Wells developed with compressed air or high-velocity jetting for a minimum of 12 hours would furnish maximum yield of sand-free water.

4. The potential for additional development could be evaluated by monitoring water levels, quantities pumped, and water quality at the well field.

5. Water from wells developed in the fine-grained formations in sec. 2, T. 161 N., R. 71 W., near the valley of Wolf Creek, contains considerably more dissolved iron and manganese than water from wells developed in coarse sediments in sec. 3, T. 161 N., R. 71 W.

6. The water from the Shell Valley aquifer in the proposed well-field area is a hard calcium bicarbonate type with a dissolved-solids concentration of about 500 mg/l. The quality of the water in the Shell Valley aquifer appears to be the best available in the area for municipal use.

7. Water-level and streamflow data suggest a hydraulic connection between Wolf Creek and the Shell Valley aquifer. If a suitable connection exists, the quality of the water in the aquifer is susceptible to change if the quality of the recharge water derived from Wolf Creek is changed.

8. A dam and lake on Wolf Creek near the well field in the Shell Valley aquifer could provide additional storage of water to recharge the aquifer if the total amount of ground water developed exceeds the rate of natural recharge.

SELECTED REFERENCES

Ferris, V. G., Knowles, D. B., Brown, R. J., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, 174 p.

Lohman, S. W., and others, 1972, Definitions of selected ground-water terms--revisions and conceptual refinements: U.S. Geol. Survey Water-Supply Paper 1988, 21 p.

Randich, P. G., 1974, Ground-water availability in the Belcourt area, Rolette County, North Dakota: U.S. Geol. Survey open-file report 75-104, 37 p.

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______1962, Public health drinking water standards: U.S. Public Health Service Pub. no. 956, 61 p.

TABLE 1.--Lithologic logs of wells and test holes in the Belcourt area

EXPLANATION

MP, measuring point   Lsd, land surface datum

161-071-02CBB1
Test hole 23
Altitude 1,762 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Gravel, fine to medium, sandy; silty in places-----------------	15	17
	Silt, medium-gray, sandy in places; some gravel streaks-------------	21	38
	Gravel, fine to medium-------------	1	39
	Clay, medium-gray, silty-----------	1	40

161-071-02CBB2
Test hole 24
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brown, sandy-------------	1	1
	Gravel, medium to coarse, sandy----	6	7
	Gravel, fine to coarse; about 25 percent coarse sand-------------	5	12
	Gravel, granule to medium, sandy---	15	27
	Sand, medium to coarse, gravelly, silty----------------------------	3	30
	Gravel, fine to coarse-------------	4	34
	Sand, medium, silty----------------	4	38
	Gravel, medium to coarse, sandy to silty----------------------------	6	44
	Till, olive-gray, silty------------	6	50

Installed 35 ft of 1¼-inch steel pipe and No. 12-slot screen 35-41 ft. MP 1.00 ft above lsd.

161-071-02CBC1
Test hole 25
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black, sandy--------------	2	2
	Gravel, fine to coarse; fine to coarse sand----------------------	5	7
	Gravel, medium to very coarse; fine to coarse sand------------------	8	15
	Gravel and cobbles, granule to very coarse, rounded-----------------	7	22
	Till, olive-gray, sandy------------	3	25

Installed 14 ft of 1¼-inch steel pipe and No. 12-slot screen 12-20 ft. MP 2.00 ft above lsd.

161-071-02CBC2
Test hole 26
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Gravel, fine to very coarse; fine to coarse sand------------------	21	23
	Sand, medium-gray, silty (no samples, all carried in the mud)-	15	38
	Gravel, fine; about 50 percent very fine to medium sand--------------	6	44
	Till, olive-gray, silty to sandy---	6	50

Installed 35 ft of 1¼-inch steel pipe and No. 12-slot screen 34-40 ft. MP 1.00 ft above lsd.

161-071-02BCD
Test hole 27
Altitude 1,768 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, fine to coarse, gravelly-----	6	8
	Gravel, fine to medium, sandy------	12	20
	Sand, very fine to medium, silty---	12	32
	Till, olive-gray, very sandy; interbedded with thin lenses of gravel----------------------------	8	40

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-02BDC
Test hole 28
Altitude 1,765 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel; cobbles--------------------	4	5
	Sand, fine to medium, silty to clayey----------------------------	5	10
	Sand, fine to coarse; interbedded with thin lenses of silty clay---	8	18
	Gravel, fine to medium, sandy------	4	22
	Sand, fine to coarse, silty--------	8	30
	Till, olive-gray, sandy------------	6	36
	Gravel, fine, sandy----------------	2	38
	Till, olive-gray, sandy------------	2	40

Installed 21 ft of 1¼-inch steel pipe and No. 12-slot screen 20-26 ft. MP 1.00 ft above lsd.

