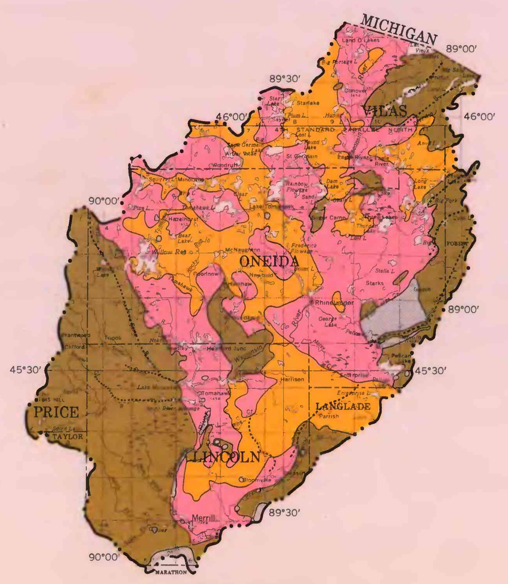
GROUND WATER

Large undeveloped supplies of good-quality ground water are available in the upper Wisconsin River basin. About 95 billion gallons of water is stored in glacial drift. This is about 1.8 million gallons for each person in the basin. Ground-water use in 1972 was about 3 percent of this total ground-water storage.

Aquifers in the basin supply water to wells and springs and furnish a perennial base to streamflow. The quantity of water that can be continuously pumped from a well or group of wells depends on the aquifer composition, thickness, areal extent, the rate at which water moves through the aquifer, and the rate of aquifer recharge.

The principal aquifer is glacial drift, particularly the outwash and ice-contact sand and gravel. Bedrock generally does not yield much water, although locally it is tapped for small domestic supplies.

Ground water will continue to meet most domestic, agricultural, and municipal needs in the basin because only a small part of the total potential is being used. Present areas of large-scale pumpage are relatively few, and the population density is low. However, ground-water availability differs locally, and detailed studies may be needed to guide ground-water development.



Ground-water supplies are adequate for domestic use almost anywhere within the basin. Nearly all the wells tap glacial sand and gravel. Where the glacial drift is thin, wells are completed in the underlying bedrock. Bedrock wells generally yield only a few gallons of water per minute.

Well yields adequate for domestic use can usually be obtained in the rolling areas of ground moraine and in the end moraine on the western border of the basin. These glacial deposits are mostly clay till of low permeability, and water is obtained from thin lenses of sand and gravel within the till.

Potential well yields differ greatly in moderately well sorted sand and gravel in hilly areas of end moraine and ice-contact deposits. Well yields may not exceed 50 gpm (gallons per minute) where water levels are deep below hilltops. However, well yields of several hundred gallons per minute can be obtained from thick saturated sand and gravel deposits.

Glacial drainageways, generally within ground moraine, are a possible source of large ground-water supplies. These valleys, most now occupied by streams, were cut by glacial melt water and have permeable sand and gravel deposits along their courses. These deposits yield moderate to large quantities (50–500 gpm) of water.

Yields from wells in glacial outwash range from a few to 2,000 gpm. Several hundred gallons per minute has been obtained from well-sorted surficial sand and gravel at several locations in the basin; wells at Rhinelander, Merrill, and Eagle River have been tested at more than 1,000 gpm.

GROUND-WATER AVAILABILITY

EXPLANATION

Probable well yield (gallons per minute)	Map symbol	Well depths[1] (feet)	Depth to water (feet below land surface)	Aquifer and terrain description	Remarks
0–10		50–150	10–40	Fractured bedrock or thin glacial drift overlying bedrock. Area of bedrock outcrops.	Higher yields are possible from deep bedrock wells or from isolated outwash patches in this area.
5–50		40–125	10–40	Thin lenses of sand and gravel within or beneath till or clay. Area is mostly rolling ground moraine but includes one area of hilly end moraine on the west edge of the basin.	In the northernmost part of the basin higher yields are possible from thicker sand and gravel. In the area of end moraine on the west border of the basin, well depths are greater (some more than 200 feet), and water levels may exceed 40 feet in depth.
50–500		40–200	25–50	Thick sections of moderately permeable sand and gravel intermixed with till in an area of hilly end moraine and ice-contact deposits.	Water levels beneath hills commonly exceed depth of 50 feet.
		20–50	10–30	Sand and gravel in valley bottoms of glacial drainageways.	Very little data on thickness or well yields.
100–2,000		20–90	10–30	Thick sections of permeable sand and gravel in an area of relatively flat glacial outwash with some ice-contact knobs and kettles.	In the two mapped areas immediately north and south of Minocqua, well depths are mostly 50–125 feet, and water-level depths are 10–60 feet.

