
**INVESTIGATION TO IDENTIFY A WATER SUPPLY
FOR THE CITY OF WESTHOPE
BOTTINEAU COUNTY, NORTH DAKOTA**

by

Alan Wanek

**North Dakota Ground-Water Studies
Number 103
North Dakota State Water Commission
David Sprynczynatyk, State Engineer**

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



ND State Water Commission

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INTRODUCTION

Statement of the Problem

In a discussion on 1 April 1992 Ronald Manchester, Westhope city engineer, requested that the Water Commission investigate possible ground-water alternatives for a municipal water supply for the City of Westhope. Alternative water sources for the city are being explored 1) because of seasonal changes in water quality from the current surface water source and 2) because of anticipated more stringent water treatment requirements for municipal water supplies taken from surface sources.

A proposal and work plan for a ground-water investigation was submitted to Margo Helgerson, Mayor of Westhope, in a letter dated 3 June 1992. The proposal calls for exploratory drilling and aquifer analysis to the east of Westhope (fig. 1).

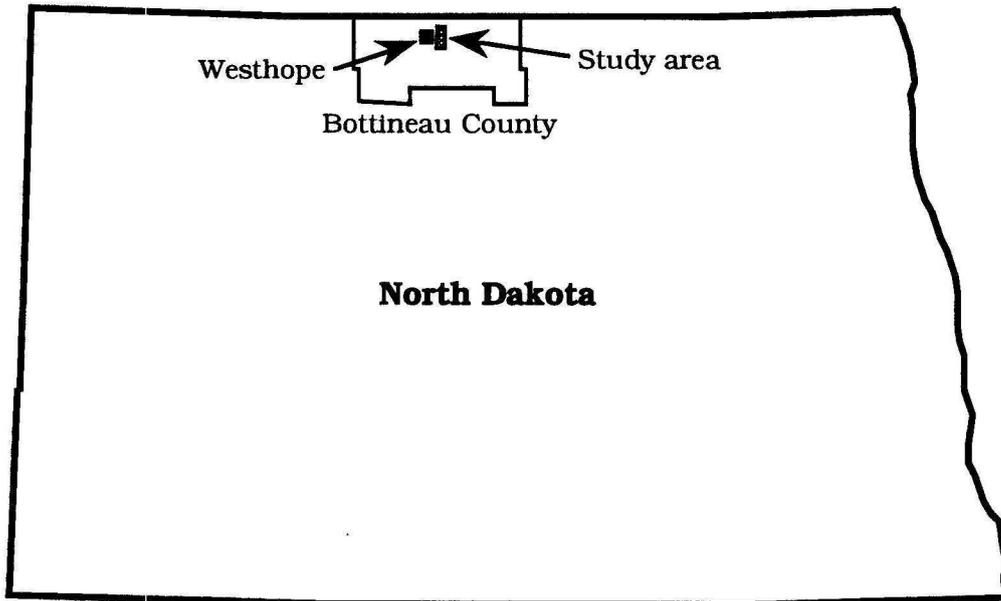


Figure 1 - Location of study area

An agreement between the city of Westhope and the North Dakota State Water Commission was signed by the Mayor of Westhope on 5 May 1993 and by the secretary of the North Dakota State Water Commission on 26 February 1993 . The agreement calls for the Water Commission to conduct an investigation to identify a

water source for the city. Costs of the study are to be paid jointly by the two parties. This report is in partial fulfillment of the agreement.

Study Areas

Two prospective ground-water sources at three locations were identified for further investigation (fig. 2):

- 1) An alluvial deposit along the west side of the Souris River valley, two miles east of Westhope in 163-79-30, along the east side of the municipal golf course,
- 2) A temporary channel of the Souris River, thought to be underlain by a buried channel deposit, in 163-79-29, and
- 3) A third location where the temporary channel joins the Souris River valley, in 162-79-5.

The study was undertaken to determine which, if any, of the prospective ground-water sources could meet the needs of the City of Westhope.

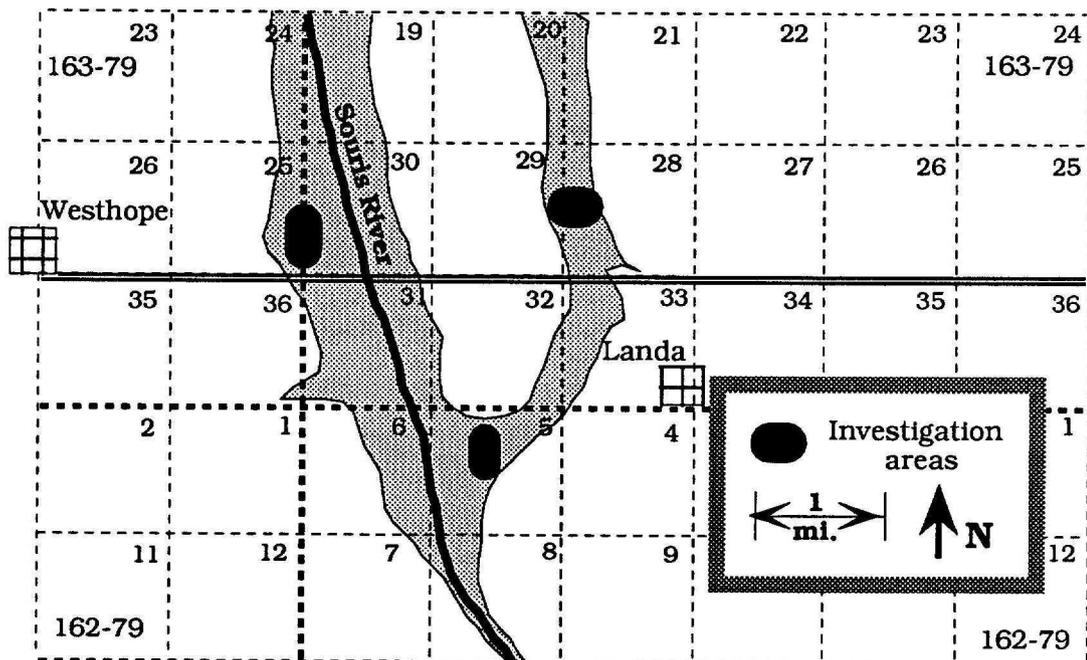


Figure 2 - Locations proposed for additional investigation

Previous Investigations

An unpublished water supply investigation for the City of Westhope was undertaken by C. A. Simpson & Son in 1953. Two test holes were drilled and one municipal well was installed. The test holes and well are located in 163-80-25CC, near an older city well, all in the vicinity of the Westhope cemetery, one mile east of Westhope.

A study of the geology and ground-water of the area, with emphasis on a possible city water source, was undertaken by J. E. Powell (1959). The study by Powell concentrated on the glacial drift section of sedimentary deposits located between Westhope and the Souris River 2 1/2 miles east of Westhope. Test drilling for the study took place in 1954.

An unpublished water supply investigation for the City of Westhope was undertaken by C. A. Simpson & Son in 1957 and 1958. Twenty-one test holes were drilled. Sixteen of the test holes were drilled within 300 feet of an "old well with hand pump," located along an east trending draw in 163-79-30CBCC, in a city park, now the site of the municipal golf course. Two test holes were located up to 1/4 mile west of the old well, upgradient along the draw. Two test holes were drilled farther west, in the direction of the old municipal wells near the city cemetery. The remaining test hole was drilled 1/4 mile south of the hand pump, near the section line road.

The geology of Bottineau County was described by Bluemle (1985) as part of the county ground-water studies program. Kuzniar and Randich (1982) compiled the ground-water data of Bottineau and Rolette Counties and Randich and Kuzniar (1984) described the ground-water resources of Bottineau and Rolette Counties.

An unpublished water supply investigation for the City of Westhope was undertaken by C. A. Simpson & Son in 1990. Three test holes were drilled and two monitoring wells installed. The two monitoring wells were installed along the east side of the municipal golf course in 163-79-30C. The test hole was drilled near the city water treatment plant in 163-80-36CCC.

An Investigation to identify a water supply for a rural water association in Bottineau County, North Dakota was undertaken by the author in 1991 and published as North Dakota Ground-water Studies Number 101 in 1993. The study included test drilling between Landa and where the Souris River enters Canada, searching for a buried valley found farther north in the Waskada oil field.

Westhope Municipal Water Source

Westhope currently obtains its municipal water supply from the Souris River 2 1/2 miles east of the city (fig. 3). The water intake is attached to a bridge which is part of a paved county road. A pipeline conveys water to a water treatment plant located on the west side of the Souris River valley, south of the paved county road. The water treatment plant has a water holding capacity of about 40,000 gallons. A holding pond near the treatment plant has a holding capacity of about 18,000,000 gallons (about a nine month supply for the city). The six inch diameter clay tile water delivery pipeline runs two miles into Westhope along the ditch of the paved road. The city water tower has a capacity of about 40,000 gallons. A cistern in Westhope has a similar capacity.

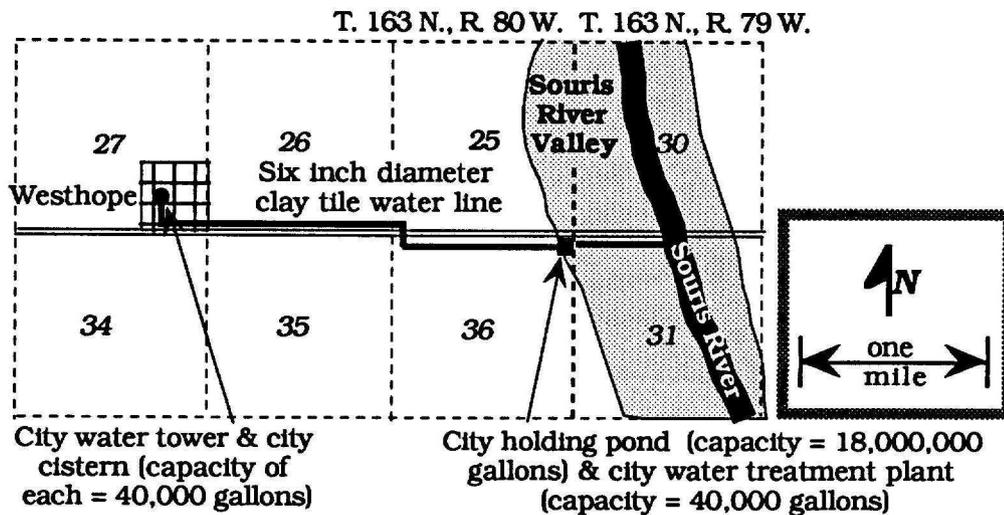


Figure 3 - Westhope municipal water delivery system

Westhope Reported Municipal Water Use

The city of Westhope's water permit #649, granted on 23 September 1955, allows 678.9 acre-feet of water per year to be withdrawn for municipal purposes, from the Souris River at 163-79-30CA, along the paved county road. Water use under the permit has been reported as shown in figure 4.

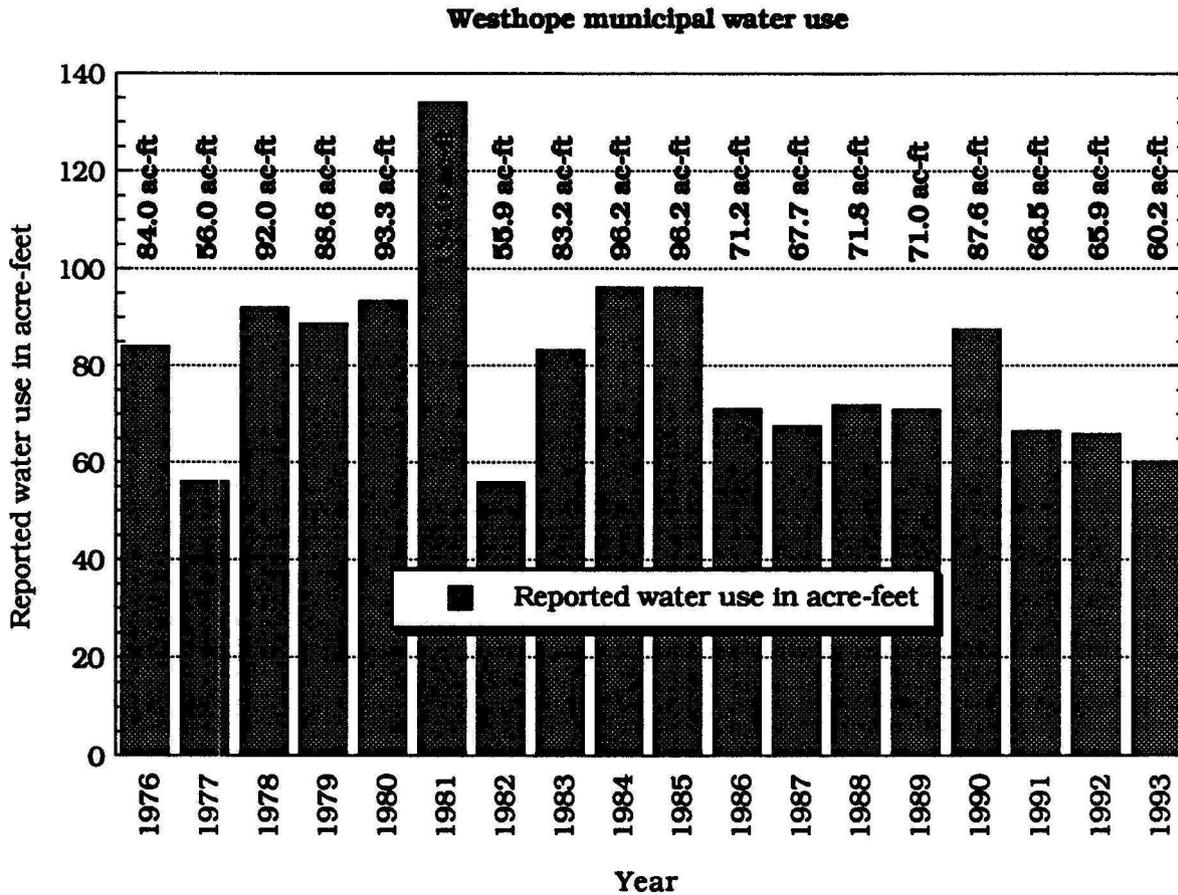


Figure 4 - Reported municipal water use by the City of Westhope

The city's 1990 census population is 578, down 22% from the 1980 census population of 742. The city currently reports serving 585 people at 200 hookups. The average daily use per person over the past three years is 98 gallons per day per person. The maximum reported monthly water use in recent years was 3,499,000 gallons in August 1990 (an average of 113,000 gallons per day - 78.4 gpm at constant pumping). The maximum daily water use according to city water superintendent, Gary Gullicks is about 170,000 gallons (118 gpm constant pumping).

Field Methods

As part of this investigation, 36 test holes were drilled totaling 4740 feet of drilling, using a forward, mud-rotary drilling rig. Test holes were drilled through alluvial or glacial drift sediments until the underlying bedrock of the Fox Hills Formation was encountered.

Ten monitoring wells were installed using two-inch diameter, polyvinyl chloride (PVC) casing and five feet of slotted PVC screen for each well. The monitoring wells were developed by collapsing *in situ* sand and gravel against the screen. The annular space between the casing and the wall of the drilled hole was filled with granular bentonite and drill cuttings. Mean sea level elevations of the monitoring wells were determined by third order differential leveling. Water levels in the wells were measured using a chalked steel 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.

Water samples were collected from the monitoring wells and from an older city monitoring well, completed in 1990 by C. A. Simpson & Son, to determine the quality of the water. The samples were analyzed for common ions and for selected metallic elements. The analyses were performed by the North Dakota State Water Commission Laboratory.

Location-Numbering System

The number and letter designation used to describe the location of a monitoring well or test hole is based upon the federal system of rectangular surveys of public land, the township and range system, (fig. 5). In the designation, 163-79-3ABC, the first number is the township north of a base line, the second number is the range west of the fifth principal meridian, and the third number is the section in which the well is located. The first letter is the quarter section, the second letter is the quarter-quarter section, and the third letter 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.

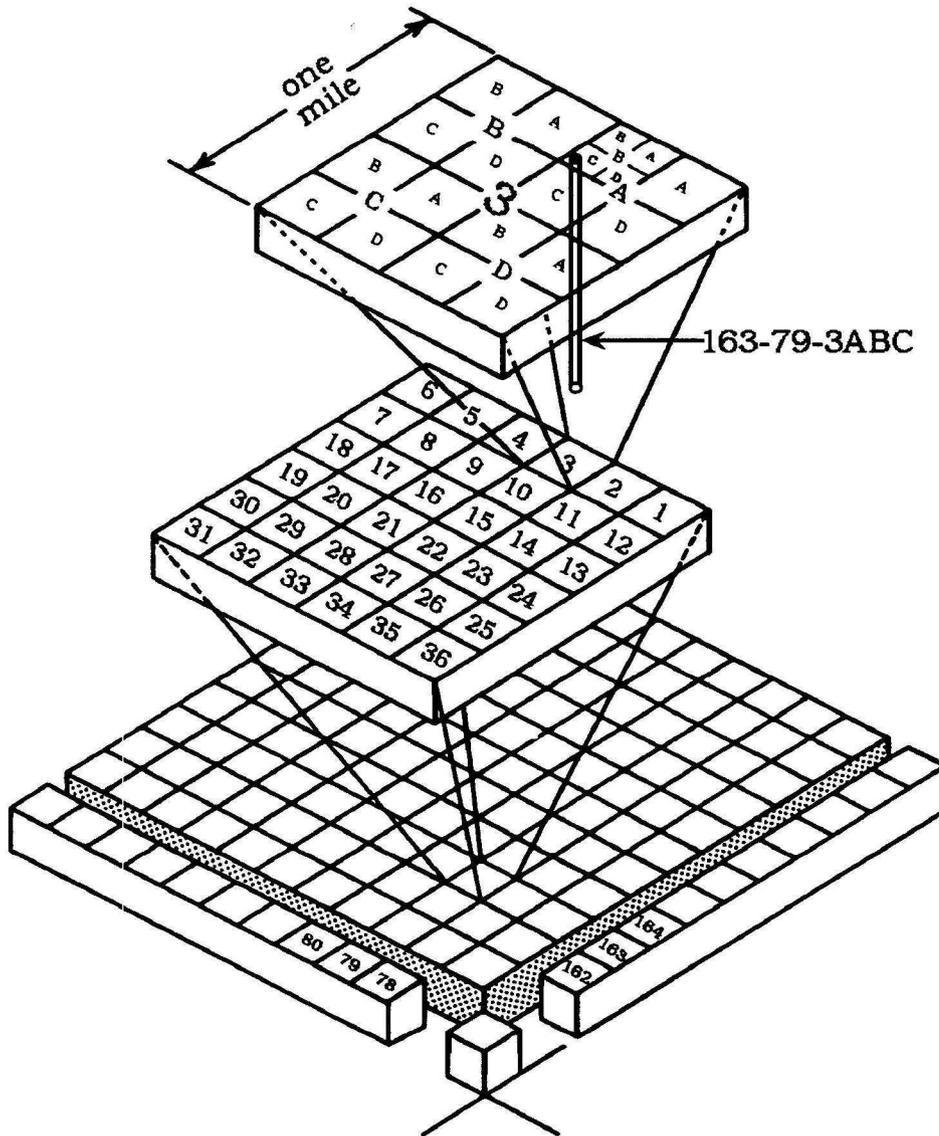


Figure 5 - Location-numbering system

GEOLOGIC SETTING

Westhope is located near the center of glacial Lake Souris. About 12,000 to 11,000 years ago a catastrophic flood is thought to have flowed from glacial Lake Regina into glacial Lake Souris. Glacial Lake Souris filled and overflowed north into glacial Lake Hind, cutting a river channel through the glacial drift sediments. Drainage in the Westhope area after the glacial lake drained is thought to have continued to follow the approximate northerly course established by the catastrophic flood.

Land surface in the Westhope area is covered with wave washed glacial till. Generally speaking, the area is underlain by between 100 and 200 feet of till. Two miles east of Westhope the Souris River valley is incised about 60 feet into the surrounding landscape. Four miles east of Westhope an abandoned, north-south trending river channel is incised about 25 feet into the landscape. The abandoned channel is probably a temporary course of the Souris River. Figure 7 is a west to east cross section between Westhope and the abandoned channel four miles east of Westhope which shows the types of sediments deposited in the glacial drift section near Westhope. The location of test holes used in constructing the cross section is shown in figure 6.

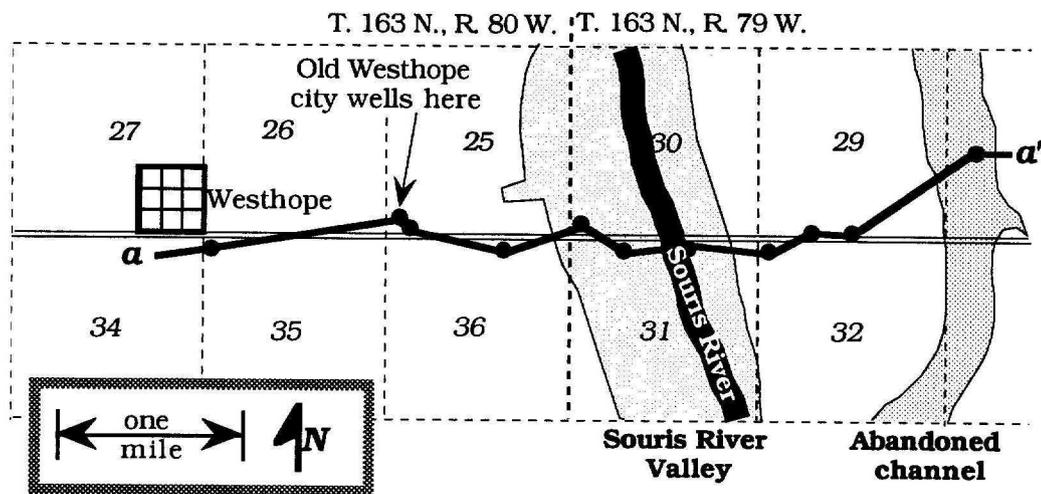


Figure 6 - Location of section a - a'

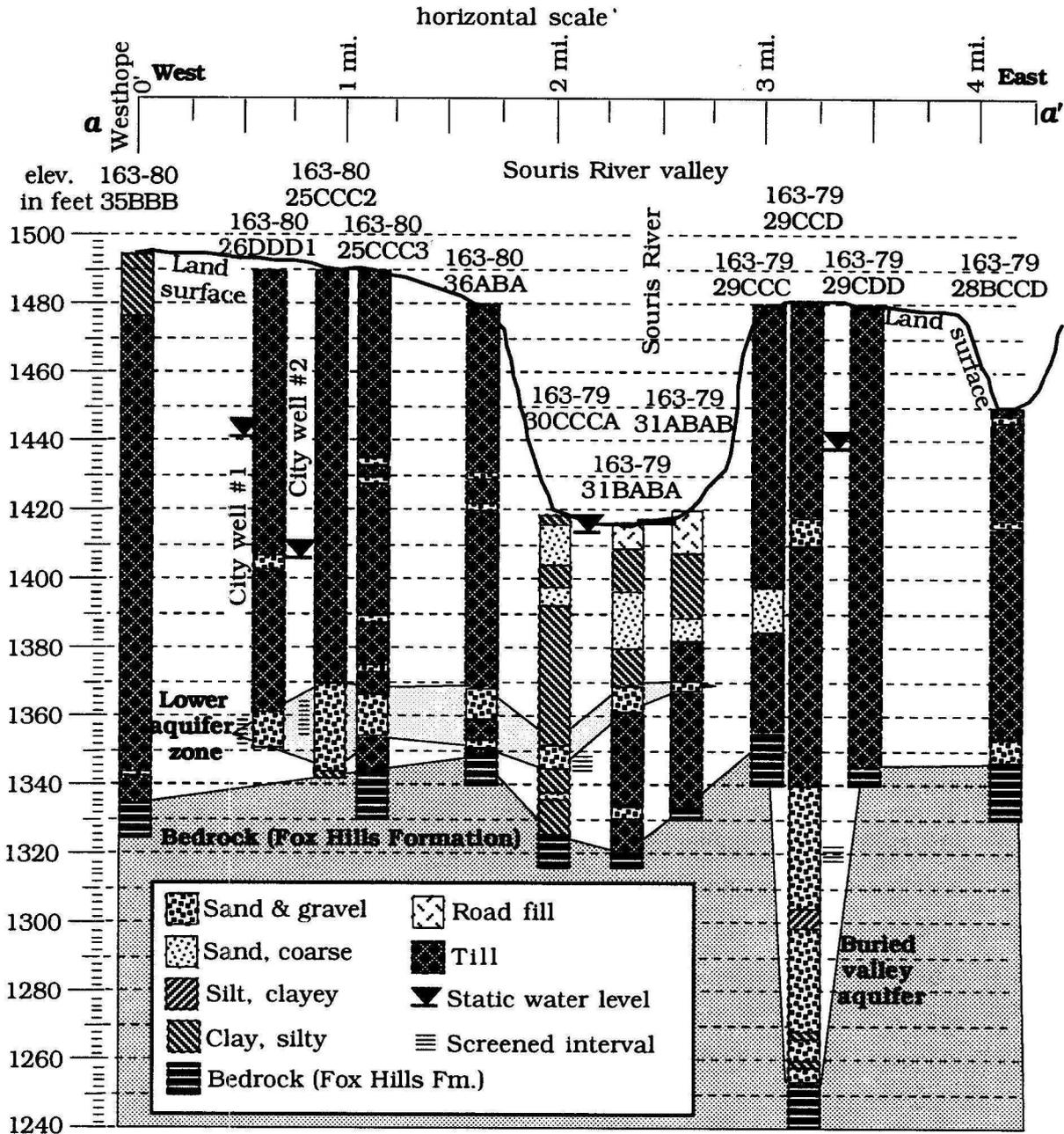


Figure 7 - Cross section a - a'

Test drilling for a municipal water source for Westhope has been undertaken by C. A. Simpson & Son in 1953, 1957-1958, and 1990 and by the State Water Commission in 1954 and 1993. Early drilling for a municipal water source in the 1953 - 1958 time period concentrated in the area generally between Westhope and the Souris River valley, including two municipal wells installed in 163-80-25CCC.

The locations of selected test holes and of the city wells are shown in figure 8, along with the sand and gravel thickness encountered.

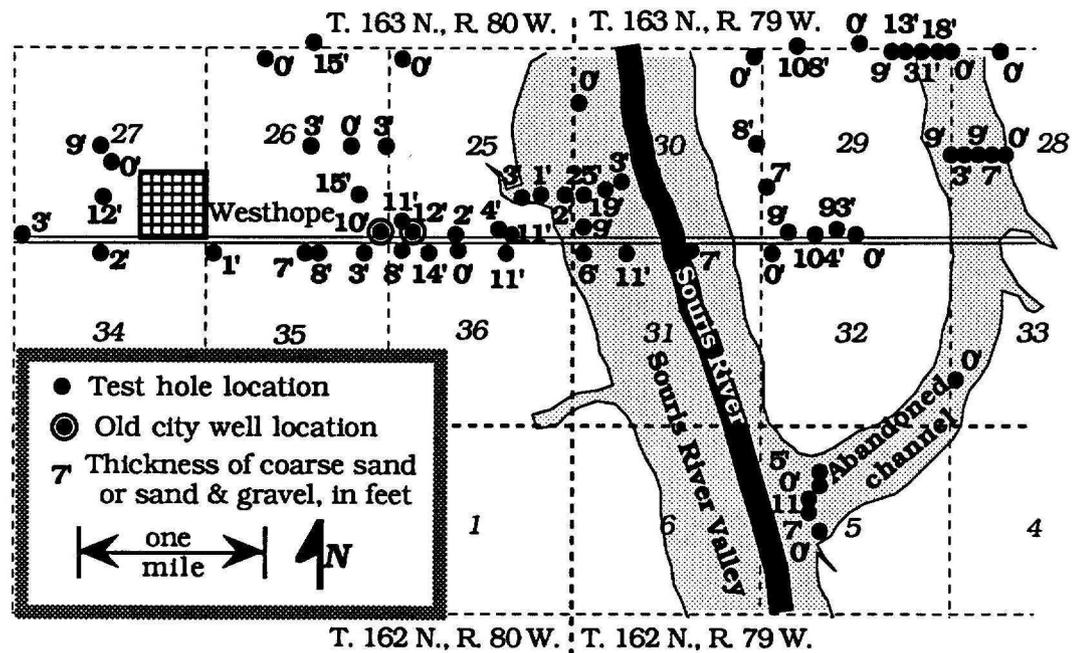


Figure 8 - Sand and gravel thickness, in feet

The first municipal well in 163-80-26DDD was constructed in 1946. The second municipal well in 163-80-25CCC was constructed in 1953, was located 500 feet east of the first city well, and was used until the city switched to the Souris River as a municipal source. Private wells located north and northeast of Westhope which are completed in a horizon of gravel about 1350-1360 feet above sea level, at about the same elevation as the city wells and which may comprise a hydraulically interconnected zone.

