GROUND WATER

Large supplies of good quality water are available from the shallow and deep ground-water reservoirs in the study area. These reservoirs are undeveloped in many areas because the demand for water is low. Also, Lake Michigan supplies water to some municipalities, water cooperatives, and industries. The ground-water contribution to streamflow is about 180 billion gallons of water each year. This is equivalent to about 150,000 gallons for each person in the basin, and represents less than one-fifth of 1 percent of the total water stored underground.

Ground-water withdrawals are greatest in the southern one-fourth of the basin, especially in the heavily populated Milwaukee area where high rates of pumping from the sandstone aquifer have caused water levels to decline markedly. Detailed studies have been made to help guide resource development and management, especially in pumping centers inland from Lake Michigan.

Information on this sheet was compiled using data from the observation wells located on the map, records from numerous other wells, and reports of Drescher (1953), Foley and others (1953), Green and Hutchinson (1965), Hutchinson (1970), Knowles (1964), Knowles and others (1964), and Newport (1962).

EXPLANATION

Area underlain by surficial outwash, sand, and gravel

Area underlain by lake deposits containing beach sand

Area containing deposits of saturated sand and gravel over 50 feet thick

The sand and gravel aquifer in the basin is a significant source of water. Sand and gravel deposits occur at the surface in the Kettle Moraine, flat outwash plains, and in beach deposits; or they may be buried beneath less permeable overburden. The map shows areas underlain by these deposits, but additional well data would greatly refine the boundaries.

Surficial outwash and beach sand are highly permeable and, therefore, are recharged very rapidly. As much as 1,200 gpm have been obtained in wells that pump water from the thick, saturated sand and gravel at West Bend. Collector wells in beach sand at Manitowoc induce recharge from Lake Michigan and yield as much as 5,500 gpm.

Buried sand and gravel deposits occur throughout the basin but are most significant as aquifers where the saturated thickness is more than 50 feet. In areas where these deposits are thin, small yields have been developed for domestic use.

SAND AND GRAVEL AQUIFER

Lake deposits after Hole (1968) and surficial outwash after Thwaites (1956 and 1957)

EXPLANATION

Area underlain by aquifer

The Niagara aquifer underlies about 98 percent of the study area and is the most widely used source of generally good quality ground water. In the northern half of the basin it is used almost exclusively because the drift in many places is thin and not an aquifer, and because drilling to the deep sandstone aquifer is costly and the water is locally saline.

Most wells in the Niagara aquifer produce at least 10 gpm, and some high-capacity wells produce as much as 1,200 gpm. Water moves through cracks, crevices, and fractures; however, the distribution of openings is not uniform in the Niagara aquifer, and well yields are not predictable. Generally, recharge to the Niagara aquifer is local, and paths of movement are short. Because much of the overburden is clay till, many parts of the Niagara aquifer are under artesian pressure. The potentiometric surface ranges from the top of the aquifer up to or above the land surface.

NIAGARA AQUIFER

EXPLANATION

Area underlain by aquifer

Area where aquifer is moderately used

Area where aquifer is intensively used

The sandstone aquifer underlies the entire study area and includes the Ordovician and Cambrian units between the Maquoketa Shale and the Precambrian rocks. Each unit in the sandstone aquifer contributes some water to wells, but the St. Peter Sandstone and Cambrian sandstones are most productive. The St. Peter Sandstone is the most widely used unit of the sandstone aquifer, but the Cambrian sandstones are the primary source for high-capacity wells in the southern part of the basin. The Prairie du Chien Group, the Trempealeau Formation, and Franconia Sandstone do not yield much water, and in the east-central part of the basin these units are missing. Because of the sparsity of deep wells there is a lack of information about the Ordovician and Cambrian units in the northern part of the basin.

The sandstone aquifer is used throughout the southern one-fifth of the basin, especially in the greater Milwaukee area. The aquifer is moderately used in the central part of the basin, near the city of Green Bay and at the city of Sturgeon Bay.

Yields from the sandstone aquifer depend primarily on the thickness of sandstone penetrated; as much as 1,500 gpm has been produced from a well in the Milwaukee area.

Most recharge to the sandstone aquifer is by lateral movement of water from an area west of the basin, although small quantities move down through the shale and through wells open to both the Niagara and sandstone aquifers in areas of heavy pumpage.

Water levels have declined steadily in the Milwaukee-Chicago pumping zone because pumpage is large, recharge through the Maquoketa Shale is small, and lateral ground-water movement is slow.