[1] These depths are the normal range for domestic wells. High-capacity wells may be deeper to take advantage of the full thickness of the aquifer.

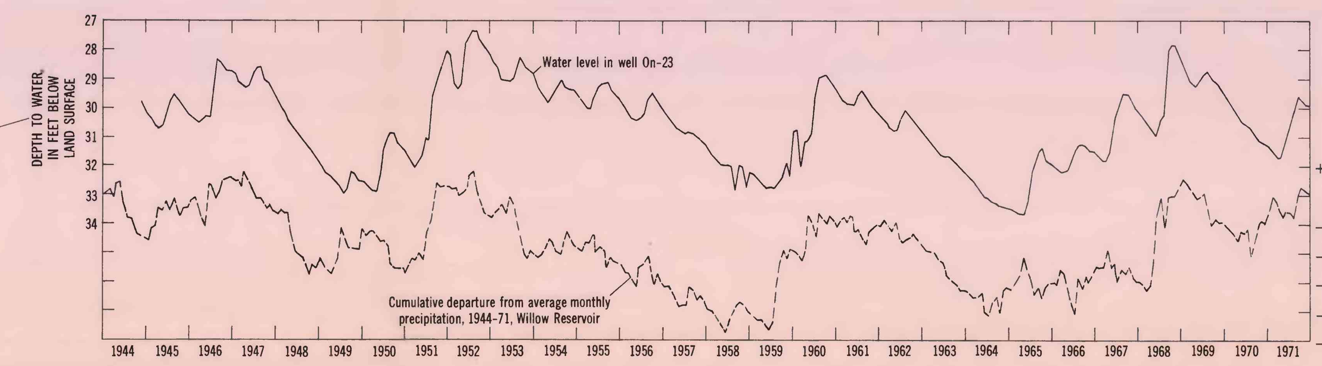
Surface-water divide

WATER TABLE AND OBSERVATION-WELL NETWORK

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

The depth to the water table in the basin depends largely on topography and ranges from land surface to almost 125 feet below land surface. It is generally less than 50 feet below land surface. Depths are greatest beneath hilltops in areas of high local relief.

The water table fluctuates with changes in recharge and discharge. The two well hydrographs illustrate these fluctuations. Records of water levels are available for the eight observation wells indicated on the map. Hydrographs are published for six of the wells (Devaul, 1967, and Erickson, 1972).

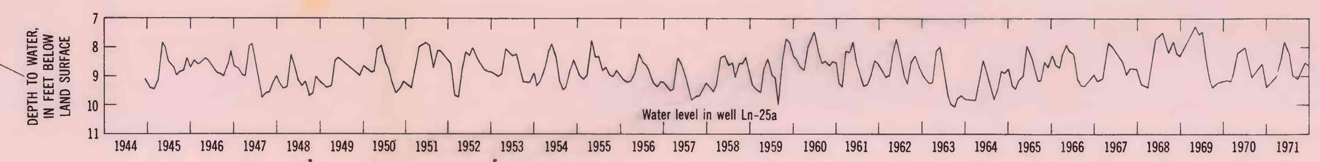


WATER LEVEL IN WELL On-23

The water level in this well, like that in Ln-25a, fluctuates annually, although fluctuations are generally greater.

Well On-23 is in a recharge area, a small area of outwash about 50 feet higher than the Tomahawk River.

