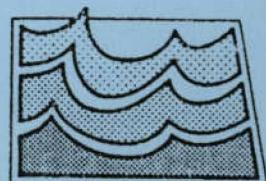

**A WATER SUPPLY INVESTIGATION
FOR THE CITY OF FORTUNA
DIVIDE COUNTY, NORTH DAKOTA**

by

Alan Wanek

North Dakota Ground-Water Studies
Number 108
North Dakota State Water Commission
Dale L. Frink, State Engineer

Prepared by the
North Dakota State Water Commission
In cooperation with the
City of Fortuna



ND State Water Commission

2001

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INTRODUCTION

Statement of the Problem

In 1997 the City of Fortuna's municipal water supply well could no longer produce enough water to meet the city's needs. A replacement well was installed in August 1997 but that too was unable to meet the city's needs. Additional test drilling by a water well contractor did not locate a suitable aquifer zone for installing a municipal well. During 1998 much of Fortuna's municipal water was hauled from a private well north of the city.

In a letter to Governor Schafer dated January 31, 1998, Paul Bauer, Executive Director of the Tri-County Economic Development Association, discussed the City of Fortuna's water supply problem and their request for Community Development Block Grant assistance in finding an alternative water supply. The North Dakota State Water Commission is cited in the letter as a technical source for identifying an alternative municipal water supply.

In an April 28, 1998 letter Milton O. Lindvig, Director of the Water Appropriations Division of the North Dakota State Water Commission, submitted a proposal and work plan for a ground-water investigation to Paul Bauer, Director of the Tri-County Regional Development Council and to Kenneth Hagen, Mayor of Fortuna. The proposal called for exploratory drilling and aquifer analysis in the vicinity of the city well field, 3/4 mile south of Fortuna.

Study Areas

The city's well field is located south of Fortuna, in northwestern Divide County, as shown in figure 1. The population of Fortuna declined from 53 at the time of the 1990 census, declined to about 30 in 1998 and 24 in 2001, limiting the resources available for developing a municipal water supply. The City requires a water supply to be in the vicinity of their in-place water storage tank and pipeline in

the southwest quarter of Section 35, Township 163 North, Range 101 West. The study area was therefore limited, for the most part, to within or near the perimeter of the southwest quarter of Section 35 (figure 2). Two test holes were drilled one half mile farther east and one test hole was drilled north of Fortuna.

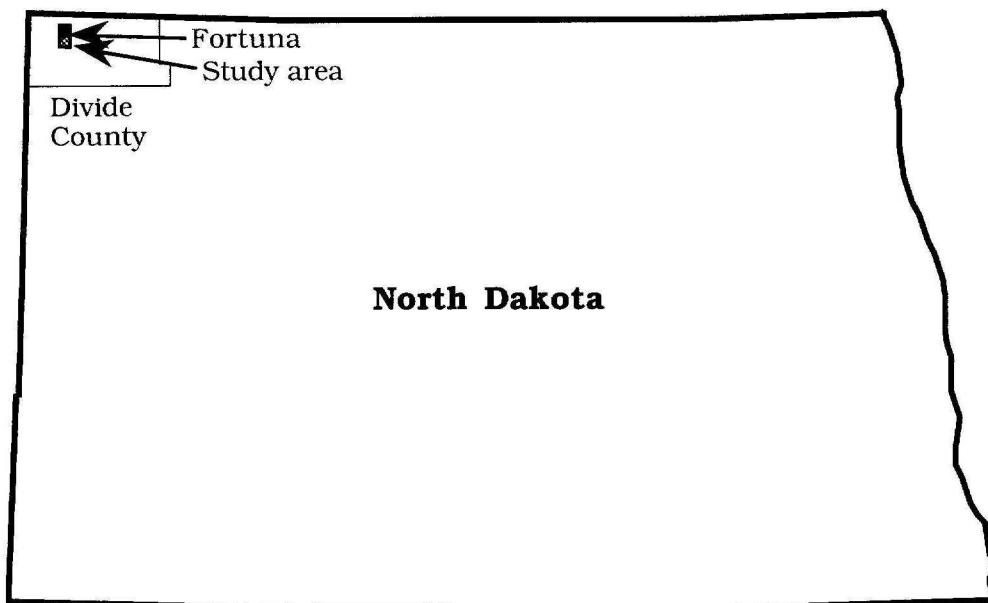


Figure 1 - Location of the study area

Previous Investigations

Two publications of a geologic nature include the study area. "The Cenozoic History of Northeastern Montana and Northwestern North Dakota with Emphasis on the Pleistocene" by Arthur David Howard was published in 1960 as United States Geological Survey Professional Paper 326. "Geology and Ground Water Resources of Divide County, North Dakota" is North Dakota State Water Commission County Ground Water Studies Bulletin 6. Part one of Bulletin 6, covering geology and written by Dan E. Hansen, was published in 1967. Part two of Bulletin 6, covering basic ground water data and written by C. A. Armstrong, was published in 1965. Part three of Bulletin 6, covering ground water resources and written by C. A. Armstrong, was published in 1967.

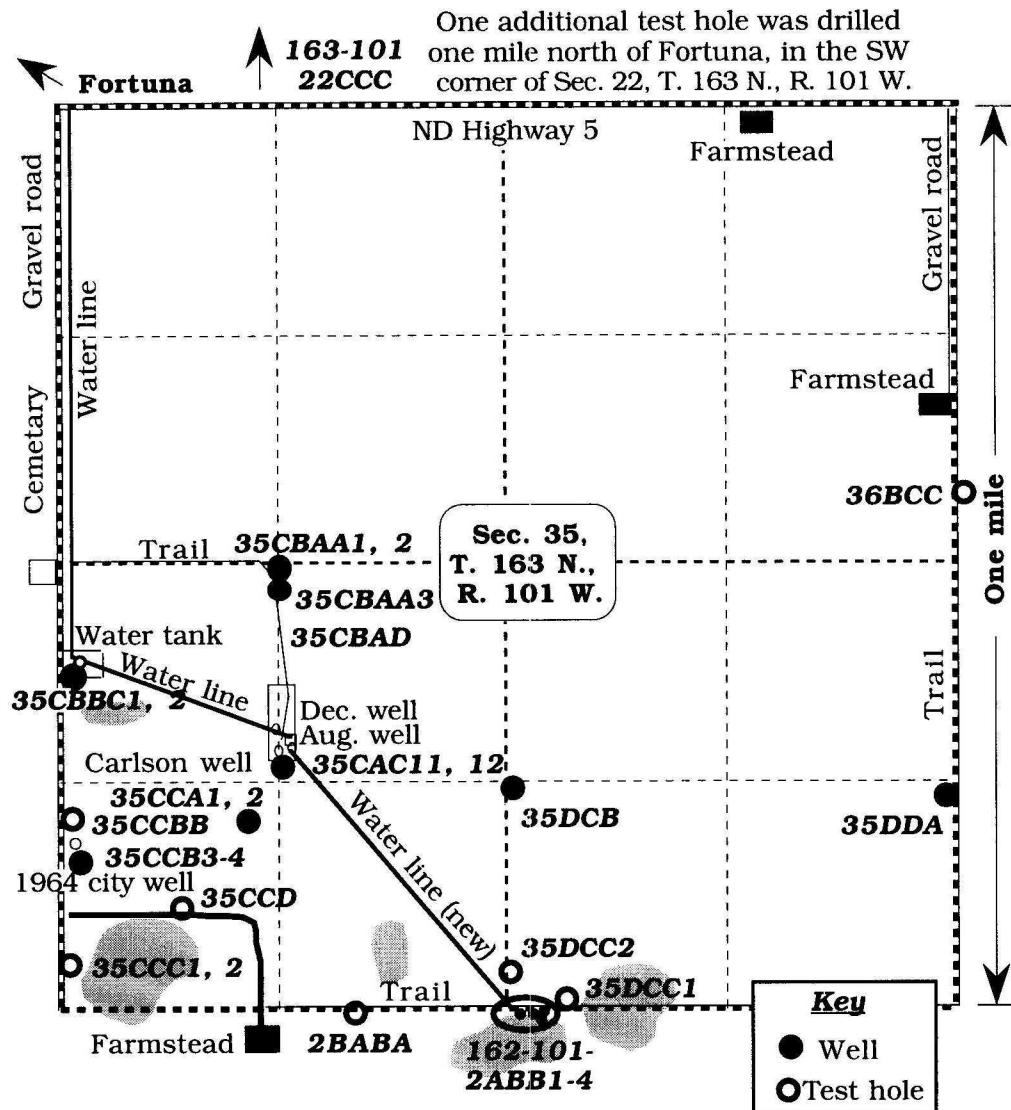


Figure 2 – 1998 test hole and monitoring well locations

Fortuna Municipal Water Source

The city of Fortuna in the past has used wells completed at depths of about 20 and 100 feet for its municipal water supply in the southwest quarter of Section 35. More recently a well screened at about 235 feet depth, called the 'Carlson' well, has supplied the city's water needs.

In 1997 the City of Fortuna contracted with a Williston based firm, Agri Industries, Inc., to develop an alternative municipal water supply. A well was completed by Agri Industries in August 1997, screened between 240 and 255 feet depth in medium sand. The 'August' well is located within 100 feet of the 'Carlson' well, which was plugged.

The static water level in the August 1997 well was more than 200 feet below land surface, at least 150 feet lower than expected, based on area ground water levels. The 'August' well, because of the low water level, proved to be insufficient to meet the city's water requirements of about 3,000 to 4,000 gallons per day

In November and December 1997 Agri Industries undertook additional test drilling, well installation and pumping. The exploratory work was in the southwest quarter of Section 35, near the center and northwest corner of the quarter section. Zones of sand or gravel penetrated in the exploratory work did not prove to be prospective for developing a municipal water source.

Fortuna Reported Municipal Water Use

The City of Fortuna reports its water use under permit #858. The municipal water permit was granted on July 18, 1960 and perfected on April 6, 1970. The permit authorizes 25 acre-feet of water per year at a maximum pumping rate of 35 gallons per minute. The authorized point of diversion is the NE1/4 SW1/4 Section 35, Township 163 North, Range 101 West, a 40-acre parcel of land 3/4-mile southeast of Fortuna. The permit was amended on April 20, 1999 adding the NW1/4 NE1/4 Section 2, Township 162 North, Range 101 West as a point of diversion. Water use under the permit has been reported as shown in figure 3.

The City of Fortuna has been reporting using about six acre-feet of water per year during the past 21 years. The reported annual use has declined slightly over time, reflecting a decline in the population served. The comparatively low amount of reported water use in 1989-1991 (about 2 or less acre-feet per year) might be a reporting error. The 11.2 acre-feet of water use reported in 1977 may also be a

reporting error. The 2.8 acre-feet (898,300 gallons) reported in 2000 equates to an average of 98 gallons per day per person, using a population of 25 as listed in the 2000 water use report.

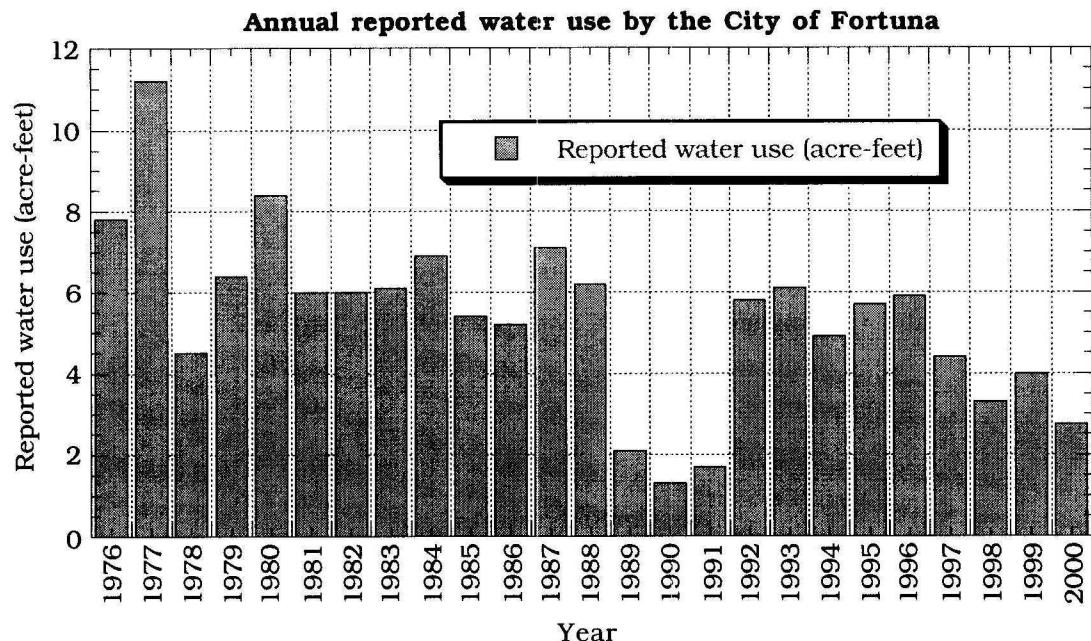


Figure 3 - Reported municipal water use by the City of Fortuna

Field Methods

Between June 15 and July 21, 1998, State Water Commission personnel, using a forward, mud-rotary rig, drilled twenty-seven test holes in the Fortuna area, totaling 5,377 feet. The deepest test hole extended to 300 feet. Underlying sediments were not explored because of expected poorer water quality, slower recharge to sand lenses, and higher costs of well completion.

Twelve monitoring wells were installed using two-inch diameter, polyvinyl chloride (PVC) casing and five feet of PVC screen per well. The monitoring wells were developed by collapsing formation sand and gravel against the screen. The annular space between the casing and the wall of the drilled hole was filled with

granular bentonite or high-density bentonite slurry. Test holes in which monitoring wells were not installed were plugged with high-density bentonite slurry and/or granular bentonite. Water levels in wells were measured using a chalked steel or electric tape. Lithologic descriptions of sediments encountered in the test holes and monitoring well completion details are included in an appendix at the end of the report. Six of the twelve monitoring wells were determined to be unnecessary for monitoring purposes and were plugged on May 31, 2000.

Water samples were collected from the monitoring wells to determine the quality of the water. The samples were analyzed for common ions. The North Dakota State Water Commission Laboratory performed the analyses.

Acknowledgments

The author wishes to thank those who helped in the siting and development of a water supply for the City of Fortuna. Paul Bauer and Mark Sovig with the Tri-County Economic Development Association assisted in funding for the project. The Leonard Biberdorf Trust allowed access, drilling, and well installation on its land. From the North Dakota State Water Commission Gary Calheim and Brian Hlibichuk drilled the test holes and installed the monitoring wells; Steve Pusc supervised test drilling; Merlin Skaley and Kelvin Kunz pumped and sampled the monitoring wells; Kelvin Kunz organized and assisted in the aquifer test; Albert Lachenmeier plugged six no longer needed monitoring wells; Garvin Muri and M. E. Osborn analyzed the chemical composition of the water samples; and Milton Lindvig oversaw the project. Agri Industries, Inc., Williston, ND (Mike Ames, President, Leo Grossman, driller) supplied information from their earlier exploration for a city water source, supplied a pump and generator for the aquifer test, and installed the municipal well. Special thanks go to Gary Rust, Water Works Superintendent for the City of Fortuna who oversaw the project for the city, provided historic information about the municipal well field, assisted in the test pumping, and has monitored water levels in the wells on a monthly basis.

Location-Numbering System

Well and test hole locations are described using a number and letter designation based upon the federal system of rectangular surveys of public land, the township and range system, shown in figure 4.

