GEOLOGY AND GROUND WATER

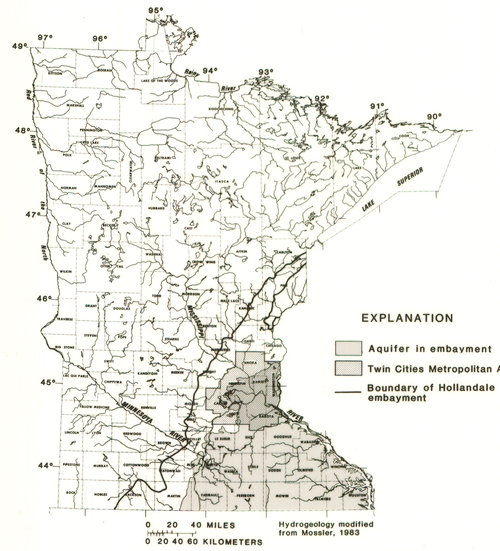


Figure 1.--Areal extent of aquifer and area of Hollandale embayment in southeast Minnesota

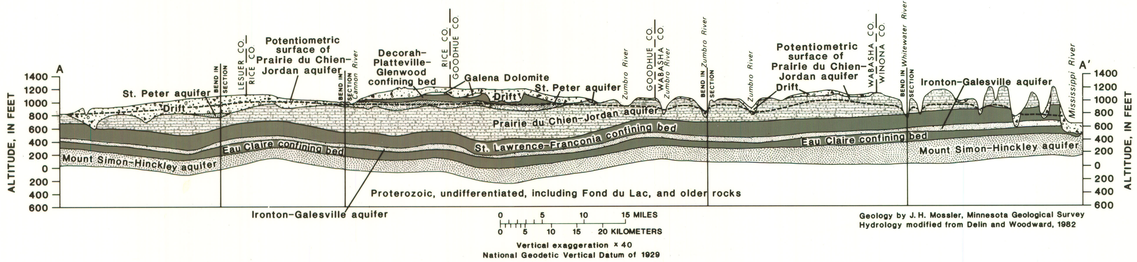
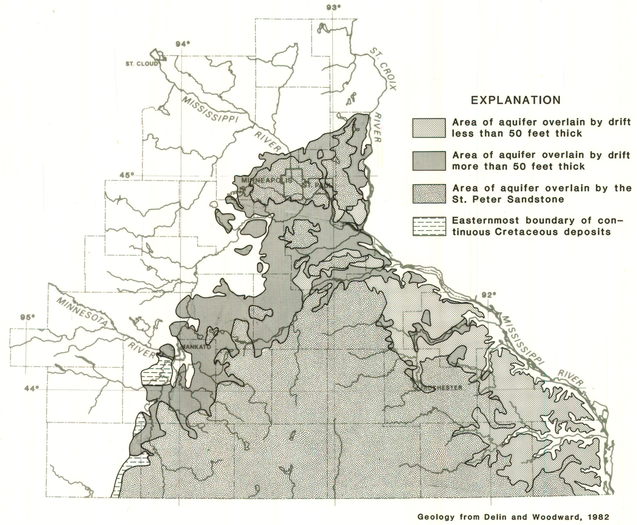


Figure 3.--Generalized section of major hydrogeologic units in the bedrock sequence of southeast Minnesota



