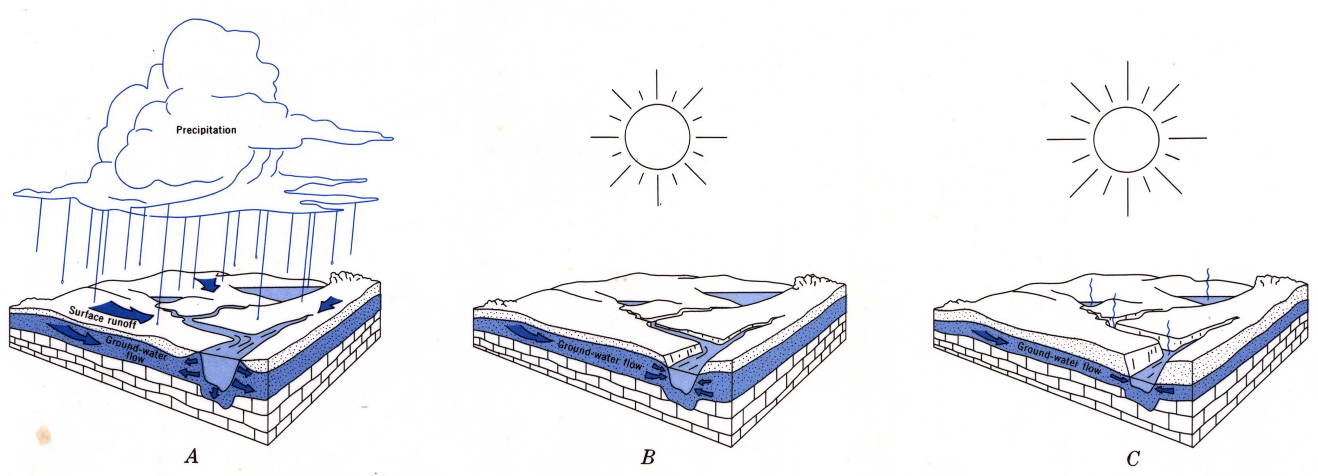
GROUND-WATER—SURFACE-WATER RELATIONSHIPS

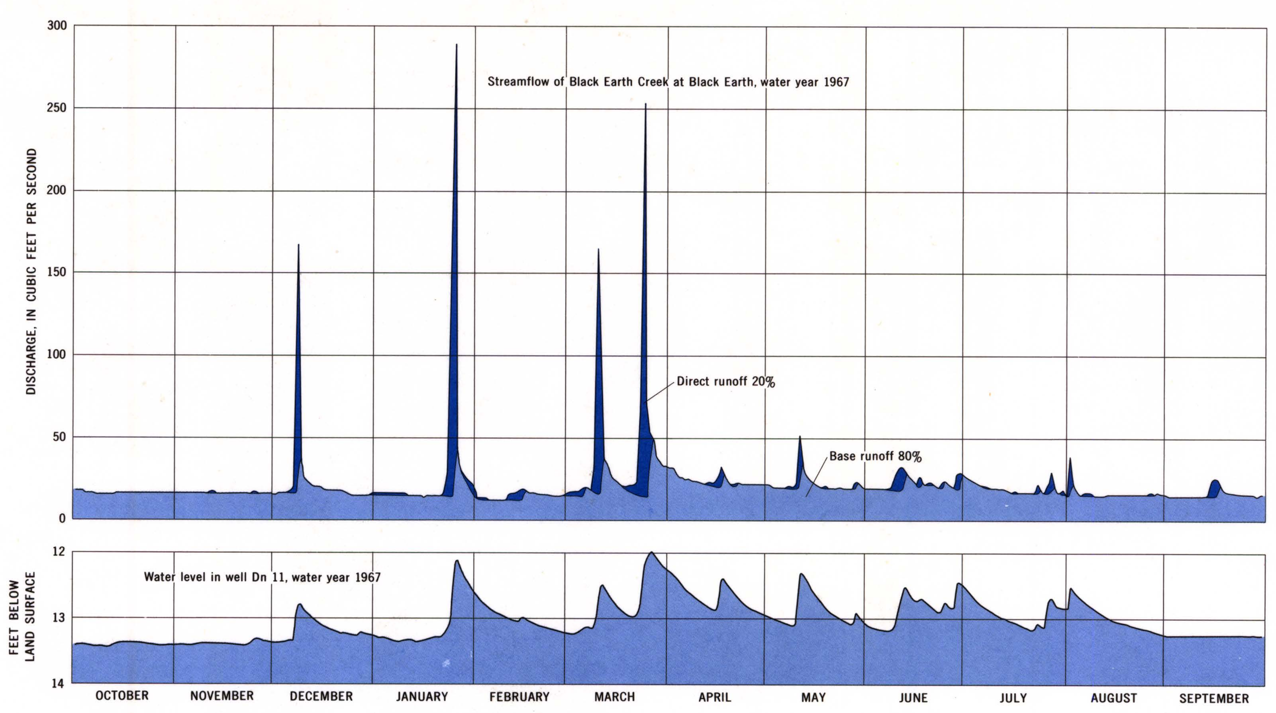
Ground and surface water are interrelated in all phases of their occurrence, and both are related to precipitation. Seasonal and long-term increases or decreases in precipitation cause corresponding increases or decreases in ground-water levels, streamflow, and lake stages. Natural or manmade changes in either ground-water levels or streamflow also cause corresponding changes in the other. Over a long period natural changes are balanced, but manmade changes may be irrevocable or cumulative. The chemical quality of ground and surface water are similar. However, surface-water quality is subject to greater variability because of overland runoff and manmade effects.



