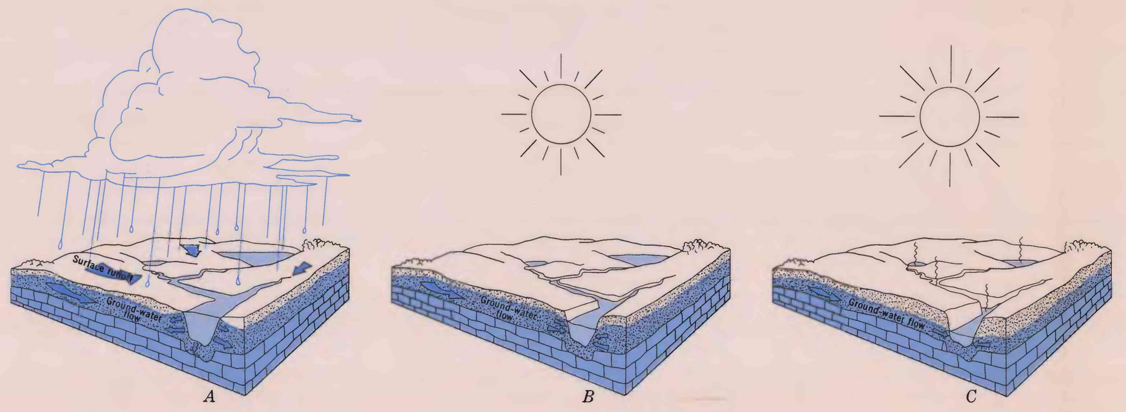
GROUND-WATER—SURFACE-WATER RELATIONSHIPS

Ground water and surface water are directly related. Both seasonal and long-term increases or decreases in precipitation cause corresponding increases or decreases in ground-water level, streamflow, and lake stage. Furthermore, manmade changes in either ground-water level, streamflow, or lake stage can cause corresponding changes in the others. The quality of ground water and surface water is similar, although surface-water quality is subject to greater variability.

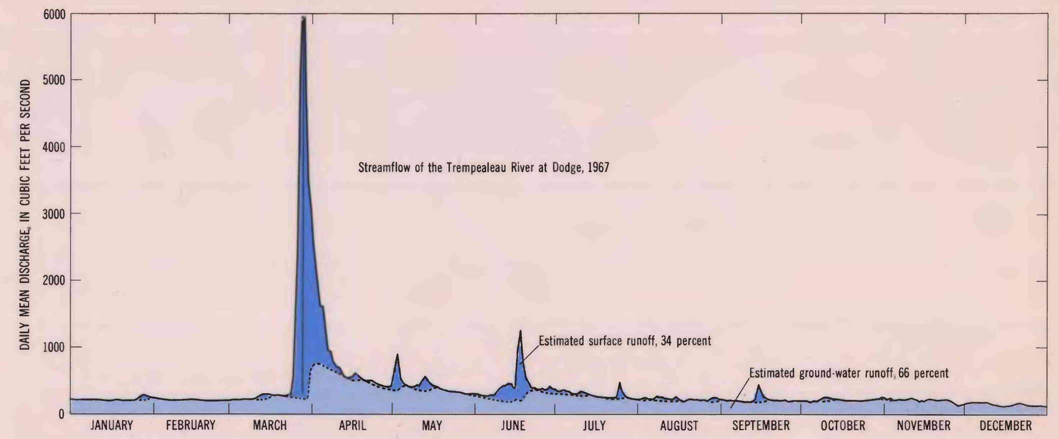


GROUND-WATER RELATION TO STREAMFLOW

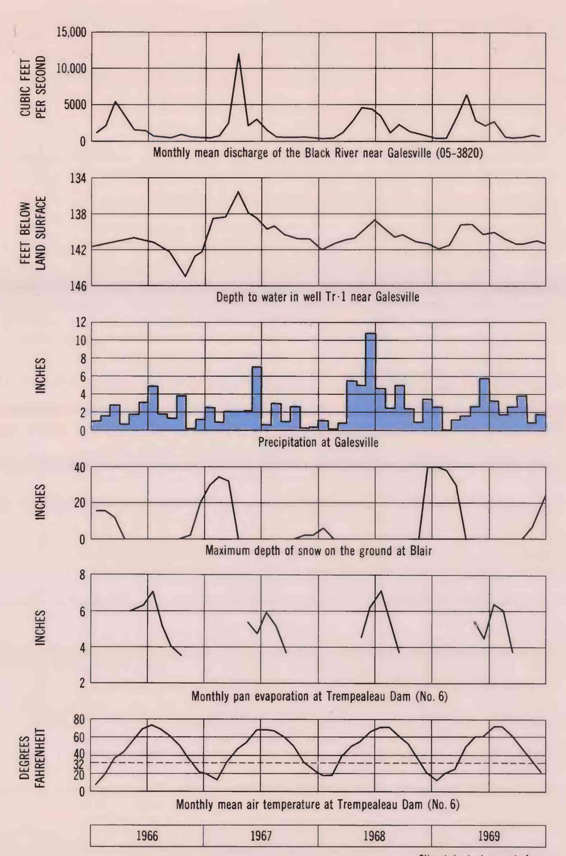
Streamflow is a combination of surface- and ground-water runoff. During rapid snowmelt and periods of prolonged heavy rainfall, direct runoff moves rapidly to streams. Water recharged to the ground-water reservoir during these periods discharges slowly and maintains streamflow during dry periods.