SANDSTONE AQUIFER

Aquifer	Age	Rock unit	Thickness (feet)	Maximum yield reported (gpm)	Well depths (feet)	Columnar section
Sand and gravel	QUATERNARY	Surface sand and gravel (mostly outwash and beach sand)	0–235	1200 (5500 from collector units)	30–120	
		Buried sand and gravel	0–300	125	50–480	
Niagara	DEVONIAN and SILURIAN	Dolomite (undifferentiated)	0–750	1200	60–700	
(Not an aquifer)	ORDOVICIAN	Maquoketa Shale	0–400	Although not generally classed as an aquifer, a few wells obtain small quantities of water from dolomite and limestone in the upper part of this unit		
Sandstone	ORDOVICIAN	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	100–340	No well is known to pump water from this unit exclusively. However, it is commonly used in combination with the sandstone and Niagara aquifers. This unit probably yields only a few tens of gallons per minute within the basin		
	ORDOVICIAN	St. Peter Sandstone	0–330	600	875–1300	
	ORDOVICIAN	Prairie du Chien Group	0–140	No well is known to pump water from this unit exclusively. However, it is commonly used in combination with the sandstone and Niagara aquifers. This unit probably yields only a few tens of gallons per minute within the basin		
	CAMBRIAN	Trempealeau Formation Franconia Sandstone Galesville Sandstone Eau Claire Sandstone Mount Simon Sandstone	0–3500?	1500	315–2010	
(Not an aquifer)	PRECAMBRIAN	Crystalline rocks	Unknown	No well is known to pump water from this unit		

Enlargement

Sand and gravel yields water from interconnected pore spaces between the grains

Enlargement

In dolomite and limestone water occurs in fractures that may be enlarged by solution

Enlargement

Shale may yield some water to wells from fractures

Enlargement

Sandstone yields water from small interconnected pore spaces between the grains. Part of the pore spaces are filled by cementing material. Some water probably comes from fractures

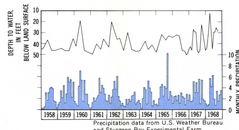
Enlargement

Crystalline rocks may yield some water from small fractures

GROUND-WATER AVAILABILITY

Ground water is available throughout the basin. Large quantities are commonly available from the sandstone aquifer and from some areas of the sand and gravel and Niagara aquifers.

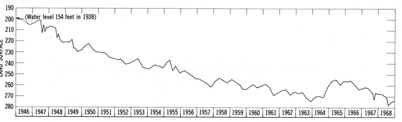
Specific capacity is a ratio of well production, in gallons per minute, to the number of feet of water-level drawdown in the well. The ratio generally reflects the degree to which an aquifer yields water and, in some part, the construction and development of the well itself. Specific capacities in the surficial sand and gravel aquifer are as much as 50 gpm (gallons per minute) per foot, in the Niagara aquifer from 0.2 to 400 gpm per foot, and in the sandstone aquifer are as much as 15 gpm per foot. The wide range of specific capacities in the Niagara aquifer probably reflects the differences between wells that penetrate unenvironmental dolomite and wells that penetrate cracks or crevices. In the sandstone aquifer the specific capacity differences are due to aquifer penetration—higher specific capacities are in wells that penetrate greater thicknesses of the aquifer.



Precipitation data from U.S. Weather Bureau and Sturgeon Bay Experimental Farm

CHANGES IN WATER LEVELS IN A WATER-TABLE AQUIFER RELATED TO PRECIPITATION

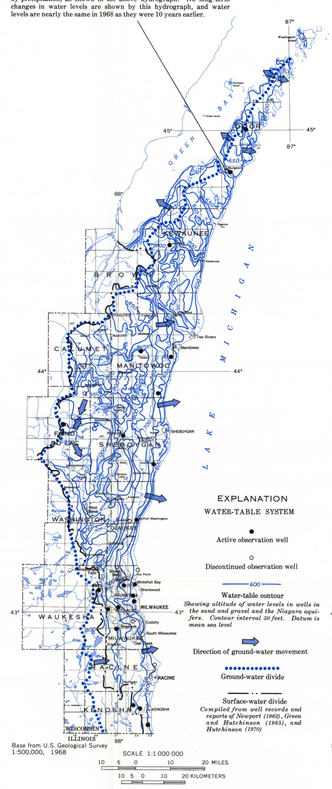
The water table is not fixed but fluctuates in response to recharge by precipitation, as shown in the above hydrograph. No long-term changes in water levels are shown by this hydrograph, and water levels are nearly the same in 1968 as they were 10 years earlier.

