UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Matt Walton, Director

PREPARED AND PUBLISHED WITH THE SUPPORT OF
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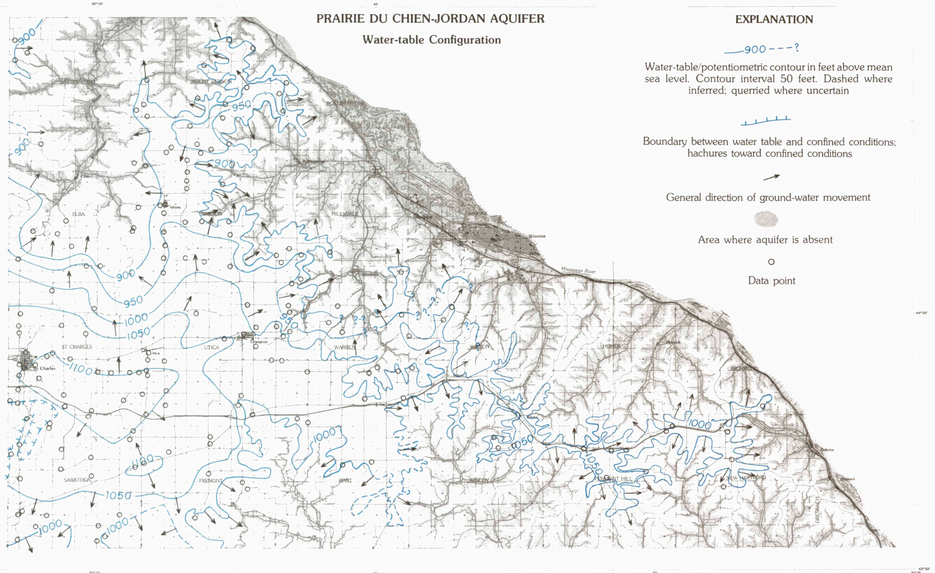
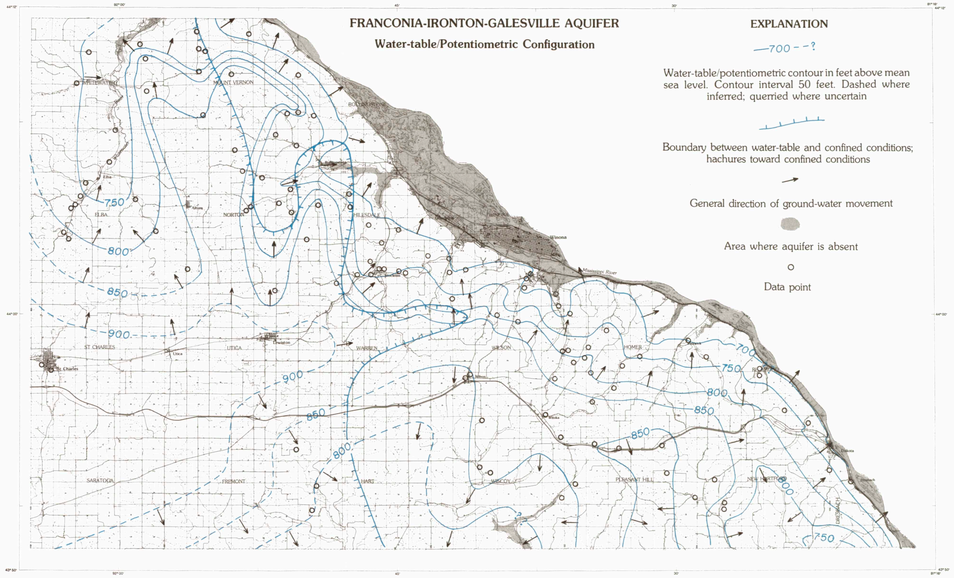
COUNTY ATLAS SERIES
ATLAS C-2, PLATE 4 OF 8
BEDROCK HYDROGEOLOGY





BEDROCK HYDROGEOLOGY

By
Roman Kanivetsky

1984

INTRODUCTION

The ground-water resources of Winona County are contained in bedrock reservoirs and unconsolidated deposits of sand and gravel. The depth to which wells must be drilled and the amount of water they will yield are a function of the ability of subsurface materials to store and to transmit water. Bedrock formations that serve as water-bearing units or aquifers in some parts of the county contain little water in others, and no single aquifer is used throughout the county. The hydrogeologic maps on this plate show the directions of ground-water movement and the estimated yields from the two major bedrock aquifer systems. Other aquifers may be used locally, but data are insufficient to describe them on a county-wide basis.

