Characteristics of the Carrington Aquifer

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Ground water research efforts at the Carrington Research Extension Center concern both ground water quality and quantity. In the late 1950s it was discovered that underlying an area north of the city of Carrington was a glacial sand and gravel deposit. It was further discovered that the buried deposit would yield significant quantities of water. Questions regarding the extent of this aquifer, together with questions concerning some quality and quantity characteristics, were partially addressed during a study completed in 1965.

The Carrington Research Extension Center is undertaking research concerning characteristics of subsurface water. Researchers from five agencies are pooling their resources to study man's influence on ground water. The effort is multidisciplinary involving agronomy, soil science, geology, hydrology, engineering, and environmental chemistry. Knowledge generated from this research will be transferrable to other hydrologic units, so the scope of this investigation may be much more than just local. As with any hydrologic study, a complete inventory concerning existing subsurface conditions is essential.

A review of the Carrington aquifer was undertaken to acquire hydraulic information from this subsurface water system. Hydraulic information attained in studying the aquifer's characteristics will be useful in evaluating impacts of current irrigation use, as well as future uses. In addition, hydraulic data will provide sound background information regarding this ground water system's characteristics.

The following report describes geological, hydrological, water level, and some water quality characteristics of the Carrington aquifer.

AQUIFER ORIENTATION

The Carrington aquifer is a buried outwash deposit of sand and gravel located north of the city of Carrington in northwestern Foster County (Figure 1). The aquifer is approximately 12 miles long and four miles wide, orientated in a northwest-southeast direction. The 30- to 60-foot thick deposit overlies Pierre shale and is overlain by approximately 40 feet of glacial till. Water from the aquifer is pumped for both irrigation and a municipal supply. Use has averaged about 1,800 acre-feet per year during the past 16 years, with a range of 600 to 3,500 acre-feet per year.

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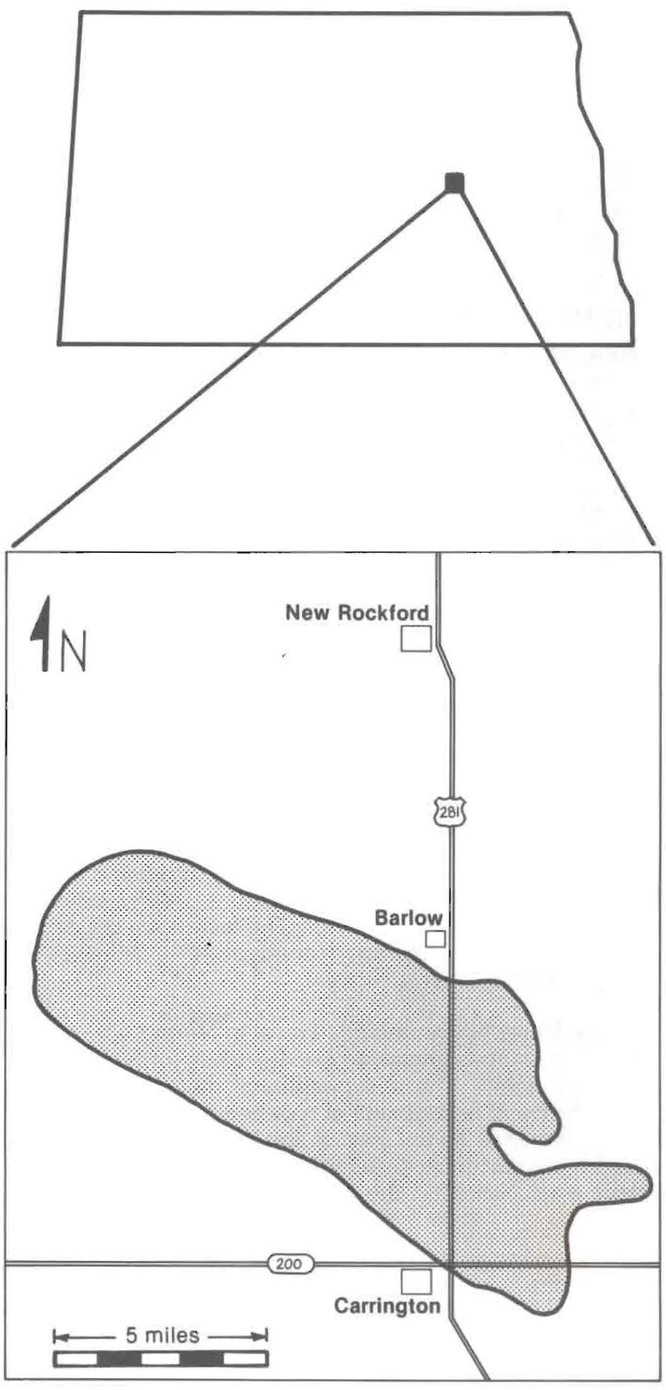