Long-term cyclic fluctuations (5–10 years) result from climatic cycles, as shown by the excellent correlation with cumulative departure from precipitation. Long-term declines in water levels result from aquifer drainage during long periods of below-normal precipitation. These same long-term fluctuations can be seen in hydrographs for wells throughout the State (Devaul, 1967, and Erickson, 1972).



WATER LEVEL IN WELL Ln-25a

The water level in this well has not fluctuated more than about 2 feet in 27 years. The well is in a low-lying discharge area less than 20 feet higher than the Wisconsin River, and has a shallow water level. It is about a mile from the river, is 22 feet deep, and is finished in outwash sand and gravel.

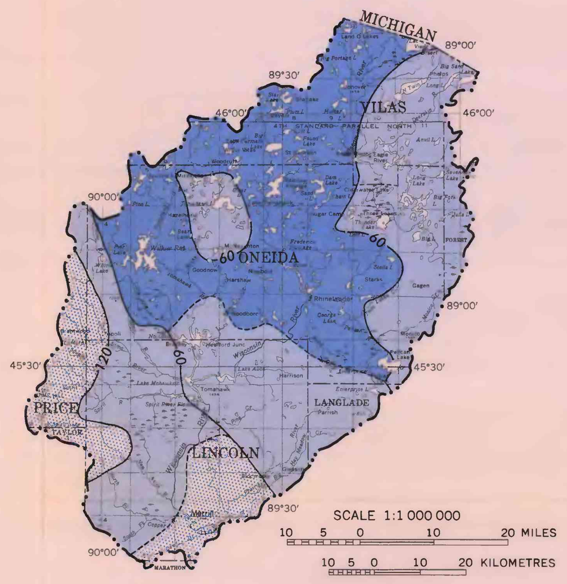
Water-level rises are caused by recharge from spring snowmelt and spring and summer rains. Declines are caused by evapotranspiration and ground-water discharge to Pine Creek.

GROUND-WATER QUALITY

Ground water in the basin is of good quality and generally has less than 150 mg/l (milligrams per litre) total mineralization. Nearly all the water is soft (0–60 mg/l as $CaCO_3$) to moderately hard (61–120 mg/l) and is principally a calcium magnesium bicarbonate type.

High iron concentration is a problem in the water of many wells completed in the glacial drift, but it is not a health hazard. The U.S. Public Health Service (1962, p. 43) suggests a maximum iron concentration for drinking water of 0.3 mg/l. Greater concentrations may cause brown precipitates or stains. Iron content in ground water is not predictable, and water from wells close together may have very different iron concentrations. Concentrations greater than 0.3 mg/l may be found almost anywhere in the basin.

Nitrate, an indicator of possible contamination by organic wastes, was not found in excessive amounts in ground water in the basin. One of 60 drift-water samples contained 40 mg/l nitrate, but 56 contained less than 10 mg/l, and 48 contained less than 2 mg/l. Drinking water standards of the U.S. Public Health Service (1962) suggest a nitrate maximum of 45 mg/l.



