WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

WATER-QUALITY INDICATORS IN THE PRAIRIE DU CHIEN-JORDAN AQUIFER, SOUTHEASTERN MINNESOTA

INTRODUCTION

The Prairie du Chien-Jordan aquifer, which consists of the dolomitic Prairie du Chien Group and the underlying Jordan Sandstone, extends over southeastern Minnesota (fig. 1). Water quality in the aquifer fluctuates areally and with depth throughout the aquifer. Differences in chemical-constituent concentrations are a result of both natural hydrogeologic conditions and human activities.

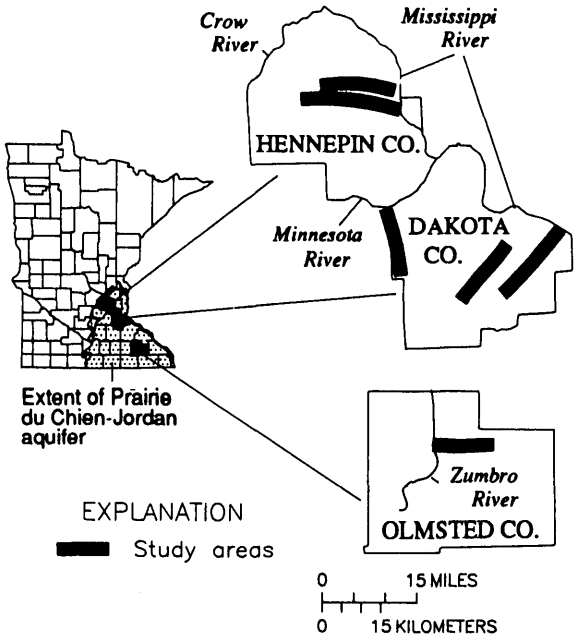

Figure 1. *Location of study areas and extend of Prairie du Chien-Jordan aquifer, southeastern Minnesota*

Water in the Prairie du Chien part of the aquifer has been documented as containing a wider range in concentration of constituents related to human activity than has water from the Jordan part of the aquifer. Researchers and planners generally consider water in the Jordan part of the aquifer to be better protected from water-quality changes caused by human activities than water in the overlying Prairie du Chien Group. However, factors that influence the concentrations of natural and human-related chemical constituents in the aquifer are not well understood. Differences in water quality can result from differences in land uses, differences in permeability of the aquifer, thickness and lithology of overlying units, flow path length, well construction, and ground-water withdrawals.

An improved understanding of the hydrogeologic factors that influence the concentrations of chemical constituents in the aquifer enhances an evaluation of the aquifer's susceptibility to contamination and provides information necessary for better management of the aquifer.

The U. S. Geological Survey (USGS), in cooperation with the Minnesota Department of Natural Resources and the Legislative Commission on Minnesota Resources, began a study in 1989 to investigate hydrogeology and water quality in the Prairie du Chien-Jordan aquifer at selected sites in southeastern Minnesota. The objectives of the study are to characterize differences in water quality between the Prairie du Chien Group and the Jordan Sandstone parts of the aquifer, to determine the geologic and hydrogeologic factors that are responsible for these differences, and to describe the susceptibility of the Jordan Sandstone part of the aquifer to contamination by various land-use practices. This Fact Sheet describes preliminary results from this study.

HYDROGEOLOGY OF THE AQUIFER

The Prairie du Chien-Jordan aquifer is composed of the upper Prairie du Chien Group, a sandy dolomite with water flowing mainly through joints, fractures, and solution cavities; and the underlying Jordan Sandstone, a variably cemented, quartzose sandstone with water flowing mainly through intergranular pore spaces. The aquifer ranges in thickness from 240 feet in the Minneapolis-St. Paul Metropolitan Area to 450 feet in the southern part of the State.

Hydrogeologic units overlying the aquifer include, in ascending order, the St. Peter confining unit (shale and silty sandstone), the St. Peter aquifer (sandstone), the Decorah-Platteville-Glenwood confining unit (shale-dolomitic limestone-shaley dolomite), the upper-carbonate aquifer (limestone), and glacial drift. Thicknesses of the overlying units differ throughout the region, and in some areas one or more of the units are missing. The St. Lawrence-Franconia confining unit underlies the Prairie du Chien-Jordan aquifer throughout the entire region.