Figure 1. Carrington aquifer boundary.

Land surface overlying the Carrington aquifer is a low relief, prairie pothole type, typical of glacial ground moraines. Surface topography generally slopes to the northeast at 10 feet per mile. Scotts Slough, a glacial marginal surface drainge feature, cuts a channel about 25 feet deep and 700 feet wide through glacial till overlying the aquifer. Rocky Run, a similar feature, cuts across the northwest end of the aquifer. Kelly Creek, a broad channel located about two miles northeast of the Carrington aquifer, is a third surface drainage feature related to both Scotts Slough and Rocky Run. These channels are relic glacial features without widespread integrated drainage areas (Figure 2).

Exploratory test drilling within and around the margins of the Carrington aquifer were completed to determine both characteristics and dimensions. Test holes were drilled at the southeast and northwest ends to determine if the aquifer extended out further than had been previously thought. Current indications are that it does not.

GEOLOGY

Wisconsinan glacial ice advances in the Carrington area deposited about 100 feet of glacial drift over bedrock shale of the Pierre Formation and blocked northeast flowing stream drainage (1). The diverted stream flow as well as glacial meltwater cut an ice marginal trench into the land surface. As the ice advanced over the trench, an outwash plain, which is now the Carrington aquifer, was formed between the glacier and a bedrock high to the southwest. Another ice advance, the Grace City phase, deposited glacial till over the outwash plain. This glacial till directly underlies the topsoil profile in the Carrington area.

Outwash sand and gravel comprising the Carrington aquifer was deposited on a northeastward sloping bedrock surface of Pierre shale. Bedrock surface slope is about 5 feet per mile in the central aquifer area, steepening on both sides of the aquifer for an average overall bedrock slope of about 20 feet per mile. The Carrington aquifer is between 30 and 60 feet thick (Figure 3) and is made of coarse to very coarse, poorly sorted sand with some gravel. The sand and gravel is comprised of 60 percent igneous or metamorphic silicates, 30 percent carbonates and 10 percent locally derived bedrock shale, silicified wood, and lignite clasts. The aquifer's upper surface slope is similar to that of the underlying bedrock surface, although much more irregular.

Forty feet of glacial till overlies the aquifer. The till is composed of approximately 45 percent sand or larger clasts, 33 percent silt and 22 percent clay.

HYDROLOGY

The potentiometric surface of the Carrington aquifer indicates the presence of a constriction in the central area dividing the aquifer into two regions (Figure 4). Water levels in the northwest region are up to 15 feet higher than levels in the southeast region. Without each region the potentiometric slope is less than 1 foot per mile and is in the direction of the nearby overlying drainage, Scotts Slough or Rocky