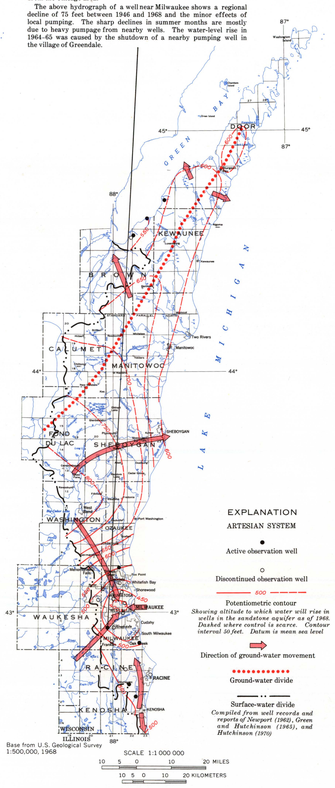


DECLINE OF WATER LEVELS IN A WELL IN THE SANDSTONE AQUIFER NEAR MILWAUKEE, 1946–68

The potentiometric surface in the artesian system is declining regionally in the southern part of the basin because of continued pumpage from the greater Milwaukee area and increased pumpage from the Chicago area.

The above hydrograph of a well near Milwaukee shows a regional decline of 75 feet between 1946 and 1968 and the minor effects of local pumping. The sharp declines in summer months are mostly due to heavy pumpage from nearby wells. The water-level rise in 1964–65 was caused by the shutdown of a nearby pumping well in the village of Greendale.





POTENTIOMETRIC SURFACES AND OBSERVATION WELL NETWORK

Ground water in the basin moves within the water-table system above the Maquoketa Shale and the artesian system, which is confined beneath the Maquoketa Shale. In the water-table system the ground-water divides generally correspond to the surface-water divides except in the southern part of the basin, where the ground-water divide is as much as 12 miles west of the surface-water divide. The ground-water basin of the artesian system does not conform to the surface drainage basin. Instead, the western limits of this system extend 15 to 20 miles west of the surface-water divide.

The water-table system is present in all parts of the basin, and its surface is described by the water-table contours. Ground water moves from high points on the water table, as arrows show, toward low areas where it discharges into streams, wetlands, and Lake Michigan. Locally ground water moves toward wells in areas of pumpage. Flow paths are short except in the southern part of the basin, where the system is confined. In the numerous areas of local confinement, nearby wells may have very different water levels.

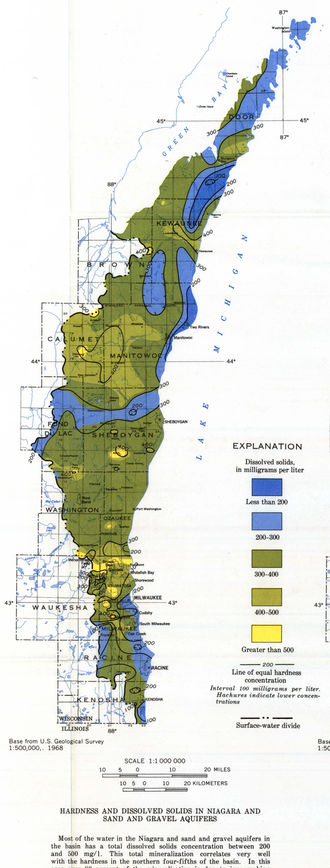
The artesian system underlies all of the basin, and most of the recharge is from the area west of the basin. Flow paths are long, and discharge is at wells located mainly in the areas of Milwaukee and Chicago and into Lake Michigan. Some recharge also takes place by leakage through the Maquoketa Shale and through wells open to both the Niagara and sandstone aquifers.

WATER QUALITY

Ground water in the Lake Michigan basin is generally of good quality and is suitable for most purposes. The persistent problem most common to all aquifers in the study area is hardness. Most ground water is very hard (greater than 180 mg/l) and requires softening for many uses. Some soft water is found locally in the Niagara aquifer in Kenosha, Racine, and southern Milwaukee Counties. The U.S. Geological Survey has classified hardness as follows: 0–60, soft; 61–120, moderately hard; 121–180, hard; and 181 and greater, very hard.