The three sketches show the general relationship between streamflow and ground water at a point on a stream in response to heavy rainfall. During periods of prolonged rainfall or snowmelt (A), stream stage and the water table rise. Surface water moves into streambanks, raising the water table adjacent to the streams. As stream stage recedes (B), water stored in the streambanks returns to the streams, and the water table declines as ground water discharges to the streams. Stream stage and the water table continue to decline (C) until the next significant rainfall or snowmelt.

The separation of the 1967 hydrograph for the Trempealeau River at Dodge shows the relatively uniform basin contribution of ground water to streamflow for most of the year and the high surface runoff during isolated short periods. Snowmelt in late March and heavy rainfall in April, May, and June produced the major high flows of the year. Ground-water runoff also increased sharply during the periods of high flow and receded slowly after the flood crest passed.



GROUND-WATER CONTRIBUTION TO STREAMFLOW



RELATION OF STREAMFLOW AND GROUND-WATER LEVEL TO CLIMATOLOGICAL ELEMENTS

The relationships between streamflow, ground-water level, and climatological factors, shown by a comparsion of records for 1966-69 in the Galesville area, apply throughout the basin. Stream discharge increases and the water table rises when snow melts and evapotranspiration is low, and in other periods when rainfall is heavy. The converse is true when water is in storage as snow, or when evapotranspiration is high.

Streamflow peaks generally are the result of heavy rainfall, spring snowmelt, or a combination of the two. Peak flows in spring are primarily from snowmelt, as in 1966, 1967, and 1969. High flows were sustained by heavy rainfall from April to July in 1968. Heavy rainfall in summer also produces peak flows except during periods of high evapotranspiration and soil-moisture deficit.

The water level in the well near Galesville is related to fluctuations in precipitation. The water table usually declines from spring or early summer until late winter because evapotranspiration and ground-water runoff exceed recharge.

EXPLANATION

Runoff, in cubic feet per second per square mile of subbasin, and percentage of total area of subbasins

Negative (1 percent)

0.00-0.09 (27 percent)

0.10-0.29 (30 percent)

0.30-0.49 (48 percent)

0.50-0.69 (13 percent)

0.70-0.99 (1 percent)

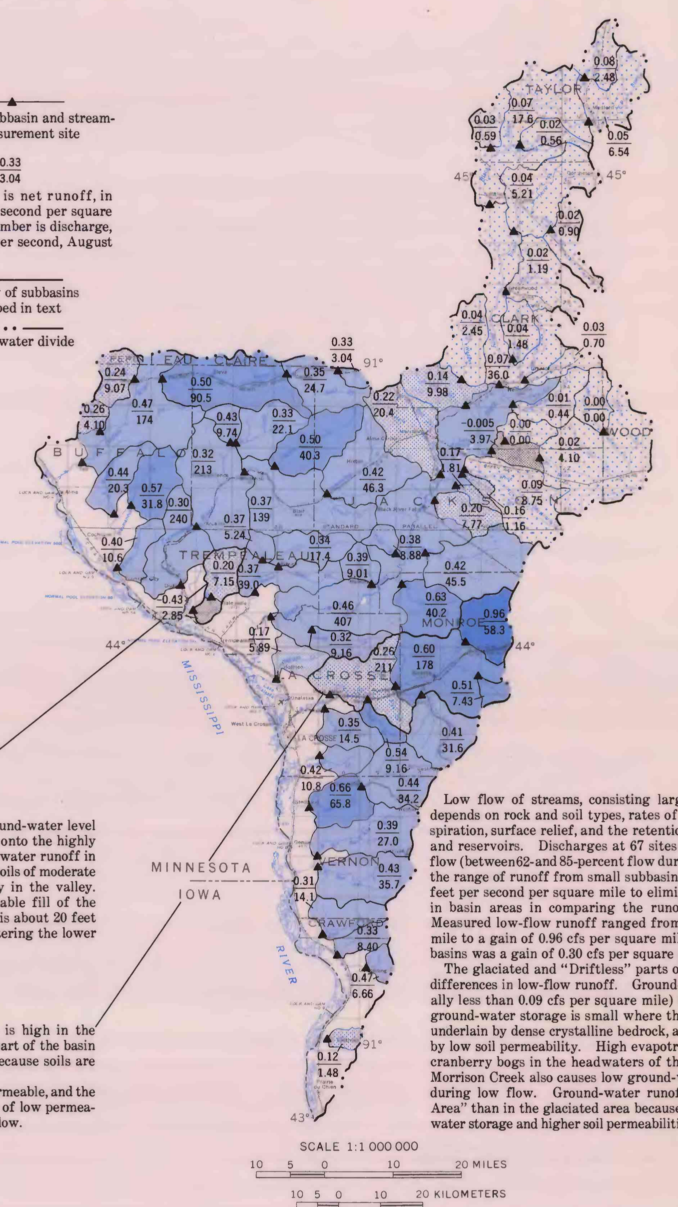
Boundary of subbasin and streamflow measurement site