OCCURRENCE

All ground water in Winona County originated as precipitation which soaked into the ground due to gravity and moved into the aquifers. The velocity of ground-water movement and the amount of water available depend on the nature of the pathways in the bedrock or unconsolidated deposits. Many subsurface materials, such as sandstone, sand, shale, and clay, are composed of rock fragments ranging in diameter from very coarse sand (2 mm) to clay (less than 1/256 mm). The size and arrangement of the voids or pores between these particles affects the amount of water that moves through them. A well-sorted, coarse-grained sandstone has much more interconnected pore space than does a shale and will yield water to pumping, whereas shale will exhibit little or no yield (Fig. 1). Sand and gravel deposits or sandstone bedrock can be used as aquifers, but layers of clay and shale tend to retard ground-water movement and may even act as confining beds between aquifers.

Carbonate bedrock, such as limestone and dolomite, is generally very well cemented and dense, and pore space tends to be minimal. However, this type of rock commonly has a secondary porosity caused by fracturing or by solution weathering. Fracturing or jointing of the bedrock formations in Winona County is common, particularly in carbonate bedrock. Horizontal and vertical joints, which give a blocky appearance to exposures of dolomite and limestone, provide pathways for ground-water movement. Also, the solution weathering of carbonate bedrock has enlarged many joints and created innumerable interconnected cavities ranging from pea size to caverns large enough for human entry. Karst geology which results from the solution of weathering of carbonate bedrock is discussed on Plate 5. The combination of jointing and karst features enables carbonate bedrock formations to serve as aquifers and permits rapid infiltration of water.

As water percolates into the ground due to gravity, it passes through an unsaturated zone where the pore spaces contain both air and water. Some water in the unsaturated zone is held tightly to rock particles by capillary attraction, and rises against the pull of gravity. The presence of air and gases in the unsaturated zone can cause physical or chemical changes to occur as the water moves downward through it. The thickness of the unsaturated zone varies within the county, ranging from less than 10 feet to more than 300 feet. It is underlain by a zone where all pore spaces are completely filled with water. The water table is the boundary between the unsaturated and saturated zones (Fig. 2).

An aquifer may be completely or only partially saturated with water. Where the Mississippi River and its tributaries have cut deeply into the bedrock aquifers, ground water discharges into them and lowers the water table within the aquifers. Aquifers may be almost completely dewatered where they are exposed along valley walls (Fig. 3).

Ground water moving through an aquifer that is overlain by an impermeable confining layer cannot move upward and will be under pressure. Artesian conditions exist when this pressure forces water to rise above the level of the aquifer in wells drilled through the overlying confining layer. Ground water that is not under pressure is said to be under water-table conditions. Discharge of ground water into stream valleys, by releasing the pressure, may produce water-table conditions near the valleys in aquifers that are under artesian conditions elsewhere.

COUNTY AQUIFERS

Sand and gravel aquifers occur in valley fill deposits, but they tend to be discontinuous and their lateral distribution is difficult to determine with existing subsurface data. Such aquifers are used for supply, particularly along the Mississippi River from Minnesota City to Winona.

Five bedrock aquifers, each consisting of one or more of the Paleozoic rock units described on Plate 2, are utilized in Winona County (Fig. 4). The aquifers are separated from each other by relatively impermeable confining layers, and each aquifer behaves as a single hydrologic unit even though it may consist of more than one rock type. The pressure or potentiometric head is fairly uniform from the top to bottom of any one aquifer. However, there is considerable potentiometric difference between aquifers, due to the presence of the confining beds or layers.

Not all of the aquifers in Winona County contain large amounts of ground water. The Galena and St. Peter aquifers are all but dewatered and have little or no yield. Near stream valleys the Prairie du Chien-Jordan and the Franconia-Ironton-Galesville aquifers are also dewatered, but these and the Mt. Simon aquifer supply most of the ground water used in the county.