GROUND-WATER—STREAMFLOW RELATIONSHIP

Streamflow is a combination of direct and base runoff. During rapid snowmelt and periods of prolonged, heavy precipitation, direct runoff is quickly carried off by streams. That part of precipitation that does not run off or is used in evapotranspiration recharges the shallow ground-water reservoir, is discharged slowly, and maintains base streamflow.

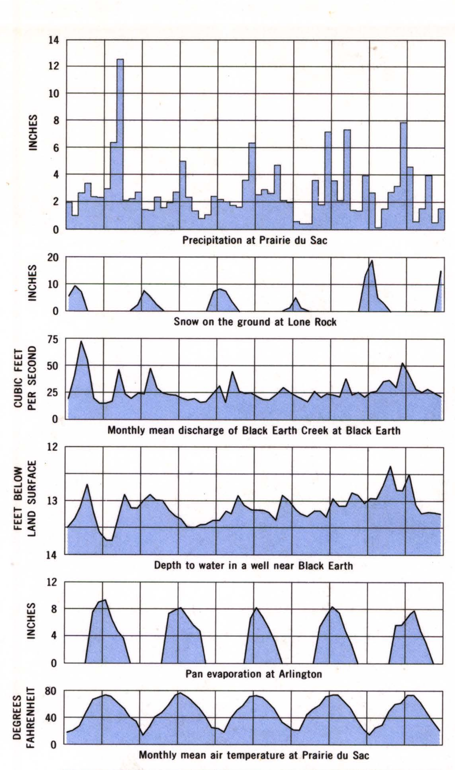
The three sketches above show the general relationship between streamflow and ground water. During periods of heavy or sustained rainfall or snowmelt, stream stages and ground-water levels rise (*A*) by direct infiltration. Water also moves into streambanks, raising ground-water levels adjacent to the streams. As stream stages recede, water stored in the streambanks returns to the streams, followed by a general decline in areal ground-water levels as the ground water discharges to the streams (*B*). Stream stages and ground-water levels continue to decline (*C*) until the next significant rainfall or snowmelt.



SEPARATION OF A STREAMFLOW HYDROGRAPH

The surface- and ground-water components of streamflow are determined approximately in the separation of the 1967 hydrograph for Black Earth Creek at Black Earth. The separation was based on the ground-water hydrograph of a nearby well. Rising ground-water levels represent periods of recharge to the ground-water reservoir. Falling water levels on the ground-water hydrograph correlate with periods of base runoff on the surface-water hydrograph. The time lag between the direct-runoff peak and the base-runoff peak was determined from the ground-water hydrograph.

The separation shows the consistent contribution of ground water to streamflow for the 12 months. Extremely high surface runoff occurred for short periods of major precipitation or snowmelt. Snowmelt or precipitation in December, January, and March produced the major high flows during the year. Base runoff, which changed very little during rising stages, increased sharply after each flood crest and then receded slowly. In 1967 Black Earth Creek had high base runoff (about 80 percent of the annual flow) because rainfall infiltrated into the highly permeable alluvium in the valley floor, leaving little water available for direct runoff.



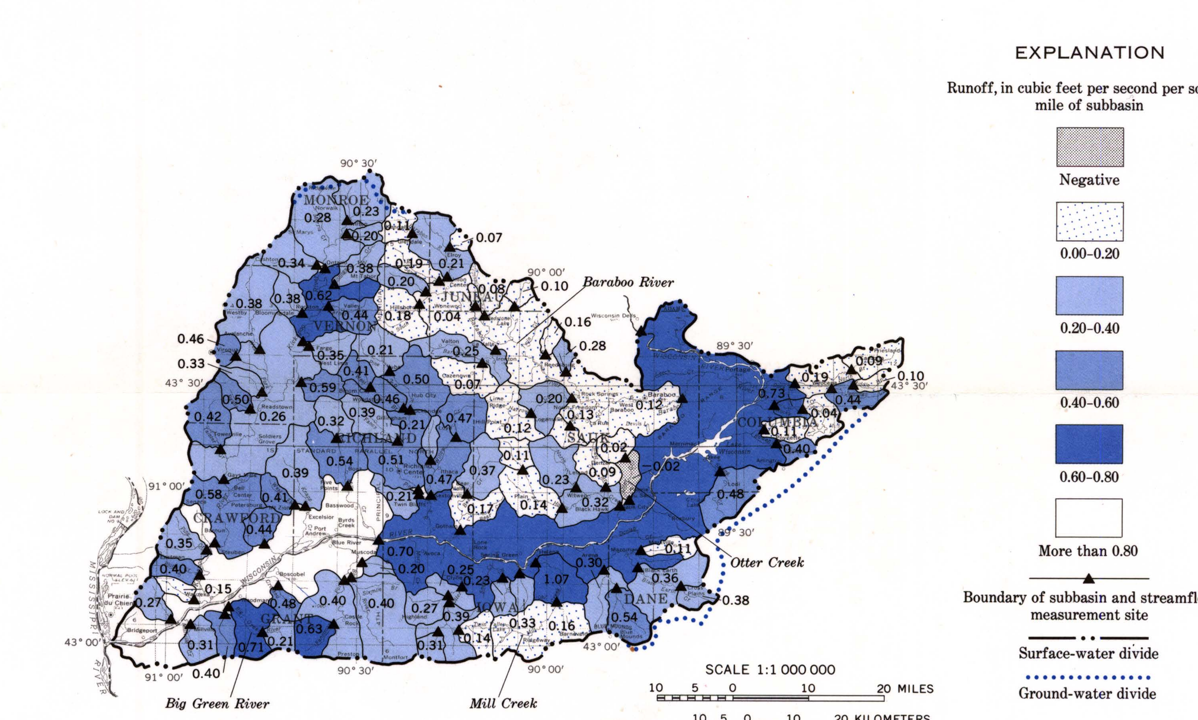
Climatological records from National Weather Service (U.S. Weather Bureau)