EXPLANATION

Dissolved-solids content, in milligrams per litre

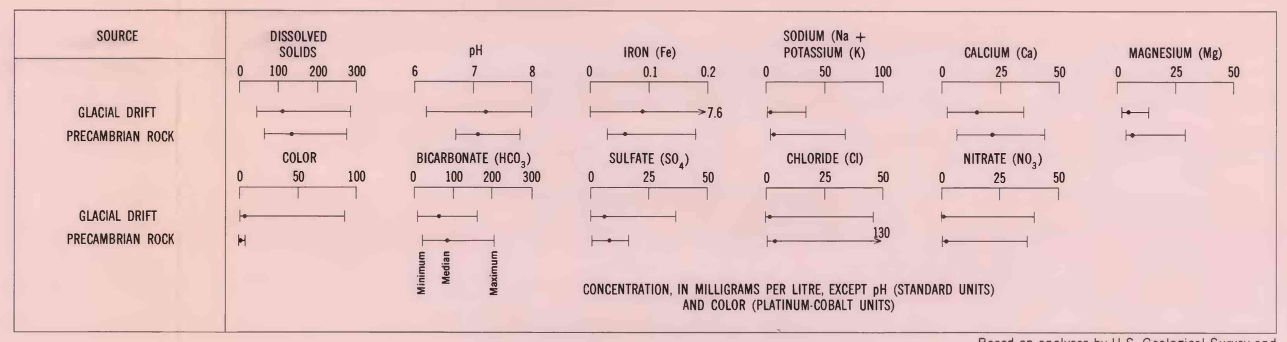
50–100 | 100–150 | 150–200

Line of equal hardness as $CaCO_3$
Interval 60 milligrams per litre

Surface-water divide

REGIONAL GROUND-WATER QUALITY

The distribution of dissolved-solids content and hardness shows some relationship to glacial geology. The least mineralized water commonly occurs in areas of outwash and ice-contact deposits of permeable drift, where wells are shallow, flow lines are short, and flow is relatively fast. Water with higher dissolved solids results from longer contact time with morainal materials. Dissolved solids may be lower than shown if wells tap shallow or perched water, or where the contact time has been short.



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

QUALITY OF GROUND WATER BY SOURCE

Major chemical constituents in ground water in the upper Wisconsin River basin are shown on this diagram according to water source. All the 72 water samples analyzed contained far less than the suggested maximum for public supplies (U.S. Public Health Service. 1962) of 250 mg/l each for sulfate and chloride and 500 mg/l for dissolved solids. Median values for the major ions shown are low, and only calcium and bicarbonate concentrations are greater than 10 mg/l. Median values for color also are low.

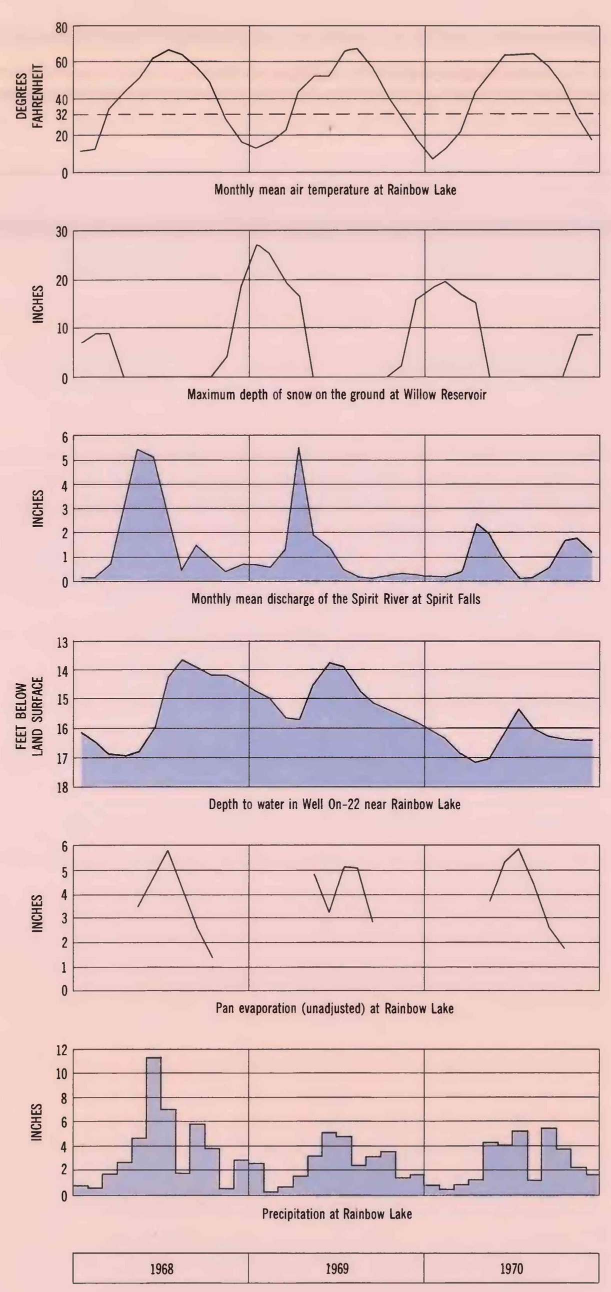
Water from Precambrian rock has a slightly higher median dissolved-solids content than that from drift, and this is reflected in high median values for all the major ions except iron. Iron had a median value of 0.09 mg/l in glacial-drift water, and 31 percent of the samples had more than 0.3 mg/l. Of the nine analyses for water from Precambrian rock, the median value for iron was 0.06 mg/l, and the maximum was 0.18 mg/l. Although its occurrence is not predictable, high iron commonly occurs in water of low pH.