The Mt. Simon aquifer is used only in the eastern areas of the county, because elsewhere it is deep, and usable bedrock aquifers are available at shallower depths. No data are available to describe hydrologic properties of the Mt. Simon aquifer for most of the county, and so maps showing ground-water movement and estimated yield cannot be prepared.

The Franconia-Ironton-Galesville aquifer underlies most of the county. It exhibits artesian conditions in the west and water-table conditions in the east where it is affected by stream drainage. Its maximum thickness is about 250 feet. Where the shallower Prairie du Chien-Jordan aquifer can be used, few wells are drilled to the Franconia-Ironton-Galesville, and thus almost no data for this aquifer are available for the southwestern quarter of the county. The Franconia Formation is composed chiefly of fine-grained sandstone interbedded with shale and siltstone, whereas the Ironton and Galesville Sandstones are composed of coarser sand with only minor amounts of shale. All three units will stand open in an uncased well, but fine sand may be pumped, especially where the aquifer exhibits water-table conditions. The underlying Eau Claire confining layer has a high percentage of very fine grained sandstone in its upper 20 feet, which locally may be hydrologically connected to the Galesville. The St. Lawrence confining layer separates the Franconia-Ironton-Galesville from the Prairie du Chien-Jordan aquifer. The difference in water level between these two aquifers is substantial, especially where the latter is completely saturated. These differences are shown on the potentiometric maps.

The Prairie du Chien-Jordan aquifer is the major source of ground water for many areas of the county. It is commonly the shallowest bedrock aquifer present and exhibits a wide range in thickness from its maximum of about 400 feet. The Prairie du Chien Group is a karst aquifer composed of dolomite and limestone and is exposed or covered by a thin mantle of unconsolidated deposits where it is the first bedrock. The contact with the underlying Jordan Sandstone is transitional over a few feet; most of the Jordan consists of poorly cemented, medium- to coarse-grained sandstone. Solution cavities, and even caverns more than 10 feet deep, have been encountered during well drilling, especially near the contact between the two units. Small potentiometric differences may exist locally within this aquifer, but no regional confining layer separates the Prairie du Chien from the Jordan. Water-table conditions occur throughout the aquifer, except in a small area in St. Charles and Saratoga Townships where it is covered by younger bedrock. The Prairie du Chien Group is mostly dewatered in the eastern half of the county, but the Jordan Sandstone contains water and is used as an aquifer.