RELATIONSHIP OF STREAMFLOW AND GROUND-WATER LEVELS TO CLIMATOLOGICAL ELEMENTS

The direct relationship between streamflow, ground-water levels, and climatological elements is shown by a comparison of records for 1965–69 in the southeastern part of the basin. These relationships apply to the basin in general. Stream discharge increases and the water table rises during periods of water surplus, mainly in the spring when snow is melting and evapotranspiration is low and in other periods when rainfall is heavy. Streamflow and ground-water levels fall during periods of water deficiency in winter when water is stored as snow, and in summer 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 but may be augmented by rainfall. Heavy rainfalls in summer and fall also produce peak flows (1965), except during periods of highest evapotranspiration (1967).

The water level in the well near Black Earth is an expression of a shallow water table. Because the well is located nearer Black Earth Creek than Prairie du Sac, its water level correlates more closely with discharge of the creek than with precipitation at Prairie du Sac.



DISTRIBUTION OF LOW-FLOW RUNOFF, AUGUST 17-19, 1970

Low-flow discharge of streams in the basin differs among subbasins and consists mainly of ground-water runoff. The generalized patterns on the map show low-flow runoff based on discharge measurements made during August 17–19, 1970. Low-flow discharge is reduced to discharge per unit area (cubic feet per second per square mile) to compare the contribution of the many subbasins of different sizes. The ground-water runoff rate for the entire basin is relatively uniform, and 51 percent of the area yields between 0.2 and 0.6 cfs per square mile. Discharges for the 3-day period of low-flow measurements fall in the 90–95 percent range on the flow-duration curves of the gaging stations.

The few exceptions to the relatively uniform runoff can be explained by characteristics of the individual subbasins. The general low runoff of the Baraboo River basin can be attributed principally to the moderately impermeable lake deposits. Otter Creek has its headwaters in an area of thin unconsolidated deposits over Precambrian crystalline rock, but downstream it flows over an area of thick, highly permeable outwash. Because the water table in the outwash is below the level of the riverbed, much of the flow from the headwaters percolates down through the outwash to the water table, leaving the stream dry much of the time. In the lower reaches of Mill Creek and Big Green River, highly permeable outwash of the Wisconsin River valley sustains the extremely high runoff. The high streamflow in the Wisconsin River is caused in part by large ground-water inflow from the thick, highly permeable outwash and in part by the regulated release of water stored in Lake Wisconsin.

Differences in area between the ground-water and surface-water basins can account for different runoff rates. In the southeastern part of the basin the ground-water divide is displaced to the southeast, making the ground-water drainage area larger than the surface-water drainage area. The rates of runoff for subbasins in this area are higher than would be obtained using the ground-water basin area.