Locally saline water, iron and manganese, nitrate, and fluoride are problems. The sandstone aquifer contains saline water in the eastern and central parts of the basin. Locally the Niagara and sand and gravel aquifers contain highly mineralized water. Objectionable quantities of iron occur locally in all aquifers, especially in the sand and gravel deposits. Manganese occurs to a much lesser extent in these aquifers.

Water temperature differs between aquifers but is generally cool. The average temperature of ground water from the Niagara and sand and gravel aquifers is about 10°C (50°F), near the mean annual air temperature. The temperature of water from the sandstone aquifer is commonly 15–17°C (55–59°F).



HARDNESS AND DISSOLVED SOLIDS IN NIAGARA AND SAND AND GRAVEL AQUIFERS

Most of the water in the Niagara and sand and gravel aquifers in the basin has a total dissolved solids concentration between 200 and 500 mg/l. This total mineralization correlates very well with the hardness in the northern four-fifths of the basin. In this area over 80 percent of the mineralization is due to ions making up carbonate hardness. A correlation can be seen between the northern part of this map, the water-table contour map, and the soil permeability map. Mineralization is generally lowest in recharge areas and areas with high infiltration rates, and it increases toward discharge areas and areas with low infiltration rates.

In the southern one-fifth of the basin a much smaller percentage of the dissolved solids is due to carbonate hardness; therefore, there is less correlation between the two. Sodium and sulfate ions make up most of the mineralization that is not due to carbonate hardness.

Several small areas of relatively high solids are present in the central part of the basin.

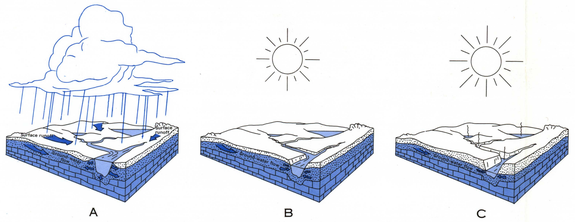
NITRATE AND FLUORIDE IN GROUND WATER

Small quantities of nitrate and fluoride are found in ground water throughout the basin. High concentrations of nitrate occur locally but are not common. Fluoride concentrations range from very low in the west to greater than 1.5 mg/l in the southeast.

Nitrate is commonly derived from human and other animal wastes, agricultural fertilizers, organic decomposition, rainfall, and rocks. Water in shallow, inadequately cased, or poorly constructed wells is particularly susceptible to pollution by wastes. In this basin nitrate concentrations greater than 3 mg/l (as NO_3) suggest degradation of water quality in the well and, possibly, in part of the aquifer. High concentrations of nitrate in water can cause abortion in cattle and methemoglobinemia in infants (Comly, 1945). The U.S. Public Health Service (1962) suggests an upper limit of 45 mg/l for nitrate in water used for human consumption, and this standard is usually accepted. There are recent indications that concentrations much less than 45 mg/l may have deleterious effects on humans (Scalf and others, 1968). Of the 300 analyses of well water studied, 31 exceeded 3 mg/l but only two exceeded 45 mg/l (see map). The isolated occurrence of high nitrates in these two wells indicates the very local nature of the problem.

Fluoride concentrations in the western half of the basin are less than 0.5 mg/l but increase to the east and southeast. Some water in the southeastern part of the study area contains fluoride in excess of the optimum concentration (1.1 mg/l) but rarely exceeds the recommended maximum concentration of 1.5 mg/l (U.S. Public Health Service, 1962). The Niagara aquifer appears to be the source of the high fluoride concentrations. Fluoride can reduce tooth decay during tooth development, but high concentrations can mottle tooth enamel.

GROUND-WATER–SURFACE-WATER RELATIONS

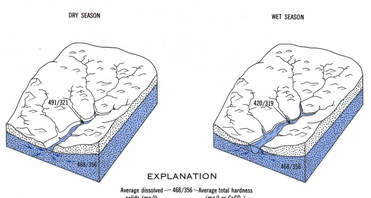


GROUND WATER RELATION TO STREAMFLOW

Streamflow is a combination of surface- and ground-water runoff. During rapid snowmelt and periods of prolonged, heavy precipitation, surface runoff is quickly carried off by streams. Water that recharges the shallow ground-water reservoir during these periods is discharged more slowly and maintains streamflow during dry periods. The three sketches above show the general relationship between streamflow and ground water.

During periods of heavy rainfall and/or snowmelt, stream stages and ground-water levels rise (A). Water 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 ground-water levels as the ground water is discharged to the streams (B). Stream stages and ground-water levels continue to decline (C) until the next significant rainfall or snowmelt.