0.33
3.04

Upper number is net runoff, in cubic feet per second per square mile; lower number is discharge, in cubic feet per second, August 11-13, 1970

Boundary of subbasins described in text

Surface-water divide



Losing reaches may occur in streams where the ground-water level is locally below stream level, such as streams flowing onto the highly permeable Mississippi River valley fill. Low ground-water runoff in the upper part of the Tamarack Creek basin is due to soils of moderate permeability and lake sediments of low permeability in the valley. The lower subbasin is primarily on the thick, permeable fill of the Mississippi valley. The water table in the valley fill is about 20 feet below Tamarack Creek, and 60 percent of the flow entering the lower subbasin is lost to the ground-water reservoir.

Ground-water runoff in the La Crosse River basin is high in the upper part, but decreases downstream. In the upper part of the basin ground-water storage is high and recharge is high because soils are very permeable and the aquifers are thick.

In the subbasin farthest downstream soils are less permeable, and the valley fill consists of very fine-grained lake sediments of low permeability; thus, ground-water recharge and discharge are low.

Low flow of streams, consisting largely of ground-water runoff, depends on rock and soil types, rates of precipitation and evapotranspiration, surface relief, and the retention of water in lakes, marshes, and reservoirs. Discharges at 67 sites during a 3-day period of low flow (between 62- and 85-percent flow duration at gaging stations) show the range of runoff from small subbasins. Flow is expressed in cubic feet per second per square mile to eliminate the effect of differences in basin areas in comparing the runoff of the several subbasins. Measured low-flow runoff ranged from a loss of 0.43 cfs per square mile to a gain of 0.96 cfs per square mile, but the average of all subbasins was a gain of 0.30 cfs per square mile.

The glaciated and "Driftless" parts of the basin show significant differences in low-flow runoff. Ground-water runoff is lower (generally less than 0.09 cfs per square mile) in the glaciated area because ground-water storage is small where the ground moraine is thin and underlain by dense crystalline bedrock, and because recharge is limited by low soil permeability. High evapotranspiration from swamps and cranberry bogs in the headwaters of the East Fork Black River and Morrison Creek also causes low ground-water runoff to those streams during low flow. Ground-water runoff is higher in the "Driftless Area" than in the glaciated area because of greater volume of ground-water storage and higher soil permeabilities, which allow more recharge.

DISTRIBUTION OF LOW-FLOW RUNOFF, AUGUST 11-13, 1970

GROUND WATER

Ground water is readily available in quantities adequate to meet present and future domestic, agricultural, municipal, and industrial needs except in the extreme northeastern part of the basin. In general, the development of ground water is small scale and is scattered throughout the basin. Present areas of moderately large pumpage are La Crosse, Sparta, and Prairie du Chien.

Aquifer	Age	Geologic unit	Columnar section	Thickness (feet)	Maximum yield reported (gpm)	Average high-capacity well yield (gpm)	Well depths (feet)
Sand and gravel	Quaternary	Surficial sand and gravel		0-230	3,600	890	11-194
		Isolated deposits of buried sand and gravel in drift		0-25	200	Only 3 wells	30-126
Sandstone	Ordovician	Prairie du Chien Group		0-100	12	None	150-460
	Cambrian	Jordan Sandstone St. Lawrence Formation Franconia Sandstone Galesville Sandstone Eau Claire Sandstone Mount Simon Sandstone		0-1,200	1,000	304	25-1,100
	Precambrian	Crystalline igneous and metamorphic rocks		Unknown	Not productive; however, in the glaciated area it must be used for domestic supplies and to supplement small municipal supplies from thin drift or sandstone. Yields generally less than 5 gpm		

Most ground water in the basin is obtained from two major aquifers. The sand and gravel aquifer is used primarily along the Mississippi River and locally in the northeastern part of the basin. The sandstone aquifer is used throughout the basin except in Taylor County.

Because these aquifers are thin or absent in much of the northeastern part of the basin, wells must be drilled into the crystalline bedrock. Most of these wells yield less than 5 gpm (gallons per minute) but a few wells yield 10-20 gpm.

More detailed information on ground-water availability in most of Clark, Taylor and Wood Counties is contained in a report by Bell and Sherrill (1973).

Ground-water availability is delineated on the map on the basis of well records and rock types.

SAND AND GRAVEL AQUIFER

Surficial deposits.—The most important deposits of sand and gravel in the basin are in the preglacial bedrock valleys of the Mississippi and Buffalo Rivers and in outwash in Jackson and Taylor Counties. A few small, isolated deposits occur in other valleys, such as at Blair and Greenwood, but are undelineated because of lack of data. The best potential for ground-water development is in areas where saturated sand and gravel is more than 50 feet thick.

Deposits in the Mississippi River valley are the most permeable, have the greatest saturated thickness and, thus, yield the largest quantities of water to wells. Of the nearly 60 high-capacity wells[1] in surficial sand and gravel one-half are in or near La Crosse and Prairie du Chien. The specific capacities of 35 high-capacity wells range from about 10 to 130 gpm per foot of drawdown, and the median is 42. One-fourth of them have specific capacities of 82 or more. Present withdrawal from these deposits is small in comparison to their potential.