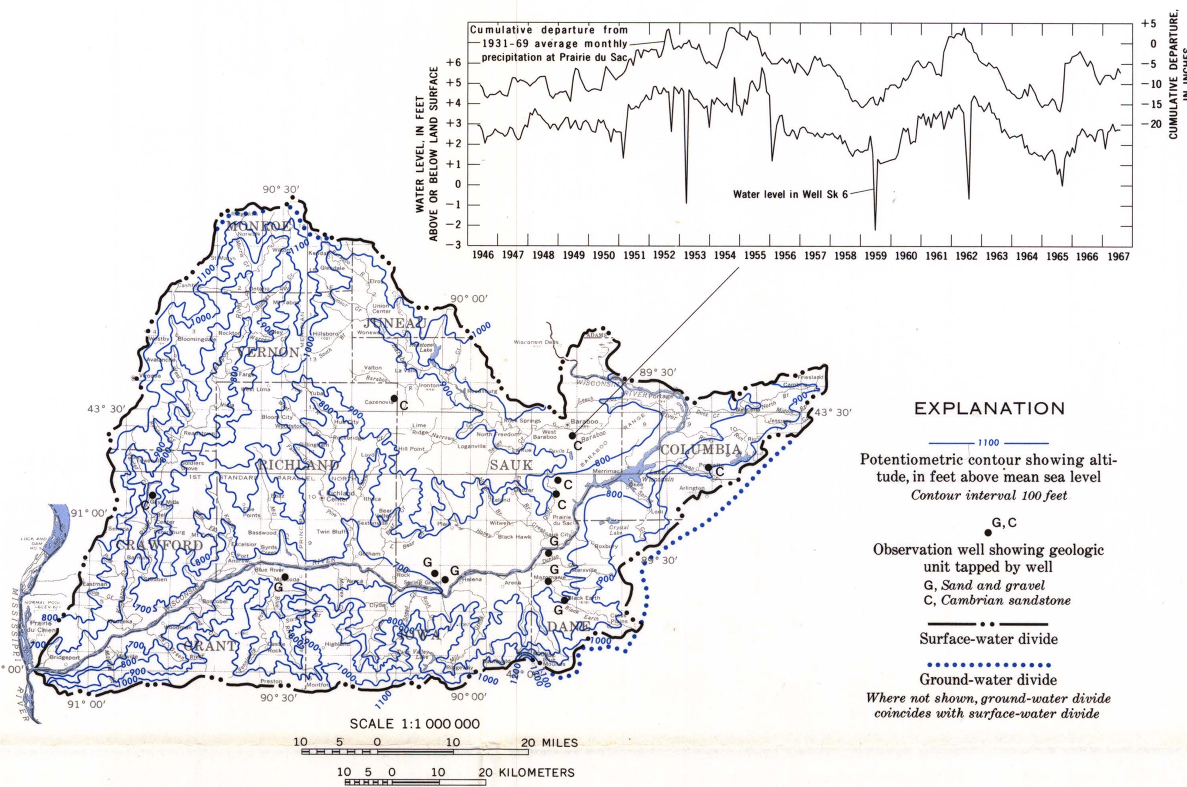
GROUND WATER

Large undeveloped supplies of good quality water are available from the ground-water reservoir in the lower Wisconsin River basin. About 475 billion gallons of ground water discharge to streams and wells each year, which is about 3.5 million gallons for each person in the study area. Yet this is only about one-half of 1 percent of the estimated total water stored underground.

Ground water, which is stored in aquifers throughout the basin, provides water to wells and springs and furnishes a perennial base of streamflow by seepage and spring discharge. The amount of water that can be continuously pumped from a well or group of wells, disregarding economic factors, depends upon the aquifer thickness and areal extent, the rate of recharge, the ease with which water moves through the aquifer, and the amount of water in storage.

Ground water will continue to meet domestic, agricultural, municipal, and industrial needs in the study area. Present areas of high pumpage are few, population density within the area is low, and only a small part of the total potential is being utilized. Because ground-water availability is not consistent areally, detailed studies may be needed to guide future large-scale ground-water developments.

Reports on springs (Wisconsin Conservation Department, written commun., 1958, 1959) list 220 springs in the basin that have flows greater than 100 gpm (gallons per minute), and 15 of these have flows greater than 400 gpm.



POTENTIOMETRIC SURFACE AND OBSERVATION-WELL NETWORK

Ground water underlies the entire study area and moves constantly from areas of higher potential (recharge areas) to areas of lower potential (discharge areas)—streams, springs, lakes, and wetlands. This ground-water system is not truly a single hydrologic system but is a combination of water-table, artesian, and perched systems. Most ground water occurs under water-table conditions, that is, under atmospheric pressure in the zone of saturation. Because of flat-lying rock of low vertical permeability, however, some ground water is either perched or under artesian pressure. Perched ground water is at atmospheric pressure but lies at a higher altitude than the true water table and is separated from it by an unsaturated zone. The low vertical permeability of the rocks supporting the perched water may also confine underlying water under artesian pressure locally.

The water-table system is present in all parts of the study area, but within the system numerous zones of local confinement produce artesian systems, so that adjacent wells may have very different water levels. The potentiometric surface on the map is a combined water-table and artesian surface.

Perched water occurs above the mapped potentiometric surface beneath many high ridges in the western part of the basin.

The ground-water divide generally lies directly beneath the surface-water divide, and they are mapped as coincident lines. Major departures are in southeastern and northern parts of the basin where the ground-water divide is displaced toward the east and south. The net displacement adds to the ground-water drainage area and accounts for the underflow entering the basin (Hydrologic budget, sheet 1).

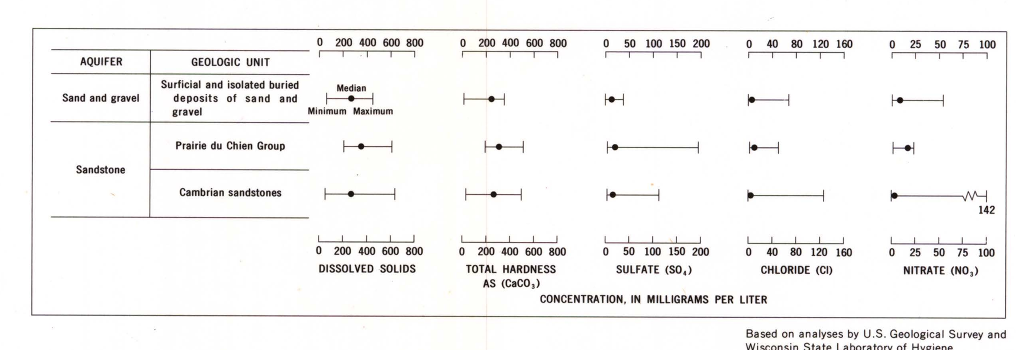
The depth to the water table in the basin ranges from zero to 500 feet below land surface. In large valleys it is generally less than 50 feet and rarely exceeds 75 feet below land surface. The extreme range in depth occurs in the south and west where the water table is near the surface in valleys and is deep below ridges. Depths of 250–500 feet are common along the basin boundary in Grant, Crawford, and Vernon Counties.