Geohydrology Along the West Side of the Souris River Valley

Sand and gravel underlying the floor of the Souris River valley forms an aquifer which is a potential municipal water source. The sand and gravel is

probably an alluvial sediment, deposited by the Souris River; although, an older, glacial origin is possible for the sand and gravel at about 70 feet depth.

The area along the west side of the Souris River valley, in 163-79-30CC (fig 9), was selected for further evaluation based in information available from earlier test drilling. The area has been previously investigated by the Water Commission and by C. A. Simpson & Son. Seven locations along the east side of the municipal golf course were drilled in 1993. Five monitoring wells were installed.

Most of the Souris River valley is no longer accessible to test drilling because of federal management of the land and because of a series of low head dams, filling the Souris River to bank full stage and making most of the valley floor too wet and soft for vehicular travel. Low head dam #357, on the Souris River five miles north of the Westhope municipal golf course, backs up water in the river channel beyond (south of) the golf course.

Two cross sections have been drawn to illustrate the nature of the sediments underlying the golf course. Section b-b' (fig. 10) is a south to north section from the ditch of the paved county road to the north boundary of the golf course. The cross section illustrates all seven test holes drilled in 1993, and two older test holes. The test holes were drilled about five feet west of the property line between the Westhope municipal golf course and the J. Clark Salyer National Wildlife Refuge, which occupies most of the Souris River valley near Westhope.

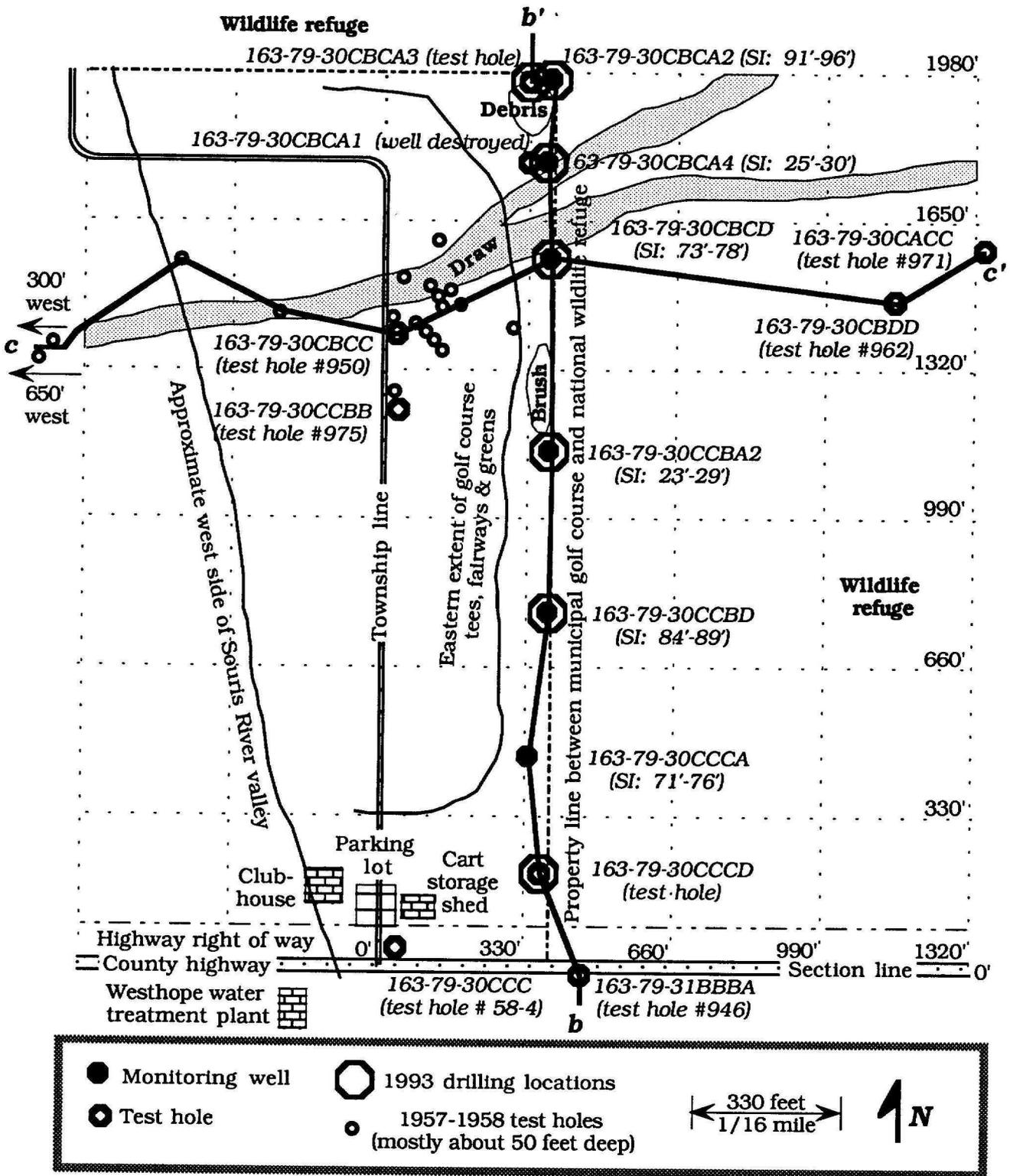


Figure 9 - Test hole locations near the Westhope municipal golf course

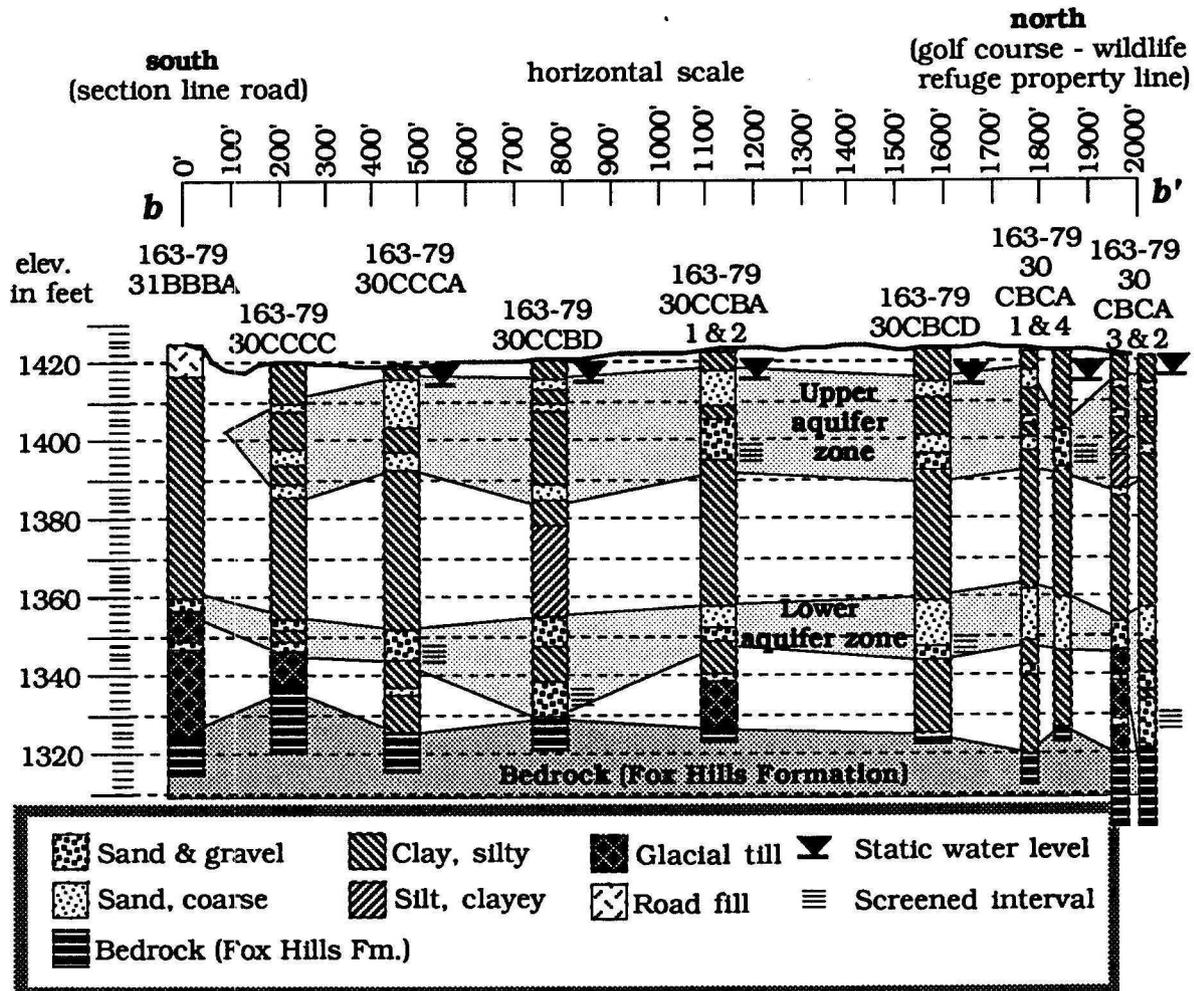


Figure 10 - South to north cross section along east side of the golf course

As a generalization, the b-b' cross section indicates the presence of a sand and gravel zone between about 5 and 30 feet depth (1415-1390 feet elevation) and a sand and gravel zone between about 60 and 80 feet depth (1360-1340 feet elevation). The two zones are composed of sand or gravel with interbedded lenses of silt and clay. The lower of the two sandy zones is commonly underlain with about 20 feet of glacial till, which is underlain by Fox Hills Formation bedrock.

The sand and gravel is composed of quartz, granite, and limestone, typical of rocks originating to the northeast on the Canadian shield, and also of shale, lignite, and sandstone, typical of rocks originating to the southwest. The glacial till is composed of approximately equal proportions of 1) sand and gravel, 2) silt, and 3) clay.

Cross section c-c' (fig. 11) is a west to east section trending about 1/4 mile north of the paved county road. The western half of the cross section, in 163-80-25, is comprised of test holes drilled along a tributary draw trending west from the Souris River valley. Little sand or gravel was found in the test holes along the draw.

The eastern half of the cross section is across the golf course and out onto the wildlife refuge in the Souris River valley, about half way to the Souris River. The eastern test holes were drilled in 1954 as part of an earlier Water Commission study. The 1954 test holes did not show a thickening of the sand and gravel portion of the alluvial fill in the central portion of the Souris River valley.

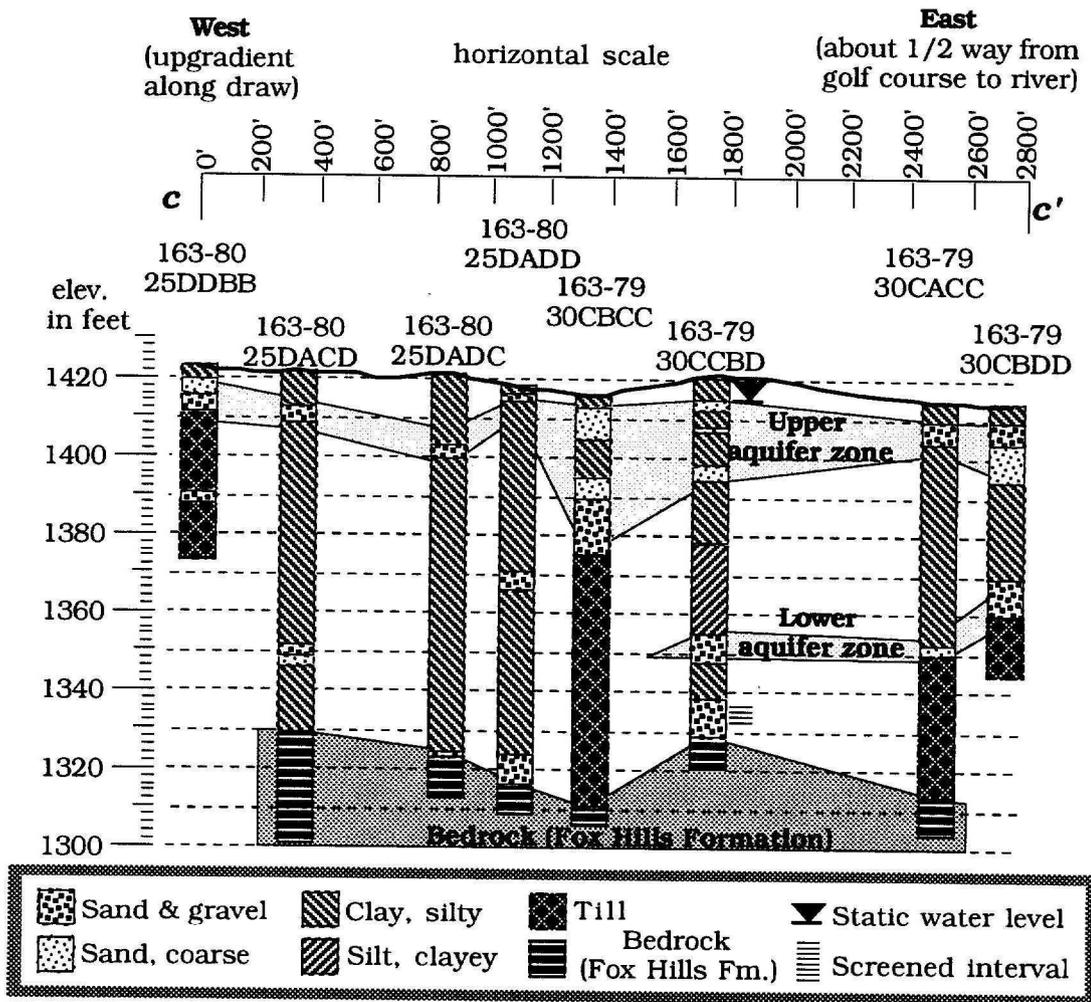


Figure 11 - West to east cross section through the municipal golf course

The lower aquifer zone, at an elevation of about 1340-1360 feet is at the same elevation and has a similar composition as sand and gravel found to the west, between Westhope and the Souris River valley. The lower aquifer zone may be hydrologically interconnected with the sand and gravel found to the west.

Although it may be hydrologically interconnected, the sand and gravel in the lower aquifer zone may well be a Souris River depositional sediment rather than a part of the sand and gravel deposit sometimes found between the glacial till and the underlying bedrock in the area between Westhope and the Souris River valley. The lower aquifer zone is overlain by silt and clay whereas the sand and gravel to the west is overlain by glacial till. The circa 1950 test drilling in the city park (now the golf course) did not encounter much sand and gravel in the 1360-1340 feet elevation interval.

Water Levels in the Souris River Valley Aquifers

Water levels in the Souris River valley aquifers were measured monthly between May 1993 and November 1993. The water levels are about seven feet below land surface.

Water-level elevations on 18 November 1993 in the lower alluvial aquifer near the Westhope municipal golf course are shown on the potentiometric surface map (fig. 12). The map indicates a north trending water table gradient of about one foot per mile near the north end of the golf course, flattening to about 0.1 foot per mile farther south.

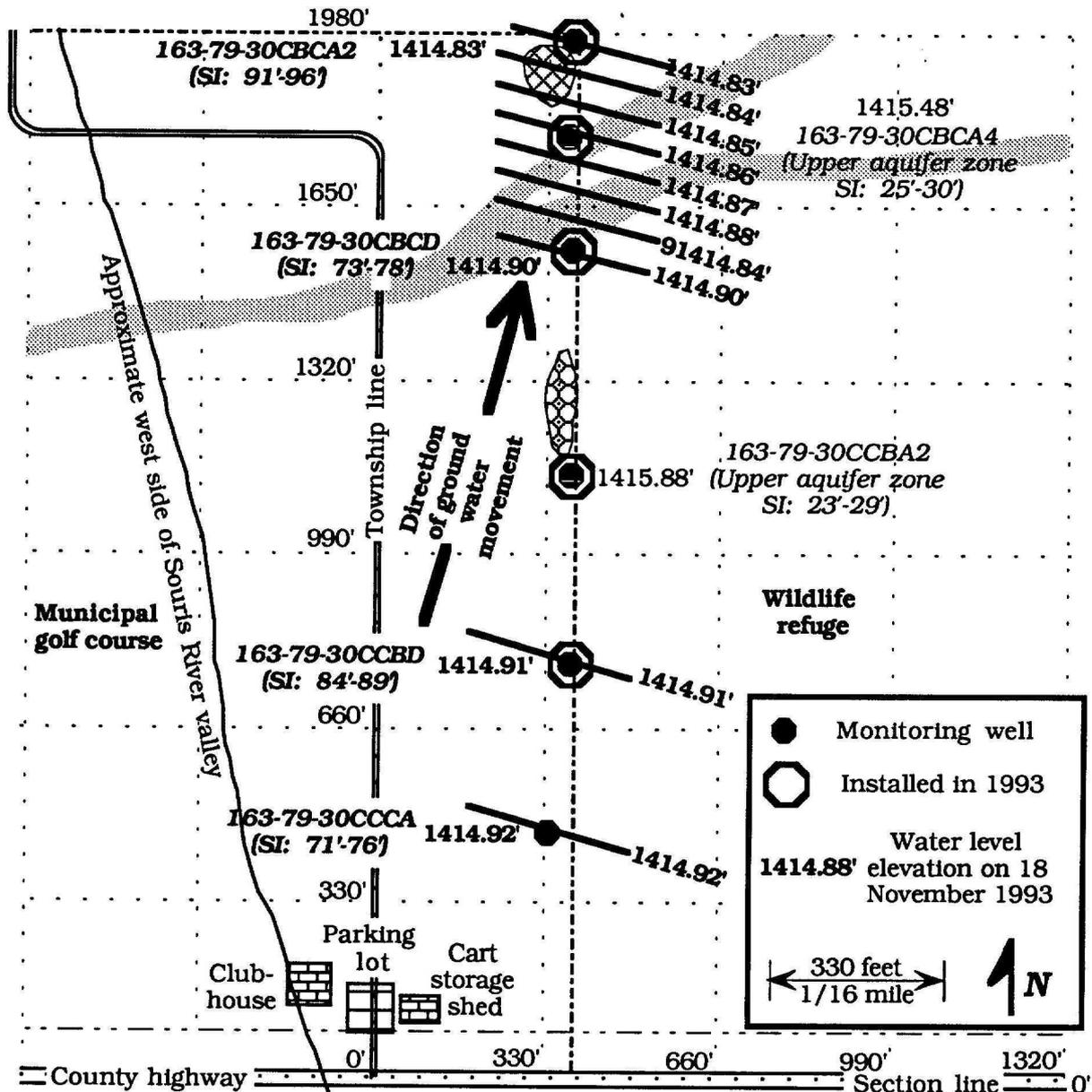


Figure 12 - Water-level elevations in the lower aquifer zone on 18 Nov. 1993

Water-level elevations on 18 November 1993 in the upper alluvial aquifer near the Westhope municipal golf course are shown on the water table map (fig. 13). The map indicates a north trending water table gradient of three feet per mile between the two wells completed in the upper alluvial aquifer. The water level in the shallow aquifer zone is about one foot higher than the water level in the lower aquifer zone.

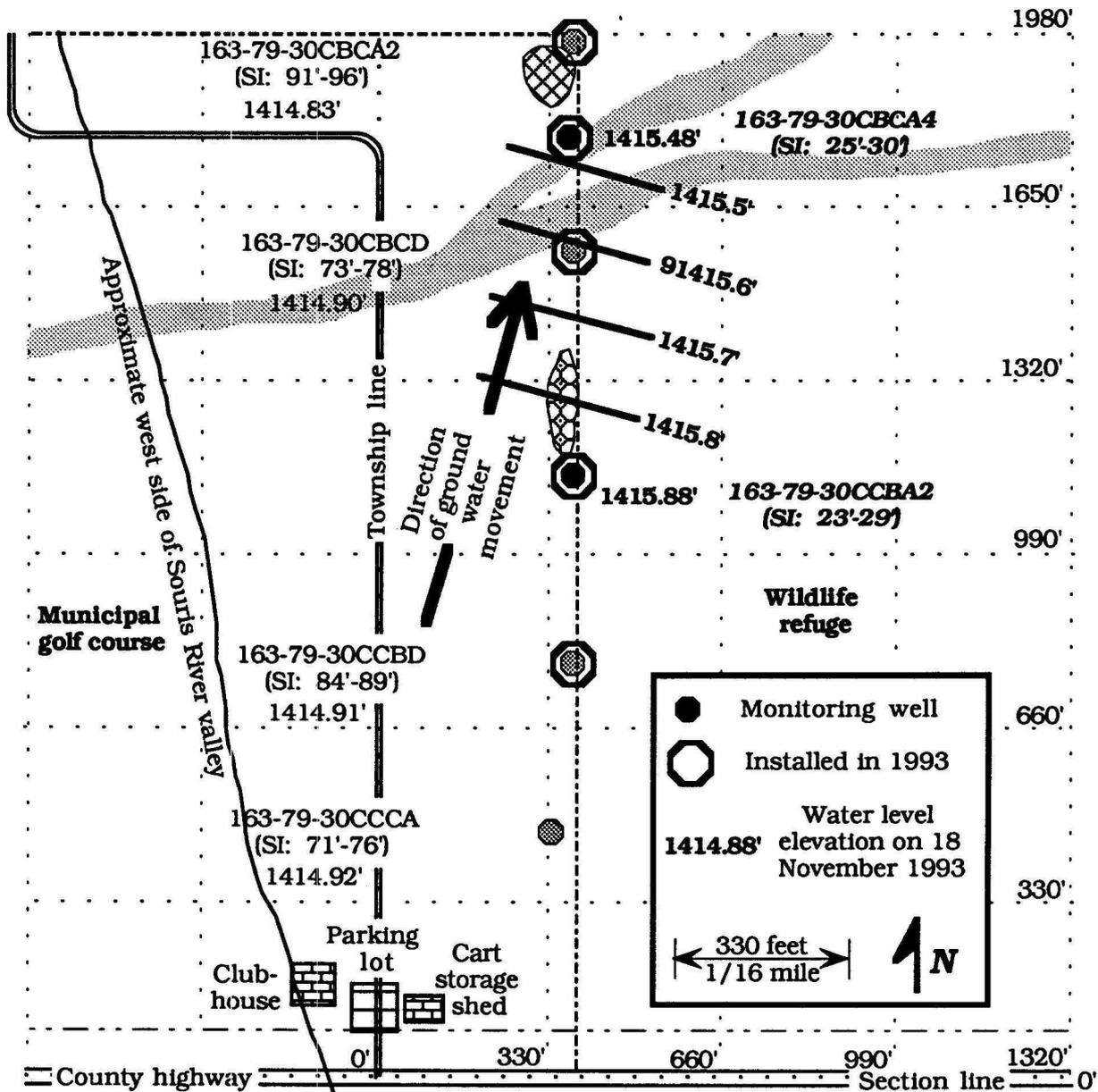


Figure 13 - Water-level elevations in the upper aquifer zone on 18 Nov. 1993

The water level elevations in the four wells completed in the lower aquifer zone are nearly the same (fig. 14). The water level in the lower aquifer has risen three feet in the past six months and the changes in each of the four wells is nearly the same. The two wells completed in the upper aquifer zone are also similar to one another, although the water level in the wells has only increased about 0.7 feet over the same six month period.

The Souris River is about 1500 feet east of the monitoring wells. The water level in the Souris River immediately east of the Westhope municipal golf course is controlled by releases made at low head dam #357, located five miles north of the golf course. The dam backs up water to about three miles south of the golf course.

The water level in the reservoir, or river channel behind low head dam #357, is recorded by the U. S. Fish and Wildlife Service. The water level elevation of the Souris River behind dam #357 during the summer of 1993 corresponded closely to the water level in the lower alluvial aquifer, as shown in figure 14.

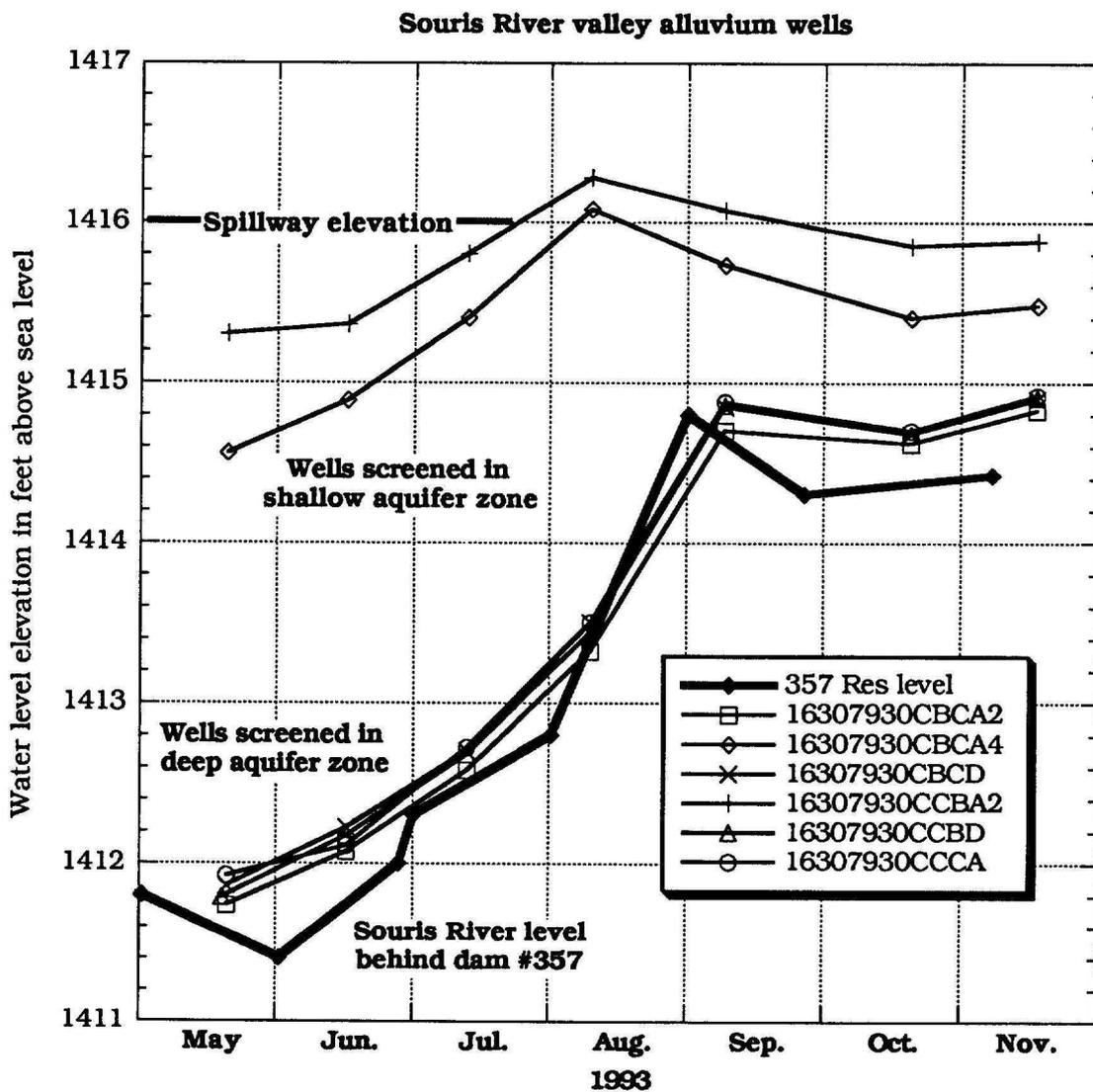


Figure 14 - Hydrograph from the Souris River and valley wells

Recharge to the alluvial aquifer may come from three sources. The glacial drift and Fox Hills bedrock sediments surrounding and underlying the Souris River valley may discharge water to the alluvium. Precipitation falling on the area as well as overland flow onto the area from surrounding topographically higher areas may infiltrate into the alluvium. Water stored in the Souris River channel behind low head dam #357 may move into the alluvium.