161-071-02CBB3
Test hole 29
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brown, sandy	1	1
	Gravel, fine to coarse, sandy	14	15
	Sand, medium, gravelly	2	17
	Gravel, fine to medium; interbedded with lenses of fine sand and silt	17	34
	Till, olive-gray, silty to sandy; very tight 38-40 ft	6	40

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26.5-32.5 ft. MP 1.50 ft above lsd.

161-071-02CBB4
Test hole 30
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy	1	1
	Gravel, fine to coarse, sandy lenses	11	12
	Sand, fine to coarse, gravelly	10	22
	Sand, fine to coarse; interbedded with lenses of silt	10	32
	Clay, olive-gray, sandy	4	36
	Sand, fine, gravelly	9	45
	Till, olive-gray, silty	5	50

Installed 35 ft of 1¼-inch steel pipe and No. 12-slot screen 33-39 ft. MP 2.00 ft above lsd.

161-071-02CBB5
Test hole 31
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel, fine to very coarse, sandy-	11	12
	Sand, fine to medium---------------	2	14
	Gravel, fine to very coarse; interbedded with lenses of very fine to coarse sand--------------	8	22
	Sand, medium; interbedded with lenses of silt and some gravel---	8	30
	Gravel, medium, sandy--------------	2	32
	Till, olive-gray, very sandy-------	3	35

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-02CBB6
Test hole 32
Altitude 1,759 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel, medium to coarse, sandy----	11	12
	Sand, medium; interbedded with lenses of silt-------------------	10	22
	Sand, medium, clayey---------------	8	30
	Sand, medium, silty----------------	3	33
	Till, olive-gray, silty------------	2	35

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-02BCC
Test hole 33
Altitude 1,770 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel, fine to coarse, sandy------	18	19
	Sand, medium; interbedded with lenses of silt------------------	11	30
	Sand, medium, gravelly-------------	6	36
	Till, olive-gray, sandy------------	2	38
	Sand, medium, gravelly, silty------	2	40

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-03CCD
Test hole 34
Altitude 1,749 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Gravel, fine to medium; about 25 percent fine to medium sand------	13	15
	Gravel, fine to medium; coarse sand----------------------------	23	38
	Clay, olive-gray, sandy to silty---	2	40

Installed 28 ft of 1¼-inch steel pipe and No. 12-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-03CDD1
Test hole 35
Altitude 1,754 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel, fine to medium; some very coarse lenses; interbedded with lenses of fine to very coarse sand----------------------------	18	19
	Sand, fine to coarse, gravelly, silty----------------------------	11	30
	Sand, fine to coarse, gravelly-----	8	38
	Gravel, fine; interbedded with very fine sand-----------------------	4	42
	Sand, very fine to medium, silty---	12	54
	Till, olive-gray, silty to sandy---	6	60

Installed 35 ft of 1¼-inch steel pipe and No. 12-slot screen 33-39 ft. MP 2.00 ft above lsd.

161-071-03CDD2
Test hole 36
Altitude 1,751 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Sand, fine to very coarse, gravelly	4	5
	Gravel, fine to medium; interbedded with fine to medium sand---------	11	16
	Sand, medium to very coarse, gravelly------------------------	14	30
	Sand, fine to very coarse; interbedded with lenses of fine gravel--------------------------	10	40

Installed 28 ft of 1¼-inch steel pipe and No. 18-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-03CDD3
Test hole 37
Altitude 1,750 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, medium to coarse, gravelly---	3	5
	Gravel, fine to coarse; inter-bedded with medium to very coarse sand------------------------------	20	25
	Sand, medium to very coarse, gravelly-------------------------	6	31
	Gravel, fine to coarse; interbedded with lenses of medium to very coarse sand---------------------	7	38
	Sand, very fine to medium, silty---	2	40

Installed 28 ft of 1¼-inch steel pipe and No. 18-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-03CDC1
Test hole 38
Altitude 1,750 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, medium to coarse, gravelly---	4	6
	Gravel, fine to coarse; interbedded with lenses of coarse sand-----	19	25
	Sand, medium to coarse; interbedded with lenses of medium to coarse sand----------------------------	10	35
	Sand, medium to coarse, gravelly---	2	37
	Gravel, fine to coarse; interbedded with lenses of medium to coarse sand----------------------------	2	39
	Sand, very fine to medium, silty---	1	40