The water table throughout most of the basin fluctuates naturally in response to changes in recharge from precipitation. On the graphs above the water-table fluctuation in the well near Baraboo correlates closely with the cumulative departure of precipitation. Long-term water-level declines due to pumpage are not evident near Baraboo or elsewhere throughout the basin.

GROUND-WATER QUALITY

Ground water in the basin is generally of very good quality and is usable for most purposes. The main chemical constituents in the water are calcium, magnesium, and bicarbonate ions, which are derived primarily from dolomite.

Minor water-use problems are caused by hardness and, locally, by high concentrations of iron or nitrate. 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 181 mg/l and greater, very hard. About 80 percent of the ground water sampled had hardness greater than 180 mg/l, and 65 percent had hardness greater than 225 mg/l; the latter needs softening for many uses. High nitrate concentrations may be caused by local contamination from surface sources, whereas high iron concentrations usually result from natural sources.



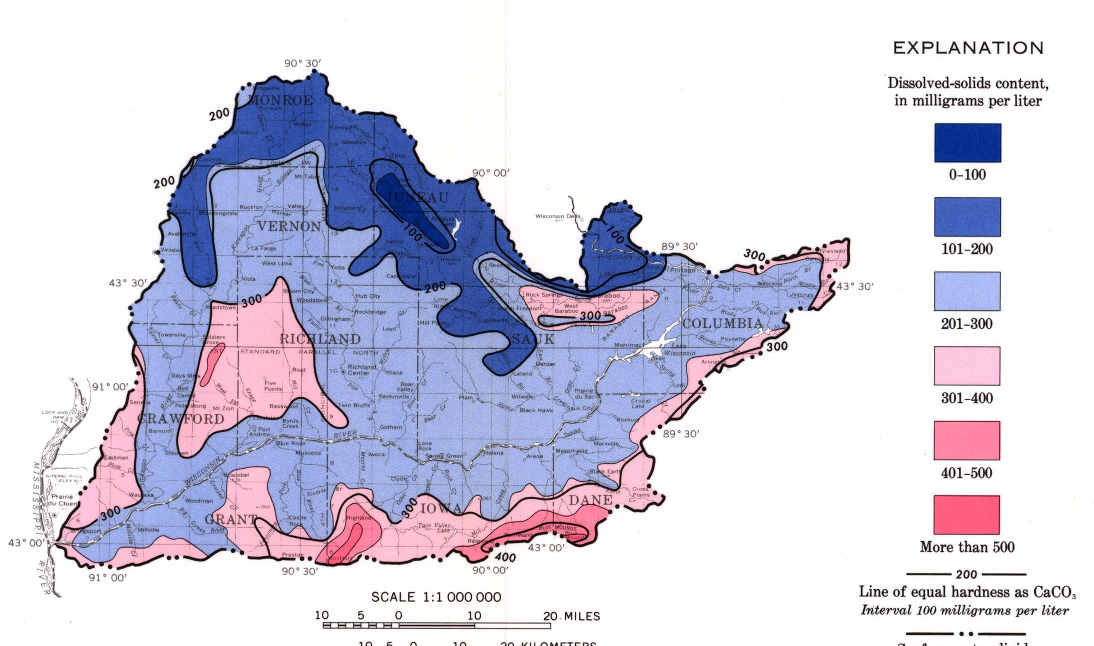
Based on analyses by U.S. Geological Survey and Wisconsin State Laboratory of Hygiene

QUALITY OF GROUND WATER BY AQUIFER

Major chemical constituents and properties of water are similar in all aquifers within the basin. Quality of ground water differs somewhat between aquifers (compare median values), but there are greater differences within individual aquifers (see maximum and minimum values). Median dissolved-solids content of the ground water is between about 260 and 350 mg/l. Values less than about 250 mg/l largely reflect carbonate hardness, but values more than about 500 mg/l reflect considerable noncarbonate hardness in addition, with sulfate as the contributing anion.

Water in the sand and gravel aquifer and water in the Cambrian sandstone are similar and generally are less mineralized than water in the Prairie du Chien Group. Water recharged through the dolomite of the Prairie du Chien Group may increase the mineralization of the water in the underlying units.