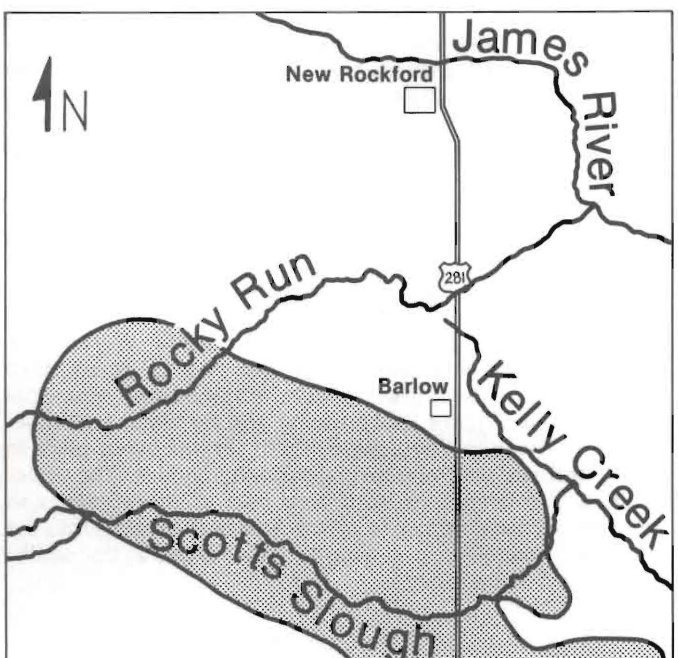

Figure 2. Surface drainage features.

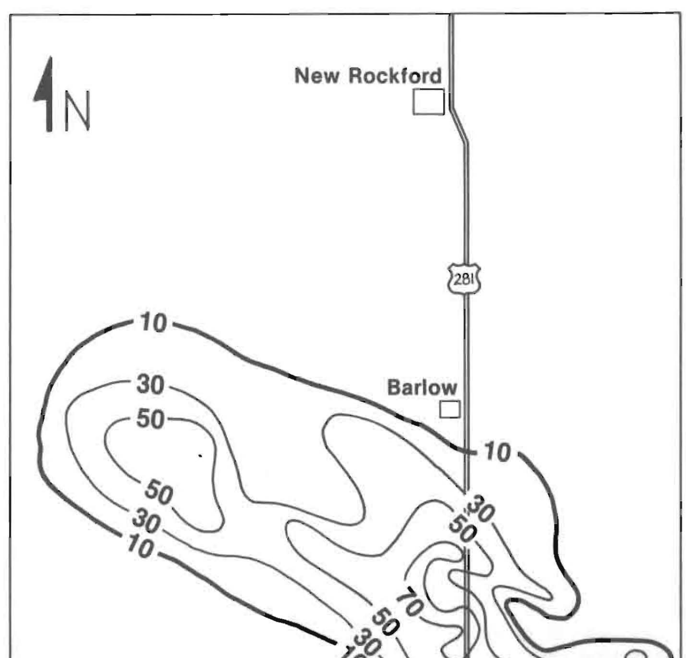

Figure 3. Aquifer thickness in feet.

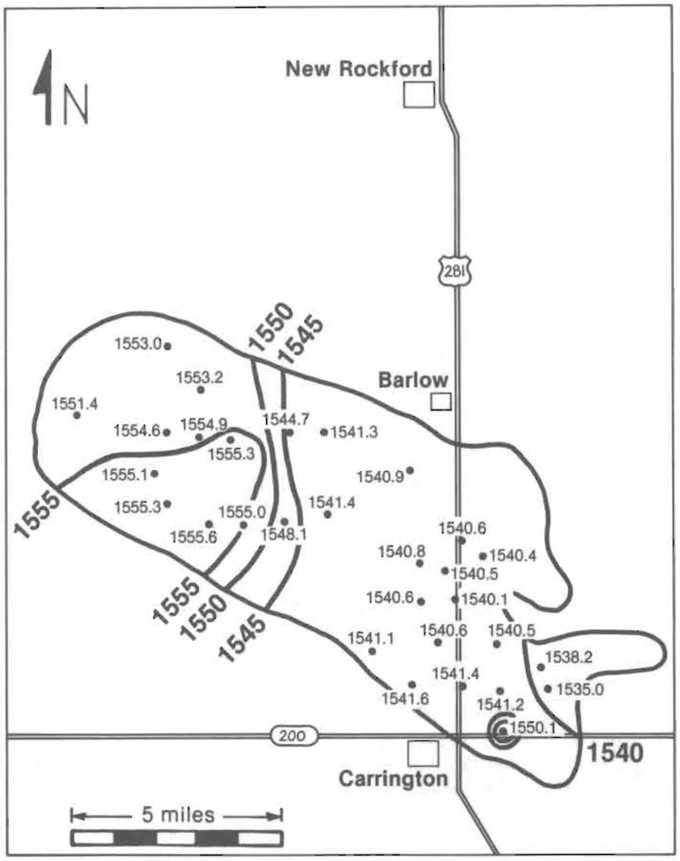

Figure 4. Potentiometric surface on 30 November 1988 (feet above sea level).