METHODS OF STUDY

Water samples were collected from existing wells in six study areas within Hennepin, Dakota, and Olmsted Counties (fig. 1). The study areas, which represent linear paths of ground-water flow through the Prairie du Chien-Jordan aquifer, averaged 13 miles long and 3 miles wide. Ground-water flow along the flow paths generally is from topographically elevated recharge areas to discharge areas along major rivers. Ground-water recharge also occurs over the areal extent of the flow paths from additions of precipitation. The study areas were selected to represent (1) two major land-use types in southeastern Minnesota -- suburban-urban and agricultural, (2) a karst area, and (3) several combinations of overlying stratigraphy. These settings provide differing conditions for investigating the distribution of natural and human-related water-quality constituents in the aquifer.

A number of criteria were used to select wells for collection of samples. For example, wells having lithologic logs that adequately describe the strata penetrated by the bore hole, and pairs of nearby wells -- one completed in the Prairie du Chien Group and the other completed in the Jordan Sandstone -- were selected. Additional wells completed in the overlying St. Peter or glacial drift aquifers were selected.

Water samples from 106 wells were collected for analysis throughout the six study areas between July and September 1990. Specific conductance, pH, water temperature, dissolved oxygen, and alkalinity were measured on site. Laboratory analyses were completed for major cations and anions, nutrients, trace elements, triazine herbicides, volatile-organic compounds, and tritium. Water levels were measured in 50 of the 106 wells. Additional water-level data were obtained from the Minnesota Geological Survey, Hennepin County Conservation District, and previous USGS projects to complete potentiometric- surface maps.

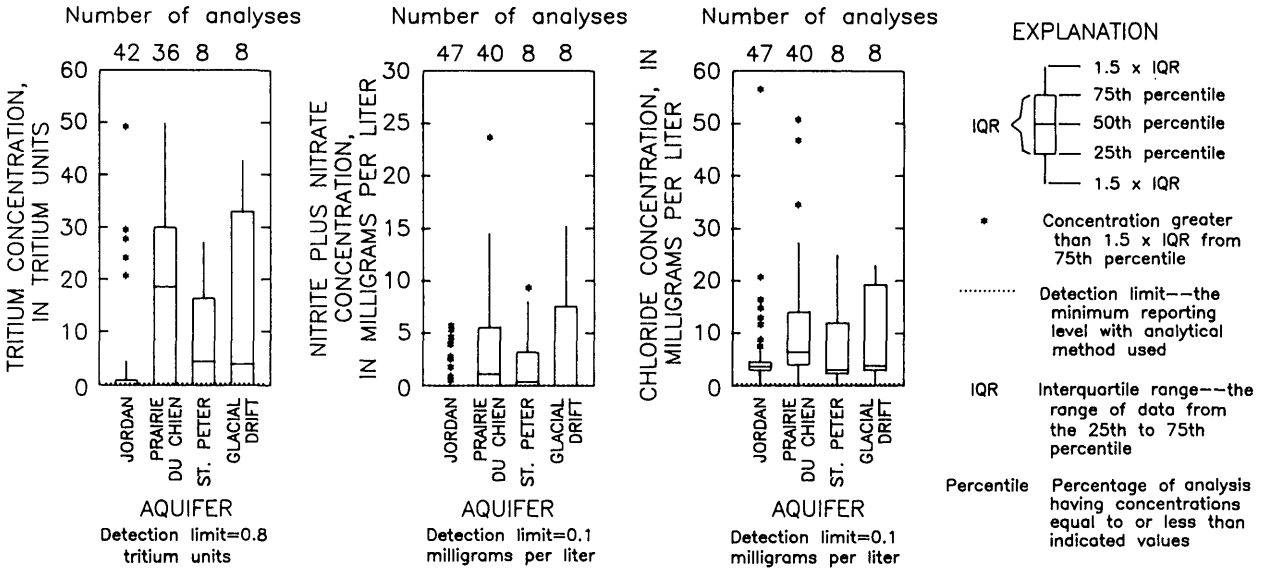

Figure 2. ***Concentration of tritium, nitrate plus nitrite nitrogen, and chloride by aquifer. (Values analyzed at below detection limit are set equal to detection limit for statistical analysis.)***