Geology from Delin and Woodward, 1982

Figure 6.--Deposits overlying the aquifer

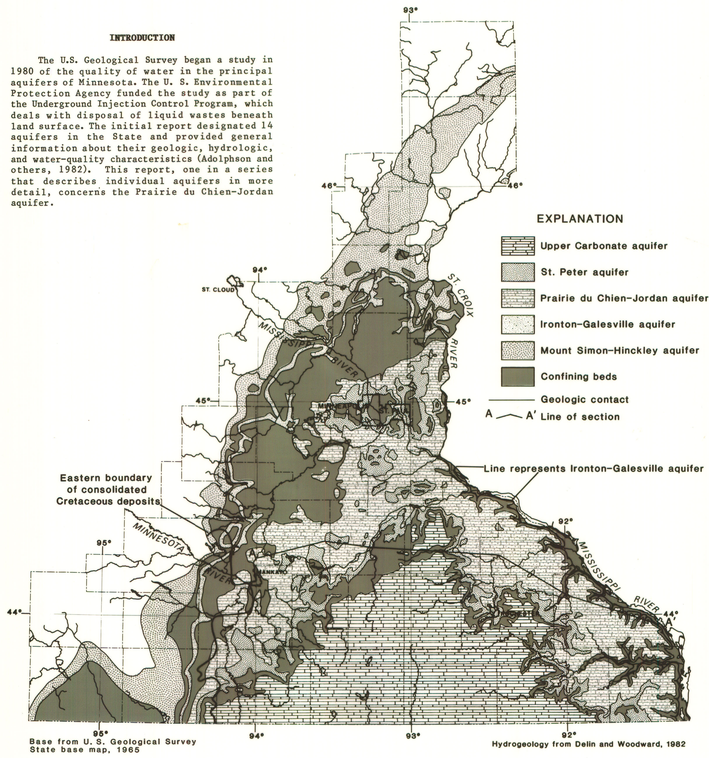
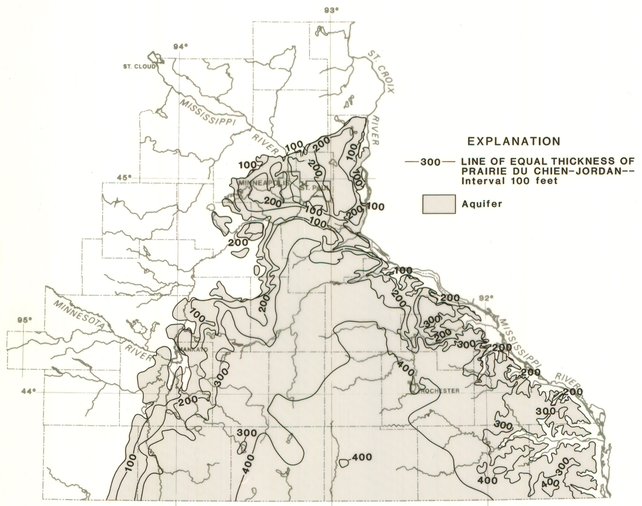
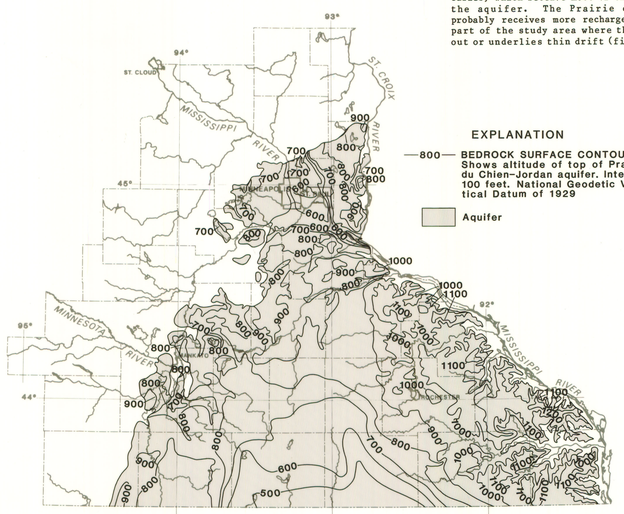