Isolated buried deposits.—Buried sand and gravel deposits may occur beneath or within most of the ground and end moraine in the northeastern part of the basin. The deposits are thickest in the end moraine on the northern divide and in a few preglacial bedrock valleys; elsewhere they are variable in occurrence and thickness. The isolated deposits have poor potential for ground-water development because of limited areal extent and saturated thickness.

The yields of buried sand and gravel deposits are small to moderate. Well yields of 5-15 gpm, adequate for domestic supplies, are obtained from lenses of sand and gravel which are commonly less than 5 feet thick. Only three wells are known to yield as much as 70 gpm from these deposits; some municipalities use wells yielding as little as 25 gpm.

SANDSTONE AQUIFER

The sandstone aquifer, important in the western and southern parts of the basin, consists of the saturated parts of the Ordovician and Cambrian formations in the basin. The latter comprise the bulk of the aquifer. The Ordovician formations generally are not saturated, but on the southern basin divide a few deep wells in Cambrian sandstone receive some water from the lower part of the Prairie du Chien dolomite. A few domestic wells are finished in perched water zones in the Galena-Platteville unit and the St. Peter Sandstone.

Where the sandstone aquifer is more than 50 feet thick, it can provide reliable supplies for municipal, industrial, domestic, stock, and irrigation uses. Yields as much as 1,000 gpm are obtained from wells in this area. Where the sandstone is less than 50 feet thick, in the northeast, it commonly provides only small, domestic supplies.

Wells must penetrate a greater saturated thickness of sandstone than of sand and gravel to obtain comparable yields, because sandstone is less permeable than sand and gravel. Adjacent wells may have different yields if they are open to different intervals within the aquifer. Depths of high-capacity wells in sandstone range from 66 to 1,100 feet; however, the median depth is 250 feet. The specific capacities of these wells generally range from 1 to 30 gpm per foot of drawdown, and the median is 5. The specific capacities of 25 percent of them are 8 or more.

[1]The Wisconsin "high-capacity" well law requires a permit from the Wisconsin Department of Natural Resources before the installation of a well with a capacity of 70 gpm or more (Wisconsin Natural Resources Committee of State Agencies, 1967, p. 16).

EXPLANATION

SAND AND GRAVEL AQUIFER

Surficial sand and gravel

Saturated sand and gravel more than 50 feet thick. Generally yields 200-1,000 gallons per minute to wells

Saturated sand and gravel less than 50 feet thick. Generally yields less than 200 gallons per minute to wells

Isolated buried deposits

Undelineated deposits of sand and gravel in end moraine. May yield 50-200 gallons per minute to wells

Undelineated deposits of sand and gravel in ground moraine. Generally yields 5-15 gallons per minute to wells