Buried Valley East of the Souris River Valley

Two investigation areas are shown in figure 2 along an abandoned channel located one to two miles east of the Souris River. The abandoned channel is 1/4 to 1/2 mile wide and is incised about 25 feet into the landscape. Thirteen test holes were drilled and four monitoring wells installed by the Water Commission in the vicinity of the abandoned channel in 1991.

The 1991 drilling was an attempt to find the Medora-Waskada channel, a buried (sediment filled) river valley which has been mapped in the Waskada oil field located between three and nine miles north of the Canada - U. S. border. The 1991 test drilling penetrated the buried valley at one location along the southwestward projection of the Medora-Waskada channel, where the projection intersects the abandoned channel incised 25 feet into the landscape. A buried valley was also penetrated at a second location along the abandoned channel, 1/4 mile south of the Canada-U. S. border, two miles west of the projection of the Medora-Waskada channel.

In May and June of 1993 twenty-six test holes were drilled and five monitoring wells installed to further trace the location of the buried valley (fig 15). The 1993 drilling penetrated the buried valley in two locations, both between the Souris River valley and the abandoned channel, rather than underlying the abandoned channel, as expected following analysis of the 1991 drilling.

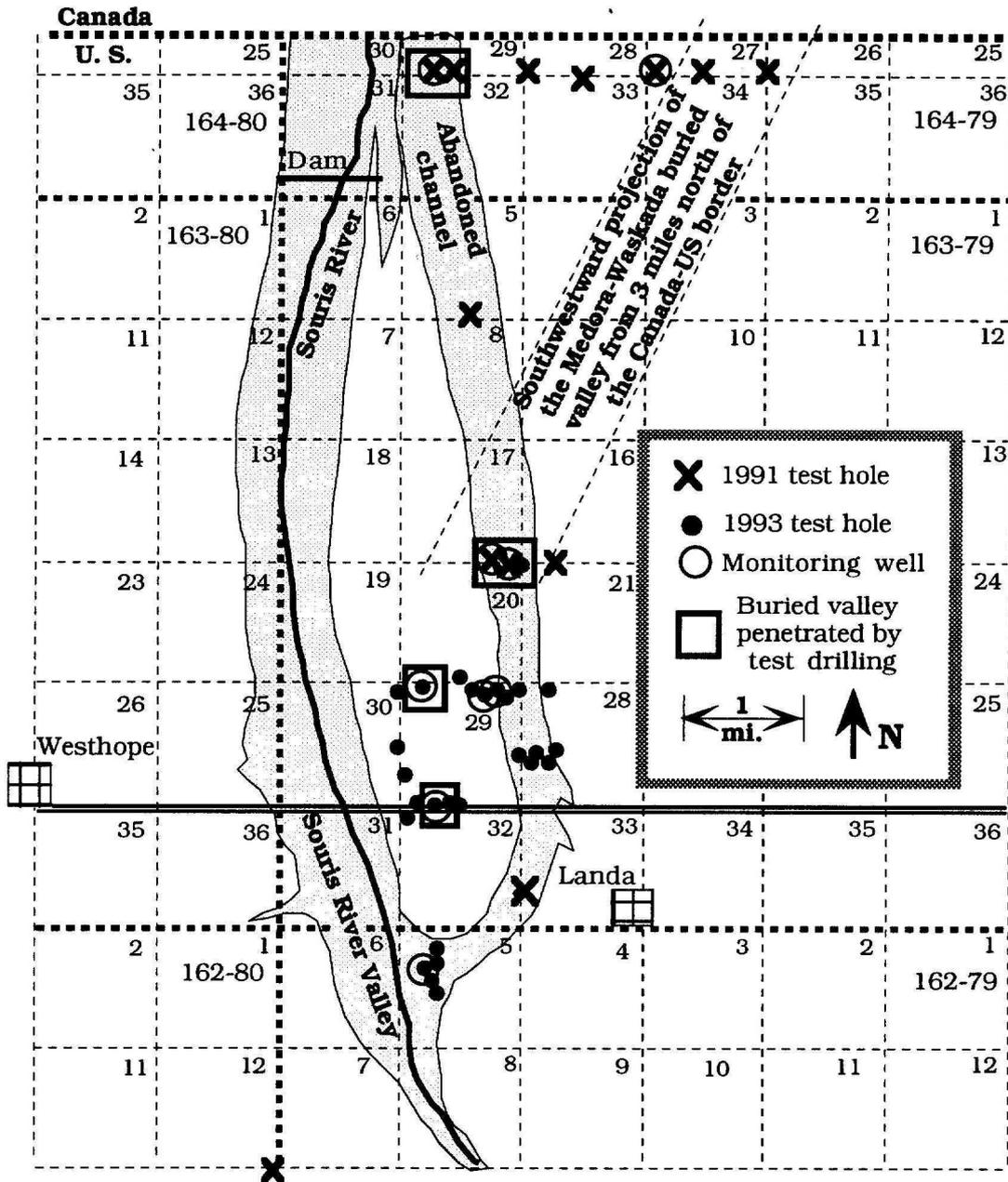


Figure 15 - Test hole locations in the buried valley area

The buried valley is incised through the glacial drift section and about 80 feet into the general level of the area bedrock. The upper 1/3 to 1/2 of the buried valley channel is filled with glacial till. The lower portion of the buried valley, the portion incised into bedrock, is filled with sand or gravel. The buried river valley is probably the course of an earlier, interglacial, or possibly preglacial drainageway.

The sand and gravel in the buried valley is a glaciofluvial sediment, that is, deposited in a river valley during the Pleistocene Epoch (glacial period). The sand and gravel encountered in the buried valley deposit is about 1/4 to 1/2 gravel and the remainder sand. The composition of the sand and gravel is shale, sandstone (probably of Fox Hills Formation or Hell Creek Formation origin), lignite, and quartz. The composition of the sand and gravel suggests a local or southwestern origin, rather than a Canadian shield origin.

Geohydrology of the Buried Valley Deposit

Six cross sections, d - d' through j - j', were constructed using information gathered from the test holes and monitoring wells installed as part of the 1991 and 1993 test drilling. An index to the cross sections is shown in figure 16.

Cross section d - d' shows the lithology penetrated in the test holes drilled 1/4 mile south of the Canada - U. S. border (fig. 17). A buried valley was found two miles west of the projected location for the Medora-Waskada channel. The buried valley was filled mostly with till and silty clay.

The sand penetrated in test hole 164-79-27CCC, 1.5 miles east of the buried channel and shown on section d - d', is apparently an isolated sand lens. The sand in 164-79-27CCC is composed mostly of Canadian shield silicates. Sand and gravel from the buried channel deposit has more shale, lignite and sandstone. A well installed in the sand at 164-79-27CCC pumped dry during development and was slow to recover. The water level in the sand is 55 feet higher than the water level in the buried channel.

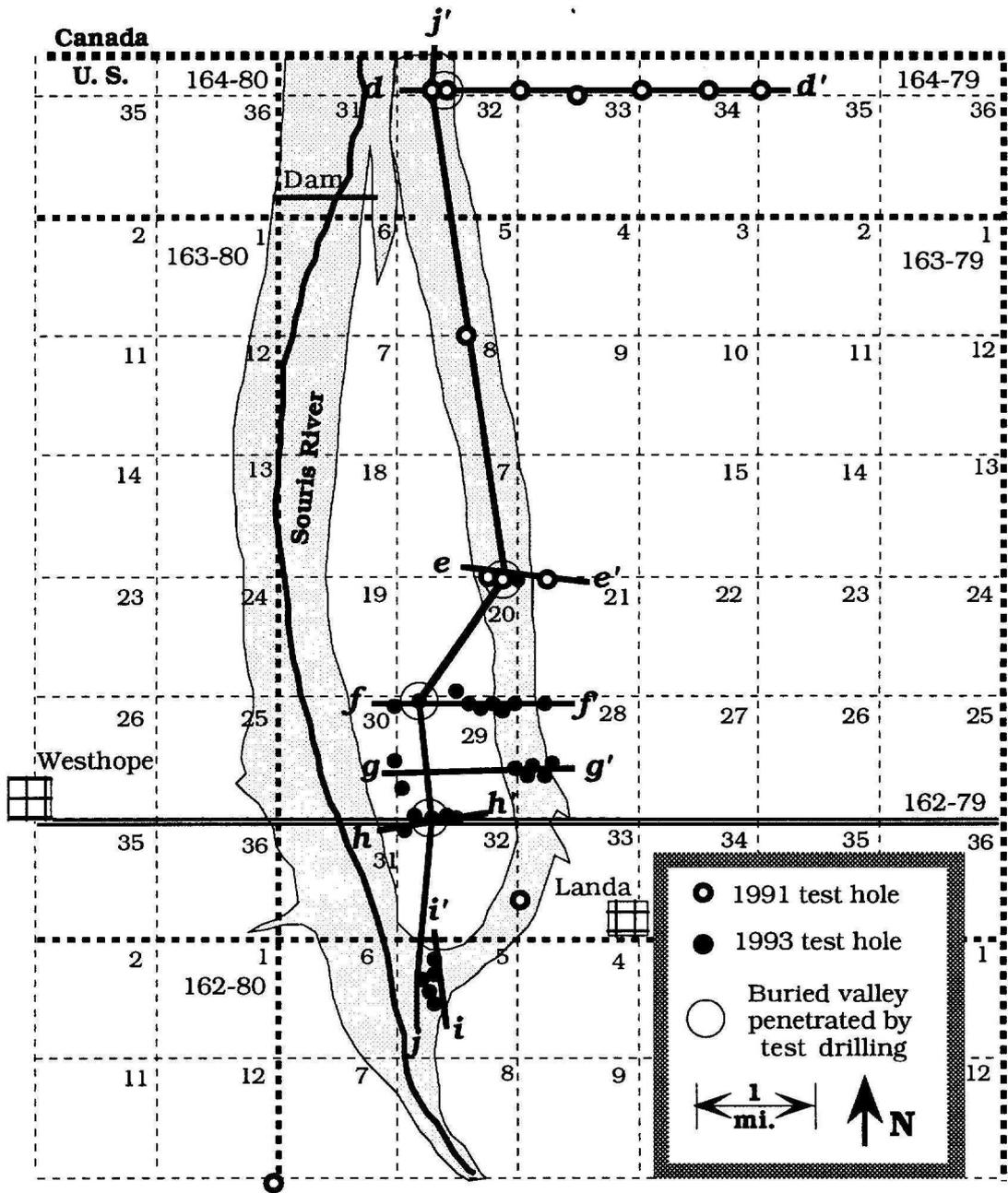


Figure 16 - Location of geohydrologic sections in buried valley area

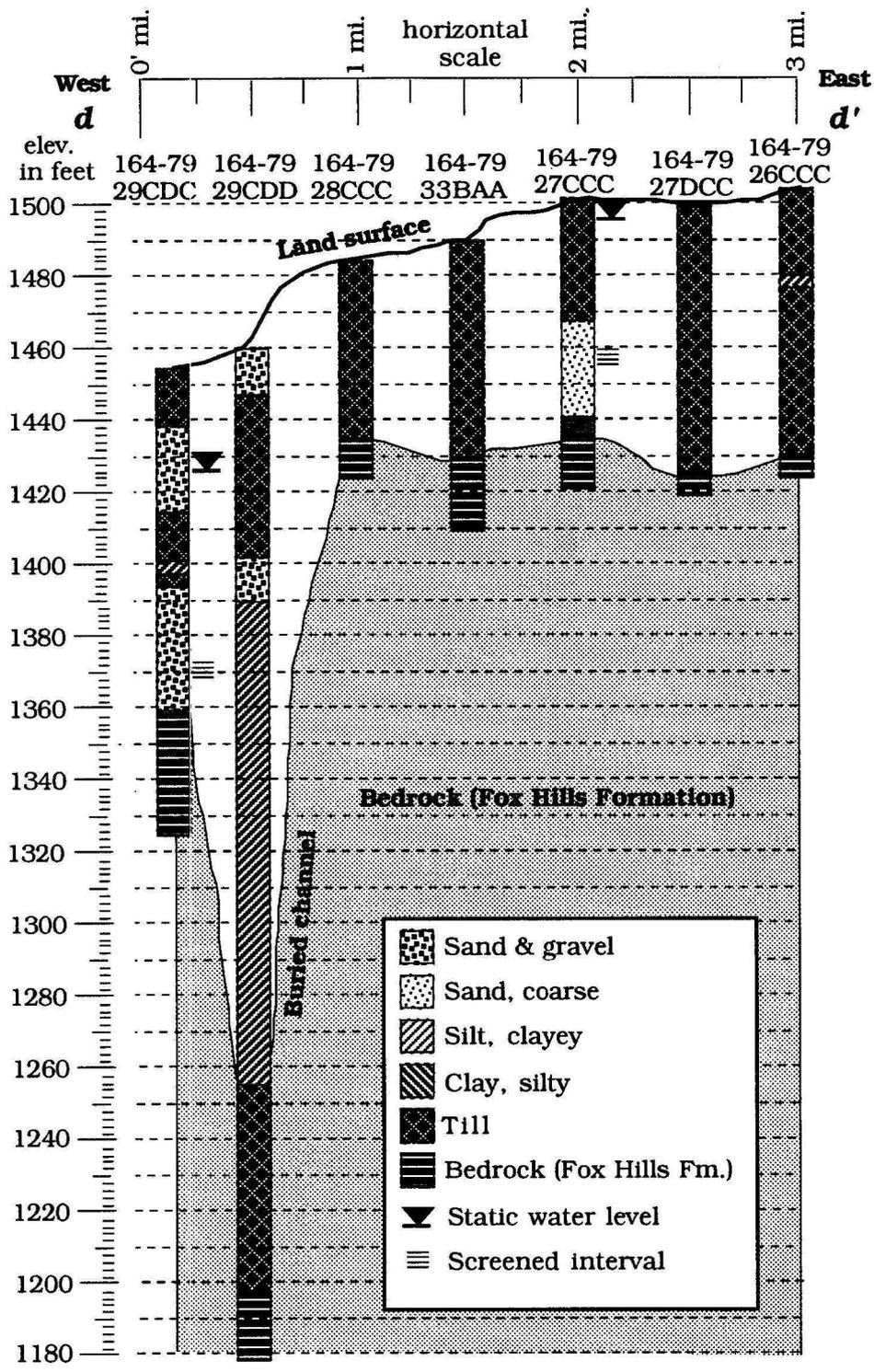


Figure 17 - West to east cross section near Canada - U. S. border

Cross section e - e' (fig. 18) shows the lithology penetrated in test holes drilled four miles south of section d - d'. A buried channel deposit of sand and gravel

(primarily sand) was penetrated. The gravel is composed of granules of Pierre shale, lignite, and sandstone of the Fox Hills and Hell Creek Formations as well as lesser amounts of Canadian shield silicates. The composition of the sand and gravel found along section e - e' is similar to the composition of the sand and gravel found in 164-79-29CDC, 1/4 mile south of the Canada - U. S. border.

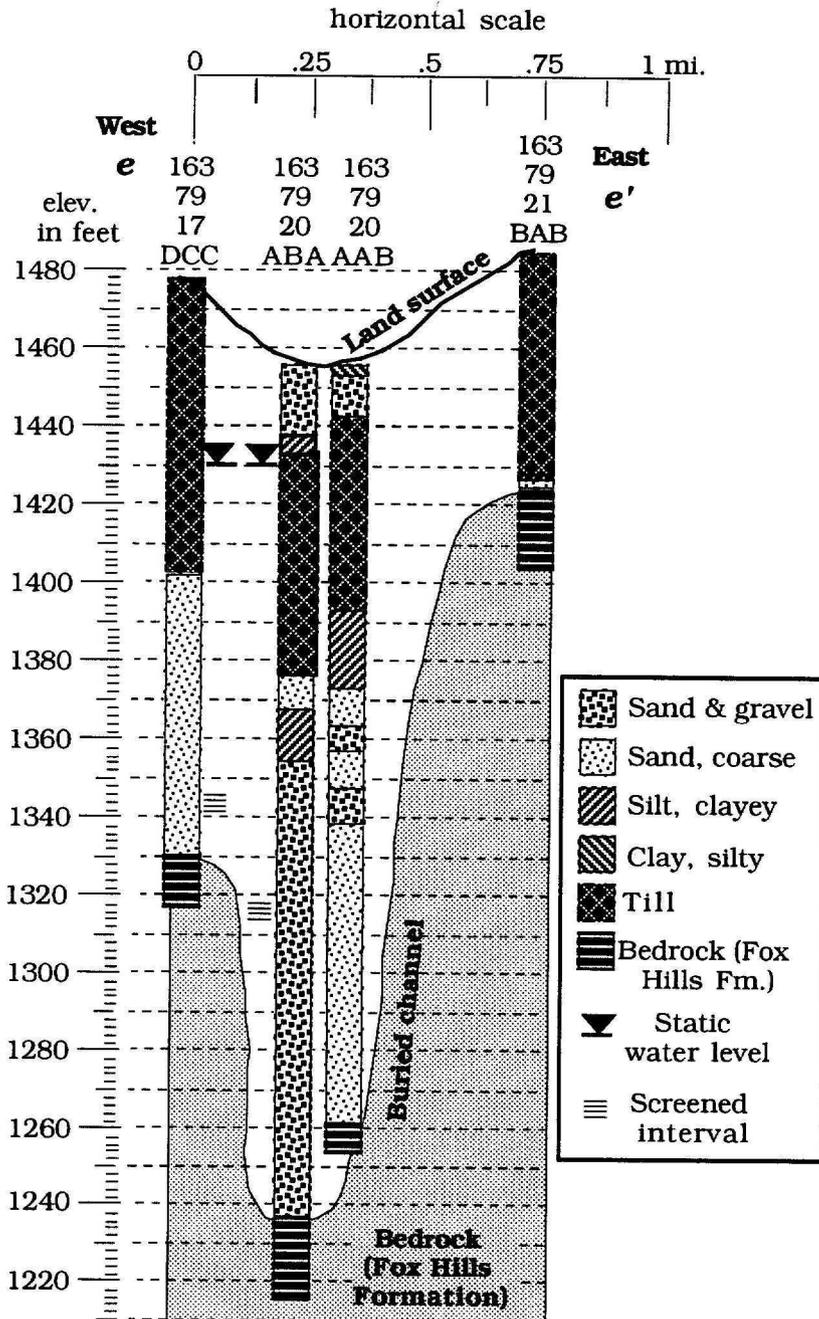


Figure 18 - West to east cross section two miles north of paved road

Cross section f - f (fig. 19) is a west to east section one mile north of the paved county road. A sand and gravel interval was penetrated in 163-79-29A, about 20 feet thick and about 15 feet above bedrock. Added test drilling encountered a buried channel deposit about 0.6 mile farther west, about midway between the Souris River valley and the abandoned channel. The water level in the 20 feet of gravel in 163-79-29A is 15 feet higher than the water level in the buried channel. The two deposits are hydraulically separated.

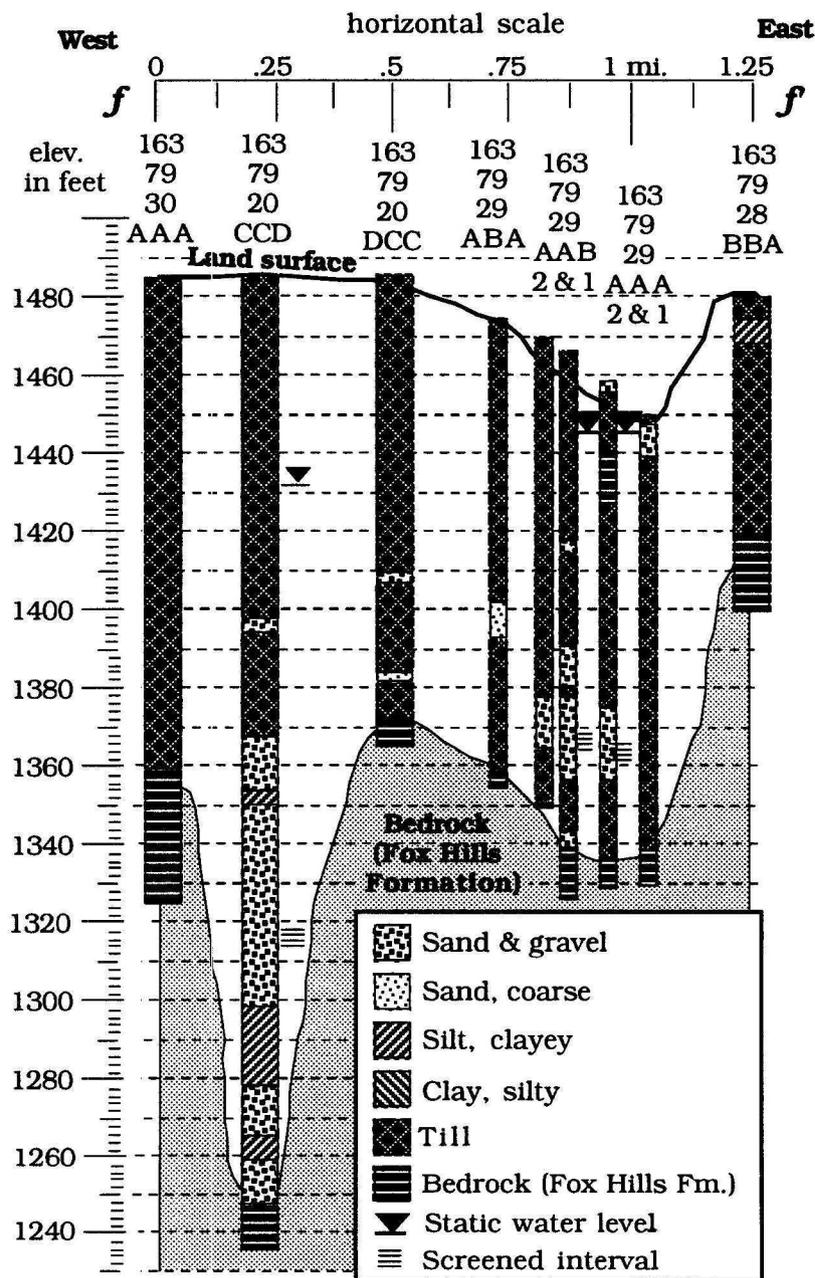


Figure 19 - West to east cross section one mile north of paved road

Cross section g - g' (fig. 20) is a west to east section one half mile north of the paved county road. The section consists of five test holes drilled in the abandoned channel and two test holes drilled along a north-south section line one mile west of the abandoned channel. The test drilling penetrated glacial till and bedrock, with a few lenses of sand or gravel, five feet or less thick.

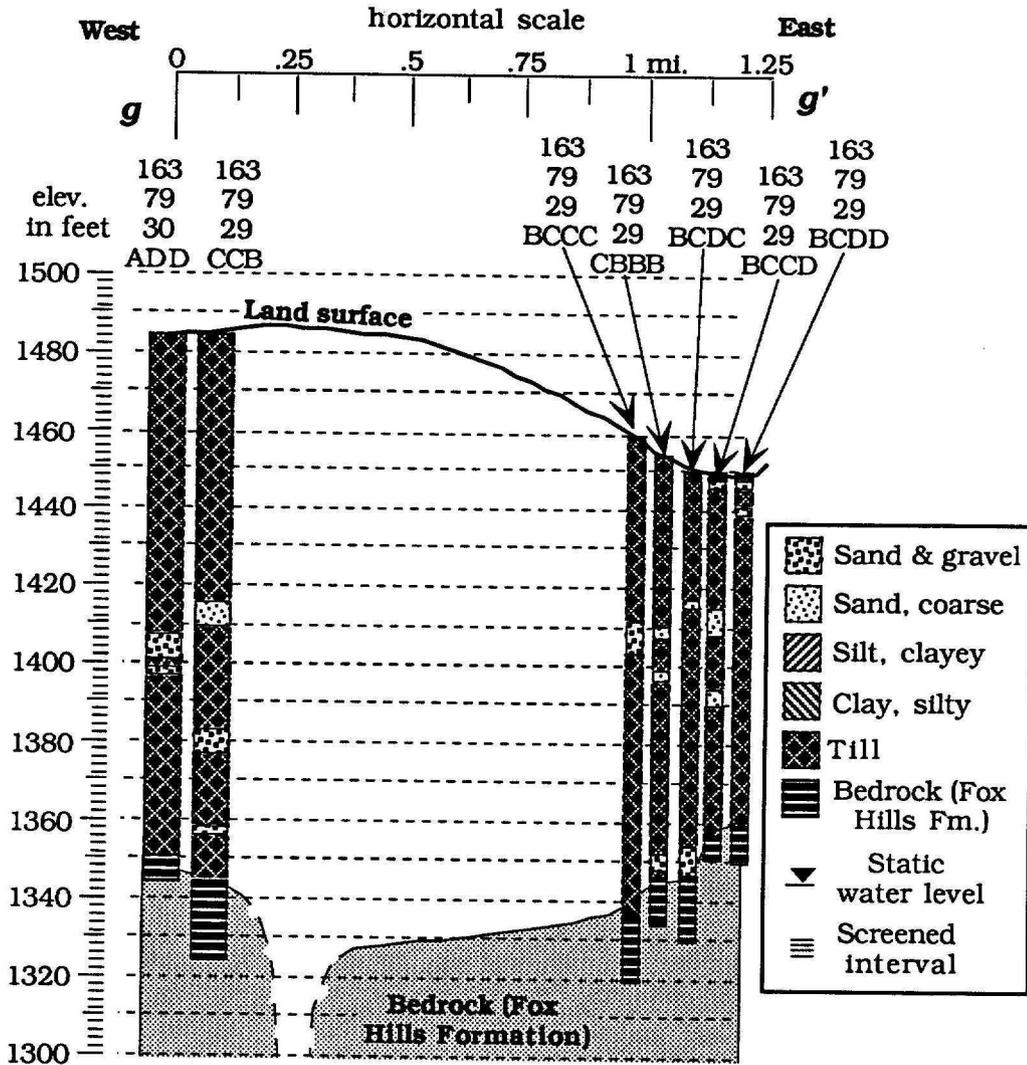


Figure 20 - West to east cross section one half mile north of paved road

Cross section h - h' (fig 21) is a west to east section along the paved county road. The section included a test hole drilled in 1954 along the east side of the Souris River valley. The section includes two test holes, spaced 600 feet apart, in which the buried channel was penetrated. Test holes 600 feet to the west and east of the two test holes through the buried valley deposit did not encounter the deposit. The buried channel at this location is therefore between 600 and 1800 feet wide.