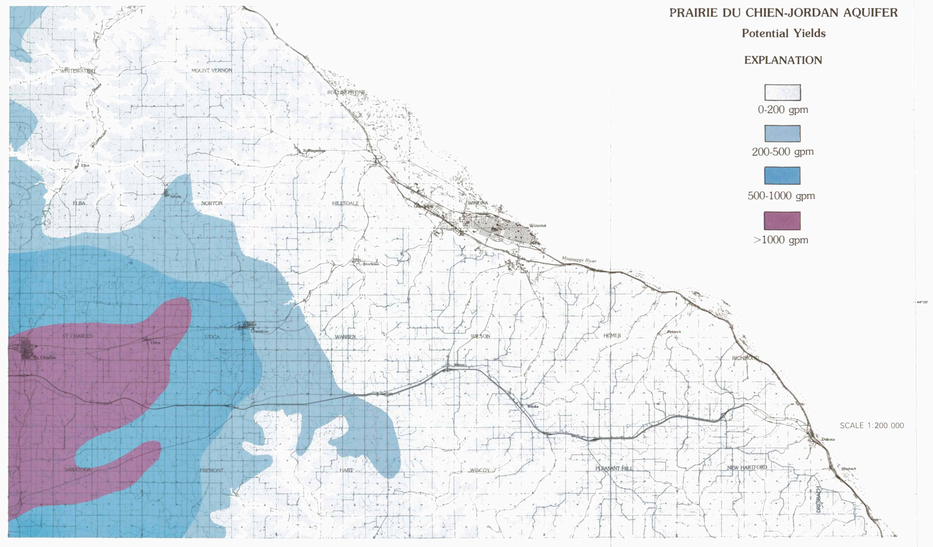
Springs and Seeps

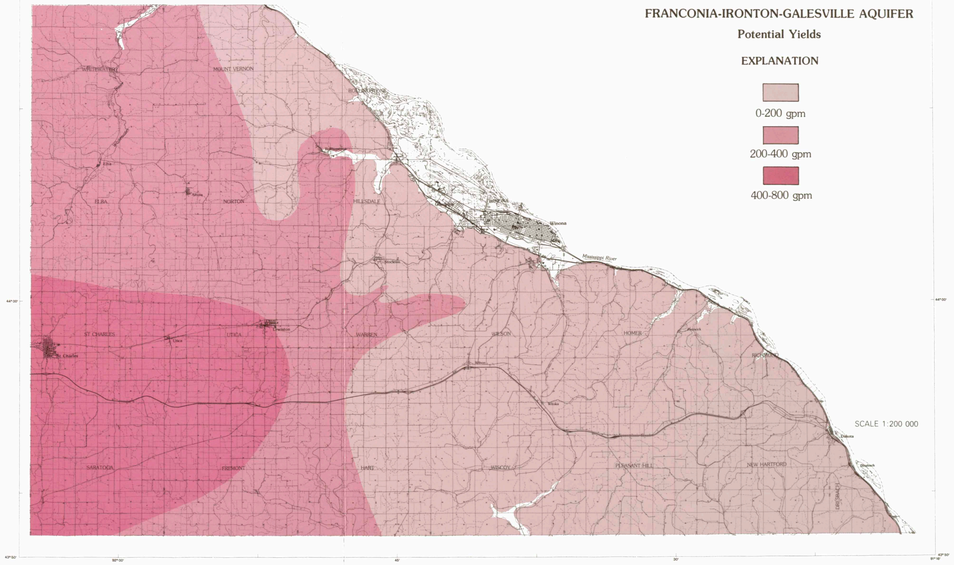
Springs discharge ground water from a source that can be identified. Seeps also discharge ground water, but they generally cover larger areas than springs, and no single source of flow can readily be determined. Springs and seeps vary in size, shape, and yield. Most seem to discharge from single aquifers, although joints, especially along ridges, may permit intermixing of waters from different aquifers. Some springs and seeps dry up during periods of low precipitation, and these probably derive their flow from the local infiltration of surface water. Others flow throughout the year, although rates of flow may vary seasonally. Continuously flowing springs and seeps probably derive at least part of their yields from regional rather than local ground-water discharge.

Springs and seeps commonly occur at the juncture of valley walls with the valley floor, where the karst aquifers have been eroded. The intersection of large joints in the bedrock, which would channel ground-water discharge into a local area, may be one mechanism for causing springs and seeps in valleys. However, some occur in karsted bedrock in upland areas and along the crests of bluffs. Regardless of their location, springs and seeps reflect local ground-water conditions and provide reference points for monitoring long-term changes in water temperature and chemistry.

ROCK UNIT		AQUIFER SYSTEM	HYDROLOGIC CONDITION	WATER-LEVEL RELATIONSHIPS
GALENA FORMATION		UPPER CARBONATE AQUIFER	MOSTLY DEWATERED	
DECORAH SHALE PLATTEVILLE FM GLENWOOD FM		CONFINING LAYER	NON-AQUIFER	
ST. PETER SANDSTONE		ST. PETER AQUIFER	MOSTLY DEWATERED	
SHAKOPEE FORMATION	PRAIRIE DU CHIEN GROUP	PRAIRIE DU CHIEN-JORDAN AQUIFER	MOSTLY UNCONFINED	Highest potentiometric surface — About 100 to 200 feet
ONEOTA DOLOMITE				
JORDAN SANDSTONE				
ST. LAWRENCE FORMATION		CONFINING LAYER	NON-AQUIFER	Potentiometric surface — About 150 feet
FRANCONIA FORMATION		FRANCONIA-IRONTON-GALESVILLE AQUIFER	ARTESIAN EXCEPT WHERE DISCHARGING INTO VALLEYS	
IRONTON & GALESVILLE SANDSTONES				
EAU CLAIRE FORMATION		CONFINING LAYER	NON-AQUIFER	
MT. SIMON SANDSTONE		MT. SIMON AQUIFER	ARTESIAN EXCEPT WHERE DISCHARGING INTO VALLEYS	Lowest potentiometric surface
PRECAMBRIAN		UNKNOWN ??	UNKNOWN	

Figure 4.—Sequence of bedrock aquifers.