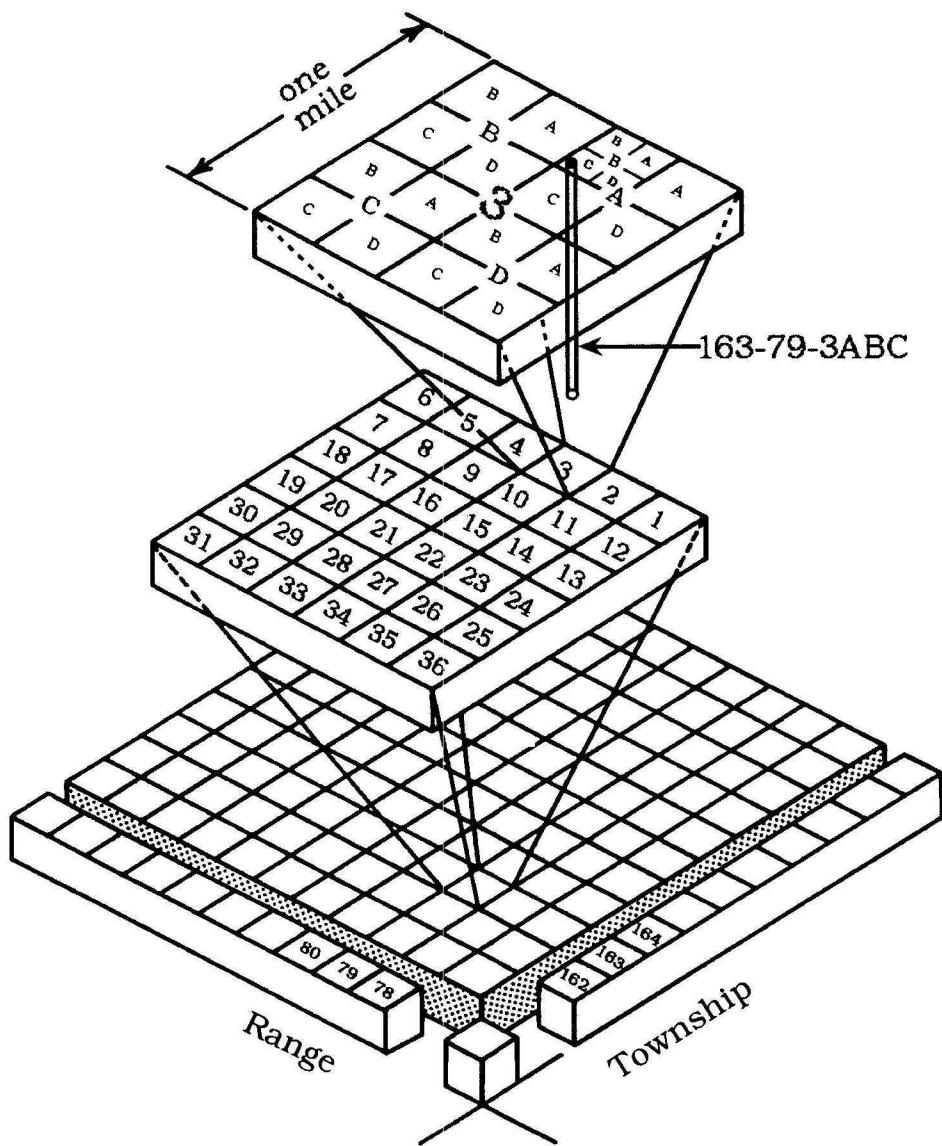


Figure 4 - Location-numbering system

In the example designation in figure 4, 163-79-3ABC, the first number, 163, is the township north of a base line, the second number, 79, is the range west of the fifth principal meridian, and the third number, 3, is the section in which the well is located. The first letter in the example, A, is the quarter section, the second letter, B, is the quarter-quarter section, and the third letter, C, is the quarter-quarter-quarter section (10 acre tract) in which the well is located. The letter "A" designates the northeast subdivision, the letter "B" the northwest subdivision, the letter "C" the southwest subdivision, and the letter "D" the southeast subdivision.

SITE SELECTION FOR A MUNICIPAL WELL

Hydrogeology of the Fortuna Well Field Area

The Fortuna well field is located in an area of rolling hills on the Missouri Coteau. Surface drainage is poorly integrated and sloughs are common. The well field is underlain by glacial ground moraine, primarily glacial till.

A temporary, interglacial diversion of the Missouri River eroded a northeast trending channel passing south of present day Fortuna. During a later glacial ice advance a leading lobe of ice, approximately centered over the valley left by the temporary river channel, extended southwest through the Fortuna area. Stagnation and melting back of the glacial lobe deposited the near surface sediments and created the landforms now covering northwestern Divide County, as shown in figure 5.

The Alkabo end moraine and the Skjermo Lake aquifer were formed during a temporary stagnation in the melting of glacial ice. Continued melting of the glacial lobe deposited the ground moraine found in the vicinity of the Fortuna well field in the southwest quarter of Section 35. Lenses of sand or sand and gravel, usually having little aerial extent and surrounded by glacial till, are common in the glacial drift in the vicinity of the Fortuna well field. The till is a mixture of clay, silt, sand, and gravel, extending to 638 feet depth in a 1963 test hole located one half mile south of Fortuna.

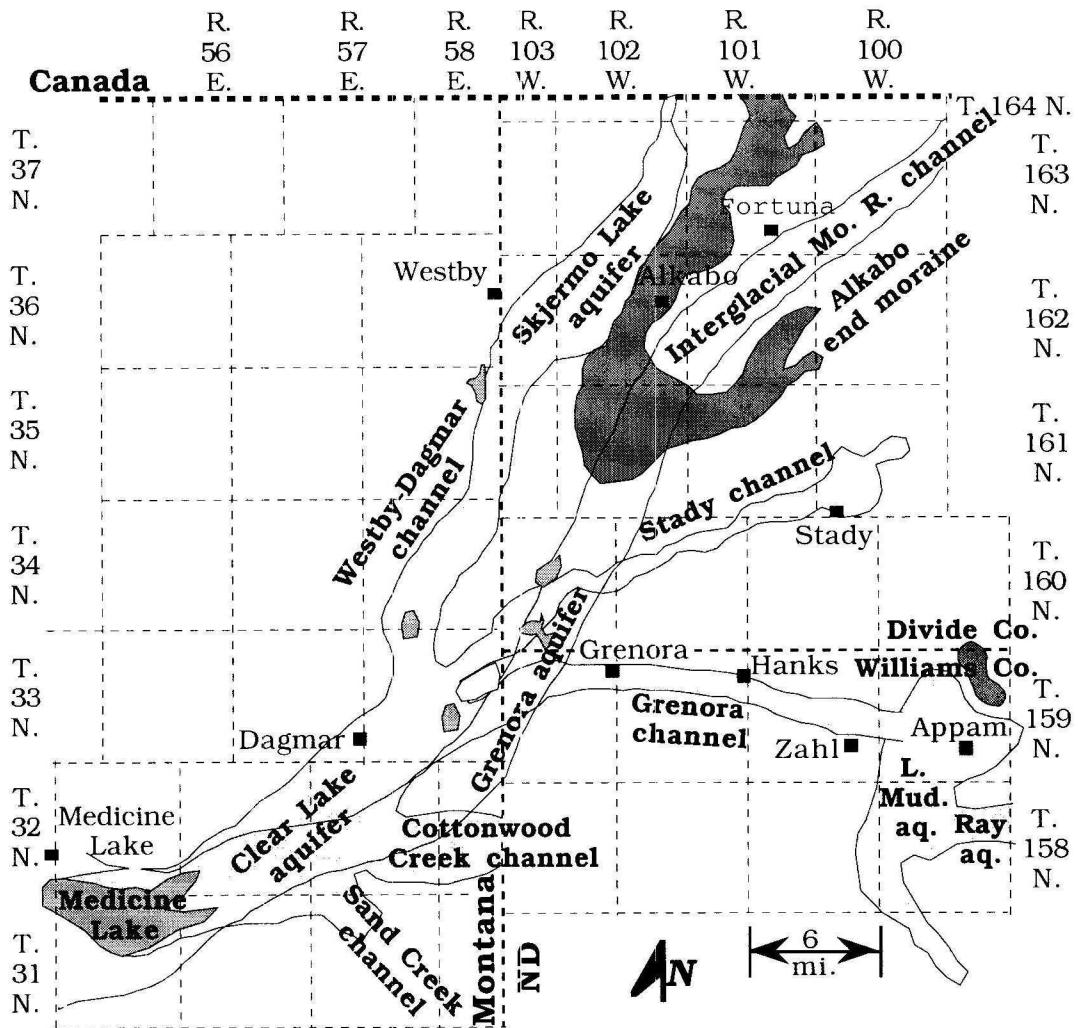


Figure 5 – Landforms deposited by the Medicine Lake Lobe

Fortuna's municipal wells have tapped into sand lenses surrounded by glacial till. The low water level encountered in the 'August' well, in the vicinity of the 'Carlson' well suggests that over the years pumping from the sand lenses has exceeded the movement of water from the surrounding glacial till into the sand lenses. The limited size of the sand lenses and slow water movement through the surrounding glacial till is thought to be the cause of declining water levels in the municipal wells.

Test drilling conducted by personnel of the North Dakota State Water Commission in 1998, like earlier exploration, encountered sandy glacial till with lenses of sand and gravel. Sediments penetrated in test holes in or near the south half of Section 35 are shown in figure 6.

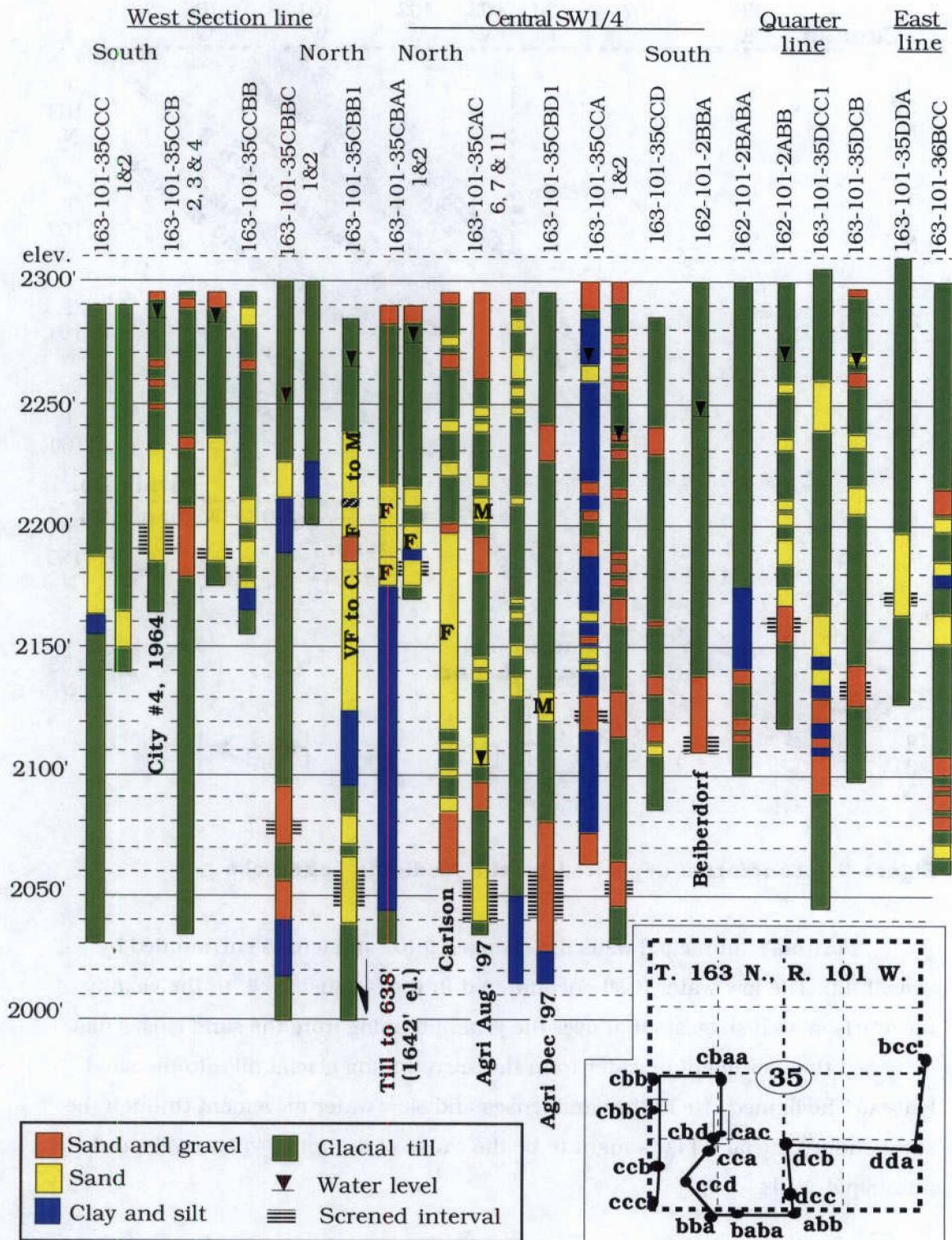


Figure 6 – Sediments penetrated in or near the south half Sec. 35

While sand lenses in the till are common, test holes drilled within a few hundred feet of other test holes frequently encountered sand lenses at different depths. At two of the 1998 drilling locations a second test hole, drilled about 15 feet from the first test hole to install a well in a shallower sand zone, did not encounter enough of the shallow sand to merit installing a well. Developmental pumping of the monitoring wells caused, in some cases, a rapid water level decline followed by slow recovery, suggesting that those wells are completed in zones of very limited aerial extent or low permeability.

Sediments encountered during the 1998 test drilling within a few hundred feet of the city well field and to the north and west did not suggest a suitable location in which to recommend installing a municipal well. Two more distant test holes, along the east section line of Section 35 and a test hole one mile north of Fortuna, also did not encounter an aquifer suitable for installing a municipal well.

Location Near a 1964 City Well

During the 1998 test drilling a possible location for a municipal wall was encountered about 1,500 feet southwest of the city well field, along the west side of Section 35. The location is near a municipal well installed in 1964 and used for only a short period of time.

Test hole 163-101-35CCB3, near the city well, penetrated sand and gravel, overlain by glacial till, between 88-115 feet depth. A two-inch diameter well, 163-101-35CCB4, was installed at the location. The well was pumped intermittently, at approximately the city's water use rate (3,400 gallons/day) for three weeks, causing an 8.2 feet water level decline. In the following week the water level recovered only 0.4 feet, then declined 1.8 feet during another week of pumping. In one month following the pumping the water level in the well recovered 1.7 feet, for a net decline of about 8 feet. A hydrograph of the water level in well 163-101-35CCB4 during and one month following the pumping is shown in figure 7. The water level in well 35CCB4 continued to steadily recover during the next two years, rising 14 feet, to a

Location Near the Northwest Corner of NE1/4 Section 2

A possible location for a water supply was encountered about 2,200 feet southeast of the city well field, near the south end of the north-south quarter line in Section 35 quarter line. Test drilling at the location encountered glacial till between land surface and about 122 feet depth. The till is underlain by sand or gravel extending to between 150 and 170 feet depth, with some interbedded clay lenses. The sand and gravel is underlain by more glacial till.

To measure the water level response to pumping a five-inch diameter well, screened between 128-148 feet depth, and four monitoring wells were installed. Monitoring wells are located 7, 58, 171, and 1322 feet from the five-inch well, as shown in figure 8. Sediments penetrated during test drilling in the area are shown on a cross section, figure 9.

The similarity of sediments penetrated the 120-180 feet depth interval in test holes one-quarter mile to the north and west of the five-inch well suggests the zone has some lateral extent. One quarter mile to the north sand and was encountered between 154-169 feet, underlain by 21 feet of interbedded till and gravel. Eleven hundred feet west of the five-inch well silt with three 2 to 7 feet sand and gravel lenses was encountered in the interval. Eighteen hundred feet northwest of the five-inch well a well was screened in sand and gravel encountered between 168-185 feet. Water levels in the 1,800 feet distant well fluctuate similar to levels in wells near the test location.

Aquifer Test

An aquifer test was conducted in August 1998, pumping water from the five-inch well installed in the northwest corner of NE1/4 Sec. 2, T. 162 N., R 101 W. A one horsepower submersible pump produced water at 11.75 gallons per minute for 40 hours. Water levels were measured in the pumped well and in four monitoring wells.