Figure 2.--Bedrock hydrogeology in southeast Minnesota



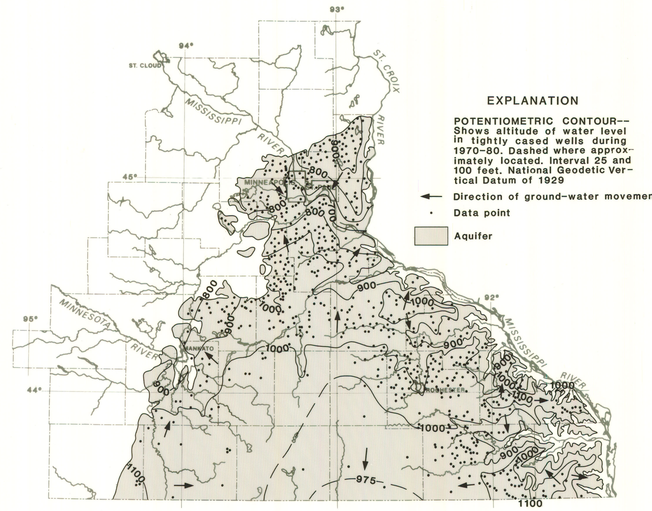
Geology from Delin and Woodward, 1982

Figure 4.--Thickness of the aquifer



Geology from Delin and Woodward, 1982

Figure 5.--Contours of the top of the aquifer



Hydrology from Delin and Woodward, 1981

Figure 7.--Flow directions and potentiometric surface of the aquifer, 1970-80

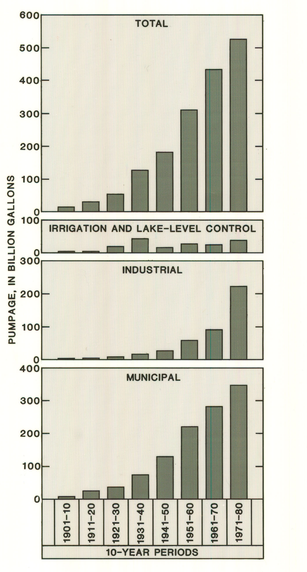


Figure 8.--Pumpage from the aquifer by major use category in the Twin Cities metropolitan area for 10-year periods from 1900 to 1980

ABSTRACT

Quality of water in the Prairie du Chien-Jordan aquifer is generally good, except for some localized contamination. Coal-tar derivatives that contaminate the aquifer in St. Louis Park, a western suburb in the Twin Cities Metropolitan Area, pose the most serious threat to water quality. High hardness and iron concentration limit suitability for municipal and industrial use in parts of extreme southeast Minnesota. Confining beds of bedrock and drift, however, protect most of the aquifer from surface pollutants.

The Prairie du Chien-Jordan aquifer is part of a sequence of sedimentary bedrock units in southeast Minnesota. The Jordan Sandstone is a white to yellow, fine- to coarse-grained sandstone. The Prairie du Chien Group comprises two dolomitic formations that are vuggy and fractured and interbedded with thin layers of shale. The aquifer formations were deposited in Paleozoic seas that occupied the Hollandale embayment. The aquifer dips toward the interior of the embayment where it is as deep as 750 feet below land surface and as thick as 500 feet.

Permeability is secondary in the Prairie du Chien Group because of solution cavities and fractures, and intergranular in the Jordan Sandstone. Water in the aquifer is confined except in the eastern part. Water generally flows to the north and east into the Minnesota and Mississippi Rivers. A ground-water divide separates part of the flow southward into Iowa. This aquifer supplies more water than any other bedrock one in the State.

Calcium magnesium bicarbonate type water is most common in the aquifer. Calcium and sulfate and, to a lesser degree sodium and magnesium, increase in concentration toward the southwestern part of the study area. Bicarbonate concentration, on the other hand, decreases toward the southwestern corner of the study area. Leakage from overlying Cretaceous deposits is the source of much of the sulfate and other minerals in the southwest.

This report is one of a series on the hydrogeology and water quality of the 14 principal aquifers in Minnesota prepared by the U. S. Geological Survey. The U. S. Environmental Protection Agency requested these studies because of the need for information to develop its Underground Injection Control Program.