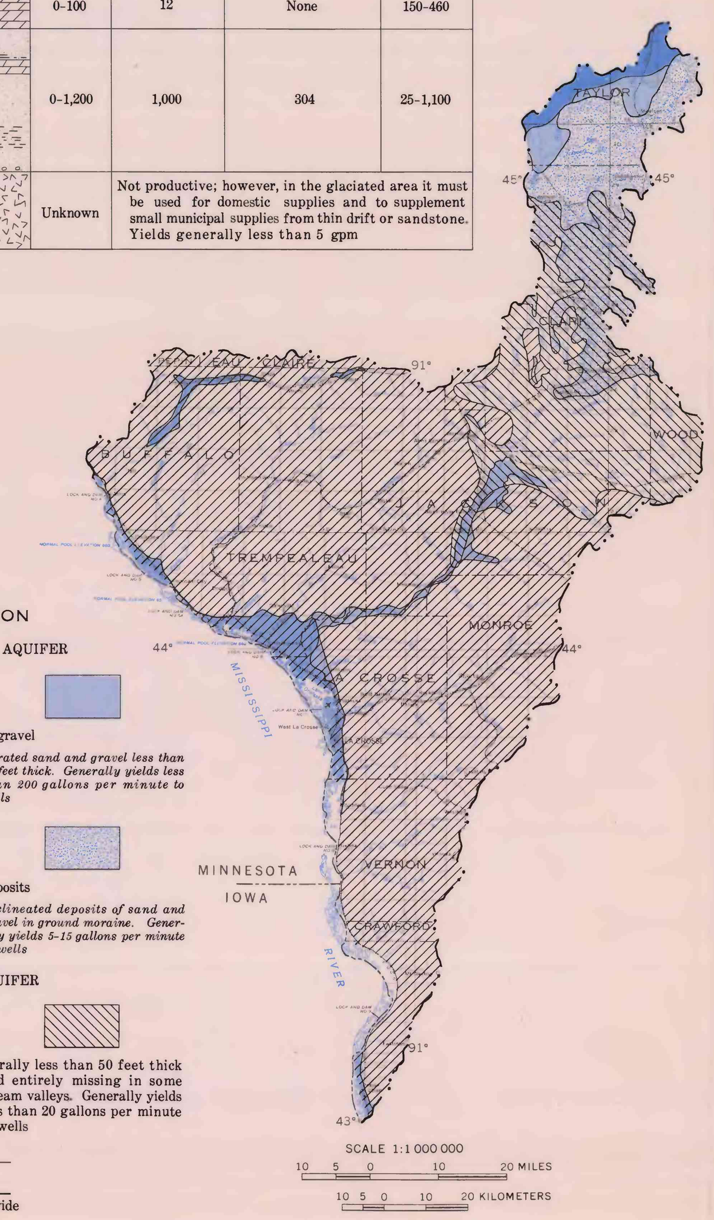
SANDSTONE AQUIFER

More than 50 feet thick. Generally yields 200-500 gallons per minute to wells

Generally less than 50 feet thick and entirely missing in some stream valleys. Generally yields less than 20 gallons per minute to wells

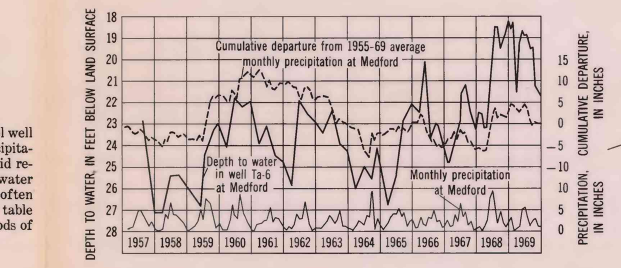
Contact

Surface-water divide



GROUND-WATER AVAILABILITY

Although the water-level record of this shallow sand and gravel well at Medford generally correlates with the long-term trend of precipitation, there are pronounced deviations because of direct and rapid response of the water table to precipitation. Sharp rises in the water table generally begin with recharge from spring snowmelt but often are sustained by summer rainfall. Sharp declines in the water table are produced by lack of recharge in the winter and during periods of consistently below normal precipitation.



EXPLANATION

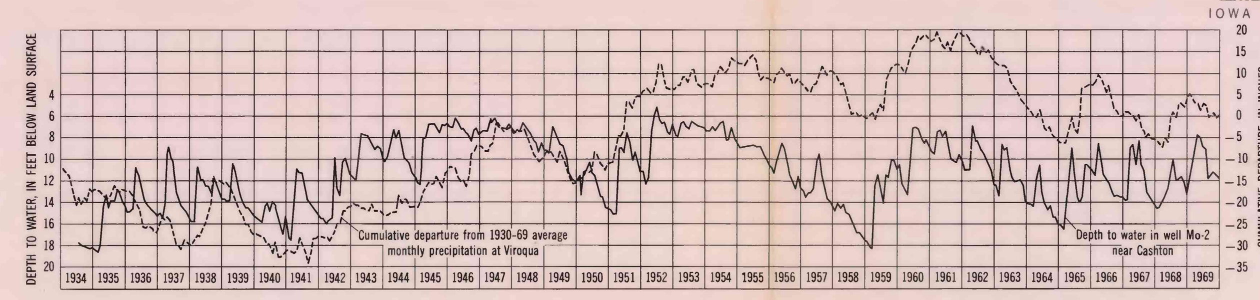
1200
Water-table contour
Shows altitude of water table. Contour interval 100 feet. Datum is mean sea level

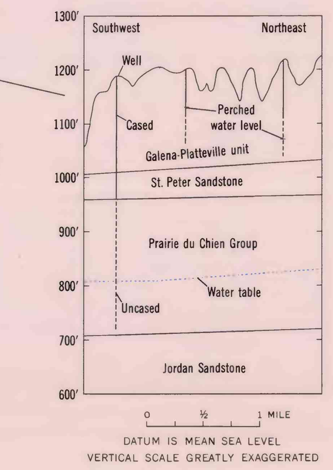
G,S
Observation well
G, *sand and gravel aquifer*
S, *sandstone aquifer*

Ground-water divide

Surface-water divide

This shallow well finished in Jordan Sandstone is in a short but deep valley tributary to the East Branch Coon Creek. The water-level record has a good correlation with the long-term trend of precipitation. Although the stream usually is dry, during periods of little recharge the shallow water table beneath the valley flat is maintained by ground water moving to the valley from adjacent ridges. A gradual decline usually occurs during winter when little recharge occurs. Rapid recharge by precipitation and snowmelt through the streambed and valley flat causes the short-term high stages of the water table.





GEOLOGIC SECTION SHOWING PERCHED WATER LEVELS

WATER TABLE AND OBSERVATION-WELL NETWORK

Ground water occurs throughout the basin, and its natural movement is from areas of recharge to lower areas of discharge (streams, springs, lakes, and wetlands). Ground-water movement is perpendicular to the water-table contours and conforms regionally to the direction of surface runoff. Because the ground-water divide and surface-water divide of the basin generally coincide, very little underflow occurs across the basin divide.

The depth to the water table in the basin depends largely on topography and ranges from 0 to almost 600 feet below land surface. In the northeast it is generally less than 50 feet but locally is more than 100 feet. The extreme depths occur in the west and south, where the water table is near the surface in valleys and is deep below ridges. Depths of 250-500 feet are common in Crawford, La Crosse, and Vernon Counties.