Installed 28 ft of 1¼-inch steel pipe and No. 18-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-03CDC2
Test hole 39
Altitude 1,750 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, fine to coarse, gravelly-----	3	5
	Gravel, fine to coarse; interbedded with thin lenses of medium sand--	11	16
	Gravel, fine to medium; interbedded with lenses of medium to coarse sand-----------------------------	19	35
	Sand, medium to coarse, gravelly---	4	39
	Sand, very fine to medium, silty---	1	40

Installed 28 ft of 1¼-inch steel pipe and No. 18-slot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-02CBB7
Test hole 40
Altitude 1,760 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, fine to coarse, gravelly-----	4	6
	Gravel, fine to coarse, sandy------	5	11
	Sand, fine to very coarse; interbedded with lenses of silt-------	3	14
	Gravel, fine to coarse; interbedded with fine to coarse sand---------	6	20
	Sand, very fine to medium, very silty----------------------------	2	22
	Gravel, fine, sandy to silty-------	3	25
	Sand, fine to medium, gravelly-----	5	30
	Sand, fine to medium; interbedded with thin lenses of gravel and silt------------------------------	5	35

Installed 11 ft of 5-inch steel pipe and 4-inch diameter No. 18-slot screen 10-18 ft. MP 1.00 ft above lsd.

161-071-03CDD4
Test hole 41
Altitude 1,752 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Sand, medium to very coarse; fine to medium gravel-----------------	16	18
	Gravel, medium, well-rounded-------	7	25
	Gravel, fine to coarse; interbedded with some lenses of medium to coarse sand----------------------	13	38
	Sand, fine to medium---------------	4	42

Used two sacks of Revert during drilling. Backwashed, jetted screen, and developed with air. Installed 30 ft of 8-inch steel pipe and 6-inch diameter No. 40-slot stainless steel screen 28-38 ft. MP 2.00 ft above lsd.

161-071-03CDD5
Test hole 42
Altitude 1,751 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	2	2
	Gravel, fine to coarse; about 30 percent fine to coarse sand------	16	18
	Sand, fine to very coarse; about 25 percent fine to medium gravel----	7	25
	Gravel, fine to medium; interbedded with about 50 percent medium to very coarse sand-----------------	15	40

Installed 28 ft of 1¼-inch steel pipe and No. 12-alot screen 26-32 ft. MP 2.00 ft above lsd.

161-071-10ABB
Test hole 43
Altitude 1,753 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy-----	1	1
	Gravel, fine to medium; interbedded with lenses of medium to coarse sand-----------------------------	7	8
	Sand, medium to very coarse; about 30 percent fine to medium gravel-	17	25
	Gravel, fine to coarse, sandy------	7	32
	Sand, medium to very coarse; about 25 percent fine gravel-----------	8	40

Installed 28 ft of 1¼-inch steel pipe and No. 25-slot screen 26-32 ft. MP 2.00 ft above lsd.

TABLE 2.--Summary of aquifer-test results from pumping well 161-071-03CDD4 for 71 hours

Well location	Well number	Static water level below lsd		Distance and direction from pumped well		Transmissivity (T)		Hydraulic conductivity (K)		Storage coefficient ("S")
		(feet)	(metres)	(feet)	(metres)	(ft^2/d)	(m^2/d)	(ft/d)	(m/d)	
161-071-03CDD1	35	12.30	3.75	135 S	41	6,830	633	260	79	0.065
161-071-03CDD2	36	10.70	3.26	223 SW	68	6,350	590	240	74	.16
161-071-03CDD4	41	10.37	3.16	0	0	7,870	730	300	92	--
161-071-03CDD5	42	9.62	2.93	330 SE	101	7,680	712	290	89	.051
161-071-10ABB	43	11.24	3.43	200 N	61	8,650	895	370	113	.14
Distance drawdown	all	--	--	--	--	7,200	668	280	86	--