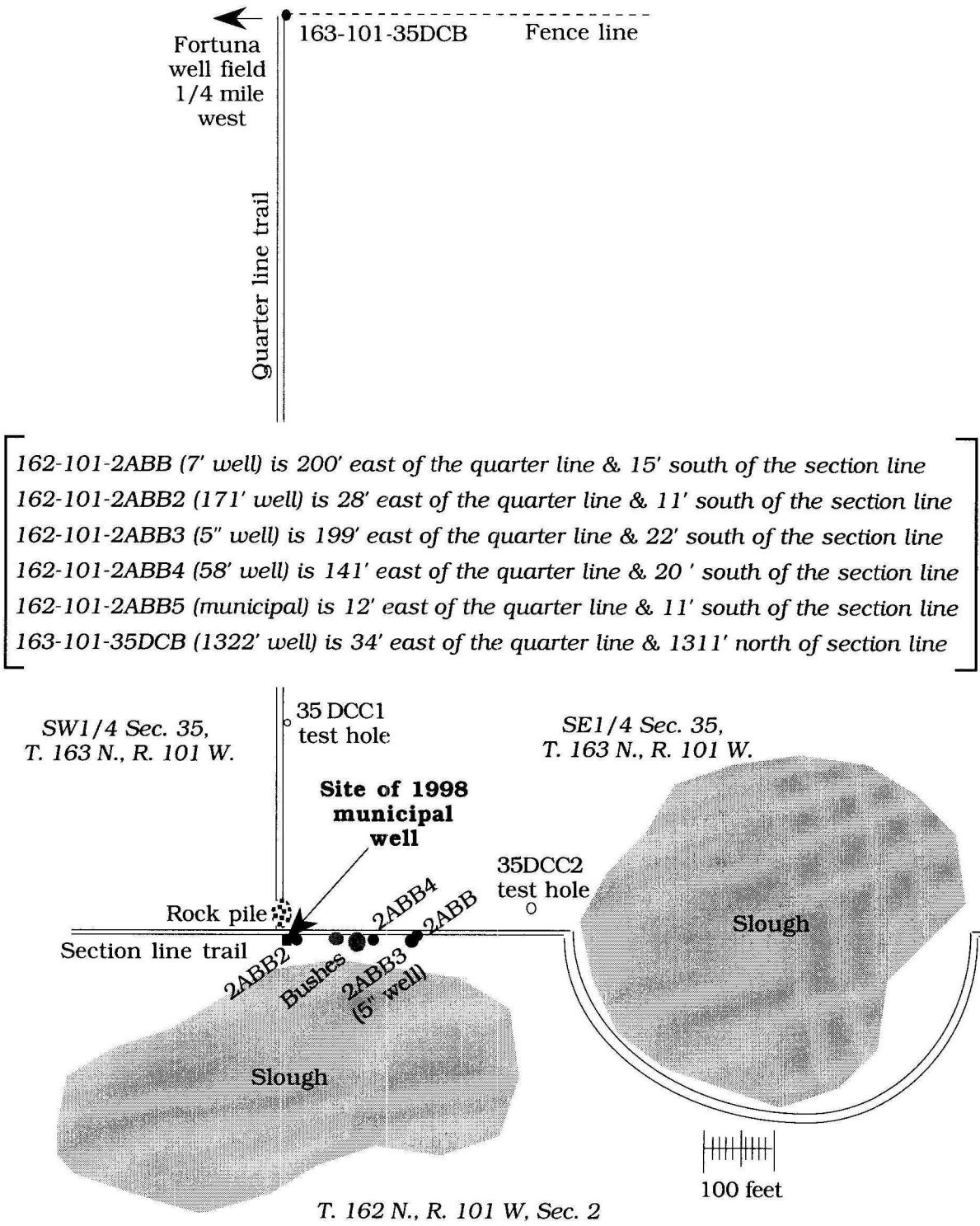


Figure 8 – Test holes and wells near the 1998 municipal well

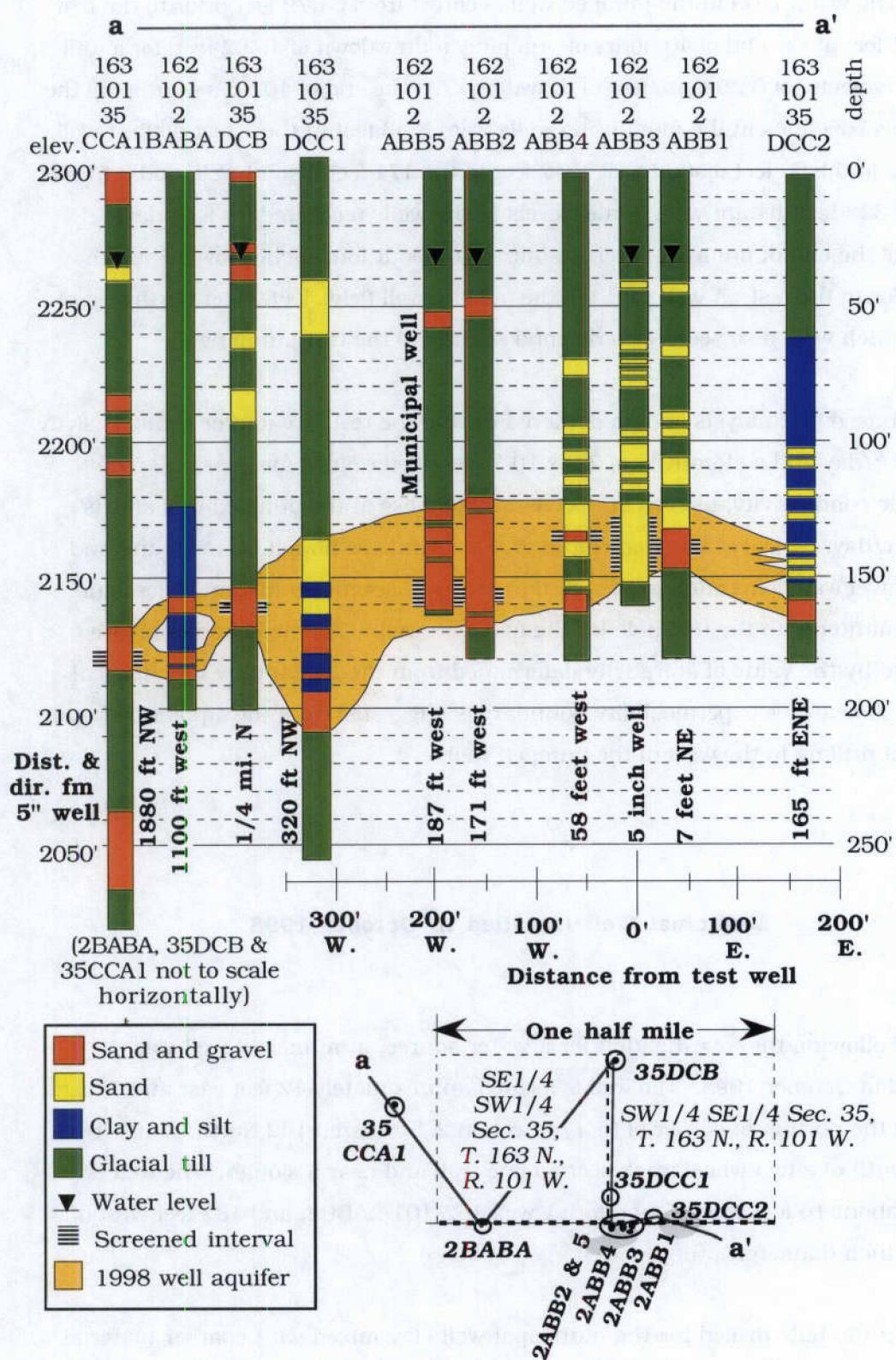


Figure 9 – Cross-section near the 1998 municipal well

The water level in the pumped well declined from 34.79 feet prior to the test to 81.71 feet at the end of 40 hours of pumping, a drawdown of 46.92 feet, for a well specific capacity of 0.25 gpm/foot of drawdown. At the end of 40 hours pumping the water level declines in the monitoring wells were 8.33 feet in the 7 feet distant well, 3.33 feet in the 58 feet distant well, 2.12 feet in the 171 feet distant well, and 0.57 feet in the 1,322 feet distant well. Water levels in the wells recovered for four days following the end of pumping, then stabilized at about four inches lower than the level prior to the test. A well south of the old city well field, 1,880 feet northwest of the five-inch well, also seemed to respond slightly to the test pumping.

Based on analysis of data gathered during the test, an aquifer transmissivity of $466 \text{ ft}^2/\text{day}$ and a storativity of 2.2×10^{-4} were determined for the sand. The hydraulic conductivity, using a 29 feet sand thickness at the pumped well site, is 16.1 feet/day, typical of fine to medium grained sand. Although coarser sand and some gravel was penetrated in the original test hole seven feet distant, finer sand was encountered in the test hole for the five-inch well. Confined conditions are indicated by the value of storativity determined from the test and by the physical setting. A nearby low permeability boundary is suggested from the aquifer test and from test drilling to the west of the pumped well.

Municipal Well Installed in October 1998

Following the investigation for a water source, a municipal well was installed in October 1998. The well is located approximately 12 feet east and 11 feet south of the northwest corner of NE1/4 Section 2, Township 162 North, Range 101 West, south of a two-wheel track section line trail and near a slough. The well is located about 16 feet west of monitoring well 162-101-2ABB2, and 187 feet west of the five-inch diameter, pumped well.

In the hole drilled for the municipal well clay mixed with coarser material (glacial till) was penetrated between land surface and 126 feet, with a sand and gravel lens between 52-57 feet. Till is underlain by medium sand and gravel between 126 and 162 feet, with clay lenses at 129-132, 137 and 142 feet. A representation of

the well is included on the cross section in figure 9. The log of the well is included in the appendix as 162-101-2ABB5.

The municipal well was completed on October 20, 1998. Five-inch diameter, 18-slot stainless steel screen was set between 151-161 feet and sand packed with #10-20 sand. Five-inch diameter, SDR 21, PVC casing was set to 151 feet depth. The annular space around the well casing was filled with high solids bentonite grout between land surface and 120 feet. A water level 36 feet below land surface was reported, consistent with the levels in nearby monitoring wells.

WATER QUALITY

Water samples were collected and analyzed from 13 monitoring wells in the Fortuna well field area. A sample was also collected from a farmstead south of the old well field. Samples obtained during the study were collected in polyethylene bottles and analyzed at the North Dakota State Water Commission Laboratory in Bismarck. Analyses are also available for samples from monitoring well 163-101-35CBB, installed in 1963 and later destroyed, from the 'Carlson', 'August', and 'December' wells in the old municipal well field, and from the 1998 municipal well.

Properties and Characteristics of Water

The physical properties and mineral constituents that affect the water's suitability for human consumption and for irrigation purposes are determined. Dissolved mineral constituents in water are usually reported in milligrams per liter (mg/l) or micrograms per liter ($\mu\text{g/l}$). A milligram per liter is one-thousandth (0.001) of a gram of dissolved material per liter of solution. At low concentrations one milligram per liter is similar to one part per million. A microgram per liter is one-thousandth of a milligram per liter or one-millionth (0.000001) of a gram of dissolved material per liter of solution. At low concentrations one microgram per

liter is similar to one part per billion. Milligrams per liter can be converted to grains per gallon by dividing milligrams per liter by 17.12 (Hem, 1970, p.81).

The analyses include determinations of specific conductance, pH, temperature, hardness, sodium-adsorption ratio, residual sodium carbonate, percent sodium; dissolved mineral concentrations of magnesium, potassium, sodium, iron, manganese, fluoride, bicarbonate, carbonate, sulfate, chloride, nitrate; and the total dissolved solids concentration.

Specific conductance, reported in micromhos per centimeter at 25° Celsius, is a measure of the ability of water to conduct an electric current. At low concentrations the dissolved solids concentration of a sample in milligrams per liter is about 65-70% of the specific conductance (in micromohs); however, this relation is not constant and will vary with the chemical composition of the water (Hem, 1970).

Hydrogen-ion concentration, (pH), is a measure of the solvent capacity of water. The hydrogen-ion concentration affects the corrosiveness of water. A pH of 7.0 indicates the water is neutral, neither acidic nor basic. Readings progressively lower than 7.0 denote increasing acidity, and those progressively higher than 7.0 denote increasing alkalinity.

Temperature of water will influence the concentration of dissolved gases and mineral matter. Water temperatures given in the tables were measured at the time of sample collection and are expressed in degrees Celsius (Centigrade). Degrees Celsius can be converted to degrees Fahrenheit using the following equation:
Degrees Fahrenheit = $(9/5)$ degrees Celsius + 32.

Hardness: is principally caused by dissolved calcium and magnesium. Hard water requires greater quantities of soap to produce a lather and forms a scale on fixtures. Hardness equivalent to alkalinity is called carbonate hardness, and any excess is called noncarbonate hardness. The carbonate hardness is the quantity that will contribute scale on heating, and the noncarbonate hardness is the quantity of hardness that will remain after removal of the carbonate hardness. Water with calcium and magnesium hardness (as CaCO₃) of 60 mg/l or less is considered soft, 61-120 mg/l as moderately hard, 121-180 mg/l as hard, and over 180 mg/l as very hard.

Sodium-adsorption ratio (SAR) relates to the degree water enters into cation-exchange reactions with soil. Sodium-adsorption ratio is expressed by the equation:

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\frac{[\text{Ca}^{++}] + [\text{Mg}^{++}]}{2}}}$$

where the concentrations of the ions are expressed in milli-equivalents per liter. The sodium-adsorption ratio of water indicates its usefulness for irrigation of different crops on different types of soil.

Residual sodium carbonate (RSC) is twice the amount of carbonate or bicarbonate a water would contain after subtracting an amount equivalent to the calcium plus the magnesium, that is, $\text{RSC} = 2(\text{HCO}_3 + \text{CO}_3 - \text{CA} - \text{Mg})$, in milliequivalents per liter.

Percent sodium: is the percentage of cations in milliequivalents per liter that are sodium. The displacement of calcium and magnesium by sodium in soils is slight unless the percent sodium is considerably higher than 50.

Calcium and Magnesium (Ca and Mg) ions are from the dissolution of limestone and similar rocks. Calcium and magnesium cause water hardness and form scale.

Sodium and Potassium (Na and K) are present in many rocks. Sodium dissolves readily and when brought into solution it tends to remain in solution. Potassium is dissolved with greater difficulty and exhibits a stronger tendency to be reincorporated into solid weathering products, especially clay minerals. In most natural water, the concentration of potassium is much lower than the concentration of sodium. Water that contains a large proportion of sodium salts may be unsatisfactory for irrigation on certain types of poorly drained soils. The presence of several hundred milligrams per liter of sodium in water can make it unsuitable for use in sodium-restricted diets (North Dakota State Department of Health, 1962).

Iron (Fe) is a widespread constituent in rocks and is easily leached by ground water under reducing conditions or in acidic water. Water containing more than 0.3 mg/l of iron, after exposure to air, may become discolored. Reddish-brown stains on

porcelain or enamelware and fixtures and on fabrics washed in the water result from the iron.

Manganese (Mn) in concentrations as low as 0.2 mg/l may cause a dark-brown or black stain on fabrics and porcelain fixtures. Ground water that contains high concentrations of iron may also have considerable amounts of manganese.

Fluoride (F) in ground water probably is derived from solution of fluorite, apatite, and hornblende minerals. High fluoride content may cause mottling of tooth enamel in children's teeth during calcification.

Bicarbonate and Carbonate (HCO_3 and CO_3) ions are the major cause of alkalinity in most water. The significance of alkalinity to the domestic, agricultural, and industrial user is usually dependent upon the nature of the cations (Ca, Mg, Na, and K) associated with it. However, moderate amounts of alkalinity do not adversely affect most uses. Alkalinity can be calculated from water analyses by using the formula: Alkalinity (as CaCO_3) = 0.82 (HCO_3) + 1.67 (CO_3).

Sulfate (SO_4) ions may be converted from metallic sulfide minerals upon weathering or with bacterial action. Sulfate also may be dissolved from beds of gypsum and deposits of sodium sulfate and other sulfosalts.

Chloride (Cl) is present in all natural waters, but the concentrations usually are low. Important sources of chloride are sedimentary rocks that were deposited under marine conditions. Chloride concentrations of 400 mg/l impart a noticeable salty taste for most people.

Nitrate (NO_3) concentrations at high levels in shallow ground water has been attributed to leaching in feedlots or to fertilizer from irrigated fields where nitrogen compounds have been applied. High nitrate content is undesirable in drinking water because of its bitter taste and it has been reported to cause methemoglobinemia (blue babies) in infants (Comly, 1945).

Total dissolved solids: (TDS) is calculated from the weight of residue on evaporation at 180° Celsius from a known volume of water.

Water Quality in the Fortuna Area

Analyses of water samples collected near the City of Fortuna's municipal well field are listed in Table 1. The analyses include samples collected in 1998 from twelve monitoring wells installed in 1998 by the State Water Commission, the farmstead well south of the old well field, and three wells installed in 1997 by Agri-Industries in the old well field (the 'August', 'December', and 113 feet monitoring wells). Also included are two analyses from the 1998 municipal well and from two earlier analyses, a 1964 analysis from a now destroyed monitoring well, 163-101-35CBB, and a 1996 analysis from the 'Carlson' municipal well, plugged in 1997.

Waters in the old well field, as sampled from the 'Carlson', 'August', and 'December' wells, 35CAC6, 35CAC7, and 35CBD1 respectively, have high concentrations of sodium (averaging 390 milligrams per liter (mg/l)), sulfate (averaging 940 mg/l), and total dissolved solids (averaging 1,840 milligrams per liter). A sample collected from 35CAC8, a 113 feet monitoring well installed by a contractor in the old well field, has a water quality much lower in dissolved solids than the three deeper municipal wells, suggesting that all of the fresh, surface water introduced drilling may not have been removed before the sample was collected.