Bodies of perched water occur beneath many high ridges in the southern part of the basin. Downward percolation of recharge is inhibited by horizontal zones of low permeability, such as shale or dense dolomite. Therefore, shallow wells finished above these zones of low permeability may have water levels considerably higher than those in deep wells that penetrate the zones. Perched water commonly occurs in the Galena-Platteville unit and the Prairie du Chien Group. The cross section shows an example of shallow water levels in two wells in the Galena-Platteville unit and a much deeper water level in a nearby well finished near the base of the Prairie du Chien dolomite.

The water table fluctuates with changes in recharge and discharge. The three well hydrographs illustrate these fluctuations. Records of water levels for 5 years or more are available for each of the 21 observation wells indicated on the map. Hydrographs are published for 18 of the wells (Devaul, 1967).

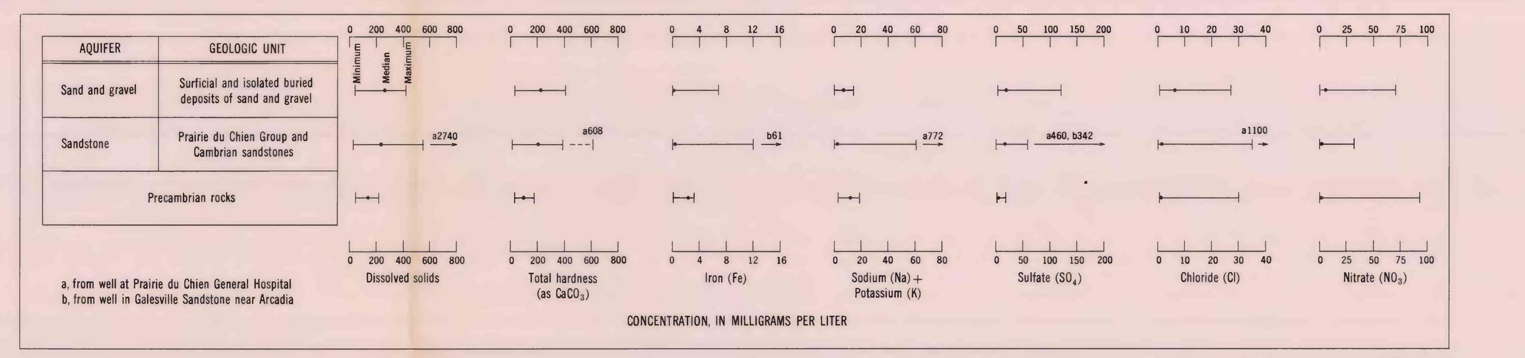
Artesian wells occur locally in low-lying areas in the western and southern parts of the basin. Weidman and Schultz (1915) reported artesian wells in Cambrian sandstone in the valleys of the Mississippi, Buffalo, Trempealeau, Black, and La Crosse Rivers, and Coon Creek. When the first wells were drilled, heads in the Mississippi River valley were 30-100 feet above river level; however, the pressure has declined because of pumpage, unchecked flow, and leaky well casings. Most artesian wells now in use must be pumped.

GROUND-WATER QUALITY

Ground water in the Trempealeau-Black River basin is generally of very good quality and is usable for most purposes. The main chemical constituents in water in the basin are calcium, magnesium, and bicarbonate ions. These ions are derived primarily from solution of dolomite and limestone and chemical decomposition of certain minerals in igneous and metamorphic rocks.

Regional differences in the quality of ground water are due to the composition, solubility, and surface area of the particles of soil and rock through which the water moves, and to the length of time the water is in contact with these materials.

Minor water-use problems are caused by hardness and, by high concentrations of iron. Hardness caused chiefly by calcium and magnesium, is classified by the U.S. Geological Survey as follows: 0-60 mg/l (milligrams per liter), soft; 61-120 mg/l, moderately hard; 121-180 mg/l, hard; and more than 180 mg/l, very hard. About 70 percent of the ground water sampled had hardness of more than 120 mg/l, and 60 percent had hardness of more than 180 mg/l; water in the latter category needs softening for many uses. Iron is commonly a problem in all aquifers and the concentration exceeded 0.35 mg/l in half of the water sampled from the sandstone aquifer.



QUALITY OF WATER BY AQUIFER

Based on analyses by U.S. Geological Survey and Wisconsin State Laboratory of Hygiene