Run. The overall direction of aquifer water movement is to the east.

The aquifer is unconfined in its southwest one-third, but the remainder is confined with an artesian head of up to 30 feet above the aquifer. Although the aquifer is confined for the most part, pumping can draw down the water level creating an unconfined zone around the well. The irregular till/ aquifer interface results in localized confined/unconfined areas.

An aquifer test was performed using a Carrington Research Extension Center irrigation well and four observation wells located in section 31 near the center of the aquifer's southeast portion. The well was pumped for 97 hours at 1,260 gallons per minute. The test indicated a transmissivity of 16,000 feet per day and a storativity of 0.03. The aquifer is about 40 feet thick at the test site; therefore, the hydraulic conductivity is 400 feet per day. The specific capacity of the irrigation well near the end of the test was 67 gallons per minute per foot of drawdown. The storativity value is probably a result of a confined to unconfined irregular transition in addition to leaky, confining conditions.

Ground water recharge into the Carrington aquifer is from precipitation, lateral inflow, and possibly from the underlying bedrock. The average annual precipitation at the Carrington Research Extension Center between 1967 and 1988 was 19.1 inches and it is hypothesized that most recharge is from precipitation. Precipitation recharge requires infiltration through approximately 40 feet of sandy, fractured glacial till. Fractures in the till overlying the aquifer may provide a potential path for surface water contaminants.

Precipitation falling in the drainage basin area of the aquifer probably eventually reaches the aquifer. An area of possible water recharge is the small drainage basin upgradient (west) of Scotts Slough. Surface runoff may flow overland, into Scotts Slough, and down the drainageway until the Carrington aquifer is reached. Scotts slough cuts into the upper sand of the Carrington aquifer, creating a hydraulic interconnection and allows water infiltration into the aquifer. An observation well located along Scotts slough where it overlies and cuts into the aquifer shows the largest increases in aquifer water levels following a spring-time snowmelt.

Except for its east corner, the Carrington aquifer directly overlies fractured shale of the Pierre Formation. An upward hydraulic gradient from the Pierre Formation would allow bedrock water into the Carrington aquifer.

Ground water discharge from the Carrington aquifer is through irrigation, municipal use, evapotranspiration, and lateral outflow. Approximately 17 quarters of land were irrigated in 1988 using 1,800 acre-feet of water from the Carrington aquifer.

Municipal water use from this aquifer is from the city of Carrington. Water withdrawn by the city (300 acre-feet per year) comprises about 17 percent of permitted water use.

Only small amounts of water from the Carrington aquifer are lost to evapotranspiration. Along Scotts Slough, evapotranspiration may extract water from the Carrington aquifer; however, the water table is often more than 10 feet below the soil surface. The potentiometric gradient, however, does indicate water movement into Scotts Slough. Most water moving laterally out of the Carrington aquifer probably surfaces along natural drainageways.

GROUND WATER LEVELS

Aquifer water levels are monitored monthly through the spring, summer, and fall. Ground water levels are monitored from 27 observation wells installed in the Carrington aquifer plus 48 additional observation wells located on or near the Research Extension Center (Figure 5). Water levels in the Carrington aquifer during the past 20 years have generally varied with precipitation. Irrigation and municipal use have been minor influences in aquifer water level fluctuations. Irrigation development thus far has taken place in the central and southeastern parts of the aquifer. The undeveloped (for irrigation) northwest part of the aquifer can therefore be used as a control area to acquire insight into the effect of irrigation use on ground water levels in the southeast part of the aquifer.