Waters southwest of the old municipal well field, in wells 163-101-35CCA1 and 2 about 500 feet from of the 'August' well, and in well 163-101-35CBB4 near the 1964 municipal well, generally are of similar quality to that in the old well field as are waters in two wells, 35CABB2 & 3, along the trail north of the old well field. Samples from monitoring wells 163-101-35CBBC1, near the water tank along the western side of Section 35, and from 163-101-35DDA, along the eastern side of Section 35, are somewhat lower in dissolved solids concentrations than samples from the old municipal well field.

Waters from wells 162-101-2ABB1-5 and 163-101-35DCB, near the 1998 municipal well, have similar quality. Concentrations of sodium are about 230 mg/l, sulfate about 560 mg/l, and total dissolved solids about 1,240 mg/l. The concentrations are about 2/3 that found in wells in the old well field (table 2), suggesting faster movement of water through the sand and better hydrologic communication with surface recharge than is normally the case in the area.

Table 1 – Water quality analyses in the Fortuna well field area

Location	162-101- 2ABB (7'NW)	162-101- 2ABB2 (171' W)	162-101- 2ABB3 (5" well)	162-101- 2ABB4 (58' W.)	162-101- 2ABB5 (Muni.)	162-101- 2ABB5 (Muni.)	162-101- 2BBA (Pvt.)	163-101- 35CAC6 (Carlson)	163-101- 35CAC7 (August)	163-101- 35CAC8 (2" obs)
Date sampled	6/30/98	8/5/98	8/12/98	8/5/98	6/22/99	10/4/00	6/30/98	11/19/96	4/29/98	8/5/98
Screen depth (ft)	138-143	156-161	128-148	132-137	151-161	151-161	138-143	?-235	240-255	103-113
Depth to water (ft)	33.05'	32.41'	32.70'	32.60'	36		33.05'		241.3'	9.90'
Cond. (μmhos)	1680	1770	1660	1610	1760	1800	1680	2230	2700	1220
pH	7.85	7.85	7.55	7.87	7.63	7.7	7.85	7.2	7.3	7.99
Temp. ($^{\circ}\text{C}$)	9.4						9.4			
Hardness (CaCO₃)	450	440	410	410	450	460	450	627	660	150
SAR	4.7	5.0	4.7	4.7	5.1	5.1	4.7	4.7	7.1	8.2
RSC	0	0	0	0	0	0	0		0	7
% Sodium	52	53	53	53	54	54	52	53	58	75
Calcium (mg/l)	120	120	110	110	120	120	120	167	170	40
Magnesium (mg/l)	37	35	33	32	37	38	37	51	57	13
Potassium (mg/l)	11	11	11	11	12	11	11	11	13	7.1
Sodium (mg/l)	230	240	220	220	250	250	230	332	420	230
Iron (mg/l)	0.05	0.61	0.67	0.53	0.88	0.19	0.05		0.1	0.07
Manganese (mg/l)	0.54	0.45	0.54	0.56	0.5	.36	0.54	0.78	0.59	0.25
Fluoride (mg/l)	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.3
Bicarbonate (mg/l)	504	543	515	482	512	517	504	554	638	604
Carbonate (mg/l)	0	0	0	0	0	0	0	0	0	0
Sulfate (mg/l)	550	560	520	510	610	560	550	855	1100	190
Chloride (mg/l)	8.3	8.1	7.9	7.9	6.9	19	8.3	13	13	4.4
Nitrate (mg/l)	0.1	0.1	0.0	0.1	.1	.1	0.1		5.6	0.1
TDS (mg/l)	1230	1260	1180	1130	1300	1290	1230	1590	2070	793

Table 1 (cont.) - Water quality analyses in the Fortuna well field area

Location	163-101-35CBA	163-101-35CBA	163-101-35CBB	163-101-35CBBC	163-101-35CBD	163-101-35CCA	163-101-35CCA	163-101-35CCB	163-101-35DCB	163-101-35DDA
	(North1)	(North2)	('64 well)	(W. tank)	(Dec.)	(South1)	(South2)	(by '64)	(East)	(Far east)
Date sampled	8/5/98	6/30/98	1964	8/5/98	4/29/98	6/30/98	6/30/98	6/30/98	6/30/98	8/5/98
Screen depth (ft)	107-112	105-110	225-240	220-225	235-255	176-181	245-250	105-110	159-165	138-143
Depth to water (ft)	15.25'	15.35'	20.67'	42.84'	210.4	34.47'	44.51'	9.8'	33.36'	21.23'
Cond. (μmhos)	2330	2870	2430	1870	2500	2350	2410	2230	1770	2040
pH	7.79	7.72	7.7	7.85	7.42	7.95	7.87	7.34	7.87	7.80
Temp. ($^{\circ}\text{C}$)	7.9			10.1	9.5	10.5	10.5	9.2	9.2	
Hardness (CaCO₃)	720	690	600	310	510	700	520	800	460	360
SAR	5.0	7.3	9.5	7.9	7.9	5.1	7.8	3.7	5.1	8.0
RSC	0	0		2	2		1	0	0	4
% Sodium	48	57	56	68	63	48	62	39	54	67
Calcium (mg/l)	190	180	144	63	130	180	130	210	120	96
Magnesium (mg/l)	59	58	58	38	46	61	48	66	38	29
Potassium (mg/l)	12	16	23	13	13	13	12	12	12	11
Sodium (mg/l)	310	440	366	320	410	310	410	240	250	350
Iron (mg/l)	0.90	0.89	0.48	0.01	0.32	0.03	0.04	2.3	0.02	0.07
Manganese (mg/l)	0.77	0.62		0.03	0.31	0.67	0.58	0.99	0.56	0.38
Fluoride (mg/l)	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bicarbonate (mg/l)	506	602	556	488	724	492	686	523	499	682
Carbonate (mg/l)	0	0	0	0	0	0	0	0	0	0
Sulfate (mg/l)	980	1100	925	650	860	1000	840	950	590	570
Chloride (mg/l)	8.4	9.3	10	11	15	13	22	7.4	8.7	14
Nitrate (mg/l)	0.1	0.1	3	2.3	0.1	0.1	0.1	0.1	0.1	0.1
TDS (mg/l)	1880	2190	1880	1370	1870	1890	1820	1820	1350	1400

**Table 2 - A comparison of water quality from the 1998 municipal well
(October 2000 sample) with that from the old municipal wells**

Well	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	TDS (mg/l)	Hardness (mg/l)
2ABB5 (1998 well)	120	38	250	560	1290	460
35CAC6 (Carlson)	167	51	332	855	1590	627
35CAC7 (August)	170	57	420	1100	2070	660
35CBD1 (Dec.)	130	46	410	860	1870	510
35CBB4 (1964)	210	66	240	950	1820	800

Dissolved mineral concentrations from Fortuna area well water samples are shown on a Schoeller diagram in figure 10. In the figure the milliequivalents per liter of calcium plus magnesium, sodium, sulfate, and bicarbonate, are graphed. Milliequivalents differ from milligrams in that the weight and electric charge of ions are taken into account.

Comparison of dissolved ion concentrations of area well water samples, as represented in the Schoeller diagram, does not reveal a consistent pattern. The variability in water quality indicated in the Schoeller diagram is consistent with the lenticular nature of the sand zones. Relatively high concentrations of common dissolved minerals are also consistent with waters passing through glacial till. Analyses from the 1998 municipal well and from the well 1/4-mile to the north are included on the Schoeller diagram. Six additional water samples collected from wells near the 1998 municipal well have similar quality and were not included in the Schoeller diagram.

Concentrations of seven 'trace' elements were determined from June 1999 and October 2000 samples collected from the 1998 municipal well. The results of the trace analysis are given in table 3, in micrograms per liter, $\mu\text{g/l}$. One microgram per liter is equal to 1/1000 of a milligram per liter. One of the trace elements for which concentration was determined, arsenic, is at a concentration of about one-half the allowable standard. For purposes of comparison available trace element analyses from shallow ground water samples in northwestern North Dakota were briefly reviewed, the review indicating that the arsenic concentration in 1998 Fortuna well is in the upper range of that found in area shallow wells.

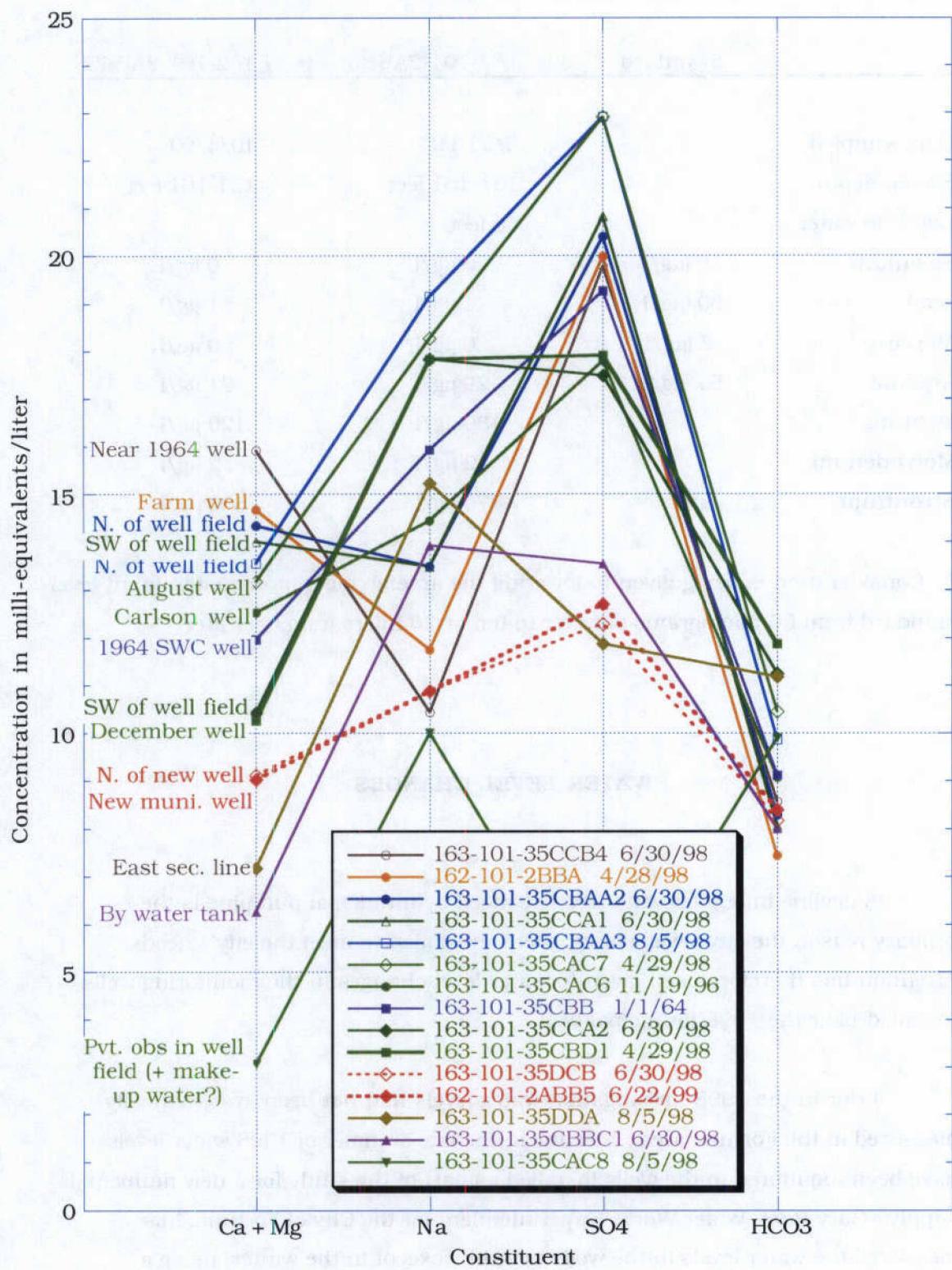


Figure 10 – Schoeller diagram illustrating water quality

Table 3 – Trace element water quality from the 1998 municipal well

	Standard	162-101-2ABB5	162-101-2ABB5
Date sampled		6/22/99	10/4/00
Screen depth		151-161 feet	151-161 feet
Depth to water		36 feet	
Selenium	10 ($\mu\text{g/l}$)	0 $\mu\text{g/l}$	0 $\mu\text{g/l}$
Lead	50 ($\mu\text{g/l}$)	1 $\mu\text{g/l}$	1 $\mu\text{g/l}$
Mercury	2 ($\mu\text{g/l}$)	0 $\mu\text{g/l}$	0 $\mu\text{g/l}$
Arsenic	50 ($\mu\text{g/l}$)*	29 $\mu\text{g/l}$	21 $\mu\text{g/l}$
Lithium		130 $\mu\text{g/l}$	120 $\mu\text{g/l}$
Molybdenum		2 $\mu\text{g/l}$	2 $\mu\text{g/l}$
Strontium		770 $\mu\text{g/l}$	800 $\mu\text{g/l}$

* Consideration is being given to lowering the arsenic maximum contaminant level standard from 50 micrograms per liter to ten or 20 micrograms per liter.

WATER LEVEL CHANGES

A decline in aquifer water levels caused by municipal pumping is the primary reason the city's wells have, over time, failed to meet the city's needs. Attention has therefore been given to water level changes in the monitoring wells installed near the 1998 municipal well.

Prior to the 1998 investigation water levels had not been systematically measured in the Fortuna area. Starting in the late summer of 1998 water levels have been monitored in the wells installed as part of the study for a new municipal supply. Gary Rust, Water Works Superintendent for the City of Fortuna, has measured the water levels in the wells monthly, except in the winter, using a chalked steel tape.

Water levels measured in the monitoring wells are shown on the following two hydrographs, figures 11 and 12. Figure 11 includes measurements made in the 12 monitoring wells installed in 1998 and in a 113 feet deep monitoring well installed by Agri Industries near the old well field. Figure 12 includes measurements made in six monitoring wells near the 1998 city well. For comparison purposes the water depths in wells have been converted to water level elevations above sea level. Well elevations were estimated using a topographic map. In moderate terrain the estimates are usually accurate to within five feet.

Water levels near the 1998 municipal well are shown more clearly in figure 12 where the vertical scale of the hydrograph is expanded by a factor of five. In the late summer and fall of 1998 water levels in the aquifer declined nearly one foot following installation of the wells and before installation of a municipal well. The water levels near the 1998 well field declined about 1 3/4 feet in November and December of 1998, after the municipal well went into operation. The water levels in the wells rose about four feet in the first half of 1999, declined about two feet over the next year, and recovered most of the decline during the first half of 2001.

Water levels in shallow wells commonly fluctuate one foot or more seasonally and with wet and dry cycles. Near the 1998 well field the natural water level fluctuations in the aquifer are amplified by the small aquifer storage coefficient together with pressure (weight) changes caused by changing volumes of water in overlying sloughs.

The aquifer near the 1998 well field is confined by glacial till and has a pressure head about 90 feet above the top of the aquifer. Confined aquifers have small storage coefficients. An aquifer's storage coefficient is a measure of the change in pressure head (well water level) when water is added to or removed from the aquifer. In an aquifer having a small storage coefficient a change in the pressure on the aquifer, such as a change in the weight of surface water overlying the aquifer, will result in a relatively large change in the confined pressure head or level of water in a well screened in the aquifer.