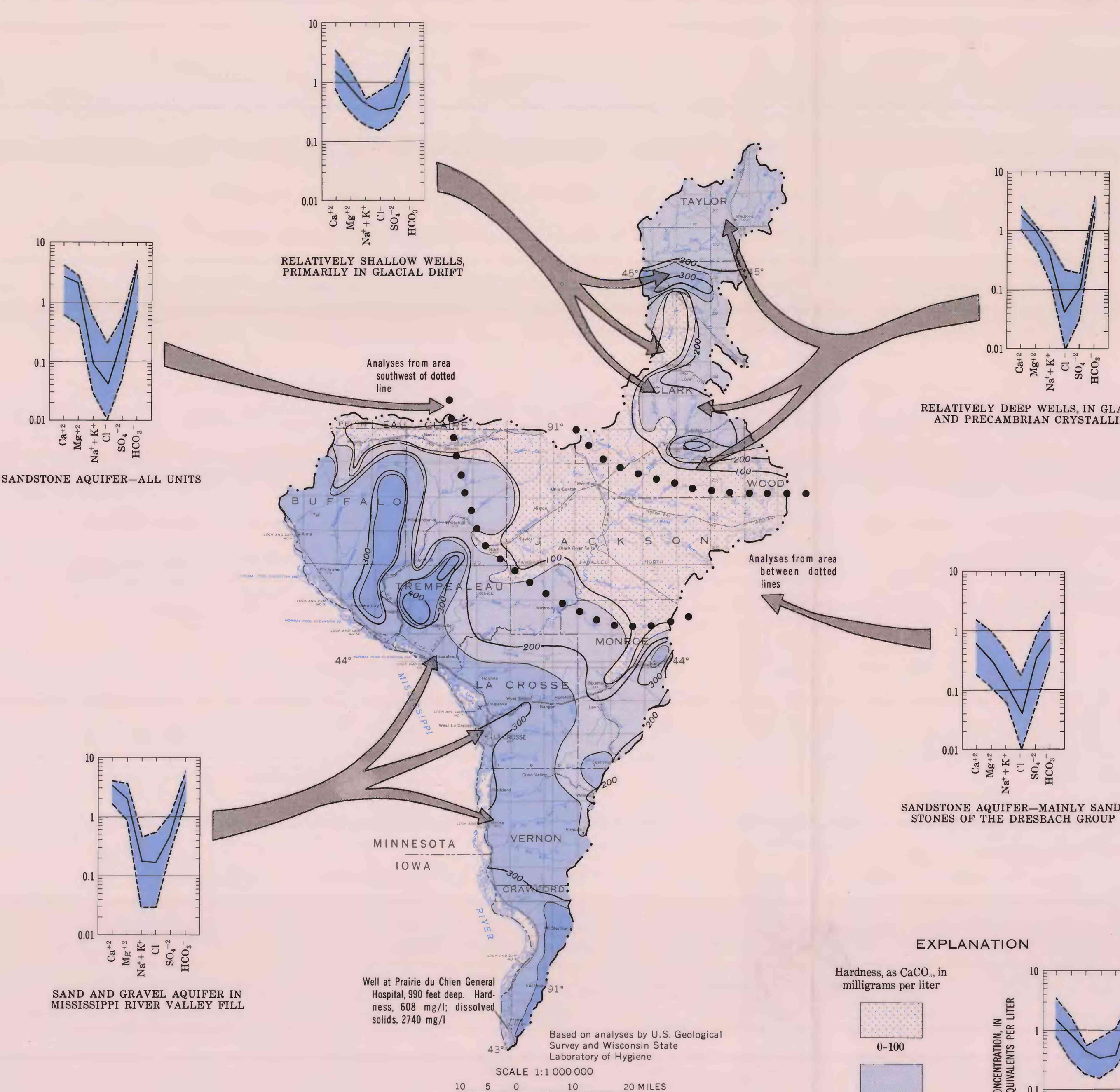
The overall characteristics of ground-water quality in the basin are fairly similar in both the sandstone and the sand and gravel aquifers. Dissolved-solids content and hardness of water from these aquifers generally are greater than in water from Precambrian rocks.

Unusually high values of constituents in water from the sandstone aquifer at Prairie du Chien and near Arcadia are shown separately. A flowing well at Prairie du Chien, 990 feet deep, yields brackish water. The water is highly mineralized because it has had a long period of contact with the rocks as it moves slowly along deep flow paths toward the Mississippi River. The well near Arcadia, 122 feet deep, is finished in the lowermost part of the Galesville Sandstone. Water from this well contained exceptionally high concentrations of iron and sulfate, probably a local occurrence.

The presence of excessive amounts of iron or manganese in water generally is unpredictable, and water from wells close together may have large differences in concentrations of these ions. Drinking water standards of the U.S. Public Health Service (1962) recommend maximum allowable concentrations of 0.3 mg/l of iron and 0.05 mg/l of manganese. The standards are based on levels that may produce objectionable taste and stains. The median concentration of iron is 0.35 mg/l in the sandstone aquifer and 2.3 mg/l in Precambrian rocks. The standard for iron is equaled or exceeded in several wells in the sand and gravel aquifer, although the median is 0.12 mg/l.

Most analyses show low concentrations of sodium, sulfate, and chloride. Except for anomalous values mentioned previously, the maximum concentrations of these constituents are 61, 120, and 35 mg/l, respectively. Drinking water standards of the U.S. Public Health Service (1962) allow a maximum concentration of 250 mg/l for both sulfate and chloride.

Nitrate concentrations are low. The medians range from 1.5 to 5.2 mg/l. The adjacent map has locations of wells with nitrate concentrations known to be more than 10 mg/l.