WATER QUALITY

Water from the Carrington aquifer is calcium-magnesium bicarbonate type. The total dissolved solids (TDS) concentrations of samples collected is normaly between 400 and 800 milligrams per liter (mg/l) (Figure 5). The sodium adsorption ratios of samples taken from the aquifer are generally less than two. Most water samples are in the C3-S1 irrigation category (water is of suitable quality for irrigation use). The water is hard (7.0 to 10.5 grains per gallon) and

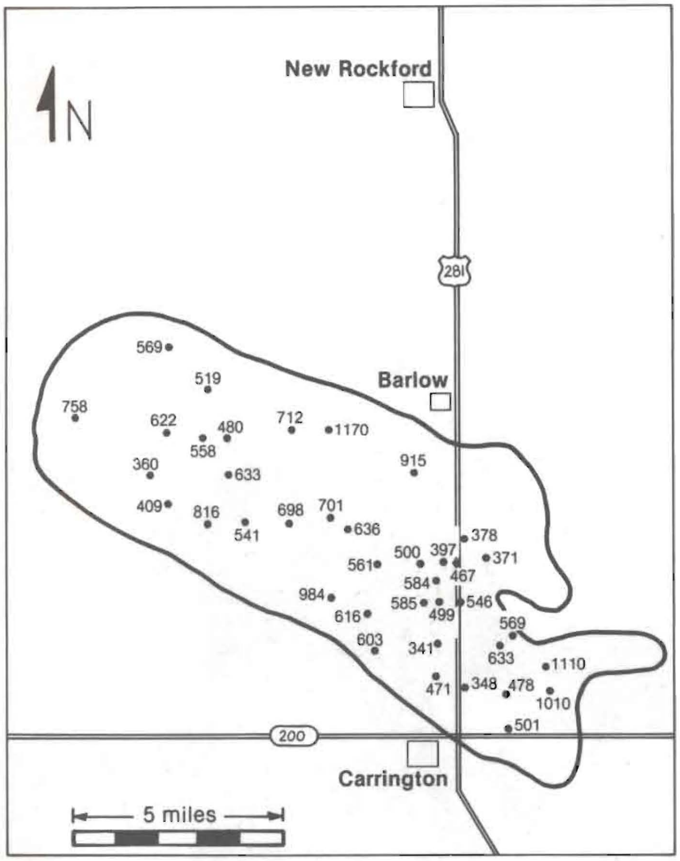

Figure 5. Water quality and observation well locations. Total dissolved solids (TDS) concentration in milligrams per liter.

high in iron (4 to 10 mg/l) for domestic use. A separate survey concerning nitrate concentrations is underway. Water quality tests thus far have rarely detected organic compounds.

Water quality is influenced by both the proximity to the aquifer's margin and the proximity of the well screen to the underlying Pierre Formation bedrock. Some wells located near the periphery of the aquifer have high TDS concentrations ranging upward to 1,200 mg/l. One water sample collected from a well screened in the Pierre Formation in the area is primarily sodium chloride-bicarbonate type and has a TDS concentration of 2,420 mg/l.

SUMMARY

A study of Carrington aquifer characteristics is being undertaken to acquire an understanding of both the subsurface water quality and the quantity available. Hydraulic information gathered during the process of this study will enable researchers to further their knowledge regarding human activities affecting ground water. In addition, data gathered will serve as important background information for future studies of this subsurface water system.

Geological, hydrological, water level, and water quality parameters have been addressed in the survey work thus far concerning the Carrington aquifer.

The aquifer is composed of coarse sand and gravel derived from glacial outwash, over which glacial till was deposited. The aquifer is about 30 to 60 feet thick and overlies Pierre Formation bedrock.

Hydrologically, the aquifer is separated into two areas. In each of the areas the potentiometric slope is less than 1 foot per mile, in the direction of Scotts Slough or Rocky Run. The aquifer is generally unconfined along its southwestern one-third and confined along its northeastern two-thirds. The irregular aquifer/overlying till interface results in rapid changes from unconfined to confined conditions.

Aquifer water levels are affected by precipitation and to a lesser extent by irrigation and municipal water use.

Aquifer water quality is extremely important. Deterioration in water quality could impact the city of Carrington. The Carrington aquifer is the city's only municipal water source. In addition, water quality also is important for irrigation suitability. Detailed water quality parameters from this subsurface water system are archived with the North Dakota State Water Commission and the Carrington Research Extension Center.

Research concerning this aquifer system is part of a larger study located at the center titled "Agriculture's Impact on Ground Water Quality." Information from this study will enable scientists to better understand interractions between man and the environment concerning ground water.

LITERATURE CITED

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