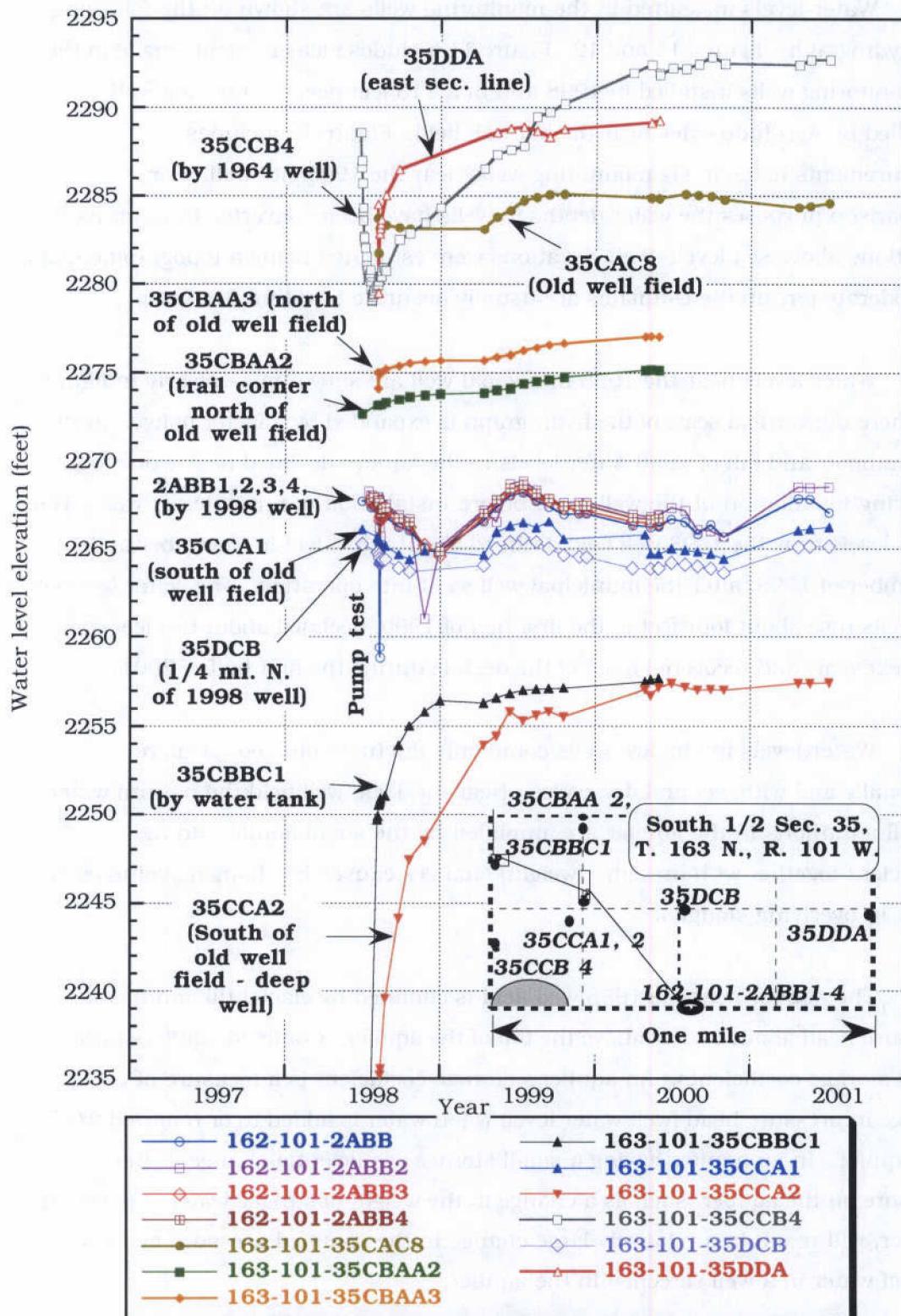


Figure 11 – Water levels in monitoring wells south of Fortuna

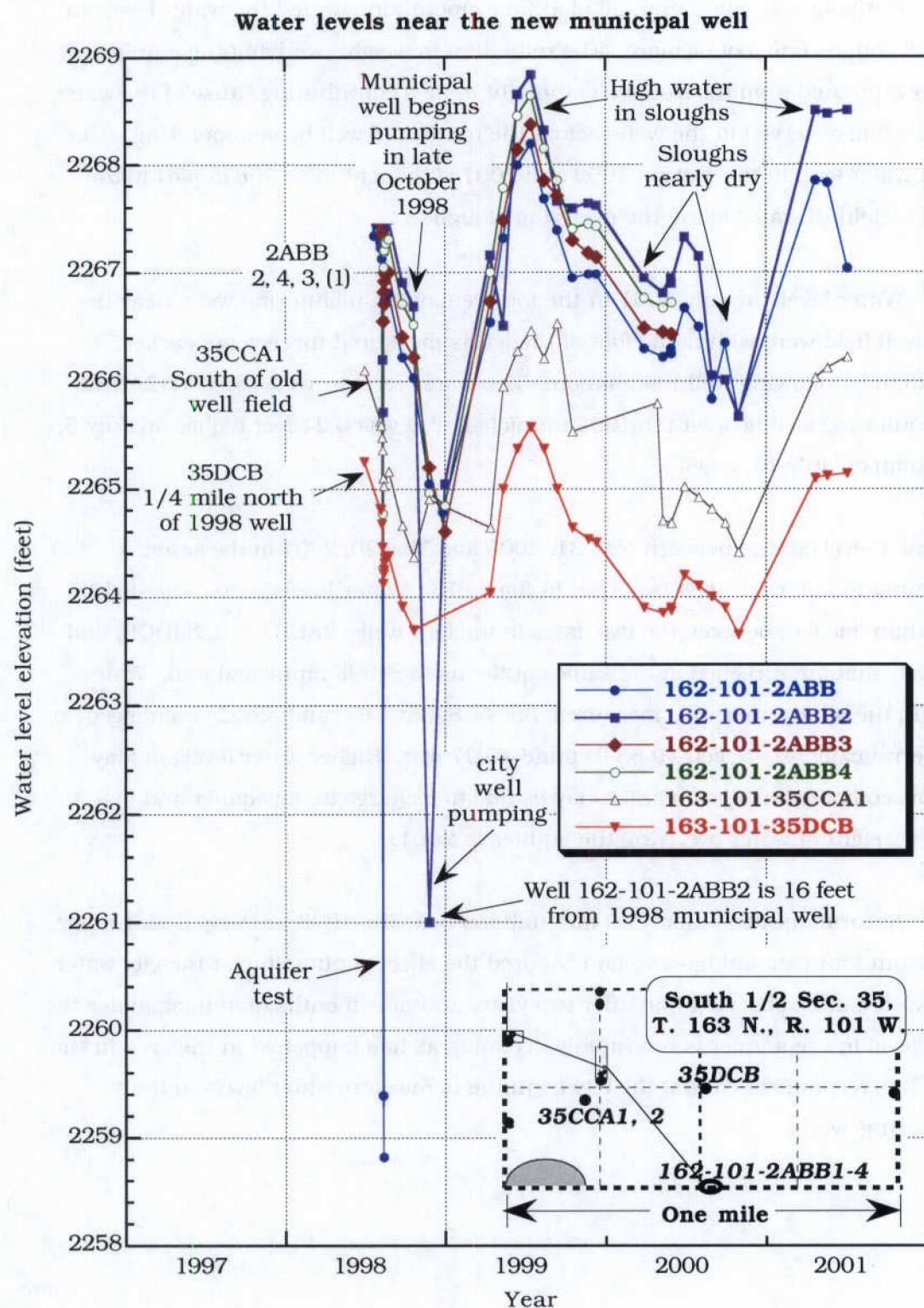


Figure 12 – Water levels in wells near the 1998 municipal source

In the late summer and fall of 1998 evaporation lowered the water levels in nearby sloughs one foot or more. The reduction in weight overlying the aquifer as water evaporated from the sloughs is thought to be a contributing cause of the water level decline observed in the wells before the municipal well began operating. The rise in water level in the wells in 1999 and 2001 is thought to be due in part to the added weight of water filling the overlying sloughs.

Water levels in July 2001 in the four remaining monitoring wells near the 1998 well field were within one foot of the levels measured three years earlier, immediately following well installation. The water level in well 162-101-2ABB2, the monitoring well nearest the 1998 municipal well was 0.24 feet higher on July 5, 2001 than on July 16, 1998.

The water level change between May 31, 2000 and May 20, 2001 in the seven remaining monitoring wells is shown in figure 13. Water levels increased slightly more than one foot between the two dates in the four wells, 2ABB1 & 2, 35DCB, and 35CCA1, that are screened in the same aquifer as the 1998 municipal well. Water levels in the other three wells measured, 35CAC8, 35CCB4, and 35CCA2, changed more erratically, -0.43 feet, +0.88 feet and +0.27 feet. Higher water levels in May 2001 as compared to a year earlier may be due to recharge to the aquifer and to a greater weight of water overlying the aquifer in 2001.

Natural aquifer water level fluctuations near the 1998 municipal well range over about four feet and have so far obscured the effect of pumping for the city water supply. It can be observed that after two years and nine months of municipal use the water level in the aquifer is not rapidly declining as has happened in the area in the past. It is recommended that the city continue to measure water levels in the monitoring wells.

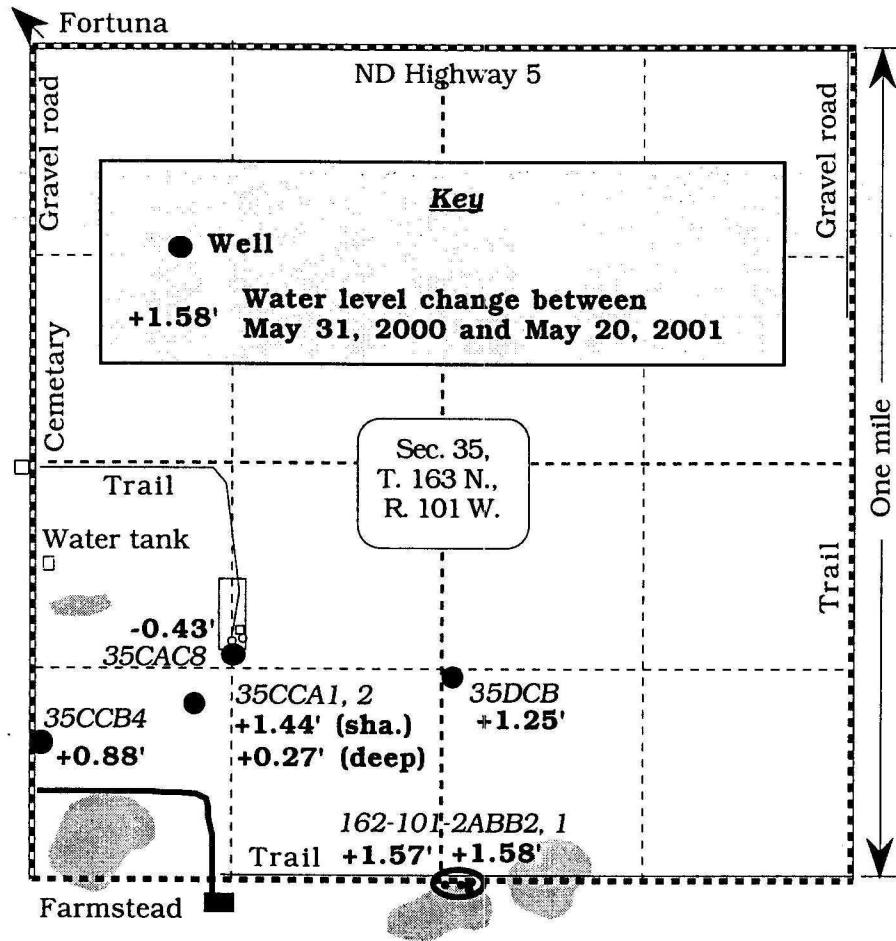


Figure 13 – Water level change between May 31, 2000 and May 20, 2001

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APPENDIX - LITHOLOGIC LOGS

Test hole and well completion information for the 27 test holes drilled in June and July 1998 and for 21 other holes or wells in the study area are presented in the appendix. Descriptions of sediments penetrated in the 1998 test holes are compiled from geologists and driller's logs written at the time the holes were drilled. Color descriptions are of wet samples and are based on a Rock-Color Chart, distributed by the Geological Society of America (Goddard, et. al. 1948). Grain size classification uses Wentworth's scale (Wentworth 1922). Information for the 21 other holes or wells are from well driller's reports or from the Divide County Basic Data compiled by C.A. Armstrong (1965). Test hole locations are shown in figure 14. In the lithologic descriptions:

Topsoil refers to the organic rich, dark colored, 'A' weathering horizon formed at land surface.

Clay refers to hydrated aluminum silicate minerals with colloidal properties, that is, the minerals are light enough with respect to their surface area to be easily suspended in water.

Silt refers to particles larger than clay and smaller than sand, that is, between 0.0004 millimeter (mm) and 0.0625 (1/16) mm in diameter.

Very fine sand refers to grains between 1/16 mm and 1/8 mm in diameter.

Fine sand refers to grains between 1/8 and 1/4 mm in diameter.

Medium sand refers to grains between 1/4 mm and 1/2 mm in diameter.

Coarse sand refers to grains between 1/2 and one mm in diameter.

Very coarse sand refers to grains between one and two mm in diameter.

Gravel refers to material larger than two mm in diameter. Gravel can be subdivided into granules, 2 to 4 mm, pebbles, 4 to 64 mm, cobbles 64 to 256 mm, and boulders, greater than 256 mm in diameter.

Till refers to a mixture of clay, silt, sand, and gravel deposited directly from a glacier without reworking and sorting by meltwater.

Bedrock refers to the older rock or sediment underlying the glacially deposited sediments.

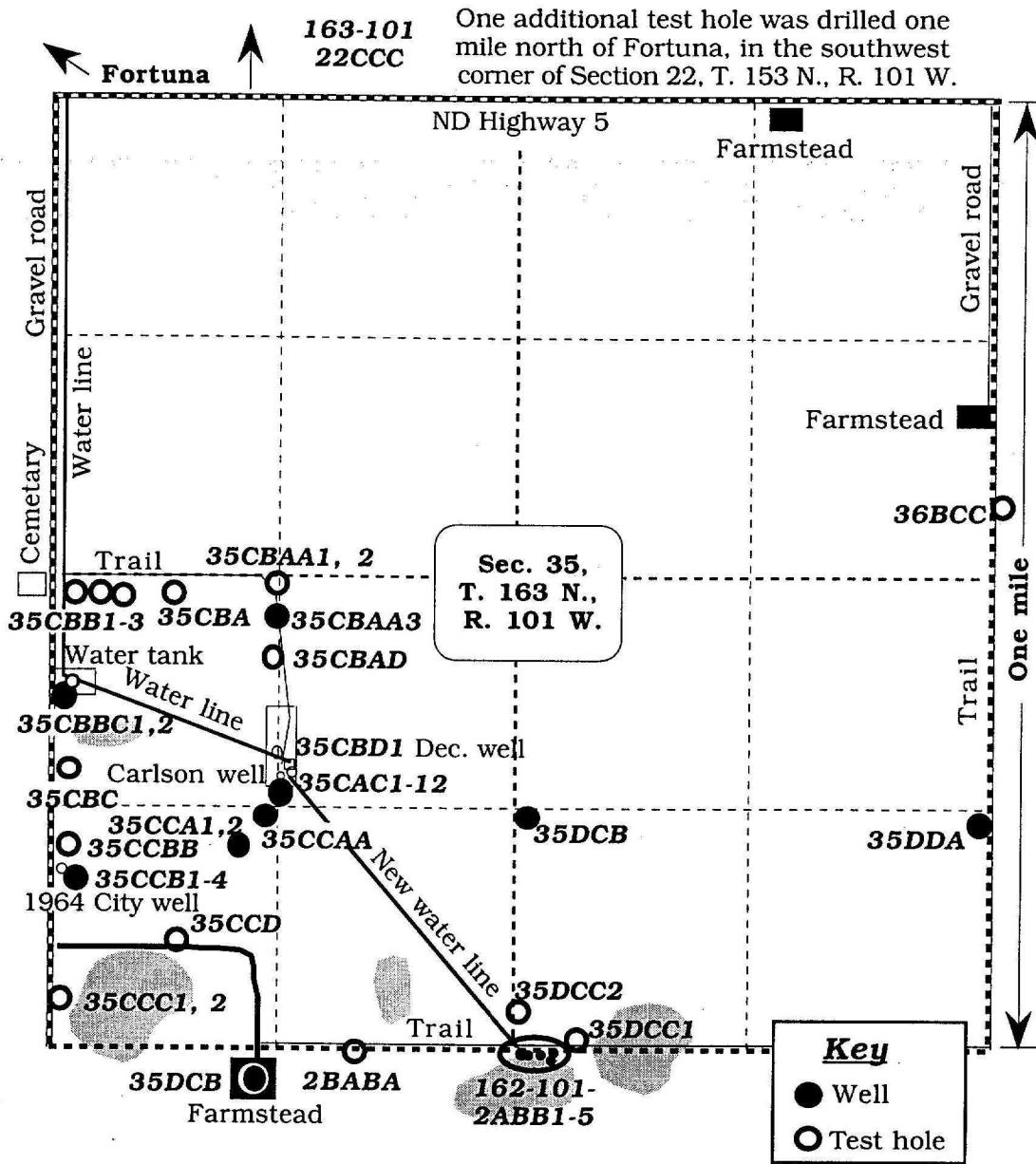


Figure 14 – Locations of test holes and wells included in the appendix

162-101-02ABB

NDSWC 13804

Date Completed: 6/25/98 Purpose: Observation Well
 L.S. Elevation (ft): 2300 Well Type: 2in. - PVC
 Depth Drilled (ft): 180 Aquifer: Undefined
 SI (ft.): 138-143 Source of Data: Steve Pusc

Completion Info: 18 slot PVC screen, sealed annulus with 4 bags of holeplug

Remarks: Located 7 feet NW of 5-inch well

Lithologic Log

<u>Depth (ft)</u>	<u>Unit</u>	<u>Description</u>
0-1	TOPSOIL	
1-23	CLAY	Yellowish brown, silty, sandy with pebbles, (oxidized till)
23-107	CLAY	Olive gray, silty, very sandy, with pebbles and rocks, sand lens at 42-44, 68-69, gravel lens at 90-92, 96-97
107-116	SAND	Fine to medium grained, drills fast but appears tight, not choppy
116-124	CLAY	Olive gray, silty, sandy, with pebbles (till)
124-132	SAND	Fine to coarse, well rounded carbonates, shales, lignite, granite
132-147	GRAVEL	Rocky, coarse sand to pea sized gravel, drills fast, takes a little water
147-180	CLAY	Olive gray, silty, sandy, with pebbles, rocky, drills slow (till)

162-101-02ABB2
NDSWC 13810

Date Completed:	7/14/98	Purpose:	Observation Well
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	180	Aquifer:	Undefined
SI (ft.):	156-161	Source of Data:	Alan Wanek
Completion Info:		Collapsed formation against 18 slot screen with air, sealed annulus with 3 bags of holeplug.	
Remarks:		Location is 11 feet south of sec. line (trail center), 28 feet east of quarter line, 171 feet west of five inch well (ABB3), 50 feet west of bush.	