EXPLANATION

Hardness, as $CaCO_3$, in milligrams per liter

0-100

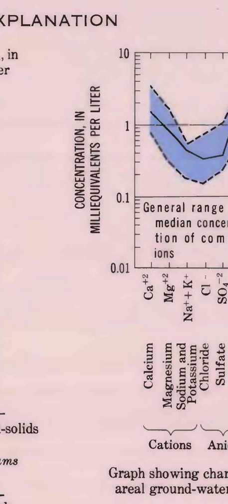
101-200

201-300

More than 300

200
Line of equal dissolved-solids content
Interval 100 milligrams per liter

Surface-water divide



Graph showing characteristic areal ground-water quality

REGIONAL QUALITY

The distribution of dissolved-solids content, and the closely related hardness, of ground water in the basin is similar to the areal pattern of the geologic units. Dissolved solids are highest in the area of thick sedimentary rocks where recharge must pass through much dolomite and some limestone to reach the deep water table. Conversely, they are lowest where the sandstone is thin, no carbonate rocks are present, and the water table is shallow. In most of the glaciated area dissolved solids are relatively low; small areas of higher dissolved solids result from longer contact times of ground water in low permeability ground and end moraines. Dissolved solids may be lower than shown if wells tap shallow or perched water, or where contact time is very short.

An unusual occurrence of very high dissolved solids and hardness in flowing wells about 1,000 feet deep at Prairie du Chien has been known for many years (Weidman and Schultz, 1915, p. 285-288). Additional parameters of this highly mineralized water are given in the section, "Quality of Water by Aquifer."

The five graphs depict regional differences in water quality. These graphs show the general range and median concentration of common ions, as determined from selected analyses in the areas designated. Concentrations of calcium, magnesium and bicarbonate ions are related directly to the hardness in areas represented by each graph.

EXPLANATION

Well
Number is concentration of nitrate (NO_3), in milligrams per liter. Arrow indicates more than 45 milligrams per liter

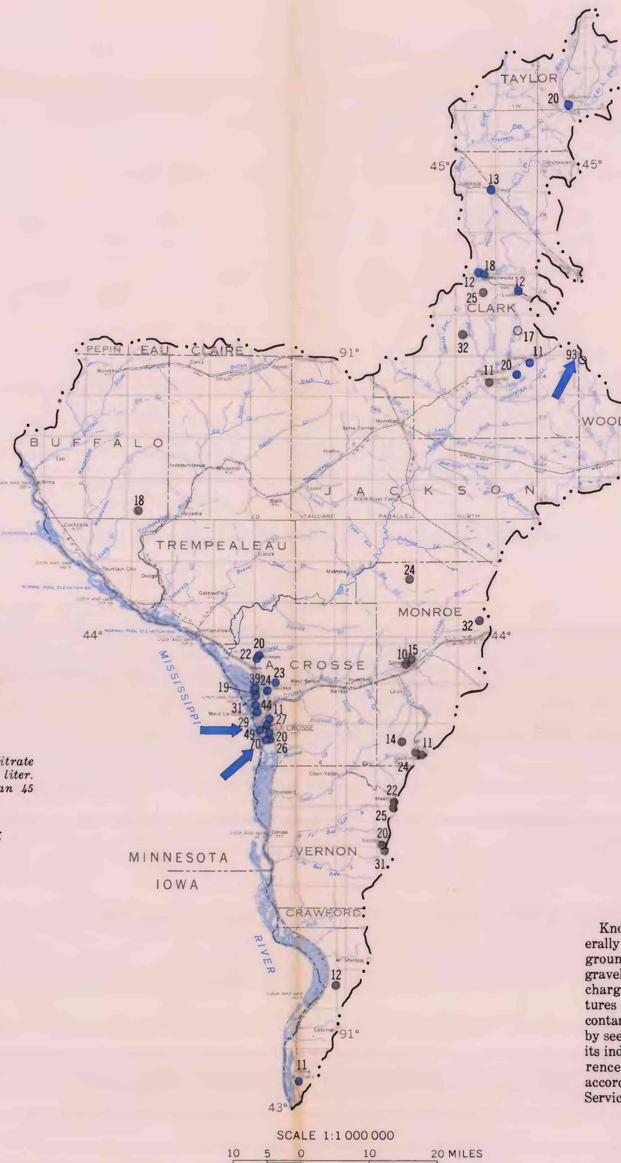
Geologic unit supplying water to well

Sand and gravel

Cambrian sandstones

Precambrian rocks

Surface-water divide



NITRATE IN GROUND WATER

Known concentrations of nitrate in ground water in the basin generally are low. Concentrations of more than 10 mg/l may result from ground-water contamination by organic wastes. Surficial sand and gravel is especially susceptible to contamination, because rapid recharge may carry contaminants. Likewise, recharge through fractures and solution channels in dolomite is not filtered and may carry contaminants. Contamination from the surface may enter some wells by seepage through leaky casings or poorly sealed wells. Apart from its indication of possible contamination, nitrate is linked to the occurrence of methemoglobinemia ("blue baby disease") in infants, and accordingly the drinking water standards of the U.S. Public Health Service (1962) set an allowable maximum of 45 mg/l.

Base from U.S. Geological Survey
1:500 000, 1968

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973—W72095

WATER RESOURCES OF WISCONSIN—TREMPEALEAU–BLACK RIVER BASIN

By
H. L. Young and R. G. Borman

1973