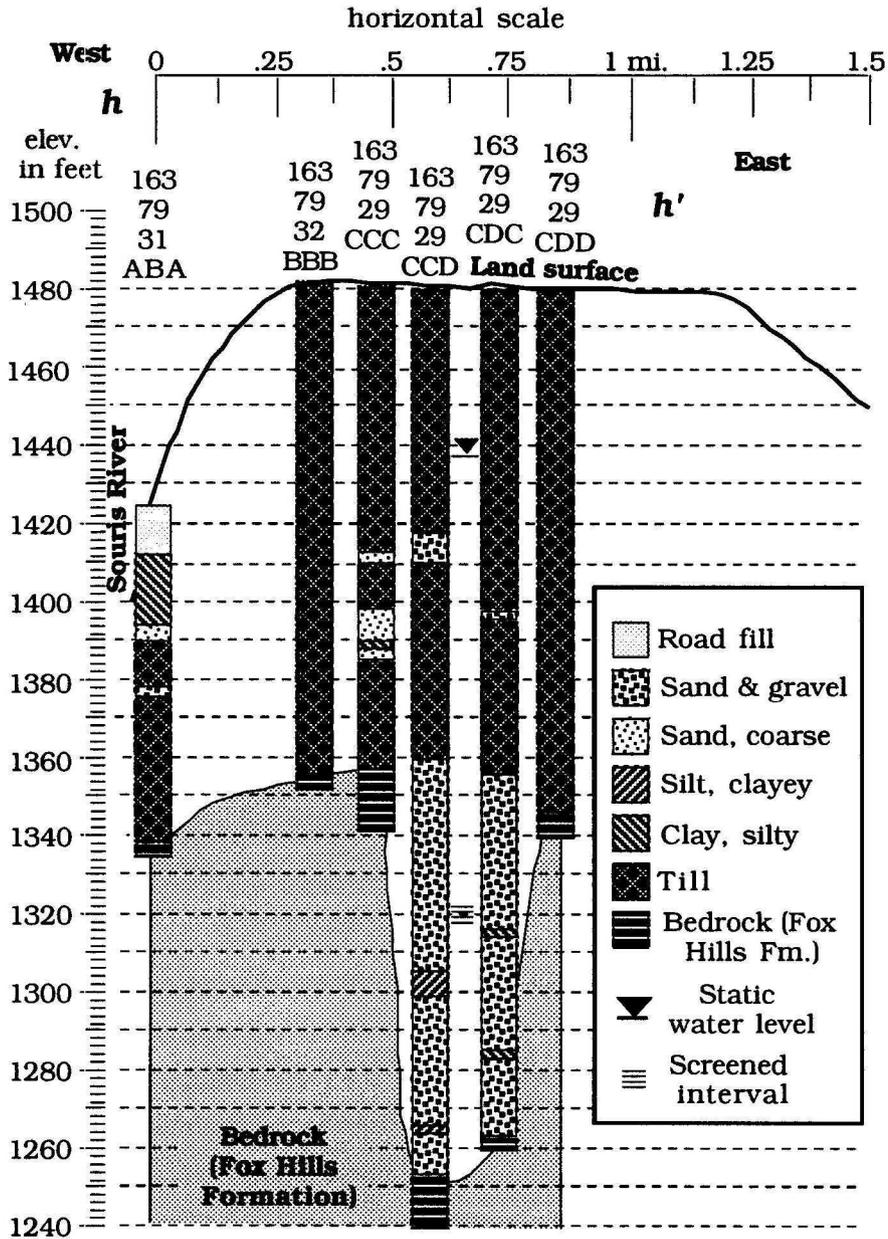


Figure 21 - West to east cross section along paved county road

Cross section i - i' (fig. 22) is a south to north section located near where the abandoned channel joins the Souris River valley. The test drilling penetrated intermittent lens of sand through the glacial till section. At one location 16 feet of sand and gravel was penetrated overlying bedrock and a monitoring well was installed.

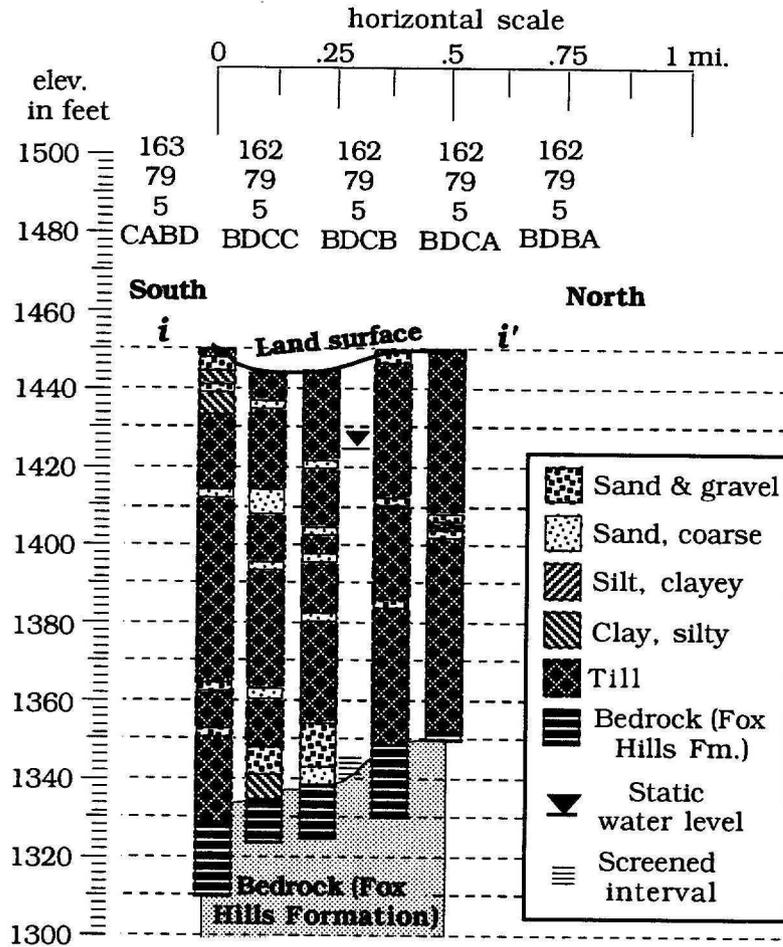


Figure 22 - South to north cross section 1 - 1 1/2 miles south of paved road

Cross section j - j' (fig. 23) is a south to north section along the axis of the buried channel. In the three southern locations the channel is filled with glacial till to about 1360 feet elevation, the approximate elevation of the bedrock surface in the area when the buried valley is not encountered. The channel is filled with sand and gravel and an occasional clay lens until bedrock is encountered at about 1255 feet elevation.

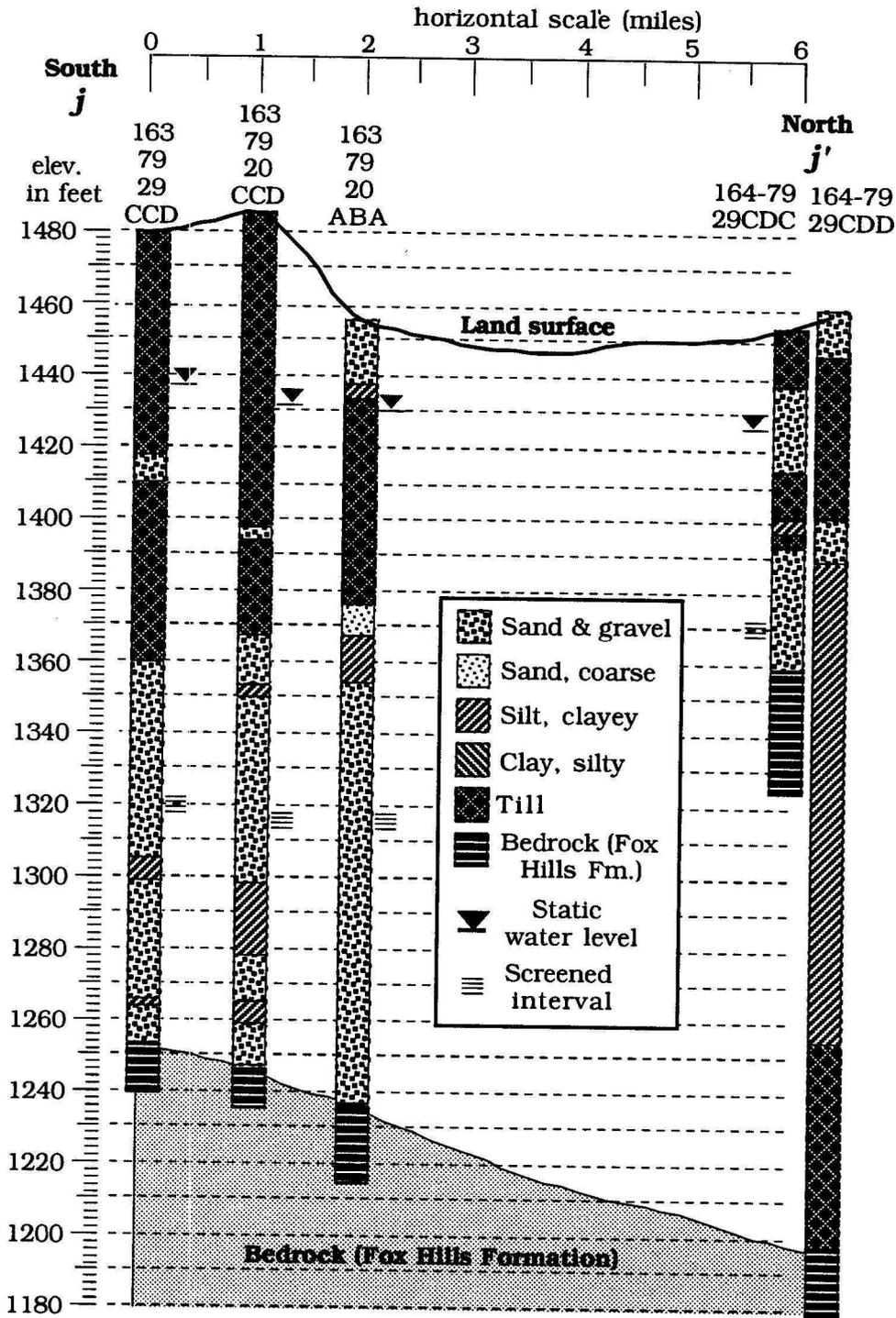


Figure 23 - South to north cross section along buried valley

The test hole penetrating a buried valley in 164-79-29CDD, the north most location, encountered glacial till and clayey silt, rather than sand and gravel, in the buried channel interval between 1200 feet and 1390 feet elevation. A test hole

located about 800 feet farther west penetrated predominantly sand and gravel through the usually till filled interval between land surface and 1360 feet elevation.

The different type of lithologic sequence penetrated in the two holes which encountered a buried valley in 164-79-29CD indicates that either the buried valley here is filled with more silt and clay and less sand and gravel or that a different buried channel was penetrated. Additional test drilling would be necessary to determine if the buried channel at 164-79-29CD is the same channel as that found in Sections 20 and 29, four to six miles farther south.

Water Levels in the Buried Channel Aquifer

Water level elevations in the buried channel aquifer are about 70 feet above the top of the aquifer and about 17 feet above the Souris River (fig. 24). The gradient is to the north. The monitoring well at 163-79-29CCD, in the paved county road ditch has a water level about five feet higher than expected, based on the level in other wells.

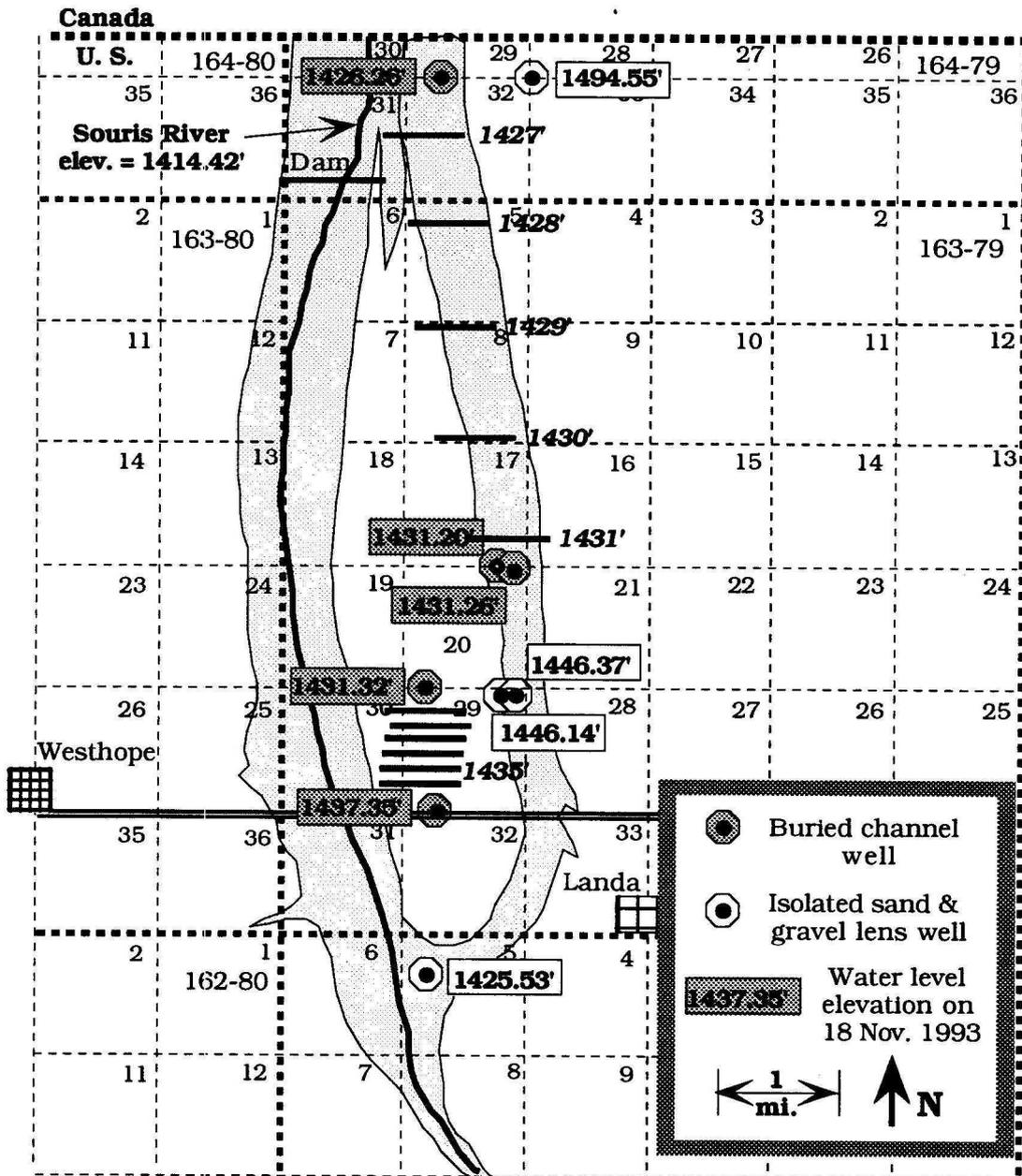


Figure 24 - Elevations of water levels in wells east of the Souris River

WATER QUALITY

Properties and Characteristics of Water

Water samples were collected and analyzed from thirteen wells in the Westhope area. The physical properties and mineral constituents of water reported include those that have a practical bearing on the value of the water for most purposes. The analyses include determinations of:

- Specific conductance
- pH
- Temperature
- Hardness
- Sodium-adsorption ratio
- Residual sodium carbonate
- Percent sodium

and dissolved mineral concentrations of:

CATIONS:

- Silica
- Calcium
- Magnesium
- Potassium
- Sodium
- Iron
- Manganese

ANIONS:

- Fluoride
- Bicarbonate
- Carbonate
- Sulfate
- Chloride
- Nitrate
- Boron

and total dissolved solids.

The samples were analyzed for 'trace' dissolved mineral concentrations of:

- Selenium
- Lead
- Mercury
- Arsenic
- Lithium
- Molybdenum
- Strontium

The water samples obtained during the study were collected in polyethylene bottles, and the analyses were made by the North Dakota State Water Commission Laboratory in Bismarck.

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. A microgram per liter is one millionth (0.000001) of a gram of dissolved material per liter of solution. Milligrams per liter can be converted to grains per gallon by dividing milligrams per liter by 17.12 (Hem, 1970, p.81).

Equivalents per million (epm) is the unit chemical combining weight of a constituent in a million weights of water. These units are usually not reported, but are used to calculate percent sodium, the sodium-adsorption ratio, or to check the accuracy of a chemical analysis.

Specific conductance (micromhos per centimeter at 25^o Celsius): Specific conductance is a measure of the ability of water to conduct an electric current. Approximately 65 to 70 percent of the specific conductance (in micromhos) is an estimate of the amount of dissolved solids (in milligrams per liter) in water; however, this relation is not constant and will vary with the chemical composition of the water (Hem, 1970).

Hydrogen-ion concentration (pH): Hydrogen-ion concentration (activity) is expressed in terms of pH units. The values of pH often are used as one measure of the solvent capacity of water. The hydrogen-ion concentrations affect 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: Temperature is important for its influence upon concentrations of dissolved gases and mineral matter in water. Water temperatures given in the tables are expressed in degrees Celsius (Centigrade). Degrees Celsius can be converted to degrees Fahrenheit using the following equation:

$$\text{Degrees Fahrenheit} = (9/5) \text{ degrees Celsius} + 32.$$

Hardness:: Calcium and magnesium are the principal cause of hardness. Hardness exhibits the characteristic of requiring greater quantities of soap to produce a lather as the hardness increases. Hard water also can contribute to the formation of scale in boilers, water heaters, radiators, and pipes, with a resultant decrease in the rate of water flow and/or heat transfer.

The hardness that is equivalent to the 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. As a general reference, the U. S. Geological Survey often uses the following classification of water hardness (Hem, 1970).

Calcium and magnesium hardness, as CaCO₃ (mg/l)

0-60	soft
61-120	moderately hard
121-180	hard
more than 180	very hard

Sodium-adsorption ratio (SAR): The term "sodium-adsorption ratio" was introduced by the U. S. Salinity Laboratory Staff (1954). Their experiments shown that the SAR relates to the degree water enters into cation-exchange reactions with soil. Sodium-adsorption ratio as 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 U. S. Salinity Laboratory Staff (1954) divided water into 16 classes, depending upon the SAR and specific conductance. The classifications indicate the usefulness of water for irrigation of different crops on different types of soil.

Residual sodium carbonate (RSC): Residual sodium carbonate 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, $RSC = 2(HCO_3 + CO_3 - CA - Mg)$, in milliequivalents per liter.

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

Silica (SiO₂): Weathering processes dissolve silica from practically all rocks. Silica affects the usefulness of water because it can contribute to the formation of scale in pipes, water heaters, and boilers in the presence of calcium and magnesium.

Calcium and Magnesium (Ca and Mg): Limestone and similar rocks are the principal source of calcium and magnesium in natural water. Calcium and magnesium cause water hardness and, with anions, can form scale on utensils and in water heaters, boilers, and pipes.

Sodium and Potassium (Na and K): Sodium and potassium 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): Iron is a widespread constituent in rocks and is easily leached by groundwater under reducing conditions or in acidic water. Water containing more than 300 µg/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): Manganese in concentrations as low as 200 µg/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): Fluoride in the ground-water probably is derived from solution of fluorite, apatite, and hornblende minerals. High fluoride content (depending on annual average maximum daily air temperature) may cause mottling of tooth enamel in children's teeth during calcification.

Bicarbonate and Carbonate (HCO₃ and CO₃): Bicarbonate and carbonate 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 the analyses by using the formula:

$$\text{Alkalinity (as CaCO}_3\text{)} = 0.82 (\text{HCO}_3) + 1.67 (\text{CO}_3)$$

Sulfate (SO₄): Metallic sulfide minerals may be converted to sulfates 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): Chloride 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 (NO₃): The occurrence of high nitrate concentrations 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).

Boron (B): Boron is a constituent of the mineral tourmaline and may be present in biotite and amphiboles. In small quantities, boron is essential for plant growth.

Excessive concentrations in soil and in irrigation water are harmful for some plants.

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

Trace elements: The metallic elements selenium, lead, mercury, arsenic, lithium, molybdenum, and strontium may be found in low ("trace") concentrations in water supplies. Maximum allowable concentrations for drinking water have been established for the elements selenium, lead, mercury and arsenic.

Water Quality in the Westhope Area

Water samples were collected in May and June 1993 from the ten recently installed monitoring wells and from three in place monitoring wells, installed in 1990 and 1991 (fig. 25).

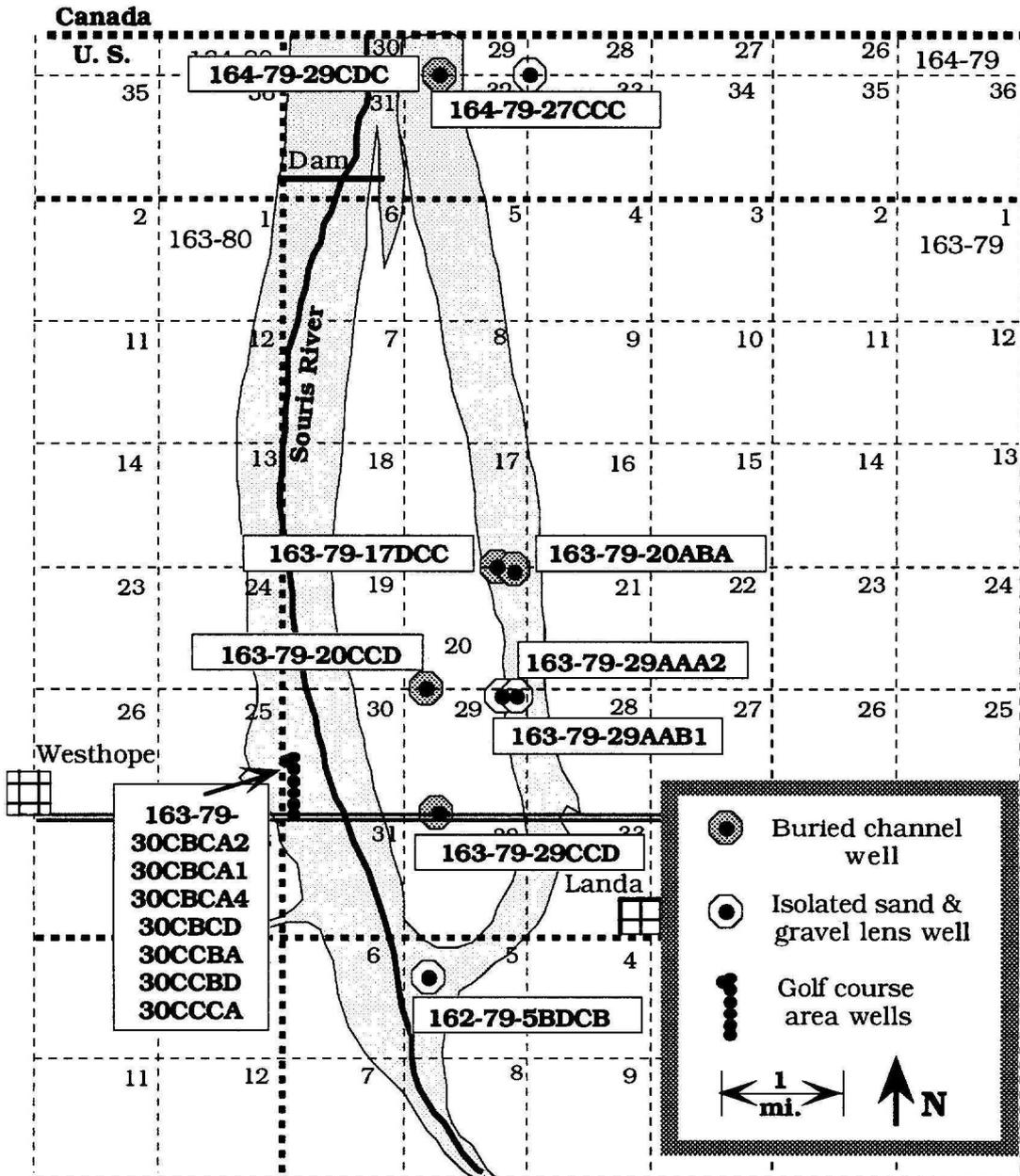


Figure 25 - Locations of sampled wells

Water quality analyses were available from three wells, sampled in 1990 and 1991, but not resampled. A 1990 water quality analysis was available from well 163-79-30BCA1, which was later destroyed. A 1991 analysis was available from well 163-79-17DCC, which was not resampled in 1993 (a well 1/4 mile away, in the same zone, was resampled). A 1991 analysis was available from well 164-79-27CCC, in an isolated zone and therefore not resampled in 1993.

Water Quality in the Souris River Valley, Lower Aquifer Zone

Water quality analyses of five samples taken from the monitoring wells in the Souris River valley, lower aquifer zone (60 to 80 feet depth, 1340 to 1360 feet elevation), near the municipal golf course, are summarized in table 1. The water in the lower aquifer zone is a sodium-bicarbonate type.

Included under the column labeled "Standard" are the Environmental Protection Agency's "non-mandatory guidelines" which are concentration limits recommended for drinking and other domestic water use (U. S. Environmental Protection Agency, 1973b). The values listed in the "Standard" column for selenium, lead, mercury, and arsenic are maximum permissible limits.

Hardness ranged between 130 mg/l (as CaCO₃) and 298 mg/l with an average of 216 mg/l. No recommended limit has been established for hardness.

The sodium concentration ranged between 390 mg/l and 510 mg/l with an average of 443 mg/l. No recommended limit has been established for sodium; however, the concentration is higher than is preferred for people on sodium restricted diets.

Iron concentration ranged between 0.01 mg/l and 1.43 mg/l with an average of 0.49 mg/l. The recommended limit for iron was exceeded in two of the five samples.

Table 1 - Water quality in the golf course area, lower aquifer zone

	Standard	163-79 30CBCA1	163-79 30CBCA2	163-79 30CBCD	163-79 30CCRD	163-79 30CCCA
Date sampled		4/19/90	6/22/93	6/22/93	5/20/93	5/18/93
Screen depth (ft)		68'-73'	91'-96'	73'-78'	84'-89'	71'-76'
Depth to water (ft)		6.79'	9.32'	11.44'	8.92	8.10
Cond. (µmhos)		2240	2350	2220	2370	2200
pH		7.72	8.03	7.72	7.98	8.10
Temp. (°C)			12	13	9	6
Hardness (CaCO3)		298	130	280	140	230
SAR		10.5	18	10	19	12
RSC			11	7	11	6
% Sodium		75.1	89	75	88	79
Silica (mg/l)			20	21	23	22
Calcium (mg/l)		81.2	35	75	38	64
Magnesium (mg/l)	125	23.1	10	22	12	18
Potassium (mg/l)		6.1	5.3	6.8	5.3	5.9
Sodium (mg/l)		415	480	390	510	420
Iron (mg/l)	0.3	1.43	.17	.19	.01	.66
Manganese (mg/l)	0.05	.15	.07	.18	.05	.19
Fluoride (mg/l)	1.5	.35	.4	.3	.4	.4
Bicarbonate (mg/l)		734	803	749	830	669
Carbonate (mg/l)		0	0	0	0	0
Sulfate (mg/l)	250	125	97	110	98	140
Chloride (mg/l)	250	323	340	310	350	320
Nitrate (mg/l)	45	0	.2	0	6.9	0
Boron (mg/l)	1		1.2	.84	1.0	.93
TDS (mg/l)	500	1330	1380	1320	1470	1360
Selenium (µg/l)	50		0	0		
Lead (µg/l)	50		0	0		
Mercury (µg/l)	2		.2	0		
Arsenic (µg/l)	50		18	14		
Lithium (µg/l)			90	110		
Molybdenum (µg/l)			28	9		
Strontium (µg/l)			430	620		

Manganese concentration ranged between 0.05 mg/l and 0.19 mg/l with an average of 0.13 mg/l. The recommended limit of 0.05 for manganese was met or exceeded in all five of the samples.