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-22	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized till)
22-48	CLAY	Olive gray, 30%, with silt, sand, and gravel (till), gravel lens at 40-41 feet
48-53	SAND & GRAVEL	20% gravel, well graded, silicates and carbonates
53-120	CLAY	gray, with silt, sand, and gravel (till), gravel lens at 94-96 feet
120-124	SAND & GRAVEL	20% gravel
124-127	CLAY	Olive gray, 30%, with silt, sand, & gravel (till)
127-135	SAND & GRAVEL	20% gravel, well graded, silicates, carbonates, lignite
135-150	SAND & GRAVEL	Interbedded with clay
150-162	SAND & GRAVEL	30% gravel, silicates, carbonates, shale, lignite, drills choppy, rock at 160-162 feet
162-165	CLAY	As above (till)
165-169	SAND & GRAVEL	As above
169-180	CLAY	Olive gray, as above (till)

162-101-02ABB3
NDSWC 13815

Date Completed:	7/16/98	Purpose:	Test Well - Plugged
L.S. Elevation (ft):	2300	Well Type:	5in. - PVC
Depth Drilled (ft):	160	Aquifer:	Undefined
SI (ft.):	128-148	Source of Data:	Alan Wanek
Completion Info:		Drilled 4 3/4 inch pilot hole to 160 feet, reamed to 154 feet using 8 3/4 inch diameter with rotary bit, set 20 feet of 16 slot, 5 inch diameter PVC screen, 2 inch check valve, collapsed formation against screen, sealed annulus with 4 bags of grout and 7 bags of holeplug, pumped with air for 11 hours, originally at about 5 gallons per minute, to about 14 gpm at end, backwashed with 4 tanks of water.	
Remarks:		Five inch diameter test well is location is 7 feet southwest of ABB(1), 20 feet south of section line and 199 feet east of quarter line.	
Plugging Info:		The test pumped well was plugged on May 31, 2000. A three-feet deep hole was dug around the casing. The casing was cut off. About ten cubic feet of clean sand were poured into the casing, filling the screen and lower 50 feet of casing. A bag of bentonite chips was added. Another five cubic feet of sand filled another 32 feet of casing. Two bags of cement mixed with 10 gallons of water were poured into the casing. The casing was topped off with bentonite chips and capped. The location was restored.	

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-24	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
24-123	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), sand lens at 41-42 feet, 66, 70-71, 76, 78, 80, 97, 99, 101-106, 112, 114, 116
123-133	SAND	Medium grained, poorly sorted, with lignite
133-152	SAND	Medium grained, as above, with more chattering, lignite
152-160	SILT	Olive gray, argillaceous, rocky at 156

162-101-02ABB4
NDSWC 13816

Date Completed:	7/21/98	Purpose:	Obs. Well - Plugged
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	180	Aquifer:	Undefined
SI (ft.):	132-137	Source of Data:	Alan Wanek
Completion Info:	Collapsed 18 slot screen against formation with air, sealed annulus with 3 bags of holeplug.		
Remarks:	Location is 15 feet south of section line (trail) and 141 feet east of the quarter line, 58 feet west of 5 inch well ABB3, 8 feet east of bush.		
Plugging Info:	The observation well was plugged on May 31, 2000. A three-feet deep hole was dug around the casing. The casing was cut off and a coupling attached. Three bags of cement mixed with 15 gallons of water were poured into the well. The casing was topped off with bentonite chips and capped. The location was restored.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-27	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
27-122	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), sand lenses at 70-75 feet, 96, 105, 115, till is sandier, faster drilling from 60 feet, with silt lenses
122-133	SAND	Medium grained, poorly sorted
133-136	SAND & GRAVEL	Chatters with drilling
136-142	SAND	Medium grained, taking some water with drilling
142-150	CLAY	Olive gray, silty
150-153	SAND	Medium to coarse grained, poorly sorted
153-156	CLAY	Olive gray, silty
156-162	SAND & GRAVEL	Rough drilling, taking water
162-180	CLAY	Olive gray, 30%, with silt, sand, & gravel (till) rock at 178 feet

162-101-02ABB5

City of Fortuna

Date Completed:	10/20/98	Purpose:	Municipal Well
L.S. Elevation (ft):	2300	Well Type:	5in. - PVC
Depth Drilled (ft):	163	Aquifer:	Undefined
SI (ft.):	151-161	Source of Data:	Leo Grossman - Agri Industries, Inc.

Completion Info: 18 slot, 5 inch diameter stainless steel screen, sand packed with 10-20 sand, grouted from 1-120 feet with volclay high density bentonite; a static water level of 36 feet is included on the well driller's report; no pumping information

Remarks: Located 16 feet west of 2ABB2, 12 feet east and 11 feet south of the north end of the quarter line.

Lithologic Log

Depth (ft)	Unit	Description
0-19	CLAY	Yellowish brown
19-52	CLAY	Gray, sandy
52-57	SAND & GRAVEL	Fine to medium
57-126	CLAY	Gray
126-129	SAND & GRAVEL	Medium
129-132	CLAY	Gray
132-137	SAND	Medium grained, gravelly
137-138	CLAY	Gray
138-142	SAND & GRAVEL	Medium
142-143	CLAY	Gray
143-161	SAND & GRAVEL	Medium
161-162	ROCKS	
162-163	CLAY	Gray

162-101-02BABA
NDSWC 13811

Date Completed:	7/14/98	Purpose:	Test Hole
L.S. Elevation (ft):	2300		
Depth Drilled (ft):	200	Source of Data:	Alan Wanek
Completion Info:	Sealed test hole with nine bags of holeplug.		
Remarks:	Location is south of trail, along fence line, where trail curves north around slough, just NE of Beaverdorf farmstead.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-39	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
39-113	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till)
113-125	CLAY	As above (sandy till), interbedded with sand and gravel lenses
125-156	SAND	Olive gray, 40% with clay, sand, & gravel (silty till), chunk of friable wood at 135 feet, sand 152-153 feet
156-163	SAND & GRAVEL	30% gravel, well graded
163-178	SILT	Olive gray, with very fine sand and clay
178-182	SAND & GRAVEL	
182-184	CLAY	(Till?)
184-186	SAND & GRAVEL	
186-200	CLAY	(Till)

162-101-02BBA

Date Completed:	9/14/81	Purpose:	Domestic Well
L.S. Elevation (ft):	2305	Well Type:	4in. - PVC
Depth Drilled (ft):	191	Aquifer:	Undefined
SI (ft.):	180-188	Source of Data:	Curtis Arcand
Completion Info:	Completed with perforated pipe, grouted at surface with cement, initial reported static water level is 55 feet, 100 feet after 2 hours pumping at 12 gpm		

Remarks:

Lithologic Log

Depth (ft)	Unit	Description
0-41	CLAY	Brown, pebbly
41-161	CLAY	Sandy
161-191	SAND & GRAVEL	

163-101-22DDD
NDSWC 13818

Date Completed: 7/21/98 Purpose: Test Hole
L.S. Elevation (ft): 2160
Depth Drilled (ft): 160 Source of Data: Alan Wanek

Completion Info: Sealed test hole with two bags of holeplug

Remarks: Located along west side of right-of-way, 400 feet north of slough

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-31	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
31-160	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till)

163-101-35CAC1

City of Fortuna

Date Completed:	Unknown	Purpose:	Municipal Well
L.S. Elevation (ft):	2295	Well Type:	36in. - Cement
Depth Drilled (ft):	20	Aquifer:	Undefined
SI (ft.):	?-20	Source of Data:	Divide Co. basic data.
Completion Info:	Completed in sand and gravel, 1964 water level of 6 feet below land surface		
Remarks:	Well 1: probably an existing well inside of a well house - Fortuna well field		

Lithologic Log

Depth (ft)	Unit	Description
No lithologic log available		

163-101-35CAC2
City of Fortuna

Date Completed: 1962 Purpose: Test Hole
L.S. Elevation (ft): 2295
Depth Drilled (ft): 100

Source of Data: Schnell

Completion Info:

Remarks: Test 2: located in the old Fortuna well field

Lithologic Log

Depth (ft)	Unit	Description
0-4	SAND & GRAVEL	
4-19	CLAY	Brown
19-29	CLAY	Blue
29-31	GRAVEL	
31-36	CLAY	Blue
36-38	GRAVEL	
38-47	CLAY	Blue
47-55	SAND & GRAVEL	
55-78	CLAY	Blue
78-99	SAND	With gravel and lignite
99-100	CLAY	

163-101-35CAC3
City of Fortuna

Date Completed: 1962 Purpose: Plugged municipal
L.S. Elevation (ft): 2295 well
Depth Drilled (ft): 91
Source of Data: Divide Co. basic data

Completion Info:

Remarks: Well 3: located in the old Fortuna well field, probably near test hole
35 CAC2

Lithologic Log

<u>Depth (ft)</u>	<u>Unit</u>	<u>Description</u>
No lithologic log available		

163-101-35CAC4
City of Fortuna

Date Completed: 1962 Purpose: Test Hole
L.S. Elevation (ft): 2295
Depth Drilled (ft): 100

Source of Data: Schnell

Completion Info:

Remarks: Test 3: located in the old Fortuna well field

Lithologic Log

Depth (ft)	Unit	Description
0-14	SAND & GRAVEL	
14-20	CLAY	Brown
20-94	CLAY	Blue
94-96	GRAVEL	
96-100	CLAY	

163-101-35CAC5
City of Fortuna

Date Completed: 1962 Purpose: Test Hole
L.S. Elevation (ft): 2295
Depth Drilled (ft): 100

Source of Data: Schnell

Completion Info:

Remarks: Test 4: located in the old Fortuna well field

Lithologic Log

Depth (ft)	Unit	Description
0-8	SAND & GRAVEL	
8-60	CLAY	
60-63	GRAVEL	
63-83	CLAY	
83-88	SAND	
88-100	CLAY	

163-101-35CAC6

City of Fortuna

Date Completed:	Unknown	Purpose:	Municipal Well - Plugged
L.S. Elevation (ft):	2295	Well Type:	Unknown
Depth Drilled (ft):	235	Aquifer:	Undefined
SI (ft.):	0-0	Source of Data:	Lloyd Carlson
Completion Info:	Plugged by Agri Industries in 1997		
Remarks:	Located in the old Fortuna well field, city municipal well from the early 1970's (?) until 1997, referred to as the Carlson well, located about 60 feet south and -60 feet west of the well house. No well driller's report, information from the City of Fortuna.		

Lithologic Log

Depth (ft)	Unit	Description
0-3	GRAVEL	
3-13	CLAY	Yellow
13-69	CLAY	(Till), sand 18-20, gravel 26-30, sand 51-55
69-75	SAND	
75-93	CLAY	(Till)
93-97	GRAVEL	Fine, lost circulation
97-98	CLAY	(Till)
98-110	SAND	With lignite
110-129	SAND	Fine grained, with lignite
129-138	SAND	Fine grained, hard (indurated?)
138-164	SAND	Fine grained
164-174	SAND	Fine grained and some gravel
174-195	CLAY	(Till), gravel at 183-183.5 and 185-186
195-197	GRAVEL	
197-205	CLAY	(Till)
205-210	SAND	
210-215	GRAVEL	Hard
215-235	GRAVEL	Fine

163-101-35CAC7
City of Fortuna

Date Completed:	8/12/97	Purpose:	Municipal Well
L.S. Elevation (ft):	2295	Well Type:	5in. - PVC
Depth Drilled (ft):	260	Aquifer:	Undefined
SI (ft.):	240-255	Source of Data:	Leo Grossman, Agri Industries, Inc.

Completion Info: 5 inch, 20 slot stainless steel screen, grouted to 230 feet with bentonite, 192 feet reported static water level, 236 feet water level after 27 hours pumping at 18 gpm.

Remarks: August well - located in the old Fortuna well field, 20 feet south of well house

Lithologic Log

Depth (ft)	Unit	Description
0-35	GRAVEL	Coarse, with sand
35-82	CLAY	Sandy (till), sand lenses at 46-50, 74-78
82-92	SAND	Medium to fine grained
92-100	CLAY	Gray (till)
100-112	SAND & GRAVEL	Medium grained
112-180	CLAY	Gray, sandy
180-192	SAND	Medium to fine grained
192-198	CLAY	Gray (till)
198-210	SAND & GRAVEL	Medium grained
210-234	CLAY	Gray (till)
234-255	SAND	Medium grained
255-260	CLAY	Gray (till)

163-101-35CAC8
City of Fortuna

Date Completed:	11/3/97	Purpose:	Observation Well
L.S. Elevation (ft):	2295	Well Type:	2in. - PVC
Depth Drilled (ft):	120	Aquifer:	Undefined
SI (ft.):	103-113	Source of Data:	Leo Grossman, Agri Industries, Inc.
Completion Info:	2 inch diameter PVC, wire wrapped, 20 slot casing, annulus sealed with volclay from 0-100 feet.		
Remarks:	Located in the old Fortuna well field		

Lithologic Log

Depth (ft)	Unit	Description
0-31	SAND & GRAVEL	
31-75	CLAY	Gray (till), sand lens 41-43 feet
75-80	CLAY	Gray, sandy, w/gravel (sandy till)
80-88	SAND	
88-101	CLAY	Gray (till)
101-113	SAND & GRAVEL	Medium
113-120	CLAY	Gray (till)

163-101-35CAC9
City of Fortuna

Date Completed:	11/8/97	Purpose:	Test well, removed
L.S. Elevation (ft):	2295	Well Type:	5 in. - PVC
Depth Drilled (ft):	120	Aquifer:	Undefined
SI (ft.):	100-110	Source of Data:	Leo Grossman - Agri Industries
Completion Info:	Set 5 inch stainless steel screen, grouted 20-90 feet with volclay; static water level of 15.5 feet, pumping water level of 97.6 feet after 2 hours at 3 gpm, casing and screen removed, hole plugged		
Remarks:	Located in the old Fortuna well field		

Lithologic Log

Depth (ft)	Unit	Description
0-12	SAND & GRAVEL	
12-45	CLAY	Gray (till)
45-47	SAND	
47-78	CLAY	Gray (till)
78-83	CLAY	(Till) with sand and gravel
83-87	SAND	
87-98	CLAY	Gray (till)
98-111	SAND & GRAVEL	Medium
111-120	CLAY	Gray (till)

163-101-35CAC10
City of Fortuna

Date Completed:	12/4/97	Purpose:	Test well, removed
L.S. Elevation (ft):	2295	Well Type:	5 in. - PVC
Depth Drilled (ft):	260	Aquifer:	Undefined
SI (ft.):	See completion info, below	Source of Data:	Leo Grossman - Agri Industries, Inc.