INTRODUCTION

The U.S. Geological Survey began a study in 1980 of the quality of water in the principal aquifers of Minnesota. The U. S. Environmental Protection Agency funded the study as part of the Underground Injection Control Program, which deals with disposal of liquid wastes beneath land surface. The initial report designated 14 aquifers in the State and provided general information about their geologic, hydrologic, and water-quality characteristics (Adolphson and others, 1982). This report, one in a series that describes individual aquifers in more detail, concerns the Prairie du Chien-Jordan aquifer.

HYDROGEOLOGIC DESCRIPTION

The Prairie du Chien Group and Jordan Sandstone are part of a sequence of sedimentary rocks that are predominantly sandstone, limestone, dolomite, and shale. Deposition of these rocks began in Proterozoic time and continued to the Devonian Period of the Paleozoic Era. These rocks were deposited in seas that occupied the Hollandale embayment, a shallow depression that extended northward from Iowa into southeast Minnesota (Austin, 1972). Figure 1 shows the areal extent of the Mount Simon-Hinckley aquifer and the embayment.

The Paleozoic sedimentary rocks and underlying Proterozoic Hinckley Sandstone in southeast Minnesota comprise five major bedrock aquifers and four major confining beds (Lindholm and Norvitch, 1976; Delin and Woodward, 1982). Table 1 shows this aquifer classification scheme and schematically represents the vertical position of these hydrologic units, including Cretaceous deposits and drift. Kanivetsky and Walton (1979) and Adolphson and others (1981) have proposed classifications that are slightly different because they include the Franconia Formation as part of the Ironton-Galesville aquifer and the Fond du Lac Formation as part of the Mount Simon-Hinckley aquifer. Figure 2 shows the areal extent of the aquifers and confining beds listed in table 1 for southeaast Minnesota. Figure 3 is a generalized section of the hydrogeologic units along an east-west line through southeast Minnesota.

Geologic Features

The Prairie du Chien Group comprises two principal formations, the Oneota Dolomite and the overlying Shakopee Formation. These consist mainly of thin- to thick-bedded dolomite separated by the New Richmond Sandstone Member of the Shakopee Formation (Austin, 1972). The two formations are predominantly light gray or buff, vuggy and fractured, and interbedded with some thin layers of grayish-green shale (Kanivetsky and Walton, 1979). The underlying Jordan Sandstone consists of a white to yellow, quartzose, fine- to coarse-grained sandstone, which ranges from massive or thick-bedded to thin-bedded (Kanivetsky and Walton, 1979).

The Prairie du Chien Group was deposited when the interior of the Hollandale embayment was subsiding more rapidly than the margins (Austin, 1972). Consequently, the thickness increases to about 400 feet in the interior of the embayment where subsidence was greatest (fig. 4). The thickness of the Jordan Sandstone, which is fairly uniform, averages about 85 feet (Austin, 1972). The thickness of the aquifer ranges from 450 to 500 feet in the deepest part of the embayment; it thins toward the margins of the embayment and the Mississippi River (fig. 4).

The top of the Prairie du Chien-Jordan aquifer is as much as 750 feet below land surface in the deepest part of the Hollandale embayment. The top of the aquifer rises close to land surface near the margins of the embayment and crops out in a few places along the Mississippi River. The depth to the aquifer increases locally in the Twin Cities Metropolitan Area because of the Twin Cities basin. The structure of the aquifer is shown in figure 5. The aquifer and underlying bedrock units form a southerly plunging synclinorium.

Hydrologic Characteristics

The Prairie du Chien-Jordan aquifer includes two geologic units that behave as a single aquifer because they are hydraulically connected. Hence, pumping from one of the units causes a combined lowering of hydrostatic pressures in both aquifer units (Norvitch and others, 1973, p. 27). Confining units of small areal extent locally disrupt the normal continuity of the aquifer and may cause the static water levels to differ slightly.