TABLE 3.--Chemical analyses of ground water from the Shell valley aquifer

Well location	Well number	Depth of well (ft)	Date of sample	Pumping time (hrs)/ rate (gal/min)	Dis-solved silica (SiO_2) (mg/l)	Dis-solved iron (Fe) (µg/l)	Dis-solved man-ganese (Mn) (µg/l)	Dis-solved cal-cium (Ca) (mg/l)	Dis-solved magne-sium (Mg) (mg/l)	Dis-solved sodium (Na) (mg/l)	Dis-solved potas-sium (K) (mg/l)	Bicar-bonate (HCO_3) (mg/l)	Phos-phate ortho dis-solved as (P) (mg/l)	Phos-phate dis-solved ortho (PO_4) (mg/l)	Phos-phorus dis-solved as (P) (mg/l)	Total alka-linity (as $CaCO_3$) (mg/l)	Dis-solved sulfate (SO_4) (mg/l)	Dis-solved chlo-ride (Cl) (mg/l)	Dis-solved fluoride (F) (mg/l)	Dis-solved nitrate (N) (mg/l)	Dis-solved boron (B) (µg/l)	Dis-solved solids (resi-due at 180°C) (mg/l)	Hard-ness (Ca,Mg) (mg/l)	Non-car-bonate hard-ness (mg/l)	Per-cent sodium	Sodium ad-sorp-tion ratio	Specific conduct-ance (µmhos/cm 25°C)	pH (units)	Temper-ature (°C)
161-071-02BCD	27	32	11-06-74	8/6	25	80	590	100	27	23	7.1	327	0.04	0.12	0.05	268	140	4.4	0.1	0.00	110	506	360	93	12	0.5	749	8.1	5.0
161-071-02BDC	28	26	11-06-74	8/3	24	320	520	92	28	14	5.2	321	.03	.09	.04	263	110	3.1	.1	.03	50	447	350	82	8	.3	673	8.0	5.0
161-071-02CBB2	24	41	11-06-74	12/2	24	60	370	98	35	23	5.1	331	.02	.06	.01	271	160	5.3	.1	.03	80	523	390	120	11	.5	780	8.2	5.0
161-071-02CBC1	25	20	11-13-74	12/5	24	20	140	91	48	23	4.1	363	.01	.03	.01	298	170	5.1	.2	1.5	90	566	420	130	10	.5	847	8.0	5.0
161-071-03CCD	34	32	11-05-74	12/5	25	10	20	73	57	14	4.8	360	.05	.15	.01	295	140	4.7	.2	3.3	70	532	420	120	7	.3	808	8.1	5.0
161-071-03CDC1	38	32	11-05-74	10/5	25	10	10	83	50	17	4.9	356	.04	.12	.01	292	150	5.1	.2	2.8	90	529	410	120	8	.4	802	8.1	5.0
161-071-03CDD1	35	39	11-05-74	10/5	22	20	90	78	33	7.5	3.1	249	.05	.15	.03	204	130	4.9	.1	2.9	40	438	330	130	5	.2	649	8.0	5.0
161-071-03CDD4	41	38	11-21-74	4/150	23	20	50	66	27	12	3.3	258	.03	.09	.03	212	83	3.3	.1	3.5	60	364	280	64	9	.3	576	7.8	5.0
161-071-03CDD4	41	38	11-21-74	12/150	23	30	40	65	29	13	3.6	258	.02	.06	.02	212	83	3.4	.1	3.5	50	365	280	70	9	.3	576	7.7	5.0
161-071-03CDD4	41	38	11-22-74	24/120	15	60	60	68	27	15	3.9	260	--	--	--	--	85	2.9	.4	.4	0	352	280	67	10	.4	580	7.8	5.0
161-071-03CDD4	41	38	11-25-74	50/120	23	10	40	65	29	13	3.5	259	.02	.06	.01	212	80	2.3	.1	3.0	50	323	280	69	9	.3	578	7.7	5.0
161-071-03CDD4	41	38	11-27-74	71/120	23	10	30	66	29	13	3.4	260	--	--	.05	213	83	2.3	.1	3.4	80	362	280	71	9	.3	583	7.7	5.0

TABLE 4.--Chemical analyses of water for minor elements

from test well 161-071-03CDD4

(Dissolved mineral constituents are in micrograms per litre ($\mu g/l$) except as indicated)

Constituent	(1) Nov. 11, 1974 after pumping 26 hours at 150 gal/min	(2) Nov. 27, 1974 after pumping 71 hours at 120 gal/min
Aluminum (Al)	10	10
Arsenic (As)	1	2
Barium (Ba)	<100	<100
Beryllium (Be)	<10	<10
Cadmium (Cd)	0	0
Chromium (Cr)	<10	<10
Cobalt (Co)	0	0
Copper (Cu)	2	2
Cyanide (CN) (mg/l)	.00	.00
Lead (Pb)	3	1
Lithium (Li)	30	30
Mercury (Hg)	<.1	<.1
Molybdenum (Mo)	3	2
Nickel (Ni)	0	2
Selenium (Se)	0	1
Silver (Ag)	<1	<1
Strontium (Sr)	260	260
Vanadium (V)	2.2	1.8
Zinc (Zn)	30	30