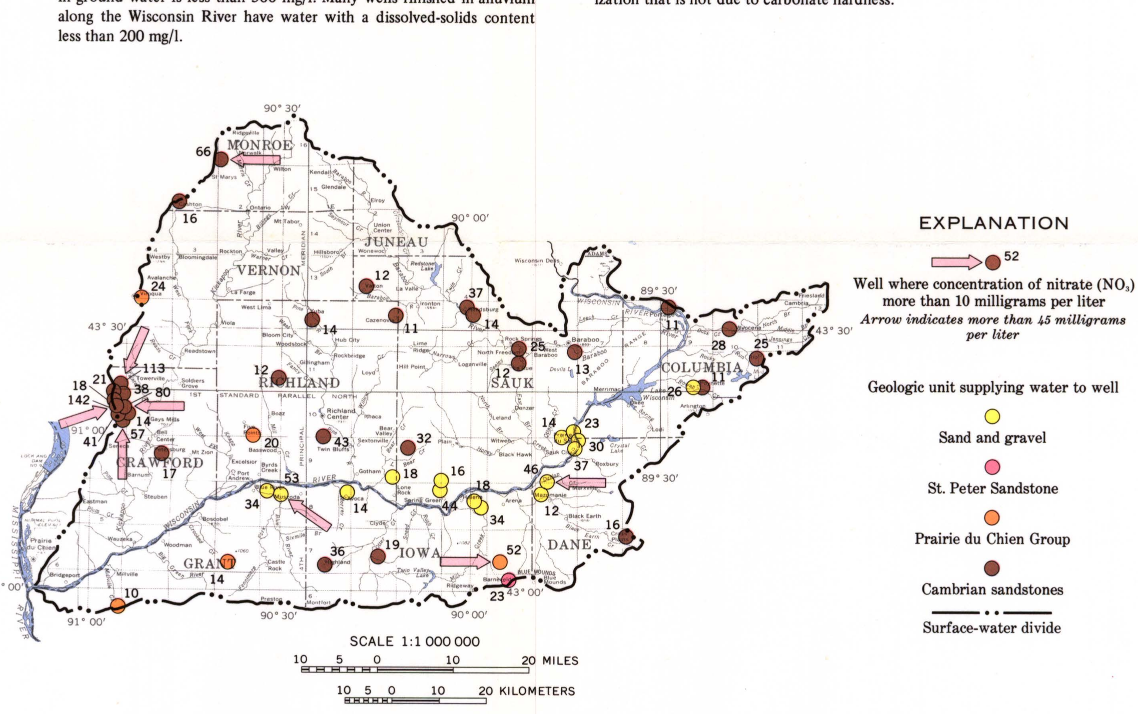
Analyses of water taken from the Galena-Platteville aquifer, St. Peter Sandstone, and Precambrian rocks were not included in the illustration above because of insufficient data to determine representative maximum, minimum, and median values. However, those data available indicate that water from the Galena-Platteville unit and St. Peter Sandstone is similar to that in the Prairie du Chien Group, and water in the Precambrian rocks is similar to water in the Cambrian sandstone.



DISSOLVED SOLIDS AND HARDNESS IN GROUND WATER

Most ground water in the basin has a dissolved-solids content between 100 and 400 mg/l. The areas of high concentration generally are found where the Galena-Platteville unit, St. Peter Sandstone, or Prairie du Chien Group is the surficial geologic unit (Bedrock geology, sheet 1) and ground-water recharge is through these units. Where the Ordovician units are thin or absent the concentration of dissolved solids in ground water is less than 300 mg/l. Many wells finished in alluvium along the Wisconsin River have water with a dissolved-solids content less than 200 mg/l.

Total mineralization generally correlates well with hardness in areas where the dissolved-solids content is less than 300 mg/l. In these areas more than 90 percent of the water mineralization is due to carbonate hardness. In areas where the dissolved-solids content and hardness exceed 300 mg/l, a lesser percentage of the dissolved solids is due to carbonate hardness. Sodium and sulfate ions make up most mineralization that is not due to carbonate hardness.



NITRATE IN GROUND WATER

The natural concentrations of nitrate in ground water in the basin generally are low. However, concentrations more than about 10 mg/l may not be from natural sources but may be from contamination by organic wastes. Surficial sand and gravel is especially susceptible to contamination because of easy access by contaminants. Likewise, recharge through near-surface fractures and solution channels in dolomite make this aquifer susceptible to direct infiltration of contaminants. Apart from indicating possible ground-water contamination, nitrate is linked to the occurrence of methemoglobinemia in infants; thus, drinking water standards of the U.S. Public Health Service (1962) recommend a maximum nitrate content of 45 mg/l.

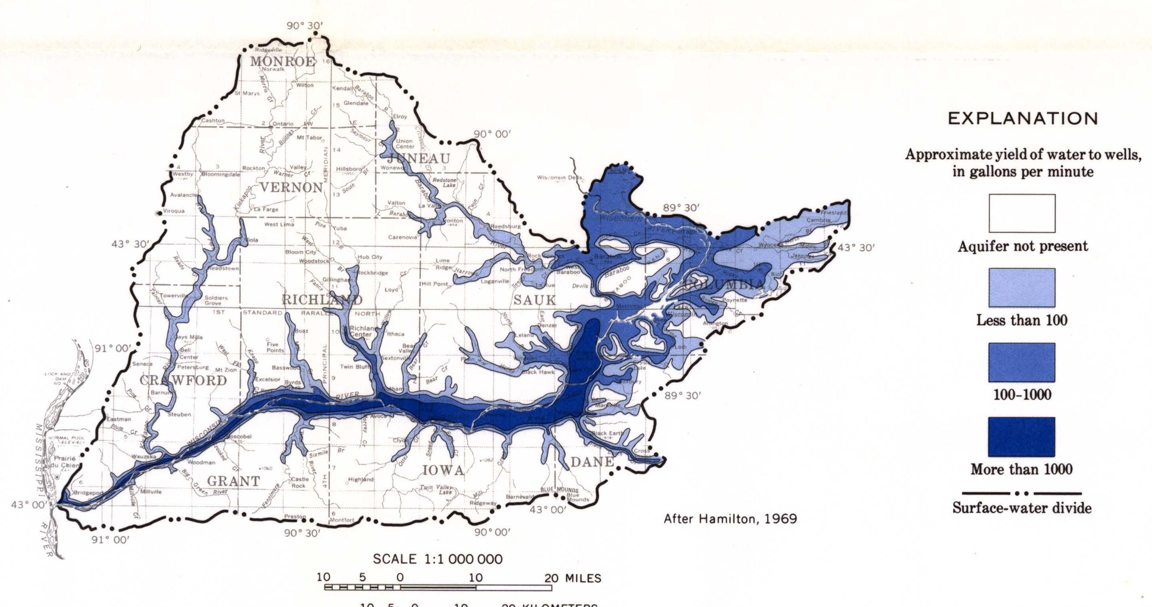
High nitrate concentrations seem to be common along the western basin boundary where thin soil covers fractured dolomite, and along the Wisconsin and lower Baraboo River valleys where the chief aquifers are permeable sand and gravel and thin Cambrian sandstone.