The Prairie du Chien-Jordan aquifer is confined by the basal part of the St. Peter Sandstone or by drift except along the east side of the study area where the upper part of the aquifer is unsaturated (fig. 3). Water levels drop toward the Mississippi River and its tributaries, which receive most of the discharge from the aquifer. The Prairie du Chien-Jordan probably receives more recharge in the eastern part of the study area where the aquifer crops out or underlies thin drift (fig. 6).

Ground-water flow in the Prairie du Chien-Jordan aquifer is northward and eastward from the southwestern part of the study area around a ground-water divide approximately located in the north-central part of the Hollandale embayment (fig. 7). Ground water generally flows southward into Iowa on the south side of the divide, and to the north and northwest into the Minnesota and Mississippi Rivers on the north side of the divide (fig. 7). North of the Mississippi River the flow is to the south. Potentiometric-surface mounds, which indicate recharge, occur in the eastern part of the study area where they cause local variations in the flow system (Delin and Woodward, 1982). Water moves from these mounds both northward and southward into tributaries of the Mississippi River, and eastward directly into the Mississippi River (fig. 7).

Transmissivity values determined from 11 aquifer tests for the Prairie du Chien-Jordan aquifer in the Twin Cities Metropolitan Area range from 5,000 to 26,500 ft^2/d, and average 11,050 ft^2/d (Norvitch and others, 1973). The permeability of the Prairie du Chien Group is secondary because of solution cavities and fractures. Values for horizontal and vertical hydraulic conductivities of the Prairie du Chien group are unavailable, but transmissivity values based on pumping tests in the Twin Cities Metropolitan Area are in the range of 6,350 to 7,350 ft^2/d (Norvitch and others, 1973). The permeability of the Jordan Sandstone is primarily intergranular. Horizontal and vertical hydraulic conductivities of the Jordan Sandstone range from 4.6 to 166.0 ft/d and 1.0 to 4.6 ft/d, respectively, on the basis of laboratory analyses of rock samples (Norvitch and others, 1973). Transmissivity values for the Jordan Sandstone, based on 12 pumping tests in the Twin Cities Metropolitan Area, range from 1,900 to 10,700 ft^2/d and average 5,900 ft^2/d (Norvitch and others, 1973).

Large quantities of water are available from the aquifer; typical yields are between 500 and 1,000 gal/min (Lindholm and Norvitch, 1976). The Jordan Sandstone is very productive except where it crops out in river valleys, particularly those valleys in extreme southeast Minnesota (Anderson and others, 1975; Broussard and others, 1975). Yields are high in the Prairie du Chien Group, particularly in the Oneota Dolomite where fractures and solution cavities are prevalent (Anderson and others, 1974; 1974a; 1974b; 1975).

Table 1.—Stratigraphic nomenclature for southeast Minnesota and general descriptions of the corresponding aquifers and confining beds