The sulfate concentration ranged between 97 mg/l and 140 mg/l with an average of 114 mg/l. The recommended limit of 250 mg/l for sulfate was not exceeded in any of the samples.

The chloride concentration ranged between 310 mg/l and 350 mg/l with an average of 329 mg/l. The recommended limit of 250 mg/l for chloride was exceeded in all five of the samples.

Total dissolved solids concentrations in the five wells completed in the lower aquifer zone, ranged between 1330 mg/l and 1470 mg/l with an average of 1372 mg/l. The guideline recommended limit of 500 mg/l was exceeded in all five of the samples.

The permissible limits for selenium, lead, mercury, and arsenic were not exceeded in the three samples analyzed for these elements. Limits have not been set for lithium, molybdenum, and strontium. Concentrations of lithium, molybdenum, and strontium in the samples tested are in the normal range of North Dakota ground-water samples.

Water Quality in the Souris River Valley, Upper Aquifer Zone

The water quality from the shallow aquifer zone along the east side of the municipal golf course is listed in table 2. Two wells were completed in the shallow aquifer zone, at depths of 30 and 28 feet.

Table 2 - Water quality in the golf course area, upper aquifer zone

	Standard	163-79 30CBCA4	163-79 30CCBA
Date sampled		6/22/93	5/20/93
Screen depth (ft)		25'-30'	28'-28'
Depth to water (ft)		7.94'	7.78'
Cond. (µmhos)		1390	2000
pH		7.69	7.86
Temp. (°C)		13	8
Hardness (CaCO ₃)		390	560
SAR		3.5	4.8
RSC		0	0
% Sodium		46	50
Silica (mg/l)		21	21
Calcium (mg/l)		110	150
Magnesium (mg/l)	125	29	45
Potassium (mg/l)		10	13
Sodium (mg/l)		160	260
Iron (mg/l)	0.3	.13	.03
Manganese (mg/l)	0.05	.27	.08
Fluoride (mg/l)	1.5	.1	.1
Bicarbonate (mg/l)		425	548
Carbonate (mg/l)		0	0
Sulfate (mg/l)	250	350	560
Chloride (mg/l)	250	53	96
Nitrate (mg/l)	45	0	0
Boron (mg/l)	1	.36	.46
TDS (mg/l)	500	956	1490
Selenium (µg/l)	50	0	
Lead (µg/l)	50	7	
Mercury (µg/l)	2	0	
Arsenic (µg/l)	50	1	
Lithium (µg/l)		50	
Molybdenum (µg/l)		1	
Strontium (µg/l)		330	

The water quality from samples taken from the shallower (28 and 30 feet deep) wells along the east side of the municipal golf course differs from the water in the lower aquifer zone. The difference is demonstrated on a Schoeller diagram (fig. 26), which illustrates the quantity of the major dissolved constituents in milli-equivalents per liter, a unit of dissolved chemical concentration that takes into account the weight and reactivity (chemical valence) of the individual constituents.

The diagram indicates that the water quality of the shallower zone is higher in the concentration of calcium, magnesium, and sulfate, but lower in the concentration of sodium (Na), chloride, and bicarbonate (HCO₃), as compared to the deeper aquifer zone.

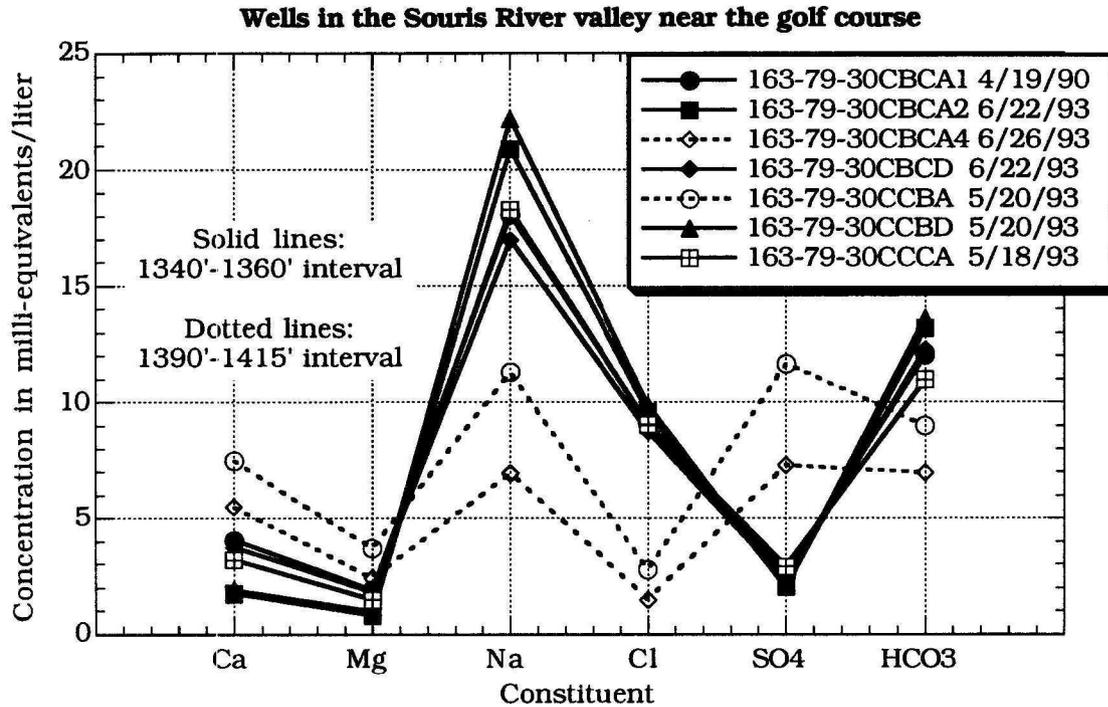


Figure 26 - Schoeller diagram illustrating valley aquifer water quality

Water Quality in the Buried Valley East of the Souris River Valley

Water quality analyses of five samples taken from the monitoring wells in the sand and gravel of the buried valley east of the Souris River valley are summarized in table 3. The water in the buried valley is a sodium-sulfate/bicarbonate type.

Table 3 - Water quality in monitoring wells in the buried channel

	Standard	163-79 17DCC	163-79 20ABA	163-79 20CCD	163-79 29CCD	164-79 29CDC
Date sampled		8/21/91	5/20/93	6/23/93	6/23/93	5/20/93
Screen depth (ft)		132-137	138-143	168-173	158-163	82-87
Depth to water (ft)		46.85'	24.93'	54.14'	42.78	28.50
Cond. (µmhos)		2310	2050	2210	1980	3120
pH		7.71	8.10	7.95	8.18	7.90
Temp. (°C)		10	7			7
Hardness (CaCO ₃)		691	539	290	260	1300
SAR		4.8	5.5	10	9.7	4.0
RSC		0	0	4	4	0
% Sodium		47	54	74	74	36
Silica (mg/l)		38	28	25	34	31
Calcium (mg/l)		160	120	65	59	370
Magnesium (mg/l)	125	71	56	31	27	88
Potassium (mg/l)		11	10	8.6	8.5	11
Sodium (mg/l)		290	290	400	360	330
Iron (mg/l)	0.3	.79	.96	.03	.18	5.9
Manganese (mg/l)	0.05	.09	.10	.05	.09	.37
Fluoride (mg/l)	1.5	.2	0.2	.2	.2	.1
Bicarbonate (mg/l)		583	572	587	586	462
Carbonate (mg/l)		0	0	0	0	0
Sulfate (mg/l)	250	880	580	470	440	1400
Chloride (mg/l)	250	18	9	160	98	73
Nitrate (mg/l)	45	1	7	0	0	4.6
Boron (mg/l)	1	.59	.48	.55	.51	.34
TDS (mg/l)	500	1780	1520	1460	1320	2750

In the southern four samples from the buried valley aquifer hardness ranged between 260 mg/l (as CaCO₃) and 691 mg/l with an average of 445 mg/l. The hardness of the northern buried valley sample was 1300 mg/l.

In the four southern buried valley samples the sodium concentration ranged between 290 mg/l and 400 mg/l with an average of 335 mg/l. The sodium concentration of the northern buried valley sample was 370, in the same range as the other buried valley samples. No recommended limit has been established for sodium; however, the concentration is higher than is preferred for people on sodium restricted diets.

Iron concentration in the southern four buried valley samples ranged between 0.03 mg/l and 0.96 mg/l with an average of 0.49 mg/l. The iron

concentration in the northern sample is 5.9 mg/l. The recommended limit for iron was exceeded in two of the southern four samples.

Manganese concentration in the southern four samples ranged between 0.05 mg/l and 0.10 mg/l with an average of 0.08 mg/l. The manganese concentration in the northern sample was 0.37 mg/l. The recommended limit of 0.05 for manganese was met or exceeded in all five of the samples.

The sulfate concentration in the southern four samples ranged between 440 mg/l and 880 mg/l with an average of 660 mg/l. The sulfate concentration in the northern sample was 1400 mg/l. The recommended limit of 250 mg/l for sulfate was exceeded in all of the samples.

The chloride concentration in the southern four samples ranged between 9 mg/l and 160 mg/l with an average of 71 mg/l. The chloride concentration in the northern sample was 73 mg/l. The recommended limit of 250 mg/l for chloride was not exceeded in any of the samples.

Total dissolved solids concentrations in the southern four sampled wells ranged between 1320 mg/l and 1780 mg/l with an average of 1520 mg/l. The total dissolved solids concentration in the northern sample was 2750 mg/l. The guideline recommended limit of 500 mg/l was exceeded in all five of the samples.

The analyses indicated a somewhat different water quality in the sample from the well 1/4 mile south of the Canada-U. S. border, at 164-79-29CDC, as compared to the other four samples from wells in the buried valley and located four to six miles farther south. The sample from the northern well has a higher concentration of dissolved calcium and sulfate, as shown in the Schoeller diagram (fig. 27).

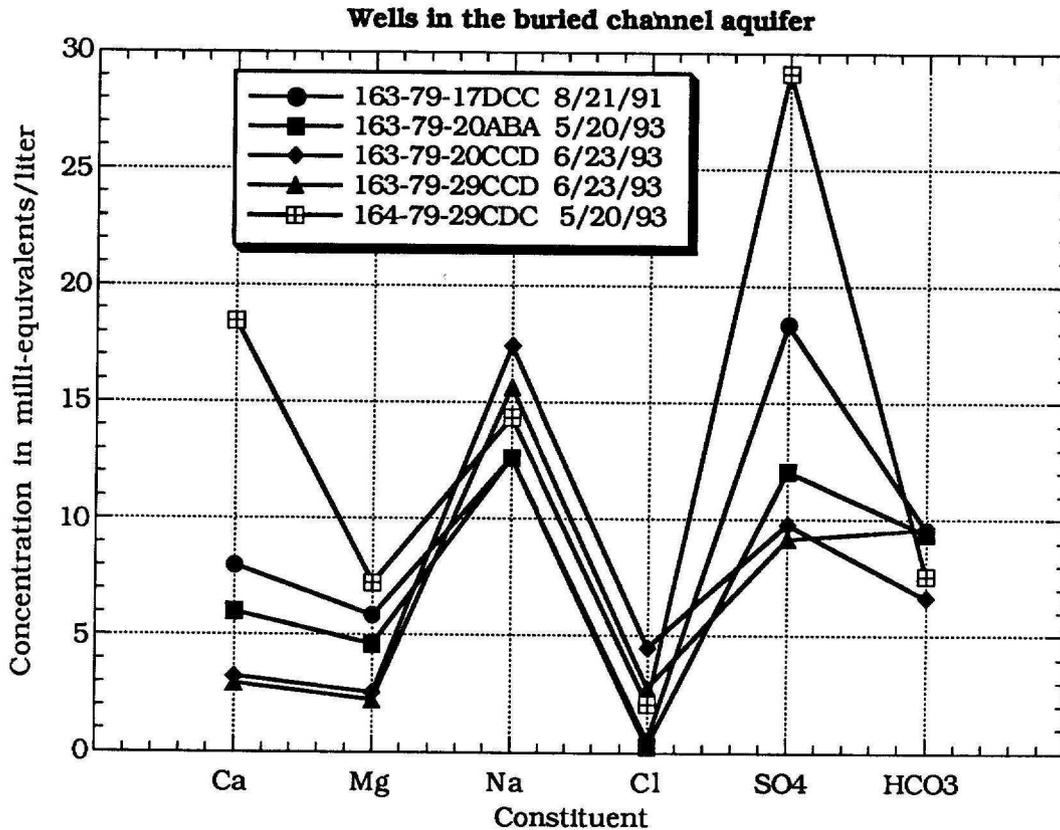


Figure 27 - Schoeller diagram illustrating buried channel aquifer quality

Water Quality in Isolated Sand and Gravel Lenses

Four wells were completed in isolated sand and gravel lenses while searching for the buried valley east of the Souris River valley. Water quality analyses of four samples taken from the monitoring wells in the isolated sand and gravel lens east of the Souris River valley are summarized in table 4. The water is a sodium-sulfate/bicarbonate type.

Table 4 - Water quality in monitoring wells in isolated sand & gravel lenses

	Stan- dard	162-79 5BDCB	163-79 29AAA2	163-79 29AAB1	164-79 27CCC
Date sampled		5/19/93	6/23/93	6/23/93	
Screen depth (ft)		98-103	93-98	98-103	42'-47'
Depth to water (ft)		21.86'	18.37	25.28	31.96'
Cond. (µmhos)		2320	2550	2710	2760
pH		8.30	7.89	8.10	7.68
Temp. (°C)		6			9
Hardness (CaCO ₃)		120	360	200	572.57
SAR		20	11	17	8.0
RSC		8	2	8	0
% Sodium		90	73	85	62
Silica (mg/l)		20	21	20	20
Calcium (mg/l)		33	93	52	150
Magnesium (mg/l)	125	9	31	17	48
Potassium (mg/l)		4.9	7.5	5.5	12
Sodium (mg/l)		510	470	550	440
Iron (mg/l)	0.3	.04	.02	.02	.05
Manganese (mg/l)	0.05	.04	.28	.09	.41
Fluoride (mg/l)	1.5	.4	.4	.5	.2
Bicarbonate (mg/l)		640	577	745	538
Carbonate (mg/l)		0	0	0	0
Sulfate (mg/l)	250	540	750	520	1100
Chloride (mg/l)	250	100	100	190	14
Nitrate (mg/l)	45	6.3	0	0	.3
Boron (mg/l)	1	1	.67	1.2	.71
TDS (mg/l)	500	1580	1800	1790	2090

Total dissolved solids concentrations in the four sampled wells in isolated sand and gravel lenses ranged between 1580 mg/l and 2090 mg/l, with an average of 1815 mg/l. The guideline recommended limit of 500 mg/l was exceeded in all four of the samples. Samples from the isolated wells have a similar quality, except for the dissolved sulfate concentration, as indicated in the Schoeller diagram (fig. 28).

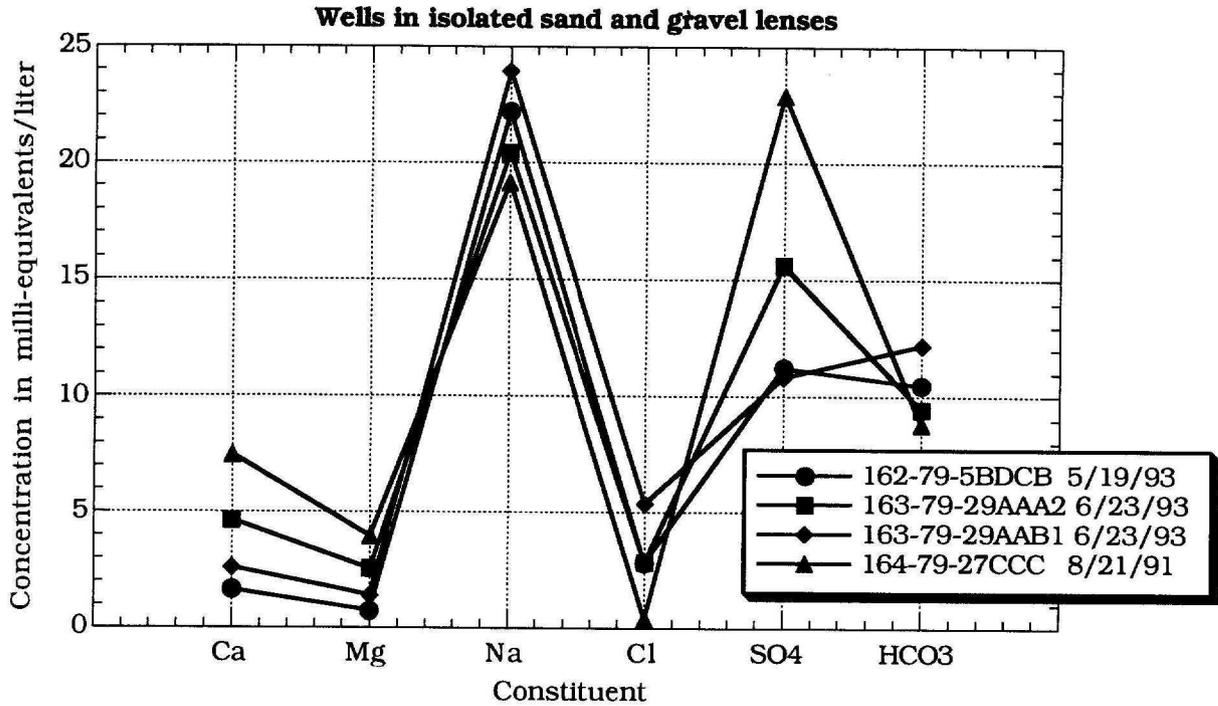


Figure 28 - Schoeller diagram illustrating water quality in isolated lenses

Comparison of Water Quality in the Westhope Area

For purposes of comparison, a representative water quality sample from each of the three sand and gravel deposits (the lower aquifer zone in the Souris River valley, the buried channel east of the valley, and an isolated lens) is shown in a Schoeller diagram (fig. 29). Included in the Schoeller diagram is the information from two area bedrock wells, completed at 155 feet and 160 feet depth in the Fox Hills Formation, one mile east of Westhope at 163-80-26DDC and seven miles south of Westhope at 162-80-35ADD.

The upper portion of the Fox Hills Formation, with the overlying lower Hell Creek Formation, forms a regional aquifer. The Fox Hills-Hell Creek aquifer usually has a sodium bicarbonate type water. Locally the Fox Hills-Hell Creek aquifer is a sodium bicarbonate/chloride/sulfate type water with a dissolved solids concentration of 1245 mg/l.

Westhope area wells

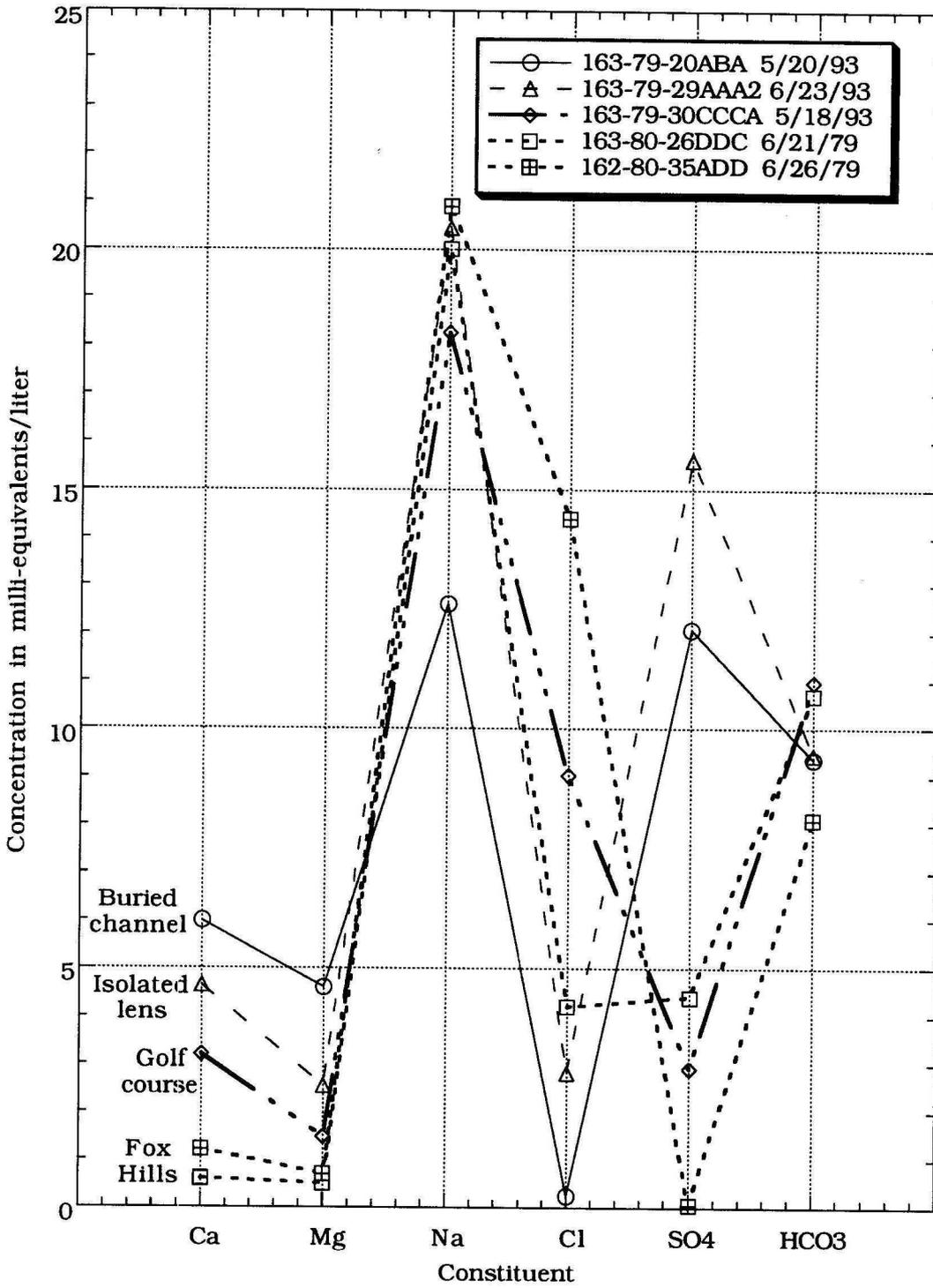


Figure 29 - Schoeller diagram illustrating water quality in Westhope area

The buried channel aquifer has a water with a higher concentration of calcium, magnesium, and sulfate and a lower concentration of sodium and chloride than the water in the Souris River valley. The quality of the water in the Souris River valley resembles the water quality of the area bedrock. Water from the Fox Hills-Hell Creek aquifer may pass through the Souris valley alluvium, then discharge to the Souris River.

The water quality from either the Souris River valley alluvium or from the buried channel aquifer is higher in dissolved solids, particularly sodium, than is preferred. The only potential municipal water source in the Westhope area which is not high in dissolved solids, including sodium, is the Souris River at times of high flow. The only observed significant difference in the dissolved mineral water quality between the samples from the Souris River valley alluvium and the buried valley is the higher chloride concentration in the alluvium samples and the higher sulfate concentration in the buried valley samples.

The water quality in the two aquifers showing the most favorable potential for use as a city supply is compared to the quality from the current city water source in a Schoeller diagram (fig 30). The diagram includes analyses of samples from the southernmost monitoring well in the golf course area, 163-79-30CCCA and from the southernmost monitoring well in the buried channel, 163-79-29CCD. The diagram also includes analyses of samples taken from the City of Westhope's current water supply, the Souris River, at high and low flow periods.

The concentrations of the major ions from the two aquifers, as shown in the Schoeller diagram, generally fall between the concentrations from samples collected at low flow and at high flow from the Souris River. Exceptions are the consistently higher concentration of sodium in the ground-water analyses and the higher concentration of chloride in the analysis from the well completed in the Souris River valley alluvium, along the east side of the municipal golf course.

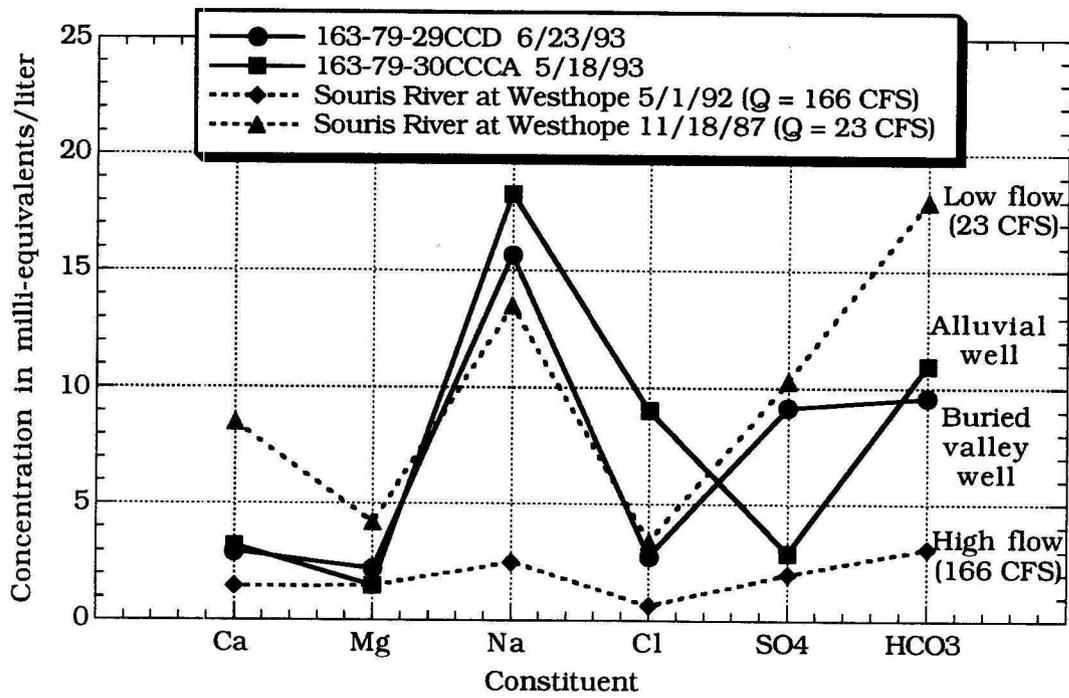


Figure 30 - Schoeller diagram comparing river and aquifer water quality

RECOMMENDATIONS

Location

Based on the test drilling performed in May and June 1993 and on other available information, two possible alternative water sources are recommended for the City of Westhope. The first alternative is the sand and gravel found at about 60 to 80 feet depth in the Souris River valley, along the east side of the municipal golf course in 163-79-30C. The second alternative is the buried valley aquifer trending north-south and passing through 163-79-29C (fig 31).