Completion Info: Screened 100-110, 18 slot SS screen, 14.5 feet water level, 105 feet after 2 hours pumping at 3.5 gpm, pulled casing & screen; drilled to 195 feet, screened 180-190, 167 feet static, 185 feet water level after 2 hours pumping at 3 gpm, pulled casing and screen and drilled to 260 feet, screened 225-235; 233 feet static water level, pulled casing and screen, plugged hole

Remarks: Located in the old Fortuna well field

Lithologic Log

Depth (ft)	Unit	Description
0-12	SAND & GRAVEL	
12-98	CLAY	(Till), fine sand 45-47 feet; gravelly from 78-83 feet; sand and gravel from 83-87 feet
98-111	SAND & GRAVEL	Medium
111-179	CLAY	(Till), fine sand 131-135
179-190	SAND	Medium grained with clay lenses
190-219	CLAY	Gray
219-235	SAND	Medium grained with clay lenses
235-240	CLAY	Gray
240-260	CLAY	(Till) gray

163-101-35CAC11
NDSWC 13797

Date Completed: 6/15/98 Purpose: Test Hole
L.S. Elevation (ft): 2295
Depth Drilled (ft): 280 Source of Data: Steve Pusc

Completion Info: Plugged test hole

Remarks: Located in the old Fortuna well field, 60 feet south of City of Fortuna production well installed August 1997

Lithologic Log

Depth (ft)	Unit	Description
0-5	GRAVEL	Sandy, with rocks (oxidized)
5-11	CLAY	Olive gray, silty, sandy, with pebbles (till, first foot oxidized)
11-15	SAND	Fine to medium grained, with gravel
15-26	CLAY	Olive gray, very silty, sandy, with pebbles (till)
26-36	SAND	Gravelly, drills fast, fine, silty in first two feet
36-244	CLAY	Olive gray, very silty, sandy, with pebbles (till); sand lenses at 39-41, 48-49, 84-86, 126-127, 130-132, 142-143, 157-162
244-280	CLAY	Very silty with very fine sand, drills smooth

163-101-35CAC12
NDSWC 13817

Date Completed:	7/21/98	Purpose:	Test Hole
L.S. Elevation (ft):	2295		
Depth Drilled (ft):	280		
		Source of Data:	Alan Wanek
Completion Info:	Sealed test hole with six bags of holeplug		
Remarks:	Located in the old Fortuna well field, 45 feet south and 60 feet west of the 'August' well, thought to be within ten feet of the plugged Carlson well		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-11	SAND & GRAVEL	50% gravel, well graded, silicates and carbonates (oxidized)
11-26	CLAY	Olive gray, 30%, with silt, sand, and gravel (silty till), gravel at 22-23 feet
26-36	SAND	Coarse grained, some gravel
36-110	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), rocky at 75 feet, 100 feet
110-117	SAND & GRAVEL	40% gravel, drills hard, does not take water
117-144	CLAY	Olive gray, 30% with silt, sand, and gravel (sandy till)
144-160	CLAY	With silt and very fine sand, (till?), gravel lens at 150, 156 feet
160-280	CLAY	Olive gray 30%, with silt, sand, & gravel (till), gravel lens at 266, 268 feet

163-101-35CBA
City of Fortuna

Date Completed: 11/28/76 Purpose: Test Hole
L.S. Elevation (ft): 2290
Depth Drilled (ft): 216 Source of Data: MonDak Drilling

Completion Info:

Remarks:

Lithologic Log

Depth (ft)	Unit	Description
0-14	GRAVEL	Sandy
14-28	CLAY	Gray
28-44	SAND	Coarse grained, with lignite at 38 feet
44-65	CLAY	Gray, lignite at 52, 54 feet
65-69	GRAVEL	
69-101	SAND	With abundant lignite 69-72, 78-80, 87-94
101-110	SAND	Clayey, with abundant lignite
110-116	SHALE	
116-174	CLAY	Hard
174-186	SAND	Coarse, with clay
186-195	SAND	Coarse grained, with lignite
195-208	SAND	Coarse grained
208-214	SAND	Fine grained
214-216	CLAY	

163-101-35CBAA1
NDSWC 13799A

Date Completed: 6/18/98 Purpose: Test Hole
L.S. Elevation (ft): 2290
Depth Drilled (ft): 260 Source of Data: Steve Pusc

Completion Info: Sealed with 3 bags of grout, 4 bags of holeplug;

Remarks: Located by curve where the trail curves south off the quarter line to the city well field.

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-8	GRAVEL	Sandy, rocky, (oxidized)
8-23	CLAY	Yellowish brown, silty, sandy, with pebbles (oxidized till)
23-75	CLAY	Olive gray, silty, sandy, with pebbles (till)
75-90	SAND	Very fine to medium
90-102	CLAY	Very silty
102-112	SAND	Very fine grained, silty
112-144	CLAY	Olive gray, very silty
144-196	CLAY	Very silty, sandy
196-260	CLAY	Olive gray, silty, sandy, with pebbles (till), sand lens 203-207

163-101-35CBAA2
NDSWC 13799B

Date Completed:	6/22/98	Purpose:	Obs. Well - Plugged
L.S. Elevation (ft):	2290	Well Type:	2in. - PVC
Depth Drilled (ft):	120	Aquifer:	Undefined
SI (ft.):	107-112	Source of Data:	Steve Pusc

Completion Info: 12 slot PVC screen, sealed annulus with 4 bags of holeplug

Remarks: North well, location is northeast of bend in trail going to city well field. The well was pumped for a number of hours by suction, testing the sand lens as a possible site for a municipal well.

Plugging Info: The observation well was plugged on May 31, 2000. A two-feet deep hole was dug around the casing. The casing was cut off and a coupling attached. Two bags of cement mixed with 10 gallons of water were poured into the well. The casing was topped off with bentonite chips and capped. The location was restored.

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-5	GRAVEL	Oxidized
5-22	CLAY	Silty, sandy, with pebbles (oxidized till)
22-76	CLAY	Olive gray, silty, sandy (till)
76-81	SAND	Very fine to fine grained, taking a little water
81-90	CLAY	Olive gray, silty, sandy (till)
90-100	SAND	Very fine to fine grained, clayey, silty
100-102	CLAY	Silty
102-116	SAND	Very fine grained to fine grained, with lignite
116-120	CLAY	Olive gray, silty, sandy (till)

163-101-35CBA3
NDSWC 13808

Date Completed:	7/13/98	Purpose:	Obs. Well - Plugged
L.S. Elevation (ft):	2292	Well Type:	2in. - PVC
Depth Drilled (ft):	160	Aquifer:	Undefined
SI (ft.):	105-110	Source of Data:	Alan Wanek
Completion Info:		Collapsed formation against 18 slot screen with air; sealed annulus with three bags of holeplug.	
Remarks:		South well (200 ft South of cbaa2), location is south of corner of road going into the city well field.	
Plugging Info:		The observation well was plugged on May 31, 2000. A three-feet deep hole was dug around the casing. The casing was cut off and a coupling attached. Two bags of cement mixed with 10 gallons of water were poured into the well. The casing was topped off with bentonite chips and capped. The location was restored.	

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-3	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, silty till)
3-12	SAND & GRAVEL	Well graded (oxidized)
12-25	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
25-30	CLAY	Olive gray, 30%, with silt, sand, & gravel (sandy till)
30-33	SAND & GRAVEL	30% gravel, well graded, primarily silicates and carbonates
33-38	CLAY	Olive gray, as above (sandy till), interbedded with lenses of sand and gravel
38-51	CLAY	Olive gray, with silt, sand & gravel (sandy till)
51-64	SAND & GRAVEL	20% gravel, carbonates, silicates, lignite, loose, running into drilled hole, taking water
64-104	CLAY	Olive gray, 30% with silt, sand & gravel (argillaceous till)
104-120	SAND	Medium grained to fine grained, moderate sorting, abundant lignite
120-144	CLAY	Olive gray, 30% with silt, sand, and gravel (till, as above)
144-160	CLAY	Olive gray, silty

163-101-35CBAD
NDSWC 13809

Date Completed: 7/14/98 Purpose: Test Hole
L.S. Elevation (ft): 2293
Depth Drilled (ft): 140 Source of Data: Alan Wanek

Completion Info: Sealed test hole with three bags of holeplug.

Remarks: Location is along the east side of the trail to the city well field, 200 feet south of CBAA3 well.

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-29	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
29-44	CLAY	Olive gray, 30%, with silt, sand & gravel (sandy till)
44-56	SAND	Fine grained, silty, argillaceous
56-140	CLAY	Olive gray, 30%, with silt, sand, & gravel (sandy till), sand lens at 123-126

163-101-35CBB
NDSWC 3075

Date Completed:	10/9/63	Purpose:	Obs. Well - Plugged
L.S. Elevation (ft):	2265	Well Type:	1.25in. - PVC
Depth Drilled (ft):	665	Aquifer:	NE Missouri Buried
SI (ft.):	225-240	Source of Data:	Channel Roger Schmid
Completion Info:	15 feet of rigid plastic pipe was perforated		
Remarks:	Located east of section line and south of quarter line		

Lithologic Log

Depth (ft)	Unit	Description
0-32	CLAY	Moderately yellowish brown, clay through gravel, sandy, cohesive, unsorted, abundant limestone, calcareous, oxidized (oxidized till)
32-47	CLAY	Olive gray, clay through gravel, very cohesive, unsorted, shale, limestone, granite and lignite, calcareous (till)
47-74	SAND	Very fine to medium grained, coarser first few feet, silty below 76 feet, abundant subrounded quartz, some limestone, granite, lignite and shale, clay lens 74-76
90-100	GRAVEL	Medium sand through large pebble, limestone, quartz, granite, lignite, unsorted, varied composition subangular to rounded, clay lenses in lower half
100-160	SAND	Very fine to coarse, quartz, lignite and limestone, with olive gray silty clay lenses
160-190	SILT	Olive gray, clayey, some sand and detrital lignite
190-204	CLAY	Olive gray, clay through gravel, shale limestone quartz and lignite fragments, (a few sand lenses), calcareous, (till)
204-212	SAND	Very fine sand to small pebbles, unsorted, varied composition, limestone, granite, quartz, etc., subangular-subrounded
212-222	CLAY	As above, (till)
222-248	SAND	Sand, fine to very coarse, with a few very angular chips from larger pebbles to boulders, limestone, quartz, granite, etc., generally subrounded
248-638	CLAY	Olive gray, clay through gravel, shale limestone, quartz, granite and lignite, unsorted, cohesive, granite boulder at 384, less gravelly to 500, more gravelly from 565, greenish granite boulder at about 585, (till)
638-665	SILT	Light olive gray (lighter than the till), clay and some very fine sand, some black and green specks, highly calcareous, drills smooth, at 665 feet is limestone, very highly calcareous, light gray, very well indurated, drills very hard (bedrock)

163-101-35CBB2
City of Fortuna

Date Completed: 12/10/76 Purpose: Test Hole
L.S. Elevation (ft): 2290
Depth Drilled (ft): 230 Source of Data: MonDak Drilling

Completion Info:

Remarks:

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-40	CLAY	Yellow (till)
40-46	GRAVEL	Sandy
46-52	CLAY	Sandy
52-67	CLAY	Gray, sandy, lignite at 64 feet
67-96	SAND	With lignite
96-101	CLAY	
101-109	SAND	With abundant lignite
109-116	SAND & GRAVEL	Primarily shale
116-144	CLAY	Sandy
144-184	CLAY	Blue
184-188	SAND & GRAVEL	
188-191	SAND	Primarily lignite
191-196	CLAY	Sandy
196-230	CLAY	Blue

163-101-35CBB3

City of Fortuna

Date Completed:	12/19/97	Purpose:	Test well, removed
L.S. Elevation (ft):	2290	Well Type:	5 in. - PVC
Depth Drilled (ft):	360	Aquifer:	Undefined
SI (ft.):	177-187	Source of Data:	Leo Grossman - Agri Industries, Inc.

Completion Info: Set 5 inch diameter stainless steel, 20 slot screen; recorded a static water level of 102.2 feet and a pumping water level of 153.2 feet after two hours at 5 gpm. Following pumping the casing and screen was withdrawn and the hole filled.

Remarks:**Lithologic Log**

Depth (ft)	Unit	Description
0-23	CLAY	Yellow
23-98	CLAY	Gray (till), fine sand lens 37-38
98-108	SAND	Fine grained
108-177.5	CLAY	Gray (till)
177.5-187	SAND & GRAVEL	Medium
187-220	CLAY	Gray (till)
220-232	CLAY	Gray, sandy, silty
232-360	CLAY	Gray

163-101-35CBBC1
NDSWC 13800A

Date Completed:	6/22/98	Purpose:	Obs. Well - Plugged
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	300	Aquifer:	Undefined
SI (ft.):	220-225	Source of Data:	Steve Pusc
Completion Info:		18 slot PVC screen, 11 bags of no. 10 sand, sealed annulus with 4 bags of grout, plus holeplug	
Remarks:	Location is a few feet southwest of the city water tank, in the ditch		
Plugging Info:	The observation well was plugged on May 31, 2000. A three-feet deep hole was dug around the casing. The casing was cut off and a coupling attached. Two bags of quickcrete, a sand and cement powder mix, were poured into open annular space between the well casing and the wall of the drilled hole. Six bags of cement were mixed with water were poured into the well. The casing was capped. The location was restored.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-33	CLAY	Yellowish brown, iron stained, silty, sandy with pebbles (oxidized till)
33-74	CLAY	Olive gray, silty, sandy, with pebbles (till), sand lens 41-42
74-88	SAND	Very fine to medium grained, drills smooth, takes a little water
88-111	CLAY	Olive gray, very silty, detrital lignite, interbedded with fine sand
111-205	CLAY	Olive gray, silty, sandy, with pebbles (till), interbedded with sand and silty clay
205-229	SAND & GRAVEL	And detrital lignite (50-60%), drills choppy, takes very little water, poor returns
229-244	CLAY	Olive gray, silty, sandy, with pebbles (till)
244-260	SAND & GRAVEL	With lignite, poor returns, drills choppy, may be interbedded with clay
260-283	CLAY	Olive gray, silty, sandy
283-300	CLAY	Olive gray, silty, sandy, with pebbles, rocky (till)

163-101-35CBBC2
NDSWC 13800B

Date Completed: 6/23/98 Purpose: Test Hole
L.S. Elevation (ft): 2300
Depth Drilled (ft): 100

Completion Info: Test hole plugged with granular bentonite (holeplug)

Remarks: Located near city water tank, north of 35CBBC1

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-33	CLAY	Yellowish brown, iron stained, silty, sandy, with pebbles, (oxidized till)
33-74	CLAY	Olive gray, silty, sandy, with pebbles, occasional rock, sand from 41-42, (till)
74-88	CLAY	Gray, very sandy
88-100	CLAY	Olive gray, very silty, detrital lignite, interbedded with fine sand

163-101-35CBC
City of Fortuna

Date Completed: 1964 Purpose: Test Hole
L.S. Elevation (ft): 2295
Depth Drilled (ft): 120 Source of Data: Tony Mann

Completion Info: Hole plugged

Remarks: Village of Fortuna, test 6

Lithologic Log

Depth (ft)	Unit	Description
0-42	CLAY	(Till)
42-44	GRAVEL	
44-52	CLAY	(Till)
52-73	GRAVEL	With layers of clay
73-80	CLAY	(Till)
80-107	SAND	
107-120	CLAY	(Till)

163-101-35CBD1
City of Fortuna

Date Completed:	12/14/97	Purpose:	Municipal Well
L.S. Elevation (ft):	2295	Well Type:	5in. - PVC
Depth Drilled (ft):	280	Aquifer:	Undefined
SI (ft.):	235-255	Source of Data:	Leo Grossman
Completion Info:	5 inch diameter, 18 slot stainless steel screen, static water level reported at 237.5 feet with a 250.1 water level after 12 hours pumping at 5 gpm, casing and screen (?) later removed and hole filled		
Remarks:	Called December well, located along northern side of old city well field, 55 feet north and 65 feet west of the well house		

Lithologic Log

Depth (ft)	Unit	Description
0-26	CLAY	Yellow, sand lens at 23-24 feet
26-54	CLAY	Gray, (till)
54-68	SAND & GRAVEL	And fine sand
68-160	CLAY	Gray (till)
160-172	SAND	Fine to medium grained
172-216	CLAY	Gray (till)
216-268	SAND & GRAVEL	Medium to fine, tight drilling
268-280	CLAY	Gray

163-101-35CCA1
NDSWC 13798A

Date Completed:	6/16/98	Purpose:	Observation Well
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	237	Aquifer:	Undefined
SI (ft.):	176-181	Source of Data:	Steve Pusc
Completion Info: 18 slot PVC screen sand packed with 5 bags of no. 10 sand, grout and hole plug opposite casing.			
Remarks:	Southeast well of pair, 480 feet south and 230 feet west of August well, near gravel pit, access location from city well area to the north		