In this area low pH usually is related to organic acid from swamps or bogs. Of the analyses of glacial-drift water where iron content was 1.5 mg/l or more, all but one sample had a pH of 7.0 or less.

GROUND-WATER—SURFACE-WATER RELATIONSHIPS

Ground water and surface water are directly related in this basin and both are replenished by precipitation. Seasonal and long-term increases or decreases in precipitation cause corresponding increases or decreases in ground-water level, streamflow, and lake stage. Also, manmade changes in either ground-water level, streamflow, or lake stage may 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.

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.

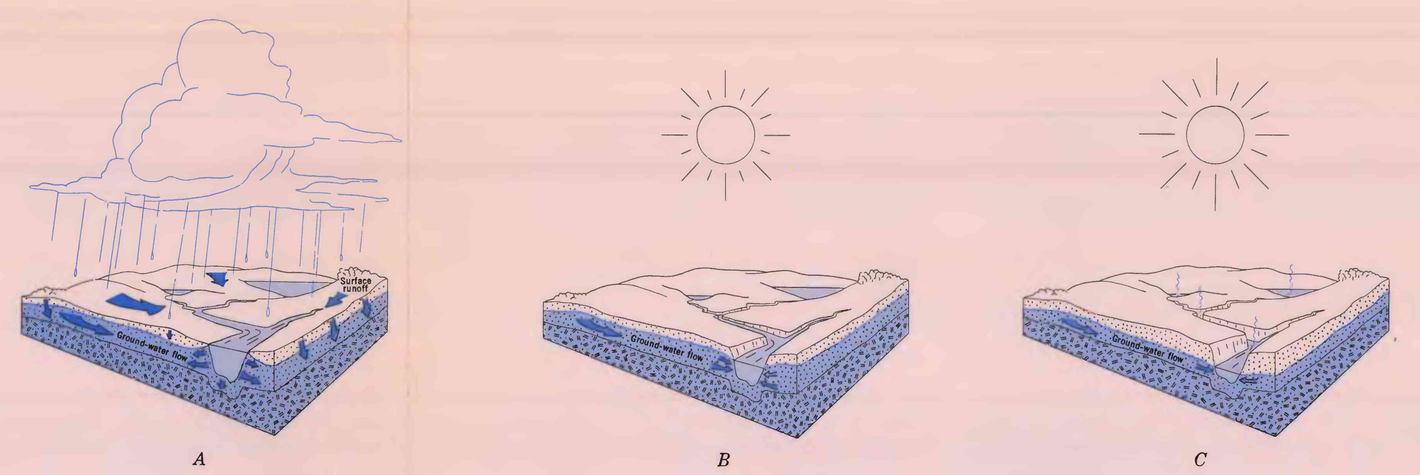


RELATION OF HYDROLOGIC AND CLIMATIC ELEMENTS

The relationships between streamflow, ground-water levels, and climatic factors, shown by a comparison of records for 1968–70, apply throughout the basin. Stream discharge increases and the water table rises during snowmelt, when 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.