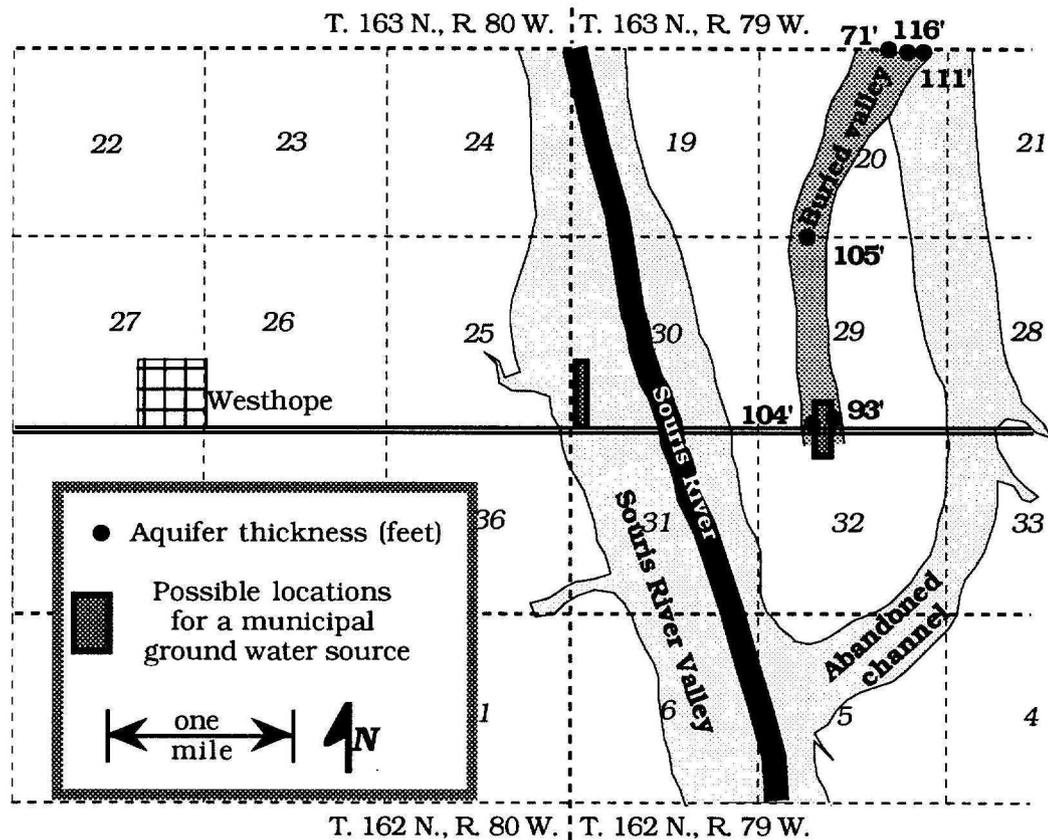


Figure 31 - Recommended location for municipal water supply wells

Either alternative is expected to be capable of providing a sufficient quantity of water to meet the city's water use requirement of about 70 acre-feet of water per year (43.4 gpm constant pumping), its peak monthly water use of 3,499,000 gallons (78.4 gpm constant pumping), and its peak daily water use of about 170,000 gallons

per day (118 gpm constant pumping). Sufficient pumping capacity to meet fire protection needs may further increase the required pumping capacity of the municipal water source.

Aquifer Test

It is recommended that an aquifer test be conducted on the chosen water source to determine the hydraulic characteristics of the aquifer, including the aquifer's ability to transmit water (hydraulic conductivity) and store water (storativity). An aquifer test consists of pumping a production well at a constant rate for a period of about 100 hours. During this period the drawdown of the water level is measured in the production well as well as several observation wells located at different distances from the production well. After pumping is discontinued the recovery of the water level is measured for a period of time equal to that of pumping. From this information the ability of the aquifer to yield water to wells can be determined along with appropriate well spacing and optimum pumping rate.

Water Quality

Both of the suggested alternative water sources have a higher concentration of dissolved solids (about 1400 mg/l) than is recommended by secondary water quality guidelines (500 mg/l). The dissolved mineral water quality in the suggested alternative water sources is somewhat similar to the present source, the Souris River, at times of low flow.

As discussed in the section comparing water quality in the Westhope area, the difference in the quality of the water from the Souris valley alluvium and from the buried channel farther east is primarily in the chloride and sulfate concentrations. The difference in water quality between the two possible sources does not provide a criteria to recommend one source over the other.

It is recommended that the dissolved mineral water quality be periodically tested. The dissolved mineral concentrations of calcium, magnesium, sodium, iron, manganese, bicarbonate, sulfate and chloride in particular are of interest, as well as the total dissolved solids concentration in the water from the well field.

Annual water quality sampling is recommended initially from a municipal water source well field. Knowing of changes in dissolved mineral concentrations may be helpful in adjusting the water treatment at the city treatment plant. Water quality may slowly change over time as water is drawn into the pumped wells from an expanding cone surrounding the wells. The rapidly changing water quality experienced when surface water is used as a source is not expected to occur from a ground-water source. The Water Commission is available for advice about sampling methods and constituents to be determined.

Monitoring Water Levels

It is recommended that water level measurements be taken and recorded from monitoring wells completed in the aquifer selected as a municipal water source. Monitoring of the water levels in the well field will allow for timely decisions to be made about any possible future need for expanding the well field. The Water Commission has been making monthly water level measurements in the areas of the Westhope area since May 1993, and on a less frequent basis since 1991.

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APPENDIX - LITHOLOGIC LOGS

Included in the appendix are the 36 test holes drilled in May and June 1993, the 13 test holes drilled in 1991, and 42 older test holes in the Westhope-Souris River area for which information is available. The locations of the test holes are shown on the area map (fig. 32). The locations of test holes in 163-79-30C are shown in figure 33.

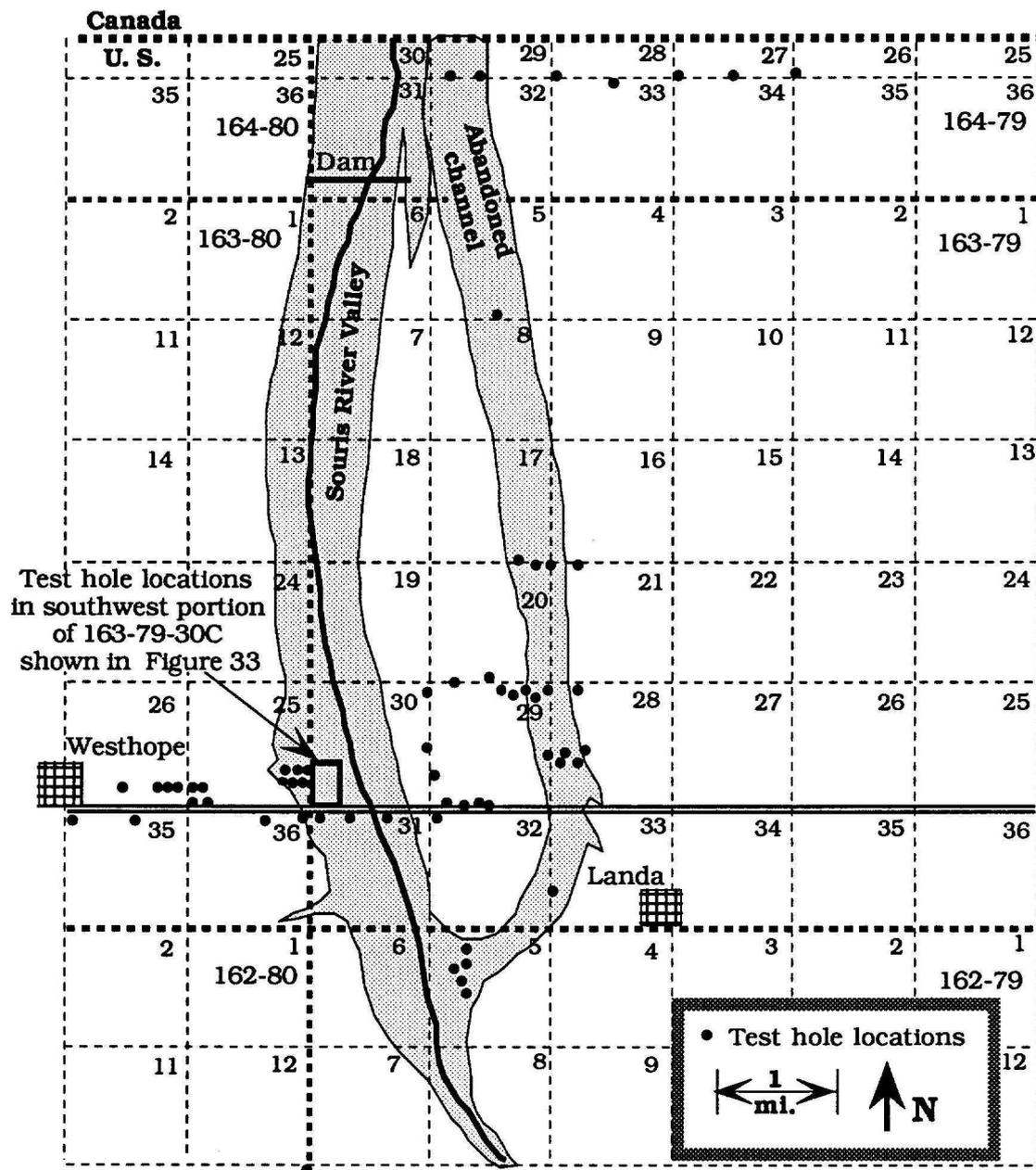


Figure 32 - Test hole locations

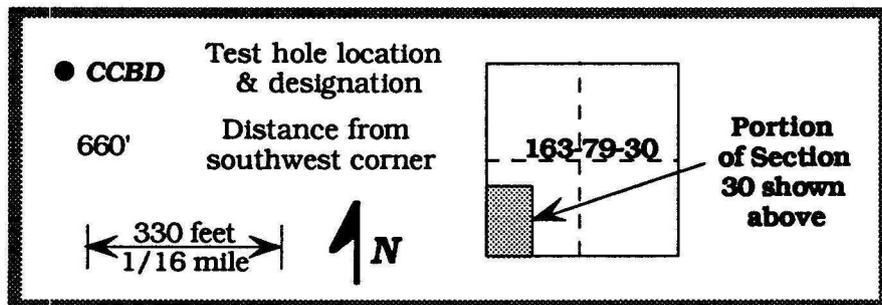
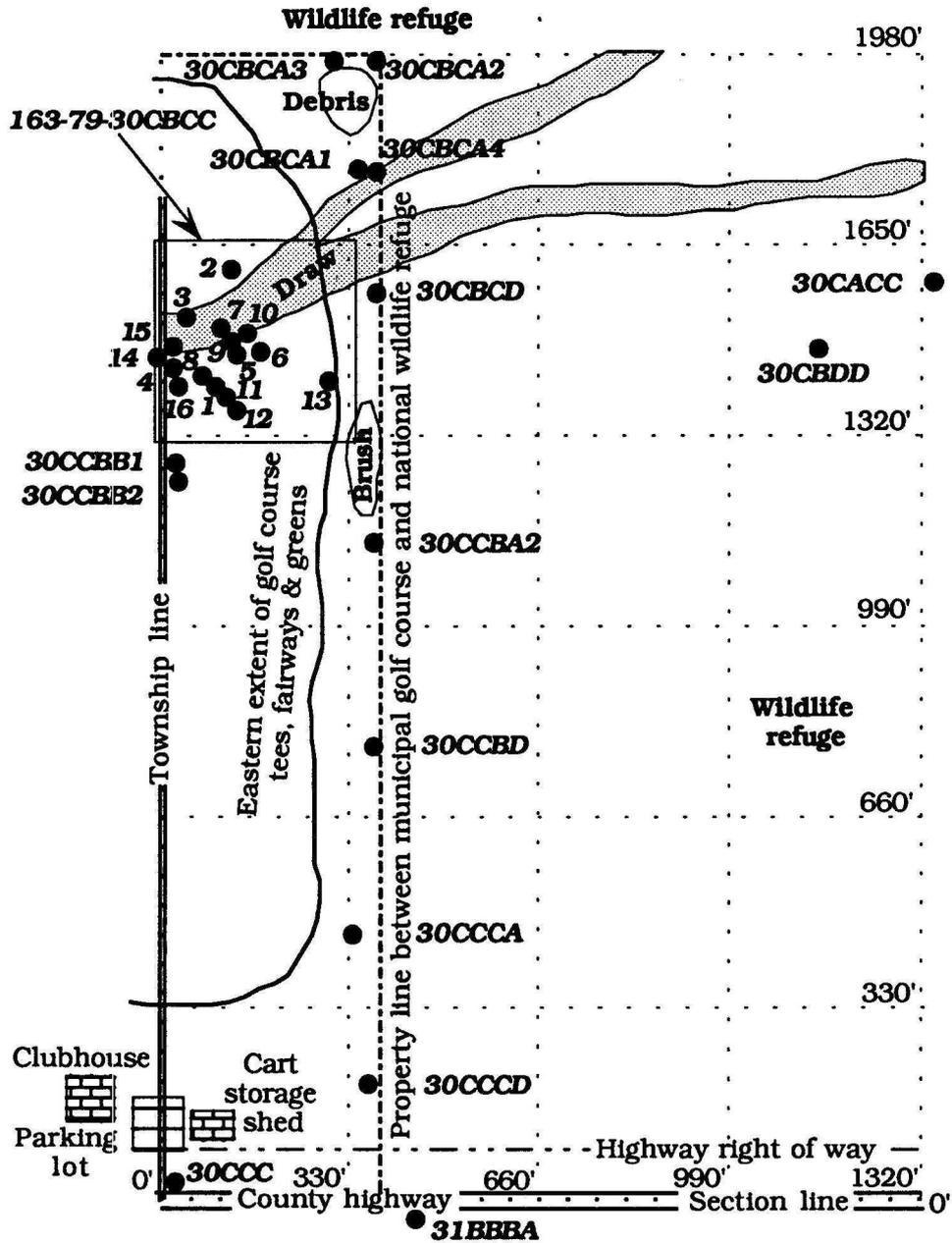


Figure 33 - Test hole locations in 163-79-30C

162-079-05BDBA

NDSWC 13154

Date Completed: 5/14/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 100
Source: NDSWC

Completion Info: 2 bags hole plug
Remarks: Northwest corner of gravel pit, 100' south of drop off into creek valley, & 150' east of drop off into same valley

Lithologic Log

Unit	Description	Depth (ft)
SAND & GRAVEL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand & gravel (oxidized till)	1-11
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	11-42
SAND & GRAVEL	30% gravel, well graded, silicates predominate	42-45
CLAY	As above (till)	45-47
SAND & GRAVEL	As above	47-49
CLAY	Olive gray, as above (till)	49-98
CLAY	Olive gray, hard, dark (bedrock - lower Fox Hills)	98-100

162-079-05BDCA

NDSWC 13153

Date Completed: 5/13/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 120
Source: NDSWC

Completion Info:
Remarks: Southwest corner of gravel pit

Lithologic Log

Unit	Description	Depth (ft)
GRAVEL	Coarse, with sand (gravel pit, no topsoil)	0-3
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	3-26
CLAY	Olive gray, 30%, w/clastics (till), gravely at 38', 64'-66' sand lens, 96' slightly gravely	26-101
CLAY	Olive gray, tight, 'greasy', (bedrock - Fox Hills, Trail City Member)	101-120

162-079-05BDCB

NDSWC 13150

Date Completed: 5/13/93 Purpose: Observation Well
L.S. Elevation (ft): 1445.1 Well Type: 2" PVC
Depth Drilled (ft): 120 Aquifer: Unnamed
Screened Interval (ft): 98-103 Source: NDSWC

Completion Info: 1.5 bags of hole plug, .018 inch slotted screen
Remarks: Along preserve fence, 100' S. of E-W draw

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Rocky	0-2
CLAY	Dark Yellowish brown, 25%, w/silt, sand, & gravel (rocky, oxidized till), sand lens at 23' & 25', slightly less oxidized at 31'	2-40
CLAY	Olive gray, 30%, w/silt, sand, & gravel (sandy till), sand lens at 41', 43', 47' to 49', 66'	40-90
SAND & GRAVEL	35% gravel, poorly sorted, app. equal amounts of silicates, carbonates, & shale	90-101
SAND	Coarse, poorly sorted, 10% gravel, rock at 105'	101-106
CLAY	Olive gray to olive black (bedrock - Fox Hills)	106-120

162-079-05BDCC

NDSWC 13151

Date Completed: 5/13/93 Purpose: Test Hole
L.S. Elevation (ft): 1445
Depth Drilled (ft): 120
Source: NDSWC

Completion Info: 3 bags of hole plug
Remarks: SW corner of field, along refuge fence line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till), sand lens at 7'	2-25
CLAY	Olive gray, 30%, w/clastics (till)	25-30
SAND	Coarse grained, moderate sorting	30-36
CLAY	Olive gray, as above (till), sand lens at 46', 52', 83', 86', gravely from 86'	36-96
SAND & GRAVEL	30% gravel, poorly sorted	96-103
CLAY	Gravely	103-105
CLAY	Olive gray to olive black (bedrock - Fox Hills)	105-120

162-079-05CABD

NDSWC 13152

Date Completed: 5/13/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 140
Source: NDSWC

Completion Info: 3 bags of hole plug
Remarks: Along preserve fence, west of trees along draw

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND & GRAVEL		2-5
CLAY	Gravelly, lenses of gravel	5-16
CLAY	Dark yellowish brown, 30%, w/silt, sand & gravel (oxidized till)	16-31
CLAY	Olive gray, 30%, w/clastics (till), sand lens at 37', gravel lens at 86'-88', 97', 99'	31-121
CLAY	Olive gray, (bedrock - Fox Hills)	121-140

162-080-13AAA

NDSWC 12850

Date Completed: 8/14/91 Purpose: Test Hole
L.S. Elevation (ft): 1485
Depth Drilled (ft): 160
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch west of road, 50' south of section line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel (oxidized)	2-38
TILL	Clay, olive gray, 30%, with silt, sand, & gravel, gravel lenses at 121', 131'	38-146
CLAY	Olive gray to dark greenish gray, silty, (bedrock - Fox Hills or Pierre Formation)	146-160

163-079-05CDD

NDSWC 12848

Date Completed: 8/14/91 Purpose: Test Hole
 L.S. Elevation (ft): 1462
 Depth Drilled (ft): 120
 Source: NDSWC

Completion Info:

Remarks: Ditch north of trail, 150' west of 1/4 line & low, north & east of farmstead

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel (oxidized)	2-24
TILL	Clay, olive gray, 30%, with silt sand, & gravel	24-60
SAND & GRAVEL	30% gravel, well graded, subangular, silicates predominate	60-62
TILL	Olive gray, as above	62-66
SAND & GRAVEL	As above	66-74
TILL	Clay, olive gray, as above, with pieces of bedrock	74-94
CLAY	Olive black, consolidated, drills slow, (bedrock - Fox Hills or Pierre Formation)	94-120

163-079-17DCC

NDSWC 12839

Date Completed:	8/9/91	Purpose:	Observation Well
L.S. Elevation (ft):	1478.44	Well Type:	2" PVC
Depth Drilled (ft):	160	Aquifer:	Unnamed
Screened Interval (ft):	132-137	Source:	NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Located in ditch north of road at 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel (oxidized)	2-51
TILL	Clay, olive gray, 30-35%, cohesive, with silt, sand, & gravel	51-76
SAND	Very coarse grained, some gravel, poor to moderate sorting, subangular, shale, quartz, lignite, silicates, carbonates, 101'-120' has pieces of Fox Hills sandstone, abundant lignite, coarser below 123',	76-147
CLAY	Olive gray, consolidated, (bedrock - Fox Hills or Pierre Formation)	147-160

163-079-20AAB

NDSWC 13207

Date Completed: 6/14/93 Purpose: Test Hole
 L.S. Elevation (ft): 1455
 Depth Drilled (ft): 200

Source: NDSWC

Completion Info: 4 bags of hole plug
 Remarks: 400' east of well in 20ABA

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark Yellowish brown, silty	1-3
SAND & GRAVEL	25% gravel, well graded, first two feet are oxidized, lithology is primarily carbonates and shale clasts	3-13
CLAY	Olive gray, 30% w/silt, sand, & gravel (till)	13-63
SILT	with clay, olive gray w/interbedded sand & some gravel	63-82
SAND	Very coarse grained, poorly sorted, a little gravel, some silt or clay lenses	82-91
SAND & GRAVEL	40% gravel, poorly sorted, carbonates, shale, silicates, some sandstone, somewhat resembles surface gravel	91-97
SAND	Very coarse, as above	97-107
SAND & GRAVEL	As above, lignite chips at 116'	107-116
SAND	As above, interbedded w/silt & clay, some light gray, bentonitic looking clay, somewhat similar to 63-82 interval, w/lignite, more silt & clay w/depth	116-193
CLAY	Olive gray, slightly silty, 'greasy', compact, (Bedrock - Hell Creek)	193-200

163-079-20ABA

NDSWC 12838

Date Completed:	8/8/91	Purpose:	Observation Well
L.S. Elevation (ft):	1456.28	Well Type:	2" PVC
Depth Drilled (ft):	240	Aquifer:	Unnamed
Screened Interval (ft):	138-143	Source:	NDSWC

Completion Info: .018 inch slotted screen
Remarks: Located in ditch south of road, west of 1/4 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND & GRAVEL	40% gravel, well graded, subangular, silicates, carbonates, sandstone, shale	2-17
SILT	olive gray to dark yellowish brown, sandy, argillaceous	17-22
TILL	Clay, olive gray, 30% with silt, sand & gravel, sandier below 70'	22-78
SAND	Very coarse grained, fair sorting, subangular, shale, lignite, quartz	78-88
SAND	Fine grained, silty, argillaceous, overall dark greenish gray color	88-101
SAND & GRAVEL	25% gravel, subrounded to subangular, shale, sandstone, lignite, drills choppy, clay lenses at 105', 111', 154-158', rocky at 215-217'	101-217
CLAY	Olive gray, slightly silty, drills slow, (bedrock - Pierre or Fox Hills Formation)	217-240

163-079-20CCD
NDSWC 13208

Date Completed:	6/15/93	Purpose:	Observation Well
L.S. Elevation (ft):	1485.47	Well Type:	2" PVC
Depth Drilled (ft):	250	Aquifer:	Unnamed
Screened Interval (ft):	168-173	Source:	NDSWC

Completion Info: 3 bags of hole plug, .018 inch slotted screen
 Remarks: Ditch north of road 880' east of section line, east of approach

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand & gravel (oxidized till), sand lens at 11'	1-38
CLAY	Olive gray, w/silt, sand, & gravel (till), sand lens at 75'	38-88
SAND & GRAVEL	25% gravel, shale, sandstone, carbonates, silicates, (drilled fast, lithology similar to one mile north)	88-91
CLAY	Olive gray, as above (till)	91-118
SAND & GRAVEL	30% gravel, well graded, shale, carbonates, lignite, silicates, sandstone, drills choppy, (lithology looks like channel one mile north)	118-132
SILT	Greenish gray, argillaceous	132-136
SAND & GRAVEL	60% gravel, as above, maybe coarser, from 144' there is abundant shale & other broken up area bedrock	136-160
SAND & GRAVEL	40% gravel, carbonates & silicates as well as sandstone and shale, similar to 118-132 interval	160-187
SILT	Olive gray	187-191
SAND & GRAVEL	60% gravel, as above	191-220
SILT	Argillaceous, olive gray	220-227
SAND & GRAVEL	As above	227-238
CLAY	Olive gray, silty, compacted, drills slow (Bedrock - Hell Creek)	238-250

163-079-20DCC

NDSWC 13204

Date Completed: 6/10/93 Purpose: Test Hole
 L.S. Elevation (ft): 1485
 Depth Drilled (ft): 120
 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch north of road, 20 feet east of 1/4 line approach

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-40
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand lens at 76-78', 82', 102-105', rock at 112'	40-113
CLAY	Olive gray, cohesive (Bedrock - Hell Creek)	113-120

163-079-21BAB

NDSWC 12840

Date Completed: 8/12/91 Purpose: Test Hole
 L.S. Elevation (ft): 1485
 Depth Drilled (ft): 80
 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch south of road at 1/4, 1/4 approach-tree row to south, east of approach

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, 30%, dark yellowish brown, cohesive, with silt, sand, & gravel (oxidized)	2-32
TILL	Clay, 30%, olive gray, cohesive, with silt, sand & gravel	32-56
SILT	Olive gray, argillaceous, drills slow	56-58
SAND	Very coarse grained, fair sorting, subrounded to subangular, silicates	58-60
SANDSTONE	Medium to fine grained, well sorted, indurated, grains are dark greenish gray, green, black, & clear, interstitial clay, (bedrock - Fox Hills Formation)	60-80

163-079-28BBA

NDSWC 13120

Date Completed: 6/10/93 Purpose: Test Hole
 L.S. Elevation (ft): 1480
 Depth Drilled (ft): 80
 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch south of road, 100' west of 1/4 mile approach, south of farmstead

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-6
SILT	Dark yellowish brown, sandy, argillaceous	6-12
CLAY	Dark yellowish brown, as above (till)	12-32
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	32-61
SILT	Olive gray, sandy, argillaceous, firm, drills slowly, sometimes greenish-brownish (Bedrock - Hell Creek)	61-80

163-079-28BCCC

NDSWC 13155

Date Completed: 5/14/93 Purpose: Test Hole
 L.S. Elevation (ft): 1460
 Depth Drilled (ft): 140
 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch east of road, north of 1/4 line approach, SW of gravel pit

Lithologic Log

Unit	Description	Depth (ft)
CLAY	Dark yellowish brown, 30%, w/silt, sand & gravel (oxidized till), gravely at surface (topsoil stripped off), sand lens at 23', 36'	0-12
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	12-47
SAND	Medium grained, moderate sorting, silicates	47-56
CLAY	Olive gray, 20%, w/silt, sand, & gravel (till), sand lens 58'-60', 76'-78', 108', 110'-111'	56-122
CLAY	Olive gray, stiff (bedrock - Fox Hills)	122-140

163-079-28BCCD

NDSWC 13159

Date Completed: 5/17/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 120
Source: NDSWC

Completion Info: 3 bags of hole plug
Remarks: East side of abandoned farmstead, 50' NE of trees, near shed

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till), sand & gravel lens at 3'-4', 5'-7'	2-8
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand lens at 33'-34'	8-96
GRAVEL	Rocks, 70% gravel, coarse, poorly sorted, silicates	96-103
CLAY	Dark greenish gray, consolidated (bedrock - lower Fox Hills)	103-120

163-079-28BCDC

NDSWC 13157

Date Completed: 5/17/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 100

Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Mid valley, 500' east of farm buildings

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	2-3
SAND & GRAVEL	(Oxidized)	3-4
CLAY	Dark yellowish brown, as above (till)	4-9
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	9-36
SAND	Medium grained, moderate sorting, quartz, dark silicates, carbonates, loose, runs into hole	36-42
CLAY	Olive gray, as above (till), sand lens at 44', 47', 56'	42-57
SAND	Medium grained, as above	57-60
CLAY	Olive gray, as above (till)	60-93
CLAY	Olive gray to dark greenish gray, (bedrock - Fox Hills, Trail City Member)	93-100

163-079-28BCDD

NDSWC 13158

Date Completed: 5/17/93 Purpose: Test Hole
L.S. Elevation (ft): 1450
Depth Drilled (ft): 100
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Edge of field, east side of valley, 700' east of farm buildings

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till), gravel at 3'	2-12
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till - 10'-16' is transition zone from oxidized to reduced)	12-91
CLAY	Dark greenish gray to olive black, consolidated, drills slow (bedrock - Fox Hills, Trail City Member)	91-100

163-079-28CBBB

NDSWC 13156

Date Completed: 5/17/93 Purpose: Test Hole
L.S. Elevation (ft): 1455
Depth Drilled (ft): 120
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch south of approach to farmhouse, SW corner of farmstead