Stratigraphic nomenclature			Hydrogeology	
Erathem	Period or system	Geologic unit (group, formation, or bed)	Hydrogeologic unit (aquifers or confining beds)	Water-bearing characteristics and dominant lithology
Cenozoic	Quaternary	Drift	Surficial sand and gravel aquifer	Largly outwash, but includes alluvium along major streams and local ice-contact deposits. Slightly used, with additional development of supplies possible. High potential for contamination because the water table is at or near land surface. Yields as much as 1,000 gal/min in places.
			Confining beds	Till and clay of low permeability. Not a source of water to wells.
			Buried sand and gravel aquifers	Outwash and ice-contact deposits confined by till of low permeability. Slightly to moderately developed for water supplies with potential for additional development, especially in buried valleys. Yields range from 100 to 1,000 gal/min.
Mesozoic	Cretaceous	Cretaceous beds	Cretaceous confining beds	Shale beds of low permeability. Not a source of water.
			Cretaceous aquifer	Sandstone lenses near base of predominantly shale section. Slightly developed, may yield additional small supplies. Typical yields to wells are 5 to 50 gal/min, but may be as much as 250 gal/min. Water is highly mineralized, particularly in the basal units along the western border of the State.
Paleozoic	Devonian	Cedar Valley Limestone	Upper Carbonate aquifer	Limestone, dolomite, and dolomitic limestone. Major aquifer in the south-central part of embayment. Wells generally yield 200 to 500 gal/min from solution channels, joints, and fissures.
	Ordovician	Maquoketa Shale	Confining bed	Relatively impermeable shale, dolomitic limestone, and limestone. Platteville yields about 25 gal/min from local fractures and solution channels.
		Dubuque Formation Galena Dolomite Decorah Shale Platteville Limestone Glenwood Shale		
		St. Peter Sandstone	St. Peter aquifer	White, fine- to medium-grained sandstone. A major aquifer, but seldom used for public supply because larger yields are available from wells in other aquifers. Typical yields range from 100 to 250 gal/min.
			St. Peter confining bed	Contains siltstone and shale that restrict vertical flow. Areal extent unknown. Not a source of water to wells.
		Prairie du Chien Group	Prairie du Chien-Jordan aquifer	Mainly dolomite and sandstone. The major aquifer in the area. Commonly yields 500 to 1,000 gal/min. Supplies 75 percent of water in Twin Cities Metropolitan area. Karstic conditions are common in extreme southeast.
	Cambrian	Jordan Sandstone		
		St. Lawrence Formation	Confining bed	Silty, sandy dolomite interbedded with layers of fine-grained sandstone and siltstone. Generally a poor source of water to wells; however, yields from the Franconia in the northwest part of the area are adequate for domestic use.
		Franconia Formation		
		Ironton Sandstone	Ironton-Galesville aquifer	Very fine to coarse-grained sandstone interbedded with shale, siltstone, and dolomite; an important aquifer outside the limits of other major aquifers. Yields range from 250 to to 500 gal/min.
		Galesville Sandstone		
		Eau Claire Sandstone	Confining bed	Sandstone, siltstone and shale, gray to reddish brown. Normally not a source of water; however, sandstone beds may yield small quantities to wells in the south.
		Mount Simon Sandstone	Mount Simon-Hinckley aquifer	Thick sequence of sandstone, siltstone, and shale. The secondary aquifer in Twin Cities area and only bedrock aquifer used in the northern part of the Hollandale embayment. Little used for water supply in extreme southeast. Wells generally yield from 400 to 700 gal/min, but may be as much as 2,000 gal/min.
Precambrian	Proterozoic	Hinckley Sandstone		
		Fond du Lac Formation	Hydrologic properties little known	Fond du Lac Formation, in combination with Hinckley Sandstone, yields water north of the Twin Cities metropolitan area where the Mount Simon is absent. Elsewhere, the Fond du Lac is deeply buried and undeveloped as a source of water supply.
		Sedimentary, metamorphic, and igneous rocks	Hydrologic properties unknown	Lack of detailed subsurface information precludes evaluation of hydraulic characteristics.

Water Use

The Prairie du Chien-Jordan is the principal aquifer in southeast Minnesota. This aquifer supplies approximately one-third of all ground water used in the State and about 80 percent of the ground water used in the Twin Cities area (Horn, 1983). Wells open to the aquifer are generally concentrated in the Twin Cities Metropolitan Area and counties along the Mississippi River.

Total pumpage from the aquifer in the Twin Cities Metropolitan Area increased from about 15 billion gallons during 1910-20 to nearly 530 billion gallons during 1970-80 (fig. 8). Industrial use increased the most but has decreased somewhat since the mid-1960's (fig. 8). Municipal use increased rapidly in the early 1940's and approached the level of industrial use during the 1970's. Irrigation and lake-level control have accounted for relatively small amounts of use during the 1960's and 1970's.

HYDROGEOLOGIC AND WATER-QUALITY CHARACTERISTICS OF THE PRAIRIE DU CHIEN-JORDAN AQUIFER, SOUTHEAST MINNESOTA

BY
J. F. RUHL, R. J. WOLF AND D. G. ADOLPHSON, 1983