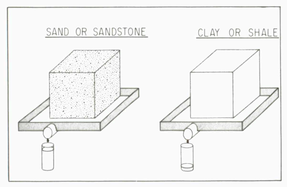


Figure 1.—Comparative yields.

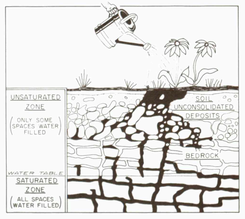


Figure 2.—Zones of water saturation.

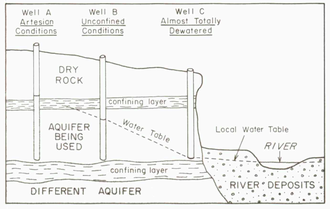


Figure 3.—Variability in aquifer conditions due to discharge into valleys.

POTENTIOMETRIC MAPS

Water pressure within an aquifer is reflected in the water level of a well which uses only that aquifer. Non-pumping or static water levels are usually measured in feet below the land surface and can be expressed as elevations above sea level. The compilation of static water-level elevations from throughout the county shows the differences in water pressure in an aquifer. The potentiometric contours shown on the maps are lines of equal pressure elevation. Thus, a potentiometric map displays the changes in aquifer pressure expressed as contours and shows water movement from areas of higher to lower potential. Arrows have been added to assist the reader in noting local directions of flow.

The potentiometric surfaces shown on the maps are approximations. The primary sources of data are water-well logs which report static water levels when the wells were constructed. As a result, these data describe aquifer pressures at different seasons of the year and over a period of many years. However, to determine potentiometric differences precisely, static elevations should be measured over brief time periods. In order to supplement the well-log data, staff members of the Minnesota Geological Survey measured the static water levels in more than 100 wells which used either the Prairie du Chien-Jordan or the Franconia-Ironton-Galesville aquifer.

The Mississippi River drainage system has a great effect on local directions of ground-water movement. Except in the extreme southwestern corner of the county, the ground water discharges toward the Mississippi River valley in a direction almost opposite to the shallow dip of the bedrock aquifers. Local tributary valleys, such as the Whitewater or Wiscoy, alter this eastward trend by causing bedrock aquifers to discharge into their drainages. These local changes in the direction of ground-water movement may substantially lower aquifer water levels and may even dewater an aquifer in proximity to a large tributary valley.

The Prairie du Chien-Jordan aquifer exhibits much higher static water-level elevations than does the Franconia-Ironton-Galesville aquifer. Therefore, in addition to the eastward direction of lateral flow, Prairie du Chien-Jordan water will move vertically downward if the St. Lawrence confining layer contains any joints or other pathways open to the Franconia-Ironton-Galesville. The amount of this vertical recharge and the areas where it is most likely to occur cannot be determined with existing information.

YIELD MAPS

The value of an aquifer as a potential source of water depends on its ability to store and yield water. A sustained yield rating is a measure of the amount of water that can be obtained by continuous withdrawal from a well that is at least 6 inches in diameter and (1) uses the total saturated aquifer thickness, (2) pumps continually while causing the maximum allowable drawdown, and (3) is not interfered with by competing wells using that aquifer. The sustained yield rating is an index to the maximum yield capacity of an aquifer that can be sustained without irreversible depletion of the aquifer. The values shown are approximations and are useful on a county-wide scale. Determining site-specific aquifer performance requires test pumping because hydrologic conditions may vary locally.

The major reason for the variability in aquifer yield as shown on the maps is the effect of ground-water discharge into valleys. No large-scale changes in rock type are known to occur in either aquifer system, so their yields are directly related to the degree of water saturation rather than to permeability. However, the Prairie du Chien-Jordan aquifer has a greater maximum yield potential than the Franconia-Ironton-Galesville, because it is about 150 feet thicker and can store more water. It also contains significantly less shale and clay than the Franconia-Ironton-Galesville.