GROUND-WATER AVAILABILITY

Aquifer	Age	Geologic unit	Thickness (feet)	Maximum reported yield (gpm)	Average high capacity well yield (gpm)	Well depths (feet)
Sand and gravel	Quaternary	Sand and gravel	0–390	2,000	743	5–383
Galena-Platteville	Ordovician	Galena Dolomite	0–230	30	No reported high capacity wells	18–165
		Decorah Formation				
		Platteville Formation				
Sandstone	Ordovician	St. Peter Sandstone	0–250	348	Only 2 reported high capacity wells	110–435
		Prairie du Chien Group	0–250	30	No reported high capacity wells	60–460
	Cambrian	Jordan Sandstone	0–1,200	1,850	500	340–1,100
		St. Lawrence Formation				
		Franconia Sandstone				
		Galesville Sandstone				
		Eau Claire Sandstone				
		Mount Simon Sandstone				
	Precambrian	Crystalline rocks	Unknown	20	No reported high capacity wells	97–560

Ground water is available everywhere within the basin at depths ranging from about 5 to 500 feet. The aquifers are, in order of importance, the sandstone aquifer, the sand and gravel aquifer, and the Galena-Platteville aquifer. Although not generally classified as an aquifer, some water is available from Precambrian crystalline rock. Where the three aquifers are thin or absent, wells are finished in Precambrian rock.

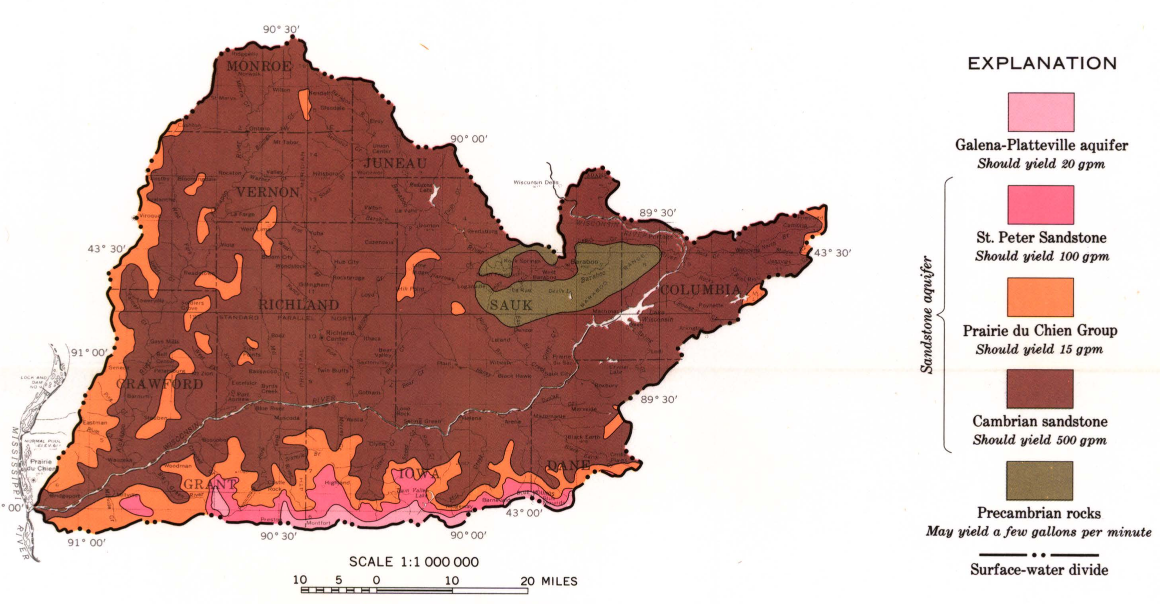
The physical properties of the geologic units control ground-water movement and, hence, well yields. The Prairie du Chien Group and the Galena-Platteville unit are composed mainly of dense dolomitic rock that yields water from fractures and solution channels rather than from intergranular pore spaces as in sandstone or sand and gravel. Because the distribution of fractures and channels is much less uniform than the distribution of intergranular pore spaces, well yields from dolomitic rock are difficult to predict. Precambrian crystalline rock yields water from fractures, and well yields also are difficult to predict.



SAND AND GRAVEL AQUIFER

Most sand and gravel deposits in the basin are in the preglacial bedrock valleys of the Wisconsin, Baraboo, Kickapoo, and Pine Rivers and Black Earth Creek. Deposits in the Wisconsin River valley are the most permeable, have the greatest saturated thicknesses, and thus yield the largest quantities of water to wells. All high-capacity wells (those having yields greater than 70 gpm) in the sand and gravel aquifer are in the Wisconsin River valley. Specific capacities of these wells range from 5 to 300 gpm per foot of drawdown, with a median of 36. Present withdrawal from these deposits is insignificant compared with their great potential for use.