INDICATORS OF GROUND-WATER SUSCEPTIBILITY TO CONTAMINATION

Concentrations of tritium, dissolved nitrite plus nitrate, and chloride are used in this study to compare water from different parts of the aquifer and to define areas where the aquifer might be hydraulically connected to the land surface. These observations are used to understand how water moves in the aquifer and what areas are susceptible to contamination. Tritium isotope concentration is an indicator of ground-water susceptibility to contamination because it provides an approximation of the length of time water has been in the ground. Tritium concentration in water indicates one of three general age classifications. Concentrations less than 1 tritium unit (TU) indicate "old" water that entered the ground-water system before 1954, when atmospheric testing of nuclear weapons began and levels of tritium in the atmosphere increased by 1 to 2 orders of magnitude. Concentrations greater than 10 TU indicate "recent" water that entered the ground-water system after 1954. Concentrations from 1 to 10 TU represent water that probably is a mixture of recent and old water.

Nitrite plus nitrate and chloride commonly are used as nutrient and chemical indicators of human activities that affect ground water. These two constituents, which dissolve readily in water, can be introduced into an aquifer by land-use practices such as agricultural and residential fertilizer and pesticide applications, barnyard runoff, road deicing, and industrial chemical spills. Background levels of nitrite plus nitrate as nitrogen in the Prairie du Chien-Jordan aquifer are less than 1 milligram per liter (mg/L). Naturally occurring background levels of chloride in the aquifer are 2 to 3 mg/L. Concentrations of nitrite plus nitrate as nitrogen or chloride greater than the background levels are considered to indicate a human-related effect on the ground-water system.

Boxplots of tritium, nitrite plus nitrate as nitrogen, and chloride concentrations for the study sites are shown in figure 2. These boxplots indicate water-quality differences within the aquifer and from water in geologic units above the aquifer. The distribution of tritium concentrations indicates that the water from the Jordan Sandstone is older than water from the Prairie du Chien Group and overlying units. The water from the Jordan Sandstone generally is older than 36 years as of 1990. The wide range in tritium concentrations in water samples from wells completed in the Prairie du Chien Group and the glacial drift indicates a high degree of variability in the age and mixing of these waters, compared with water from the Jordan Sandstone. The fact that water from the Jordan Sandstone is older than water from the Prairie du Chien Group indicates that ground water in the two units is not thoroughly mixing throughout the aquifer. The concentrations of nitrite plus nitrate and chloride generally are greater in the Prairie du Chien Group and overlying hydrogeologic units than they are in the Jordan Sandstone.

The distribution of data in these boxplots indicates that water in the Jordan Sandstone is older than water in the overlying Prairie du Chien Group, St. Peter Sandstone, or glacial drift deposits; the older, deeper water appears less likely to be affected by human activities; and the relative concentrations of tritium, nitrite plus nitrate, and chloride in the ground water are directly correlated with each other.

ADDITIONAL WORK IS NEEDED TO CORRELATE WATER QUALITY WITH HYDROGEOLOGIC FACTORS

The hydrogeologic setting of overlying bedrock and glacial drift units is important in understanding why contaminants have reached the Prairie du Chien or Jordan parts of the aquifer in some areas but not at others. Comparison of the distribution of constituent concentrations in water samples from the aquifer with overlying lithology indicates that the following hydrogeologic and well characteristics could be important factors in explaining differences in water quality: (1) thickness of the glacial drift; (2) continuity and permeability of confining layers overlying the aquifer; (3) regions where the Prairie du Chien-Jordan aquifer is the uppermost aquifer; (4) vertical location of the open interval of wells completed in the aquifer; and (5) proximity of the well to buried bedrock valleys. Collection and analysis of data to quantify the effects of these hydrogeologic factors on water quality in the Prairie du Chien-Jordan aquifer is planned for the next year of this study.

SELECTED REFERENCES

Alexander, S. C., and Alexander, E. C., 1989, Residence times of Minnesota Groundwaters: Journal of the Minnesota Academy of Science, v. 55 No. 1, pp. 48-52.

Delin, G.N., and Woodward, D. G., 1984, Hydrogeologic setting and the potentiometric surfaces of regional aquifers in the Hollandale Embayment, southeastern Minnesota, 1970-1980: U.S. Geological Survey Water-Supply Paper 2219, p. 56

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