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, 30%, moderately cohesive, w/silt, sand, & gravel (oxidized till)	2-6
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand lens at 41'-42', 56'-57' (coarse, abundant shale), rock at 76'	6-102
SAND & GRAVEL	25% gravel, poorly sorted, silicates, carbonates, shale	102-105
CLAY	Olive gray, as above (till)	105-108
CLAY	Olive black, consolidated, (bedrock - Fox Hills, Trail City Member)	108-120

163-079-29AAA1

NDSWC 13200

Date Completed: 6/10/93 Purpose: Test Hole
 L.S. Elevation (ft): 1450
 Depth Drilled (ft): 120

Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch 30' south & 50' west of section corner road intersection

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30% w/silt, sand, & gravel(oxidized till)	1-3
SAND & GRAVEL	35% gravel, coarse, poorly sorted, silicates, carbonates, shale, (oxidized)	3-11
CLAY	Dark yellowish brown, (till, as above)	11-12
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand lens at 43-44', 53-54'	12-111
CLAY	Olive black, solid, consolidated, drills slow (bedrock - Upper Cretaceous)	111-120

163-079-29AAA2

NDSWC 13206

Date Completed:	6/11/93	Purpose:	Observation Well
L.S. Elevation (ft):	1458.38	Well Type:	2" PVC
Depth Drilled (ft):	130	Aquifer:	Unnamed
Screened Interval (ft):	93-98	Source:	NDSWC

Completion Info: 2 bags of hole plug, .012 inch slotted screen
 Remarks: Ditch south of road, 560' west of section line, 300' east of AAB well

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND & GRAVEL	15% gravel, poorly sorted, silicates predominate, oxidized	1-3
CLAY	Dark yellowish brown, 30% w/silt, sand, & gravel (oxidized till)	3-16
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	16-18
CLAY	Olive gray to olive black, slightly silty, 'greasy', stiff to claystone (more competent than usual bedrock (bedrock block)	18-32
CLAY	Olive gray, 30%, w/silty, sand, & gravel (till)	32-84
SAND & GRAVEL	Interbedded with clay	84-89
SAND & GRAVEL	20% gravel, poorly sorted, primarily silicates & carbonates	89-102
CLAY	Olive gray, as above (till)	102-122
CLAY	Olive gray, stiff, 'greasy', (bedrock - Upper Cretaceous)	122-130

163-079-29AAB1

NDSWC 13202

Date Completed:	6/10/93	Purpose:	Observation Well
L.S. Elevation (ft):	1466.66	Well Type:	2" PVC
Depth Drilled (ft):	140	Aquifer:	Unnamed
Screened Interval (ft):	98-103	Source:	NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Ditch south of road, 860' west of section line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand & gravel (oxidized till), slightly darker at 16', sand & gravel lens at 4'	1-36
CLAY	Olive gray 30%, w/silt, sand, & gravel (till), sand lens at 48', 53'	36-56
CLAY	Olive gray, as above (till)	61-76
SAND	Fine to medium grained, moderately well sorted, quartzose	56-61
SAND & GRAVEL	20% gravel, poorly sorted, shield silicates & carbonates	76-86
CLAY	Olive gray, as above (till)	86-89
SAND & GRAVEL	40% gravel, as above, coarser	89-110
CLAY	Olive gray, as above (till)	110-123
SAND & GRAVEL	As above	123-127
CLAY	Olive gray to olive black, 'greasy', (bedrock - Hell Creek)	127-140

163-079-29AAB2

NDSWC 13205

Date Completed: 6/10/93 Purpose: Test Hole
L.S. Elevation (ft): 1470
Depth Drilled (ft): 120
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch south of road, 270' west of well at AAB1

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30% w/silt, sand, & gravel (oxidized till)	1-37
CLAY	Olive gray 30%, w/silt, sand, & gravel (till), sand lens at 51'	37-92
SAND & GRAVEL	20% gravel, primarily shield silicates & carbonates, interbedded with clay, particularly upper 1/2 of interval	92-105
CLAY	Olive gray, as above (till)	105-118
CLAY	Olive gray, (bedrock - Hell Creek)	118-120

163-079-29ABA

NDSWC 13203

Date Completed: 6/10/93 Purpose: Test Hole
L.S. Elevation (ft): 1475
Depth Drilled (ft): 120

Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Located 540' west of 13202 (29ABA1), in ditch south of road, 100'
west of 1/4, 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel, slightly darker below 30' (oxidized till)	1-38
CLAY	Olive gray, 30%, w/silt, sand, & gravel, gravel lens at 61'-62', (till)	38-73
SAND	Coarse grained, poorly sorted, some gravel, interbedded with clay	73-82
CLAY	Olive gray, as above (till)	82-115
CLAY	Olive gray to olive black, 'greasy', (bedrock)	115-120

163-079-29CCB

NDSWC 13211

Date Completed: 10/15/93 Purpose: Test Hole
 L.S. Elevation (ft): 1485
 Depth Drilled (ft): 160
 Source: NDSWC

Completion Info:

Remarks: Ditch east of road, 1/4 mile north of section corner, south of approach

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30% w/silt, sand, & gravel (oxidized till)	1-42
CLAY	Olive gray, 30% w/silt, sand, & gravel (till)	42-69
SAND	Fine grained, moderately well sorted, quartzose	69-75
CLAY	Olive gray, as above (till)	75-102
SAND & GRAVEL	25% gravel, well graded, shale, carbonates, silicates	102-107
CLAY	Olive gray, as above (till)	107-126
SAND & GRAVEL	As above	126-128
CLAY	Olive gray, as above (till), sand lens at 132'	128-140
CLAY	Olive gray, slightly silty, 'greasy', slow drilling (bedrock - Hell Creek)	140-160

163-079-29CCC

NDSWC 13213

Date Completed: 6/16/93 Purpose: Test Hole
L.S. Elevation (ft): 1480
Depth Drilled (ft): 140
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch north of paved road, 660' east of section line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-31
CLAY	Olive gray, 30%, w/silt, sand & gravel (till), sand lens at 69-71'	31-82
SAND	Medium grained, poorly sorted, quartz, other silicates, carbonates, shale, clay lens at 87-89', interbedded clay 90-95'	82-95
CLAY	Olive gray, as above (till)	95-124
CLAY	Olive gray to dark greenish gray, slightly silty, 'greasy', firm (bedrock - Hell Creek)	124-140

163-079-29CCD

NDSWC 13212

Date Completed:	6/15/93	Purpose:	Observation Well
L.S. Elevation (ft):	1479.96	Well Type:	2" PVC
Depth Drilled (ft):	240	Aquifer:	Unnamed
Screened Interval (ft):	158-163	Source:	NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Ditch north of road, 50' west of 1/4,1/4 line approach

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-36
CLAY	Olive gray 30%, w/silt, sand, & gravel (till)	36-62
SAND & GRAVEL	30% gravel, silicates, carbonates, shale, sandstone, clay lenses at 65', 68'	62-70
CLAY	Olive gray, as above (till)	70-120
SAND & GRAVEL	30% gravel, well graded, silicates, carbonates, shale, lignite, sandstone	120-175
SILT	with clay, olive gray	175-181
SAND & GRAVEL	As above	181-209
SAND & GRAVEL	As above, interbedded with silt & clay, as above	209-226
SAND	Fine grained, quartzose, in a greenish clay matrix (bedrock - Fox Hills or Hell Creek), silty clay in bottom 5'	226-240

163-079-29CDC

NDSWC 13214

Date Completed: 6/16/93 Purpose: Test Hole
L.S. Elevation (ft): 1480
Depth Drilled (ft): 220
Source: NDSWC

Completion Info:

Remarks: Ditch north of paved road, 550' east of 1/4,1/4 approach, 600'
east of well #13212

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30% w/silt, sand, & gravel (oxidized till)	1-25
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand & gravel lens at 82-83'	25-124
SAND & GRAVEL	Interbedded with clay	124-136
SAND & GRAVEL	50% gravel, many carbonates & shale, also silicates & sandstone, & lignite, from 162 much shale, some interbedded clay 162-170, 190-200, through 200-217 is coarser, less shale	136-217
SAND	Fine grained, with greenish gray clay (bedrock - Fox Hills or Hell Creek)	217-220

163-079-29CDD

NDSWC 13215

Date Completed: 6/16/93 Purpose: Test Hole
L.S. Elevation (ft): 1480
Depth Drilled (ft): 140
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch north of paved road, 580' east of CDC test hole, near unmarked 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-23
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till)	23-134
SAND	V. fine grained, with a greenish gray matrix of clay, and clay, olive gray to greenish gray, silty, 'greasy', (bedrock - Hell Creek or Fox Hills)	134-140

163-079-30AAA

NDSWC 13209

Date Completed: 6/15/93 Purpose: Test Hole
L.S. Elevation (ft): 1485
Depth Drilled (ft): 160
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch west of road, 80' north of section line, 900' west & 100' north of #13208

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, w/silt, sand, & gravel (oxidized till)	1-44
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand & gravel lens at 62', 68', 101'	44-126
CLAY	Olive gray, slightly silty, (bedrock - Hell Creek)	126-145
SAND	Very fine grained to fine grained, w/clay - greenish gray, (bedrock - Fox Hills or Hell Creek)	145-160

163-079-30ADD

NDSWC 13210

Date Completed: 6/15/93 Purpose: Test Hole
L.S. Elevation (ft): 1485
Depth Drilled (ft): 140
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch west of road, 50' north of approach at 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till), disintegrated shale boulder at 21'	1-35
CLAY	Olive gray, 30%, w/silt, sand & gravel (till)	35-77
SAND & GRAVEL	25% gravel, silicates & carbonates, shale & sandstone, runs into drilled hole	77-83
CLAY	Olive gray 30%, as above (till)	83-87
SAND & GRAVEL	As above	87-89
CLAY	Olive gray, as above, sand & gravel lens at 126-127', 132'	89-134
CLAY	Olive gray, silty (bedrock)	134-140

163-079-30CACC

NDSWC 971

Date Completed: 9/8/54 Purpose: Test Hole
L.S. Elevation (ft): 1415
Depth Drilled (ft): 70
Source: NDSWC

Completion Info:

Remarks: Danielson & McMaster's descriptive log, a second page
(sediments found below 70 feet depth) seems to have been lost

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Black	0-1
CLAY	Sandy, brown	1-2
CLAY	Yellow, and fine to medium gravel and shale pebbles	3-5
SAND & GRAVEL		5-10
SAND	Medium to coarse, silty; contains shale fragments	10-20
CLAY	Plastic, tray, and fine gravel and shale pebbles	20-45
SAND & GRAVEL		45-55
CLAY	Gray, and fine to medium gravel and shale pebbles (till)	55-70

163-079-30BCA1

Westhope 90-3

Date Completed: 4/18/90 Purpose: Test Hole
L.S. Elevation (ft): 1420
Depth Drilled (ft): 111

Source: C. A. Simpson & Son

Completion Info: Well destroyed, or covered with debris
Remarks: T. H. 90-3; Said to have been drilled about 50' west of CBCA4

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow, soft	1-5
SAND	Clayey, yellow	5-10
CLAY	Yellow	10-17
SAND		17-19
CLAY	Yellow	19-23
SAND	Yellow	23-26
CLAY	Blue, soft, thin sand layers	26-37
CLAY	Blue	37-61
SAND	Medium grained, finer on top	61-74
CLAY	Blue	74-80.5
GRAVEL		80.5-82.5
CLAY	Blue, gravely	82.5-102
SHALE		102-111

163-079-30BCA2

NDSWC 13148

Date Completed:	5/13/93	Purpose:	Observation Well
L.S. Elevation (ft):	1421.53	Well Type:	2" PVC
Depth Drilled (ft):	120	Aquifer:	Unnamed
Screened Interval (ft):	91-96	Source:	NDSWC

Completion Info: Slotted 0.018 inch screen; 2 bags of hole plug
 Remarks: NE corner of golf course property, N. & E. of debris pile

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, silty	2-7
SAND	Medium grained, poorly sorted	7-9
CLAY	As above	9-16
SAND & GRAVEL	20% gravel, silicates, carbonates	16-17
CLAY	Dark yellowish brown to olive gray, silty	17-23
SAND	Coarse grained, poorly sorted, quartzose	23-25
CLAY	Olive gray, silty, sand lens at 33', 36'	25-40
CLAY	Olive gray to olive black, 'greasy', plastic, not much silt	40-64
SAND	Coarse grained, poorly sorted, silicates, carbonates, shale	64-73
CLAY	Olive gray, 30%, w/clastics (till), gravel lens at 75'	73-81
SAND & GRAVEL	25% gravel, poorly sorted, silicates, carbonates, shale	81-85
CLAY	Olive gray	85-87
SAND & GRAVEL	As above	87-100
CLAY	Olive black (bedrock - lower Fox Hills)	100-120

163-079-30BCA3

NDSWC 13149

Date Completed: 5/13/93 Purpose: Test Hole
 L.S. Elevation (ft): 1420
 Depth Drilled (ft): 120
 Source: NDSWC

Completion Info: 3 bags of hole plug
 Remarks: 220' west of CBCA2, ND corner of golf course mowed area

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, silty	2-6
SAND	Coarse grained, poorly sorted	6-8
CLAY	As above	8-14
SAND	As above	14-17
CLAY	As above	17-20
SILT	Dark yellowish brown, clayey	20-24
SAND		24-25
SILT	As above	25-31
SILT	Olive gray, clayey	31-34
SAND		34-35
CLAY	Silty, olive gray	35-41
CLAY	Olive gray, 'greasy', plastic, not very silty, (a lot of probably Trail City & Pierre derived material)	41-68
SAND & GRAVEL	20% gravel, poorly sorted, silicates, carbonates, shale, rock at 74'	68-75
CLAY	Olive gray, 30%, w/clastics (till)	75-81
SAND		81-82
CLAY	As above (till)	82-93
SAND		93-95
CLAY	As above (till), rattle at 98'	95-101
CLAY	Olive gray, greasy, (bedrock - Fox Hills, Trail City Member)	101-120

163-079-30BCA4

NDSWC 13160

Date Completed:	5/18/93	Purpose:	Observation Well
L.S. Elevation (ft):	1422.87	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Unnamed
Screened Interval (ft):	25-30	Source:	NDSWC

Completion Info: Slotted 0.018 inch screen; 3 bags of hole plug
 Remarks: Just north of draw in northeast corner of golf course, SE corner of debris pile area

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, silty	2-20
SAND & GRAVEL	30% gravel, well graded, silicates, etc.,	20-30
CLAY	Olive gray, silty, sandy, sand lenses at 34', 36', 38', 43', 45'	30-46
CLAY	Olive gray, 'greasy', plastic, not so silty	46-63
SAND	Very coarse grained, moderate sorting, silicates predominate, gravel, rocks at 74'-75'	63-77
CLAY	Olive gray, slightly silty, sand lens at 91', sandier 85-97', gravel, rocks 96'-97'	77-97
CLAY	Olive black, bedrock (Upper Cretaceous)	97-100

163-079-30CBCC

NDSWC 950

Date Completed: 8/9/54 Purpose: Test Hole
L.S. Elevation (ft): 1415
Depth Drilled (ft): 110
Source: NDSWC

Completion Info:

Remarks: Located '16 steps southwest of city park well, 2 miles east & 1/3 mile north of Westhope'

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Sandy, black	0-1
CLAY	Sandy, brown	1-3
SAND	Fine to coarse, silty	3-11
CLAY	Yellow, oxidized	11-21
SAND	Fine to coarse, silty	21-25
GRAVEL	Coarse, silty	25-30
SAND & GRAVEL		30-40
CLAY	Gray, with fine to medium gravel (till)	40-105
SHALE	Gray, (bedrock - Fox Hills)	105-110

163-079-30CBCC1

Westhope 57-1

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 60
Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. 57-1; located 135' SE of old well with hand pump; some water 20'-30'

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-2.5
GRAVEL	Clayey, with stones	2.5-3.5
SAND		3.5-11
CLAY	Yellow, very sandy	11-20
SAND & GRAVEL	Water level about 10'	20-30
SAND	Fine, very clayey	30-38
CLAY	Blue	38-60

163-079-30CBCC2

Westhope 57-2

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 55
Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. 57-2; located 135' N. E. of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-3
CLAY	Yellow, sandy	3-3.5
SAND	Yellow, clayey	3.5-4
CLAY	Yellow, slightly sandy	4-5
SOIL	Black	5-5.5
CLAY	Yellow	5.5-10
CLAY	Very sandy	10-21
SAND	Rather fine	21-24
SAND & GRAVEL	Clayey, coarse	24-28
CLAY	Blue, gravelly	23-42
CLAY	Blue, sandy	42-48
SHALE	Gray	48-55

163-079-30CBCC3

Westhope 57-3

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 55
Source: C. A. Simpson & Son

Completion Info:
Remarks: T. H. 57-3; located 25.5' N.E. of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	With gray clay	0-2
CLAY	Yellow, sandy	2-20
CLAY	Yellow, sandy & gravelly, some water	20-35
CLAY	Blue	35-36
CLAY	Blue, with fine sand	36-47
CLAY	Blue	47-55

163-079-30CBCC4

Westhope 57-4

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 55
Source: C. A. Simpson & Son

Completion Info:
Remarks: T. H. 57-4; located 65' south (& a little east) of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	& gray clay	0-2
CLAY	Sandy	2-18
SAND & GRAVEL	Muddy, with stones	18-34
CLAY	Gray, sandy	34-38
SAND	Fine, muddy	38-46
CLAY	Blue, shaley	46-55

163-079-30CBCC5

Westhope 57-5

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 34
Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. 57-5; located 16' S.E. of #57-1 (163-70-30CBCC1)

Lithologic Log

Unit	Description	Depth (ft)
SOIL	Black	0-1.5
CLAY	Yellow	1.5-2.5
GRAVEL	Clayey, stony	2.5-3.5
SAND	Clayey	3.5-9
CLAY	Gravelly	9-10
CLAY	Very sandy	10-20
GRAVEL	Muddy	20-24
SAND & GRAVEL		24-31
CLAY	Blue, gravelly	31-34

163-079-30CBCC6

Westhope 57-6

Date Completed: 8/1957 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 35

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #57-6; located about 40' east of #57-5 (163-79-30CBCC5)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Black	0-1
CLAY	Gray	1-2
SAND	Clayey	2-5
CLAY	Sandy	5-7
CLAY	Yellow, gravelly	7-9
SAND	Yellow, very clayey	9-14
CLAY	Yellow, very gravelly & sandy	14-33
CLAY	Blue	33-35

163-079-30CBCC7

Westhope 58-7

Date Completed: 1958 Purpose: Test Hole
L.S. Elevation (ft): 1420
Depth Drilled (ft): 36

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-7; located 81.5 feet east of old well with hand pump; too much clay to make a good producing well

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Gray	2-4
CLAY	Yellow, Very sandy, 20-30' especially sandy, coarse sand at 25'	4-34
CLAY	Blue, soft	34-36

163-079-30CBCC8

Westhope 58-8

Date Completed: 1958 Purpose: Test Hole
L.S. Elevation (ft): 1423
Depth Drilled (ft): 31.5
Source: C. A. Simpson & Son

Completion Info: A test screen was set 24'-30'. Yield was about 2gpm with full drawdown
Remarks: T. H. #58-8; located 119.5' SE of old well with hand pump, or about 4 feet NW of T.H. #57-1

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Yellow, stony	2-3
SAND	Yellow, clayey	3-8
CLAY	Yellow, sandy	8-18
SAND	Clayey, with pebbles	18-24
CLAY	Yellow, very sandy	24-31.5

163-079-30CBCC9

Westhope 58-9

Date Completed: 1958
L.S. Elevation (ft): 1422
Depth Drilled (ft): 40

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-9; located 23 feet south of #57-7 (163-79-30CBCC7) or about 5 feet south of #57-5 (163-79-30CBCC5)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1.5
CLAY	Yellow, pebbly	1.5-2.5
CLAY	Yellow	2.5-3
SOIL	Black	3-4
CLAY	Yellow, sandy (drilled open to 20')	4-19
CLAY	Yellow, hard, gravelly	19-20
CLAY	Yellow, very gravelly	20-31
CLAY	Blue, sandy	31-40

163-079-30CBCC10

Westhope 57-10

Date Completed: 1958
L.S. Elevation (ft): 1423
Depth Drilled (ft): 31

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. 58-10; located east of 58-9 (163-79-30CBCC9), near #57-5 (163-79-30CBCC5); all the gravelly formations carried too much clay

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1.5
CLAY	Yellow	1.5-2
GRAVEL	Clayey, pebbles	2-8
CLAY	Yellow, sandy	8-17
CLAY	Gravelly, pebbles	17-20
GRAVEL	Clayey	20-23
GRAVEL	Somewhat clayey	23-25
SAND & GRAVEL	Very clayey	25-31

163-079-30CBCC11

Westhope 58-15

Date Completed: 1958 Purpose: Test Hole
 L.S. Elevation (ft): 1423
 Depth Drilled (ft): 40

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-15; located 128' SE of old well with hand pump, or 5'
 SE of #57-1 (163-79-30CBCC1)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1.5
CLAY	Yellow	1.5-2
SAND	Clayey, pebbles	2-3
SAND & GRAVEL	Clayey	3-10.5
CLAY	Sandy	10.5-31
CLAY	Blue, soft	31-40

163-079-30CBCC12

Westhope 58-16

Date Completed: 1958 Purpose: Test Hole
 L.S. Elevation (ft): 1423
 Depth Drilled (ft): 28

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-16; located 87.5' SE of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Yellow, sandy	2-21
CLAY	Very sandy	21-28

163-079-30CBCC13

Westhope 58-17

Date Completed: 1958
L.S. Elevation (ft): 1422
Depth Drilled (ft): 52

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-17; located approx. 300' east and 100' south of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow, slightly sandy	1-4
CLAY	Yellow, sandy	4-5
SAND		5-6
CLAY	Gray, very sandy	6-16
CLAY	Yellow, very sandy	16-29
CLAY	Blue, soft	29-33
CLAY	Gray, sandy	33-45
CLAY	Gray, or shale	45-52

163-079-30CBCC14

Westhope 58-18

Date Completed: 1958
L.S. Elevation (ft): 1422
Depth Drilled (ft): 50

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-18; located 40' SW of old well with hand pump, or shoulder of road ditch

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Yellow, sandy	2-12 12-22
SAND & GRAVEL	Fine to coarse, clayey, a little water	22-25
CLAY	Yellow, sandy, pebbles & stones	25-33
CLAY	Yellow, very gravelly	33-35
CLAY	Blue, soft	35-40
CLAY	Blue, gravelly	40-50

163-079-30CBCC15

Westhope 58-19

Date Completed:	1958	Purpose:	Observation Well
L.S. Elevation (ft):	1422	Well Type:	6" Unknown
Depth Drilled (ft):	40	Aquifer:	Unnamed
Screened Interval (ft):	29-35	Source:	C. A. Simpson & Son

Completion Info: 0.050 inch slotted screen, pumped at 8 gpm at 22' water level, and slowing up (casing & screen may have been pulled)

Remarks: T. H. #58-19; located 18' south, 4' east of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	& gray clay	0-2
CLAY	Yellow, slightly sandy	2-4
CLAY	Yellow, very sandy	4-12
CLAY	Yellow, sandy	12-29
SAND & GRAVEL	Clayey	29-32
CLAY	Yellow, gravelly	32-35
CLAY	Blue, soft	35-38
CLAY	Gray, gravelly	38-40

163-079-30CBCD

NDSWC 13147

Date Completed:	5/12/93	Purpose:	Observation Well
L.S. Elevation (ft):	1423.73	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Unnamed
Screened Interval (ft):	73-78	Source:	NDSWC

Completion Info: Slotted 0.018 inch screen; 2 bags of hole plug
 Remarks: 650' E. & 1587' N. of Sec. corner, along east property line of golf course, just south of a e-w draw

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, w/silt & sand (sandy clay)	2-6
CLAY	Dark yellowish brown, silty	6-8
SAND	Fine to medium grained	8-12
CLAY	As above	12-22
SAND	Coarse grained, silicates, carbonates, shale	22-27
SAND & GRAVEL	25% gravel, as above	27-31
CLAY	Olive gray, silty, sand lens at 36', 38', 41', 44'	31-64
SAND	Very coarse, poorly sorted, silicates, carbonates	64-76
SAND & GRAVEL	As above, 25% gravel	76-79
CLAY	Olive gray, silty (Till), sand lens at 84', 86', 96'	79-98
CLAY	Olive gray (bedrock - Fox Hills)	98-100

163-079-30CBDD

NDSWC 962

Date Completed: 8/27/54 Purpose: Test Hole
L.S. Elevation (ft): 1415
Depth Drilled (ft): 110
Source: NDSWC

Completion Info:

Remarks: Located '0.2 mile straight east of Westhope park well'

Lithologic Log

Unit	Description	Depth (ft)
CLAY	Gray, fine to medium gravel	0-5
SAND & GRAVEL		5-10
CLAY	Gray, fine to coarse sand, fine gravel	10-20
CLAY	Gray-brown, fine to medium gravel and shale pebbles	20-35
CLAY	Smooth, gray	35-62
SAND	Fine to medium, gray, silty	62-65
CLAY	Gray, fine gravel and coarse sand (till)	65-100
CLAY	Smooth, gray (bedrock - Fox Hills)	100-110

163-079-30CCBA1

NDSWC 13146

Date Completed: 5/12/93 Purpose: Test Hole
 L.S. Elevation (ft): 1423.13
 Depth Drilled (ft): 100
 Source: NDSWC

Completion Info: 5 bags of hole plug in 100' test hole
 Remarks: 665' east & 1147' north of SW sec. corner, along east golf course property line, south of brush pile

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Dark yellowish brown, silty	2-6
SAND	Coarse grained, poorly sorted	6-14
CLAY	Olive gray, silty	14-17
SAND & GRAVEL	20% gravel, poorly sorted, silicates, carbonates, shale, sandstone	17-28
CLAY	Dark yellowish brown, silty, sandy	28-36
CLAY	Olive gray, silty, sandy	36-65
SAND	Coarse grained, poorly sorted, quartz, dark silicates, carbonates, shale, lignite, grades coarser with depth	65-71
SAND & GRAVEL	25% gravel, as sand, above	71-74
CLAY	Olive gray 30%, w/silt & sand (till)	74-82
SAND & GRAVEL	As above	82-84
CLAY	As above (till), gravel lens at 96'	84-96
CLAY	Dark greenish gray to olive black (bedrock-Lower Fox Hills)	96-100

163-079-30CCBA2

NDSWC 13146A

Date Completed:	5/12/93	Purpose:	Observation Well
L.S. Elevation (ft):	1423.13	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Unnamed
Screened Interval (ft):	23-28	Source:	NDSWC

Completion Info: 2 bags of hole plug in 40' hole drilled for monitoring well 15' from original hole, .018 inch slotted screen
Remarks: 650' east & 1147' north of SW sec. corner, along east golf course property line, south of brush pile

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, silty	1-6
SAND	Coarse grained, poorly sorted	6-8
CLAY	Olive gray, silty	8-21
SAND & GRAVEL	20% gravel, poorly sorted, silicates, carbonates, shale, sandstone	21-29
CLAY	Dark yellowish brown, silty, sandy	29-32
CLAY	Olive gray, silty, sandy	32-40

163-079-30CCBB1

Westhope 58-11

Date Completed: 1958
L.S. Elevation (ft): 1423
Depth Drilled (ft): 27

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks:

T. H. 58-11; located 213' south of old well with hand pump, in NW corner of parking area; there appeared to be very little water

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow, with pebbles	1-3.5
GRAVEL	Stones	3.5-14
CLAY	Gravelly	14-20
SAND & GRAVEL		20-27
CLAY	Yellow	27-27