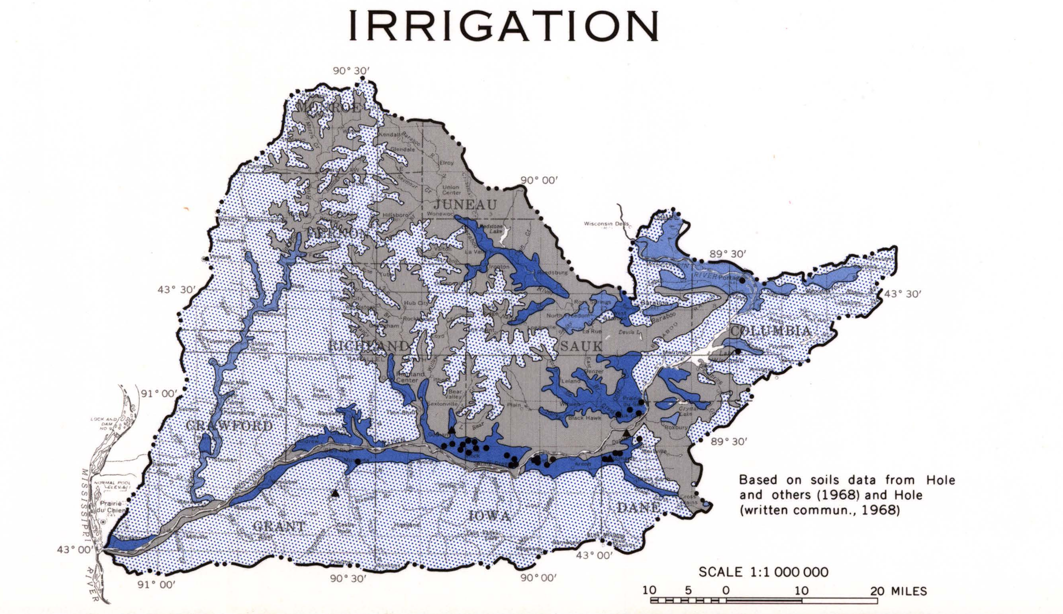
All glacial and alluvial deposits are not permeable sand and gravel; some are lake deposits or moraines that are either too thin or too impermeable to yield much water. These areas are represented on the map as yielding less than 100 gpm. Isolated deposits of buried sand and gravel occur in fine-grained valley fill and in moraines.



BEDROCK AQUIFERS

The sandstone aquifer is the most important bedrock aquifer throughout most of the basin, but water also is available from the Galena-Platteville unit and Precambrian crystalline rock. Throughout the mapped area the sandstone aquifer is more than 50 feet thick and is the basin's principal source of water for municipal, industrial, domestic, stock, and irrigation uses. Within the sandstone aquifer, the Prairie du Chien Group and the St. Peter Sandstone are not as important as the Cambrian sandstone. The Prairie du Chien Group is discontinuous in the basin and has a low permeability. The St. Peter Sandstone also is discontinuous and is unsaturated in most places where it is present. Of the 95 reported high-capacity wells in the basin, 68 are finished in the sandstone aquifer. The specific capacities of these wells generally range from 1 to 400 gpm per foot of drawdown, and the median is 10.6. The specific capacities of 25 percent of them are 17 or more. The Galena-Platteville unit is present only in a strip along the southern basin boundary and is not a major aquifer in the basin. Precambrian crystalline rock is used as a water source only in parts of Sauk and Columbia Counties, where the sand and gravel and sandstone aquifers are thin or absent.

IRRIGATION



EXPLANATION

Suitability	Characteristics	Parent material
Good	Soil is level to gently undulating and is permeable; water table is more than 4 feet below land surface	Sand, silt, loess, and sand and gravel
Good to fair if drained	Soil is wet, nearly level, and permeable; water table is within 4 feet of land surface over much of the lowland	Alluvium, sandy glacial drift, and organic material
Poor; good to fair in the few level areas; poor on slopes	Soil is moderately permeable on gently rolling to undulating glaciated uplands; it has low permeability on steep slopes and on limestone ridges in the "Driftless area"	Loess, sandy loam, and till
Poor	Mixed soil types have low to moderate permeability on ridges and high permeability on lowlands; the water table is within 1 foot of land surface over much of the lowland	Loess, sandy loam, sandstone, and alluvium

● Irrigation well ▲ Surface-water irrigation permit —··— Surface-water divide

SOIL SUITABILITY FOR IRRIGATION

About 10 percent of the basin has soils and topography suitable for irrigation of row and truck crops. The most suitable soils are silty and sandy alluvial soils on flat flood plains in the major stream valleys. Much of the basin has steep slopes that preclude use of sprinkler equipment or has soils that would not drain properly due to low permeability or a shallow water table. Based on topography, soil type, and depth to water, soils shown on the above map are classified in four groups of suitability for irrigation according to a classification by F.D. Hole (written commun., 1968). Water availability, soil fertility, and air temperature were not included in this classification and must be evaluated locally.

Although rainfall is plentiful, irrigation with ground or surface water can provide timely application of moisture for optimum crop production. In 1969 only about 25 acres were irrigated by surface water, whereas about 3,700 acres were irrigated by ground water, including 2,500 acres of field corn, 1,100 acres of potatoes, and 100 acres of truck crops. The locations of surface-water irrigation permits and irrigation wells are shown on the accompanying map.

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

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA.—1974

WATER RESOURCES OF WISCONSIN—LOWER WISCONSIN RIVER BASIN

By
S. M. Hindall and R. G. Borman

1974