Although surface runoff to streams generally is variable, depending upon the frequency and extent of precipitation, the ground-water contribution to streamflow is much more uniform. Ground water contributes about 50 percent of the average annual flow of streams in the basin.



EXPLANATION

Average dissolved — 468/356 — Average total hardness solids (mg/l) as $CaCO_3$)

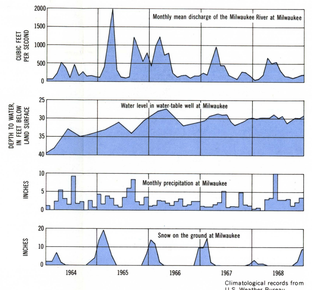
SEASONAL VARIATIONS IN WATER QUALITY

The average chemical quality of water in streams differs only slightly from that in the ground. The illustrations compare the concentrations of dissolved solids and hardness of water from these sources during wet and dry seasons. Only water samples from the main streams were analyzed to compute surface-water averages, and they may not represent average values for all parts of the basin.

Ground water does not change significantly in quality between wet and dry seasons because it moves through rocks very slowly. However, water quality in some shallow wells in permeable glacial drift might change. Ground water becomes mineralized as soluble minerals in soils and rocks dissolve, and it becomes more mineralized as the time of contact with these soluble materials increases (within the range of solubility potential).

Surface-water quality does change between wet and dry seasons. Water in streams is less mineralized during wet seasons than during dry seasons because streamflow is mostly overland runoff that has had only brief contact with soils and rocks.

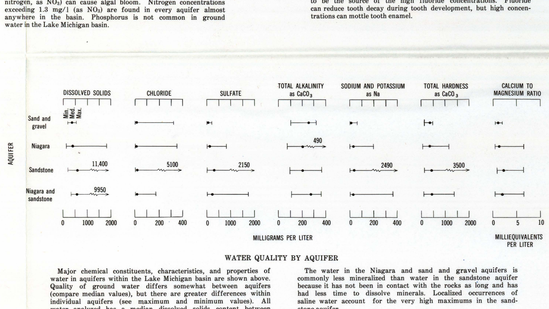
Surface-water quality during dry periods normally approaches that of ground water. However, the average dissolved solids concentration in streams during low-flow periods exceeded that of ground water, although hardness was somewhat less. This results from the addition of highly mineralized waste water. Also, precipitation may flush highly mineralized water into streams from alternately wet and dry swamps, streambeds, or from areas where water of normal mineralization has been concentrated by evaporation.



Climatological records from U.S. Weather Bureau

RELATIONSHIP BETWEEN STREAMFLOW, GROUND-WATER LEVELS, PRECIPITATION, AND SNOW COVER

The direct relationship between streamflow, ground-water levels, precipitation, and snow cover is shown by comparing 5 years of record for these parameters. Fluctuations of ground-water levels and stream discharge correspond closely. Ground-water levels respond to precipitation and snowmelt more slowly than streamflow because water percolates to the water table slowly. During late spring, summer, and fall, ground-water levels and streamflow rise in response to precipitation, but the greatest rise is in response to snowmelt during winter and early spring. Heavy precipitation in the summer may not greatly increase streamflow or raise ground-water levels because evapotranspiration is greatest at this time. Rainfall intensity and duration also control its effect on runoff and infiltration. For example, the 10 inches of rainfall during June 1968 was spread throughout the month in a series of individual rainfalls of less than 2 inches. Consequently, the effect on water levels was not marked.



WATER QUALITY BY AQUIFER

Major chemical constituents, characteristics, and properties of water in aquifers within the Lake Michigan basin are shown above. Quality of ground water differs somewhat between aquifers (compare median values), but there are greater differences within individual aquifers (see maximum and minimum values). All water analyzed has a median dissolved solids content between 375 and 550 mg/l. Lower range values largely reflect carbonate hardness, but higher range values reflect considerable noncarbonate hardness, with sulfate as the contributing anion.

The water in the Niagara and sand and gravel aquifers is commonly less mineralized than water in the sandstone aquifer because it has not been in contact with the rocks as long and has had less time to dissolve minerals. Localized occurrences of saline water account for the very high maximums in the sandstone aquifer.

WATER RESOURCES OF WISCONSIN–LAKE MICHIGAN BASIN

By
Earl L. Skinner and Ronald G. Borman

1973

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