Lithologic Log

Depth (ft)	Unit	Description
0-12	GRAVEL	Sandy, very coarse gravel to coarse sand, (oxidized)
12-16	CLAY	Yellowish brown, silty sand with pebbles
16-34	CLAY	Olive gray, silty, sandy
34-40	SAND	Very fine to medium grained, some lignite
40-83	CLAY	Olive gray, sandy, interbedded with sand, silty, takes little water, drills fast
83-88	SAND & GRAVEL	Medium sand to coarse gravel
88-93	CLAY	Gray, silty, drills smooth
93-97	SAND & GRAVEL	Medium sand to fine gravel, drills choppy
97-107	CLAY	Gray, sandy (till)
107-112	SAND & GRAVEL	Medium sand to fine gravel, with lignite
112-169	CLAY	Olive gray, silty, sand lens 135-137, sand and gravel lens 146-149, sand lens 150-154, sand lens 157-159
169-181	SAND & GRAVEL	Medium sand to gravel, lignite
181-224	CLAY	Olive gray, drills smooth
224-230	SAND & GRAVEL	Fine sand to medium gravel, shales, lignite, granite & carbonates
230-237	GRAVEL	Rocks, rough drilling, broke rock bit, hole ended in rocks

163-101-35CCA2
NDSWC 13798B

Date Completed:	6/17/98	Purpose:	Observation Well
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	270	Aquifer:	Undefined
SI (ft.):	245-250	Source of Data:	Steve Pusc
Completion Info:	18 slot PVC screen, 8 bags of no. 10 sand, sealed annulus with 5 bags of grout, 8 bags of holeplug		
Remarks:	Northwest well of pair, 475 feet south and 250 feet west of August well, near gravel pit, access location from city well area to the north		

Lithologic Log

Depth (ft)	Unit	Description
0-10	GRAVEL	Yellowish brownish red stained, sandy, (oxidized)
10-16	CLAY	Yellowish brown, iron stained, (oxidized)
16-132	CLAY	Olive gray, silty sandy with pebbles (till), layers of gravel and sand from: 22-23, 26-28, 30-36, 41-46, 61-64, 69-71, 86-87, 112-113, 116-118, 121-125
132-140	SAND & GRAVEL	Medium sand to fine gravel
140-168	CLAY	Olive gray, silty, sandy (till)
168-185	SAND & GRAVEL	Medium to fine sand, carbonates, granites, shales, lignite
185-237	CLAY	Olive gray, silty, sandy (till), gravel lens 233-235
237-256	GRAVEL	Coarse to very coarse, rocky, carbonates, granites, shale, lignite, drills rough
256-270	CLAY	Olive gray, silty, sandy with pebbles, (till)

163-101-35CCAA
City of Fortuna

Date Completed:	Unknown	Purpose:	Municipal Well - Plugged
L.S. Elevation (ft):	2295	Well Type:	Unknown
Depth Drilled (ft):	28	Aquifer:	Undefined
SI (ft.):	?-28	Source of Data:	Divide Co. basic data
Completion Info:	Water level six feet below surface in 1964 (Divide Co. basic data); completed in sand and gravel, 36 inch casing pulled		
Remarks:	Village of Fortuna well 2, listed as 35CCA		

Lithologic Log

<u>Depth (ft)</u>	<u>Unit</u>	<u>Description</u>
No lithologic log available		

163-101-35CCB1
City of Fortuna

Date Completed:	1963	Purpose:	Test Well - plugged
L.S. Elevation (ft):	2300	Well Type:	4in. - Steel
Depth Drilled (ft):	120	Aquifer:	Undefined
SI (ft.):	Unknown	Source of Data:	Schnell
Completion Info:	Divide basic data lists a October 8, 1963 water level of 10.79 feet below surface.		
Remarks:	Village of Fortuna, test 5		

Lithologic Log

Depth (ft)	Unit	Description
0-3	GRAVEL	
3-15	CLAY	Brown (till)
15-20	CLAY	Gray (till)
20-24	CLAY	Sandy, (till)
24-65	CLAY	Gray (till)
65-110	SAND	Fine to medium grained, with lignite
110-120	CLAY	Gray (till)

163-101-35CCB2
City of Fortuna

Date Completed: 5/14/64 Purpose: Municipal Well
L.S. Elevation (ft): 2300 Well Type: 4in. - Steel
Depth Drilled (ft): 135 Aquifer: Undefined
SI (ft.): 96-106 Source of Data: Marvin Mann

Completion Info: 20 slot screen

Remarks: Village of Fortuna well 4; unused since about 1964, located near west section line, north of trail leading to farmstead farther east

Lithologic Log

Depth (ft)	Unit	Description
0-4	GRAVEL	
4-26	CLAY	(Till)
26-58	GRAVEL	With layers of clay
58-64	CLAY	(Till)
64-119	SAND	
119-135	CLAY	(Till)

163-101-35CCB3
NDSWC 13801A

Date Completed:	6/23/98	Purpose:	Test Hole
L.S. Elevation (ft):	2300		
Depth Drilled (ft):	260	Source of Data:	Steve Pusc
Completion Info:	Sealed test hole with three bags of holeplug		
Remarks:	Located near city well #4 well house		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-2	CLAY	(Oxidized till)
2-5	GRAVEL	Sandy, (oxidized)
5-88	CLAY	Olive gray, silty, sandy, with pebbles (till), lenses of sand and gravel from 60-64
88-100	GRAVEL	Sandy with clay layers
100-115	GRAVEL	Sandy well rounded to subrounded, with lignite, carbonate, granite
115-260	CLAY	Olive gray, silty, sandy, with pebbles (till), sand lenses in 150-159 interval

163-101-35CCB4
NDSWC 13801B

Date Completed:	6/23/98	Purpose:	Observation Well
L.S. Elevation (ft):	2300	Well Type:	2in. - PVC
Depth Drilled (ft):	120	Aquifer:	Undefined
SI (ft.):	105-110	Source of Data:	Steve Pusc
Completion Info:	18 slot PVC screen, sealed annulus with 4 bags of holeplug		
Remarks:	Located just northwest of the city well #4 well house. The well was pumped about four weeks at the city's approximate use rate (by suction), testing the location as a possible site for a municipal well.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-6	GRAVEL	Sandy, takes some water (oxidized)
6-12	CLAY	Yellowish brown, silty, sandy, with pebbles, rocky (till)
12-60	CLAY	Olive gray, silty, sandy, with pebbles (till)
60-110	SAND	Gravelly, medium grained sand to marble sized gravel, well rounded to subrounded, carbonates, shales, granites and detrital lignite, takes water, mixed mud.
110-120	CLAY	Olive gray, silty, sandy, with pebbles (till)

163-101-35CCBB
NDSWC 13814

Date Completed:	7/15/98	Purpose:	Test Hole
L.S. Elevation (ft):	2295		
Depth Drilled (ft):	140		
		Source of Data:	Alan Wanek
Completion Info:	Sealed test hole with six bags of holeplug.		
Remarks:	Located in ditch east of gravel road, 205 feet north of 35CCB4 obs well.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-6	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till), sand lens at 4-5 feet
6-14	SAND	Very coarse grained, some gravel
14-28	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
28-31	SAND & GRAVEL	
31-86	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), sand lenses at 41, 50, 55, 57, 66-68, 77, 79 feet
86-95	SAND	Very coarse grained, poor recovery, drills fast, smooth
95-104	CLAY	Olive gray, sand lens at 102 feet
104-112	SAND	coarse to medium grained, poor recovery
112-117	CLAY	Olive gray
117-120	SAND	Medium to coarse grained
120-128	SILT	Argillaceous
128-140	CLAY	Olive gray, 30%, with silt, sand, & gravel (sandy till)

163-101-35CCC1
NDSWC 13802A

Date Completed: 6/24/98 Purpose: Test Hole
L.S. Elevation (ft): 2290
Depth Drilled (ft): 260 Source of Data: Steve Pusc

Completion Info: Plugged test hole with five bags of holeplug

Remarks: Located in ditch east of road about 300 feet south of farmstead road, northwest of slough

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-28	CLAY	Yellowish brown, silty, very sandy with pebbles (oxidized till)
28-103	CLAY	Olive gray, silty, sandy, with pebbles (till), a few interbedded lenses of sand and gravel
103-127	SAND	Fine to coarse, some fine gravel, detrital lignite, does not take much water
127-134	CLAY	Interbedded with gravel
134-260	CLAY	Olive gray, silty, sandy, with pebbles (till)

163-101-35CCC2
NDSWC 13802B

Date Completed: 6/24/98 Purpose: Test Hole
L.S. Elevation (ft): 2290
Depth Drilled (ft): 150 Source of Data: Steve Pusc

Completion Info: Nine bags of holeplug

Remarks: Located about 300 feet south of road to farmstead, ditch east of road

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-29	CLAY	(Oxidized till)
29-127	CLAY	Olive gray, silty, sandy, with pebbles (till)
127-140	SAND	With detrital lignite and clay layers
140-150	CLAY	Olive gray, silty, sandy, with pebbles (till)

163-101-35CCD
NDSWC 13803

Date Completed: 6/24/98 Purpose: Test Hole
L.S. Elevation (ft): 2285
Depth Drilled (ft): 200 Source of Data: Steve Pusc

Completion Info: Sealed test hole with four bags of holeplug

Remarks: Located north of road going into farmstead, just east of slough,
about 1/8 mile east of section line

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-17	CLAY	Yellowish brown, silty, sandy, with pebbles (oxidized till)
17-46	CLAY	Olive gray, silty, sandy, with pebbles (till)
46-56	GRAVEL	Sandy, interbedded with clay
56-173	CLAY	Olive gray, silty, sandy, with pebbles (till), layers of gravel from 127-128, 147-152, 166-172
173-176	SAND	Gravelly
176-200	CLAY	Olive gray, silty, sandy, with pebbles (till)

163-101-35DCB
NDSWC 13805

Date Completed:	6/25/98	Purpose:	Observation Well
L.S. Elevation (ft):	2298	Well Type:	2in. - PVC
Depth Drilled (ft):	200	Aquifer:	Undefined
SI (ft.):	159.5-164.5	Source of Data:	Steve Pusc
Completion Info:	18 slot PVC screen, sealed annulus with 2 bags of holeplug		
Remarks:	Located along fence, nine feet east of the center of the quarter line trail and 34 feet south of the fence marking the app. 1/4 1/4 line.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-3	GRAVEL	Sandy, (oxidized)
3-27	CLAY	Yellowish brown, silty, sandy with rocks (oxidized till)
27-30	SAND	Fine grained
30-33	CLAY	Olive gray, silty, sandy, with pebbles (till)
33-40	SAND	Gravelly, medium sand to fine gravel
40-60	CLAY	Olive gray, silty, sandy, with pebbles, interbedded gravel layers (till)
60-65	SAND	Fine to coarse grained
65-81	CLAY	Olive gray, silty, sandy, with pebbles (till)
81-92	SAND	Fine to very coarse grained, gravelly
92-154	CLAY	Olive gray, silty, sandy, with pebbles (till), some interbedded gravel lens
154-169	SAND & GRAVEL	Fine sand to fine gravel, granite, carbonate lignite
169-185	CLAY	Olive gray, silty, sandy, with pebbles (till), interbedded gravel lens
185-190	CLAY	Olive gray, silty, sandy, with pebbles (till), more interbedded gravel lenses
190-200	CLAY	Olive gray, silty, sandy, with pebbles (till)

163-101-35DCC1
NDSWC 13812

Date Completed:	7/15/98	Purpose:	Test Hole
L.S. Elevation (ft):	2305		
Depth Drilled (ft):	260	Source of Data:	Alan Wanek
Completion Info:		Test hole plugged	
Remarks:	Located along edge of field on east side of undeveloped quarter line, 245 feet north of section line (trail center), 260 feet north of 2ABB2 well.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-24	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
24-45	CLAY	Olive gray, 30%, with silt, sand & gravel (sandy till)
45-65	SAND	Fine grained, well sorted
65-141	CLAY	Olive gray, as above (sandy till), sand lens at 101-103, siltier from 120 feet
141-151	SAND	Medium grained
151-157	SAND	Very coarse grained, carbonates, silicates, lignite
157-161	SILT	Argillaceous, sandy
161-170	SAND	As above, clay at 165 feet
170-175	CLAY	Olive gray
175-184	SAND & GRAVEL	30% gravel, carbonates, silicates, lignite, drills choppy, does not take much water
184-190	CLAY	Olive gray
190-213	SAND & GRAVEL	60% gravel, carbonates, silicates, lignite, angular to subangular, takes little or no water, drills rough, clay at 204-206
213-260	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), rocks at 226-229

163-101-35DCC2
NDSWC 13813

Date Completed:	7/15/98	Purpose:	Test Hole
L.S. Elevation (ft):	2298		
Depth Drilled (ft):	180	Source of Data:	Alan Wanek
Completion Info:	Sealed test hole with seven bags of holeplug.		
Remarks:	Located 40 feet north of a trail near where the trail curves south around a slough, 160 feet north northeast of 2ABB1 obs well.		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-26	CLAY	Dark yellowish brown, 30%, with silt, sand, and gravel (oxidized, sandy till)
26-60	CLAY	Olive gray, 30%, with silt, sand & gravel (sandy, silty till)
60-150	SILT	Olive gray, argillaceous, sandy (silty till?), sand lens at 102, 105, 121-123, 131, 141, 144, 146, rock at 149, siltier from 95 feet
150-162	CLAY	Olive gray, 30%, with silt, sand, and gravel (sandy till), rock at 160 feet
162-163	SAND & GRAVEL	
163-164	CLAY	Olive gray
164-167	SAND & GRAVEL	
167-180	CLAY	Olive gray, with silt, sand, & gravel (sandy till), rocks at 226-229

163-101-35DDA
NDSWC 13806

Date Completed: 6/25/98 Purpose: Obs. Well - Plugged
L.S. Elevation (ft): 2310 Well Type: 2in. - PVC
Depth Drilled (ft): 180 Aquifer: Undefined
SI (ft.): 138-143 Source of Data: Steve Pusc

Completion Info: 18 slot PVC screen, sealed annular space with 3 bags of holeplug

Remarks: Located south of 1/4 mile east-west fence, east side of north-south quarter line prairie trail

Plugging Info: The observation well was plugged on May 31, 2000. A 2.5-feet deep hole was dug around the casing. The casing was cut off and a coupling attached. Three bags of cement mixed with 15 gallons of water were poured into the well. The casing was topped off with bentonite chips and capped. The location was restored.

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-46	CLAY	Yellowish brown, iron stained, silty, sandy with pebbles and rocks (oxidized till)
46-113	CLAY	Olive gray, silty, sandy, with pebbles (till)
113-146	GRAVEL	Sandy, medium sand to gravel, carbonates, granites, shales, 10% lignite, drills fast, not taking much water
146-180	CLAY	Olive gray, silty, sandy, with pebbles and a few rocks (till)

163-101-36BCC
NDSWC 13807

Date Completed:	6/25/98	Purpose:	Test Hole
L.S. Elevation (ft):	2300		
Depth Drilled (ft):	240	Source of Data:	Steve Pusc
Completion Info:	Plugged test hole with granular bentonite (holeplug)		
Remarks:	Located south of farmstead and just southwest of rock pile, along prairie trail		

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	
1-25	CLAY	Silty, sandy, with pebbles (oxidized till)
25-86	CLAY	Olive gray, silty, very sandy, with pebbles (till)
86-93	SAND	Gravelly, medium to very coarse grained
93-97	CLAY	Olive gray, silty, sandy, with pebbles (till)
97-101	SAND	Fine to medium grained, poor returns
101-116	CLAY	Olive gray, silty, sandy, with pebbles (till)
116-120	SAND	Fine to medium grained, lignitic
120-125	CLAY	Olive gray, silty, drills smooth
125-137	CLAY	Olive gray, silty, sandy, with pebbles (till)
137-148	SAND	Fine to medium grained
148-193	CLAY	Olive gray, silty, sandy, with pebbles (till)
193-200	SAND & GRAVEL	Poor returns
200-209	CLAY	Olive gray, silty, sandy, with pebbles (till), gravelly 200-205
209-215	SAND & GRAVEL	Poor returns, not taking water
215-218	CLAY	Olive gray, silty, sandy, with pebbles (till)
218-223	GRAVEL	Rocky, poor returns
223-229	CLAY	Olive gray, silty, sandy, with pebbles (till)
229-235	SAND	Poor returns, not taking water
235-240	CLAY	Olive gray, silty, sandy, with pebbles (till)