163-079-30CCBB1

Westhope 58-11

Date Completed: 1958
L.S. Elevation (ft): 1423
Depth Drilled (ft): 27

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. 58-11; located 213' south of old well with hand pump, in NW corner of parking area; there appeared to be very little water

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow, with pebbles	1-3.5
GRAVEL	Stones	3.5-14
CLAY	Gravelly	14-20
SAND & GRAVEL		20-27
CLAY	Yellow	27-27

163-079-30CCBB2

NDSWC 975

Date Completed: 9/9/54 Purpose: Test Hole
 L.S. Elevation (ft): 1420
 Depth Drilled (ft): 110
 Source: NDSWC

Completion Info:
 Remarks:

Lithologic Log

Unit	Description	Depth (ft)
FILL	Gravel	0-1
TOPSOIL	Black	1-2
CLAY	Yellow, with a little sand & gravel	2-6
SAND	Medium to coarse, with a little yellow clay	6-10
GRAVEL	Fine to medium, w/a few shale pebbles	10-15
SAND	Medium to coarse, with a little clay & fine gravel	15-19
CLAY	Yellow, with fine & medium gravel & shale pebbles	19-27
SAND & GRAVEL		27-28
CLAY	Gray, fine & medium gravel & shale pebbles (till)	28-60
CLAY	(lacustrine)	60-71
SAND & GRAVEL	A few shale pebbles	71-74
CLAY	Gray, w/fine & medium gravel & shale pebbles (till)	74-89
SAND & GRAVEL		89-91
CLAY	Gray, fine & medium gravel & shale pebbles (till)	91-98
GRAVEL	Fine to medium, a few shale pebbled & rocks	98-100
CLAY	Gray, fine & medium gravel & shale pebbles (till)	100-105
SHALE	Good sample in bit (bedrock at 109' - Powell interpretation of Danielson log)	105-110

163-079-30CCBD

NDSWC 13145

Date Completed:	5/12/93	Purpose:	Observation Well
L.S. Elevation (ft):	1420.71	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Unnamed
Screened Interval (ft):	84-89	Source:	NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Located 650 feet east & 803 feet north of SW sec. corner, along property line, generally along where the thicker stand of trees to the south thin out

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Light yellowish brown, silty	2-5
SAND	Fine grained, well sorted	5-8
CLAY	Yellowish brown, silty	8-12
SAND	Coarse grained, poorly sorted	12-13
CLAY	With silt, yellowish brown	13-22
SAND	Coarse grained, poorly sorted	22-26
CLAY	Dark yellowish brown, silty	26-31
CLAY	Olive gray to olive black (lacustrine)	31-42
SILT	Clayey, olive gray (lacustrine)	42-66
SAND & GRAVEL	25% gravel, mainly very coarse sand, silicates, carbonates, shale	66-73
CLAY	Olive gray, silty	73-82
SAND & GRAVEL	As above, with more shale clasts	83-91
CLAY	Olive gray to olive black (bedrock - Lower Fox Hills)	91-100

163-079-30CCCA

Westhope 90-2

Date Completed:	4/17/90	Purpose:	Observation Well
L.S. Elevation (ft):	1418.71	Well Type:	1.25" PVC
Depth Drilled (ft):	103	Aquifer:	Unnamed
Screened Interval (ft):	71-76	Source:	C. A. Simpson & Son

Completion Info: 0.025 inch slotted screen, grouted with hole plug, installed as part of an earlier study for the city
Remarks: Simpson 90-2 well, located 550 feet east and 480 feet north of the southwest corner of the section, in some trees about 100 feet east of the property line of the golf course and the wildlife refuge

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-3
SAND	Very fine, yellow, soupy	3-15
CLAY	Blue	15-21
SAND	Yellow	21-23
SAND	Yellow, soft	23-26
CLAY	Blue, soft	26-40
CLAY	Blue	40-67
GRAVEL		67-74
CLAY	Blue	74-81
SAND		81-83
CLAY	Blue, some sand layers	83-93
SHALE		93-103

163-079-30CCCC

NDSWC 58-4

Date Completed: 1958
L.S. Elevation (ft): 1420
Depth Drilled (ft): 142

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: In river bottom east of Westhope. 80 ft. east of driveway into park. 125 ft. (est.) north of county highway

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Sandy, yellow	1-25
CLAY	Blue	25-35
SAND	Clayey, and gravel, very dirty water	35-36
CLAY	Gravelly, blue	36-50
CLAY	Sandy, blue	50-91
SAND & GRAVEL		91-93
CLAY	Sandy, blue	93-98
SHALE	Rather hard, no water	98-142

163-079-30CCCD

NDSWC 13144

Date Completed: 5/12/93 Purpose: Test Hole
 L.S. Elevation (ft): 1415
 Depth Drilled (ft): 100
 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Located 650 feet east and 200 feet north of SW corner of Section 30, along property line between golf course and wildlife refuge

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Light olive gray, silty	2-5
SAND	Coarse grained, poorly sorted	5-7
CLAY	Olive gray, silty, sandy	7-12
CLAY	Dark greenish gray, silty	12-19
CLAY	Olive black, silty	19-22
SAND	Medium grained, poorly sorted	22-26
CLAY	Olive gray to medium gray	26-31
SAND	Fine grained, moderately well sorted	31-34
CLAY	Olive gray, slightly silty	36-65
SAND & GRAVEL	30% gravel, silicates, carbonates, shale, sandstone	65-68
CLAY	As above	68-71
SAND & GRAVEL	As above	71-74
CLAY	Olive gray, w/sand (clayey till)	74-82
SAND & GRAVEL		82-83
CLAY	Olive gray to olive black, (bedrock - Fox Hills, Trail City Member)	83-100

163-079-31ABA

NDSWC 948

Date Completed: 8/7/54 Purpose: Test Hole
 L.S. Elevation (ft): 1420
 Depth Drilled (ft): 90
 Source: NDSWC

Completion Info:

Remarks: Located 1/2 mile east of well #946 on south shoulder of grade

Lithologic Log

Unit	Description	Depth (ft)
FILL	Clay and gravel road fill	0-12
CLAY	Light gray, smooth	12-21
CLAY	Blue, sandy	21-31
SAND	Fine to coarse, some gravel & shale pebbles	31-35
CLAY	Gray, with fine to medium gravel, lignite (till)	35-46
SAND & GRAVEL		46-49
CLAY	Gray, w/fine to medium gravel, lignite (till)	49-70
CLAY	Gray, w/fine to medium gravel, lignite (till)	70-86
SHALE	Bit sample, (bedrock - Fox Hills Fm.)	86-90

163-079-31BABA

NDSWC 947

Date Completed: 8/6/54 Purpose: Test Hole
L.S. Elevation (ft): 1417
Depth Drilled (ft): 100
Source: NDSWC

Completion Info:

Remarks: 1/2 way between well #946 & road bridge on south shoulder of road

Lithologic Log

Unit	Description	Depth (ft)
ROAD FILL		0-8
CLAY	Yellow, fine to medium gravel	8-10
CLAY	Gray-green	10-20
SAND	Fine to medium, silty	20-37
CLAY	Sandy, gray	37-48
SAND & GRAVEL		48-55
CLAY	Gray, and fine to medium gravel (till)	55-82
SAND & GRAVEL		82-86
CLAY	Gray, and fine to medium gravel (till)	86-96
SHALE	Gray (bedrock - Fox Hills)	96-100

163-079-31BBBA

NDSWC 946

Date Completed: 8/6/54 Purpose: Test Hole
 L.S. Elevation (ft): 1425
 Depth Drilled (ft): 110
 Source: NDSWC

Completion Info:

Remarks: 2.1 miles east of Westhope in valley on south shoulder of road

Lithologic Log

Unit	Description	Depth (ft)
ROAD FILL		0-8
CLAY	Smooth, gray	8-26
CLAY	Smooth, light gray	26-48
CLAY	Smooth, gray	48-65
SAND & GRAVEL		65-68
CLAY	Gray, and fine gravel (till)	68-76
SAND & GRAVEL		76-78
CLAY	Gray, and fine to medium gravel (till)	78-101
SHALE	Gray (bedrock - Fox Hills)	101-110

163-079-32BBB

NDSWC 949

Date Completed: 8/7/54 Purpose: Test Hole
L.S. Elevation (ft): 1485
Depth Drilled (ft): 130
Source: NDSWC

Completion Info:

Remarks: Located 3 miles east of Westhope, 12 steps south of road running east & 10 steps east of approach to field

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Black	0-1
CLAY	Light gray, smooth	1-4
CLAY	Yellow, smooth	4-7
CLAY	Yellow, a few fine & medium gravel & shale pebbles	7-31
CLAY	Gray, quite a lot of fine & medium gravel & shale pebbles	31-82
SAND & GRAVEL	& shale pebbles	82-84
CLAY	Gray, w/fine & medium gravel & shale pebbles (till)	84-126
SHALE	Bit sample (bedrock - Fox Hills Fm.)	126-130

163-079-33CCB

NDSWC 12849

Date Completed: 8/14/91 Purpose: Test Hole
L.S. Elevation (ft): 1435
Depth Drilled (ft): 100

Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: Ditch east of road, valley bottom about 1/8 mi. or slightly more north of section line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand & gravel, (oxidized)	2-14
TILL	Clay, olive gray, 30%, with silt, sand & gravel, sand lenses at 31', 34', 44-46'	14-78
CLAY	Olive gray, (bedrock - Hell Creek Formation)	78-82
SAND	Fine grained, with interstitial dark greenish gray clay, (bedrock - Hell Creek Formation)	82-100

163-080-25CCB1

Westhope 53-3

Date Completed: 9/1953 Purpose: Test Hole
L.S. Elevation (ft): 1490
Depth Drilled (ft): 146
Source: C. A. Simpson & Son

Completion Info: 0.050 inch screen, water level at 96' to 98', sp. cap. est. of 15gpm/ft drawdown, well apparently pulled because of indicated lowering of water level since municipal well installed 500' away

Remarks: T. H. 53-3; located about 500 feet east of present city well, on west boundary of quarter, road property, 25 feet east and 783 feet north of south boundary of quarter

Lithologic Log

Unit	Description	Depth (ft)
CLAY	Yellow	0-25
CLAY	Blue, muddy to sandy	25-63
SAND	Blue, muddy with sandy clay	63-122
SAND	Muddy	122-134
SAND & GRAVEL		134-145
CLAY	Blue, gravelly, or shale	145-146

163-080-25CCB2
Westhope Well #2

Date Completed:	1954	Purpose:	Municipal Well
L.S. Elevation (ft):	1490	Well Type:	8" Unknown
Depth Drilled (ft):	148	Aquifer:	Unnamed
Screened Interval (ft):	136-145	Source:	C. A. Simpson & Son

Completion Info: 0.040 inch screen, baid plug on bottom & lead packer on top, water level about 98 feet from surface

Remarks: City of Westhope well #2, located about 500' east of well #1, 1 mile east of city of Westhope, ran 24 hour, 100 gpm pump test

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-35
CLAY	Blue	35-60
CLAY	Blue, sandy	60-83
CLAY	Blue, very sandy	83-100
CLAY	Interlayered with sand	100-120
GRAVEL	With clay	120-135
GRAVEL		135-146
SHALE	Blue, or clay	146-148

163-080-25CCC

NDSWC 13216

Date Completed: 6/16/93 Purpose: Test Hole
 L.S. Elevation (ft): 1490
 Depth Drilled (ft): 160
 Source: NDSWC

Completion Info:

Remarks: Ditch north of paved road, 330' east of section line be cemetery

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-37
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand & gravel lens at 55'-56', 60-62', 100-103', 117'	37-123
SAND & GRAVEL	35% gravel, well graded, silicates & carbonates, some sandstone & shale	123-130
SAND & GRAVEL	As above, interbedded with clay	130-135
CLAY	Olive gray, as above (till)	135-145
CLAY	Greenish gray, stiff (bedrock - Hell Creek)	145-160

163-080-25CCD

Westhope 53-2

Date Completed: 9/1953 Purpose: Test Hole
 L.S. Elevation (ft): 1490
 Depth Drilled (ft): 160
 Source: C. A. Simpson & Son

Completion Info: Water level at 84', apparently a screen installed, at least temporarily
 Remarks: T. H. #53-2

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Light yellow, very sandy	1-3
CLAY	Yellow	3-22
CLAY	Blue, sandy	22-58
CLAY	Gravelly	58-106
SAND	Fine to coarse	106-111
CLAY	Gravelly	111-122
CLAY	Gray, or shale	122-128
CLAY	Gray, sandy	128-130
SAND	Fine to coarse, muddy	130-131
SHALE	Blue	131-160

163-080-25DACD

Westhope 58-13

Date Completed: 1958 Purpose: Test Hole
 L.S. Elevation (ft): 1425
 Depth Drilled (ft): 120

Source: C. A. Simpson & Son

Completion Info: Overnight (water) level plus 1', would pump about 2 gpm with
 suction pump, 0.5 ppm iron (casing may have been withdrawn)
 Remarks: T. H. #58-13; located 732 feet west of #58-12 (163-80-25DADD)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark	1-4
CLAY	Yellow, sandy	4-5
CLAY	Yellow, very sandy, damp	5-9
SAND & GRAVEL	Clayey, with rocks	9-13
CLAY	Gray, sandy	13-46
CLAY	Gray	46-58
CLAY	Gray, sandy, or shale	58-70
SAND & GRAVEL	with clay	70-73
SAND	Fine, clayey	73-76
CLAY	Gray, very sandy	76-81
CLAY	Gray, slightly sandy	81-92
SHALE	Green	92-98
SHALE	Gray	98-120

163-080-25DADC

Westhope 58-14

Date Completed: 1958
 L.S. Elevation (ft): 1425
 Depth Drilled (ft): 108

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info: Very little water in this test hole, overnight level of the water in
 97'-98' vein was 13' below the surface.

Remarks: T. H. #58-14; located 231 feet northwest of #58-12 (163-80-
 25DADD)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Brown	2-8
CLAY	Gray, sandy	8-14
CLAY	Yellow, sandy	14-18
CLAY	Yellow, gravel & rocks	18-22
CLAY	Gray, very sandy	22-59
CLAY	Gray, sandy	59-85
CLAY	Gray, very sandy	85-97
SAND & GRAVEL	Clayey, some water	97-98
SHALE	Blue, or clay	98-108

163-080-25DADD

Westhope 58-12

Date Completed: 1958
 L.S. Elevation (ft): 1425
 Depth Drilled (ft): 108

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info: Set screen 48'-54', water came in only 1 gpm. Level after standing o'nite 18'. Set screen 95'-102', yielded 2 gpm at 60'.
 (Screen & casing may have been withdrawn)

Remarks: T. H. 58-12; located 274 feet west of old well with hand pump

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	& fill	0-2
CLAY	Yellow	2-2.5
GRAVEL	Stones	2.5-4.5
CLAY	Yellow, sandy, rocks at 19-21'	4.5-27
CLAY	Blue	27-42
CLAY	Blue, gravelly	42-48
SAND & GRAVEL	Blue	48-50
SAND & GRAVEL	Clayey	50-53
CLAY	Slightly gravelly	53-62
CLAY	Gray, very sandy	62-68
CLAY	Gray, slightly sandy	68-82
CLAY	Gray, sandy	82-95
SAND & GRAVEL	Clayey, with fine sand	95-100
GRAVEL	Hard, clayey	100-102
CLAY	Blue, or shale	102-108

163-080-25DDAA

Westhope 58-2

Date Completed: 1958
 L.S. Elevation (ft): 1470
 Depth Drilled (ft): 150

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-2; located toward west side of golf course, up on higher level but near place where slope to river begins

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-45
CLAY	Blue	45-60
CLAY	Blue, sandy	60-120
SAND	Clayey	120-126
SAND & GRAVEL	Coarse, rather clayey	126-130
SAND & GRAVEL	Coarse	130-138
SAND	Medium to fine, water came slowly	138-140
CLAY	Blue, sandy	140-150
SHALE	Blue	150-150

163-080-25DDAB

Westhope 58-3

Date Completed: 1958 Purpose: Test Hole
L.S. Elevation (ft): 1475
Depth Drilled (ft): 154 Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. #58-3; located west of T. H. #58-2 (163-80-25DDAA), approx. 100' east of fence; there was very little water in this hole, worst so far

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-40
CLAY	Blue	40-60
CLAY	Blue, sandy, with just a little water coming	60-70
CLAY	Blue, sandy, a little dirty water at 136'	70-150
SHALE		150-154

163-080-25DDB

NDSWC 974

Date Completed: 9/9/54 Purpose: Test Hole
L.S. Elevation (ft): 1425
Depth Drilled (ft): 50 Source: NDSWC

Completion Info:

Remarks:

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Black	0-1
CLAY	Yellow, with fine to medium gravel	1-3
SAND	Fine to coarse, with a lot of soft shale pebbles	3-8
SAND & GRAVEL	A few shale pebbles	8-12
CLAY	Gray, with fine & medium gravel, & shale pebbles, two feet of coarse sand & fine gravel at 36 feet (till)	12-50

163-080-26CDA

Westhope 46-1

Date Completed: 5/1946
L.S. Elevation (ft): 1490
Depth Drilled (ft): 160

Purpose: Test Hole

Source: C. A. Simpson & Son

Completion Info:

Remarks: T. H. (1946) #1; located 1/2 mile east of Westhope, 8 feet NW of pump house

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Yellow	2-25
CLAY	Blue	25-60
LAY	Blue, sandy	60-120
CLAY	Quite sandy	120-125
SAND	Coarse, with water	125-127
LAY	Blue, sandy	127-142
SAND	& gas	142-143
SAND	Interbedded with clay, gas & some water in the sand layers	143-153
CLAY	Blue	153-157
SHALE	Blue	157-160

163-080-26DCA

Westhope 46-2

Date Completed: 5/1946 Purpose: Test Hole
 L.S. Elevation (ft): 1490
 Depth Drilled (ft): 155

Source: C. A. Simpson & Son

Completion Info: Water from 124-126 vein came to 48 feet from surface. Test showed 15 gpm with drawdown to 90 feet. Almost no water after 126'.

Remarks: T. H. (1946) #2; located 80 rods (1/4 mi.) NE of pump house (more north than east)

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow, sandy	1-30
CLAY	Blue, sandy	30-65
CLAY	Blue, very sandy	65-120
CLAY	Blue, more sandy	120-124
GRAVEL	With water	124-126
CLAY	Blue, very sandy	126-155

163-080-26DDA
Westhope Well #1

Date Completed:	5/1946	Purpose:	Municipal Well
L.S. Elevation (ft):	1490	Well Type:	6" Steel
Depth Drilled (ft):	149	Aquifer:	Unnamed
Screened Interval (ft):	139-149	Source:	C. A. Simpson & Son

Completion Info:
Remarks: City of Westhope municipal well #1

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-35
CLAY	Blue	35-60
CLAY	Blue, sandy	60-83
GRAVEL		83-87
CLAY	Blue, sandy	87-139
SAND & GRAVEL		139-149

163-080-26DDC
Westhope Fox Hills

Date Completed:	1/1/63	Purpose:	Municipal Well
L.S. Elevation (ft):	1490	Well Type:	8" Unknown
Depth Drilled (ft):	160	Aquifer:	Fox Hills
Screened Interval (ft):	159-160	Source:	

Completion Info:
Remarks: CITY OF WESTHOPE

Lithologic Log

Unit	Description	Depth (ft)
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163-080-35ABB2

Westhope 58-5

Date Completed: 1958 Purpose: Test Hole
L.S. Elevation (ft): 1490
Depth Drilled (ft): 162

Source: C. A. Simpson & Son

Completion Info: Apparently temporary screen set in test hole, water recovery in 4 inch casing of 6 inches per minute.

Remarks: T. H. #58-5; located 1/2 mile east of corner at SE edge of City of Westhope, ND, south of road and north of railroad

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-38
CLAY	Blue	38-55
CLAY	Blue, sandy	55-75
GRAVEL	With a little water	75-82
GRAVEL	Mixed	82-87
CLAY	Blue	87-115
CLAY	Blue, sandy & gravelly	115-152
SHALE		152-162

163-080-35BBB

NDSWC 942

Date Completed: 7/30/54 Purpose: Test Hole
L.S. Elevation (ft): 1496
Depth Drilled (ft): 170
Source: NDSWC

Completion Info:

Remarks: Located on southeast corner of Westhope, 39 steps east of Highway 83 & 23 steps south of road running east

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	Black, sandy	0-1
CLAY	Brown, sandy	1-2
CLAY	Light gray, with fine gravel	2-5
LAY	Yellow, with fine to medium gravel & shale pebbles	5-19
CLAY	Gray, with fine & medium gravel, & shale pebbles, a few inches of fine sand at 68', (till)	19-70
CLAY	Gray, with fine & medium gravel, shale pebbles & a little coal, a small rock or rocks at 98' (till)	70-151
GRAVEL	Fine, & a lot of shale pebbles	151-152
CLAY	Gray, w/fine & medium gravel & shale pebbles (till)	152-161
CLAY	Light gray, smooth, or shale, bit sample	161-170

163-080-36AAAA

Westhope 90-1

Date Completed: 4/17/90 Purpose: Test Hole
L.S. Elevation (ft): 1425
Depth Drilled (ft): 123
Source: C. A. Simpson & Son

Completion Info: Plugged with cuttings
Remarks: Test hole #90-1, along west side of Souris valley, about 300-500'
SSE of treatment plant

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellow	1-19
CLAY	Blue	19-45
SAND		45-46
CLAY	Blue	46-52
SAND		52-53
CLAY	Blue	53-88
SAND		88-89
CLAY	Blue	89-96
SAND		96-97
CLAY	Blue	97-102
SAND	Fine	102-104
CLAY		104-107
SHALE		107-123

163-080-36ABA

NDSWC 13217

Date Completed: 6/16/93 Purpose: Test Hole
 L.S. Elevation (ft): 1480
 Depth Drilled (ft): 140
 Source: NDSWC

Completion Info:

Remarks: Along city land between railroad R.O.W. & county highway
 R.O.W.

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Dark yellowish brown, 30%, w/silt, sand, & gravel (oxidized till)	1-28
CLAY	Olive gray, 30%, w/silt, sand, & gravel (till), sand lens at 49-51', 60'	28-111
SAND & GRAVEL	40% gravel, well graded, silicates, carbonates, shale, lignite, sandstone	111-117
SAND & GRAVEL	Interbedded with clay	117-120
CLAY	As above (till)	120-121
SAND & GRAVEL	As above	121-122
CLAY	As above (till)	122-125
SAND & GRAVEL		125-126
CLAY	As above (till)	126-130
CLAY	Olive gray, slightly silty, compacted, tight (bedrock - Hell Creek)	130-140

164-079-26CCC

NDSWC 12843

Date Completed: 8/13/91 Purpose: Test Hole
 L.S. Elevation (ft): 1505
 Depth Drilled (ft): 80 Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: Ditch north of road, 70' east of section line, near fence

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel, (oxidized)	2-25
SILT	Dark yellowish brown	25-29
TILL	Clay, dark yellowish brown, as above	29-36
TILL	Clay, olive gray, 30% with silt, sand & gravel	36-74
CLAY	Medium gray, (bedrock - Hell Creek Formation)	74-80

164-079-27CCC

NDSWC 12841

Date Completed: 8/13/91 Purpose: Observation Well
 L.S. Elevation (ft): 1501.24 Well Type: 0" None
 Depth Drilled (ft): 80 Aquifer: Unnamed
 Screened Interval (ft): 42-47 Source: NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Located in ditch north of trail, 50' east of corner

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, cohesive, with silt, sand, & gravel (oxidized)	2-17
TILL	Clay, olive gray, 30%, cohesive, with silt, sand, & gravel	17-35
SAND	Very coarse grained, poorly sorted, subrounded to subangular, primarily silicates & carbonates	35-62
TILL	Clay, as above	62-66
SAND	Fine grained, quartz, interstitial olive to medium gray clay, (bedrock - Hell Creek or Fox Hills Formation)	66-80

164-079-27DCC

NDSWC 12842

Date Completed: 8/13/91 Purpose: Test Hole
 L.S. Elevation (ft): 1500
 Depth Drilled (ft): 80

Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: North of trail, about 500' east of 1/4 line, where trail widens slightly

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel (oxidized)	2-30
TILL	Clay, olive gray, 30%, with silt, sand, & gravel	30-74
SAND	Very fine to fine grained, well sorted, subrounded, quartz with interstitial medium gray to dark greenish gray clay, (bedrock - Fox Hills Formation)	74-80

164-079-28CCC

NDSWC 12845

Date Completed: 8/13/91 Purpose: Test Hole
 L.S. Elevation (ft): 1485
 Depth Drilled (ft): 60

Source: NDSWC

Completion Info: 2 bags of hole plug
 Remarks: North of trail, 50' east of section line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand & gravel, (oxidized)	2-28
TILL	Clay, olive gray, 30%, with silt, sand, & gravel	28-49
SAND	Very fine grained, with interstitial medium gray clay, (bedrock - Hell Creek or Fox Hills Formation)	49-60

**164-079-29CDC
NDSWC 12847**

Date Completed:	8/13/91	Purpose:	Observation Well
L.S. Elevation (ft):	1454.42	Well Type:	2" PVC
Depth Drilled (ft):	130	Aquifer:	Unnamed
Screened Interval (ft):	82-87	Source:	NDSWC

Completion Info: 2 bags of hole plug, .018 inch slotted screen
 Remarks: Located north of trail, 100 feet west of drainageway

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel (oxidized)	2-16
SAND & GRAVEL	25% gravel, well graded, subangular, silicates, carbonates, some sandstone	16-41
TILL	Clay, olive gray, 30%, with silt, sand, & gravel, sand lenses at 43' & 48'	41-54
SILT	Olive gray	54-58
TILL	Clay, olive gray, as above	58-61
SAND & GRAVEL	20% gravel, primarily very coarse sand, moderate sorting, subrounded, quartz, shale, sandstone, silicates, carbonates, lignites, some interbedded clay	61-96
CLAY	Olive gray, with interbedded lignite & some interbedded sandstone, (bedrock - Hell Creek Formation)	96-130

164-079-29CDD
NDSWC 12846

Date Completed: 8/13/91 Purpose: Test Hole
L.S. Elevation (ft): 1460
Depth Drilled (ft): 280
Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: North of trail, 350' west of 1/4 line, 60' west of trail to well

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
SAND & GRAVEL	30% gravel, well graded, subangular, silicates, carbonates	2-13
TILL	Clay, dark yellowish brown, 30%, with silt, sand, & gravel, (oxidized)	13-15
TILL	Clay, olive gray, 30%, with silt, sand, & gravel	15-58
SAND & GRAVEL	25% gravel, well graded, subangular, silicates, carbonates, shale, & sandstone	58-71
SAND	Very fine grained, silty, with olive to dark greenish gray silt	71-206
TILL	Clay, olive gray, 30%, cohesive, with silt, sand, & gravel	206-262
SAND	Fine grained, with interstitial dark to medium greenish gray clay, interbedded with clay, olive gray, (bedrock - Fox Hills Formation)	262-280

164-079-33BAA

NDSWC 12844

Date Completed: 8/13/91 Purpose: Test Hole
L.S. Elevation (ft): 1490
Depth Drilled (ft): 80 Source: NDSWC

Completion Info: 2 bags of hole plug
Remarks: South of trail, 50' west of 1/4 line

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
TILL	Clay, dark yellowish brown, 30%, cohesive, with silt, sand, & gravel, (oxidized)	2-29
TILL	Clay, olive gray, 30%, with silt, sand, & gravel, 57' to 60' is gravely	29-60
CLAY	Dark greenish gray, blocky/fissile, (bedrock - Hell Creek or Fox Hills Formation)	60-71
SAND	Fine to medium grained, argillaceous, (bedrock - Hell Creek or Fox Hills Formation)	71-80