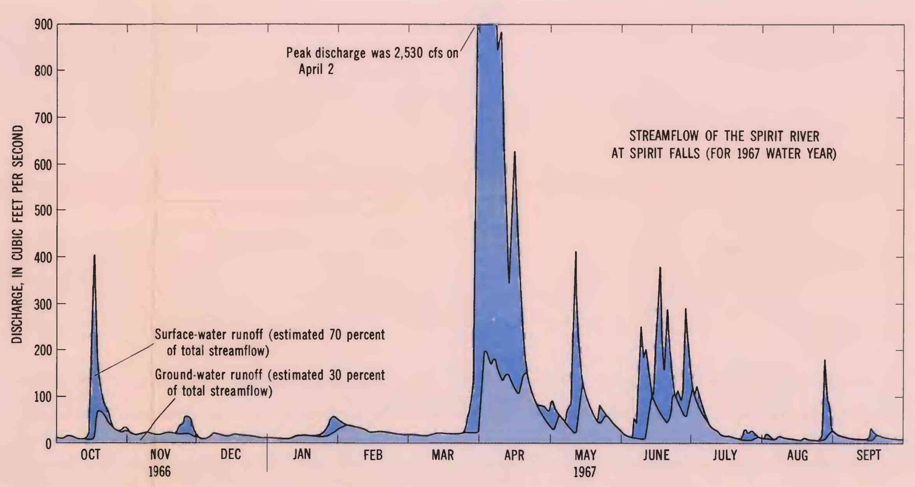
Streamflow peaks generally result from prolonged, heavy rains, spring snowmelt, or a combination of the two. Peak flows in spring are primarily from snowmelt, as in 1968 and 1969. High flows resulted from heavy rains in May–July 1968.

The water level in the well near Rainbow Lake is related to fluctuations in precipitation. The water table usually declines from midsummer until the following spring because, during this time, evapotranspiration and ground-water runoff exceed recharge.



GROUND-WATER RELATION TO STREAMFLOW

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

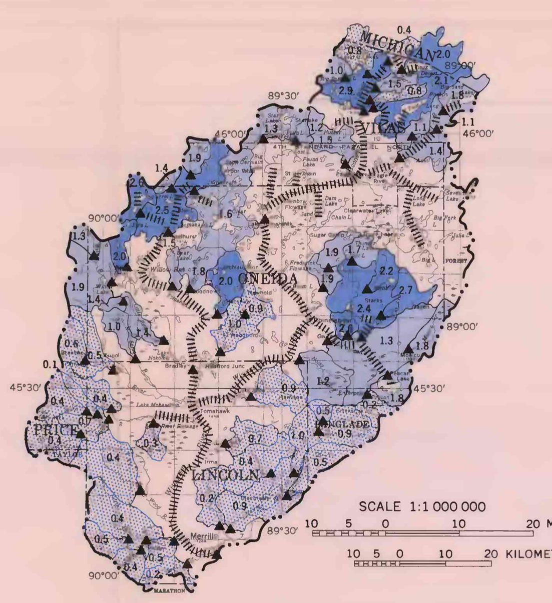


GROUND-WATER CONTRIBUTION TO STREAMFLOW

Infiltration of precipitation throughout most of the upper Wisconsin River basin is high, ground-water recharge is great, and ground-water runoff contributes more than half the total streamflow in the basin.

This hydrograph of the Spirit River at Spirit Falls has been separated into the approximate surface- and ground-water components of streamflow. This stream drains a ground-moraine area that has a lower ground-water yield than is typical in the basin. The separation shows that ground-water runoff is the more uniform part of total streamflow and that surface-water runoff is the more variable part. Ground water contributed 30 percent of the flow during the 1967 water year.

The spring peak on the hydrograph resulted from overland runoff of snowmelt in late March. Records maintained by the Wisconsin Valley Improvement Company (written commun., 1967) show that the snowmelt became rapid on March 30, when there was still 4 inches of water as snow available. This, combined with early April rains during and just after rapid snowmelt, created high surface-water runoff. Ground-water levels in the area continued to decline until early April, when they rose rapidly in response to recharge from the snowmelt and rainfall. Smaller peaks on the hydrograph occured in October, May, June, and August in response to heavy rains.



EXPLANATION

Runoff, in cubic feet per second per square mile of subbasin

Less than 1

1–2

More than 2

Boundary of subbasin and streamflow measurement site

1.2
Net runoff, in cubic feet per second per square mile of subbasin

Stream reaches where flow is controlled by release from reservoirs

Surface-water divide

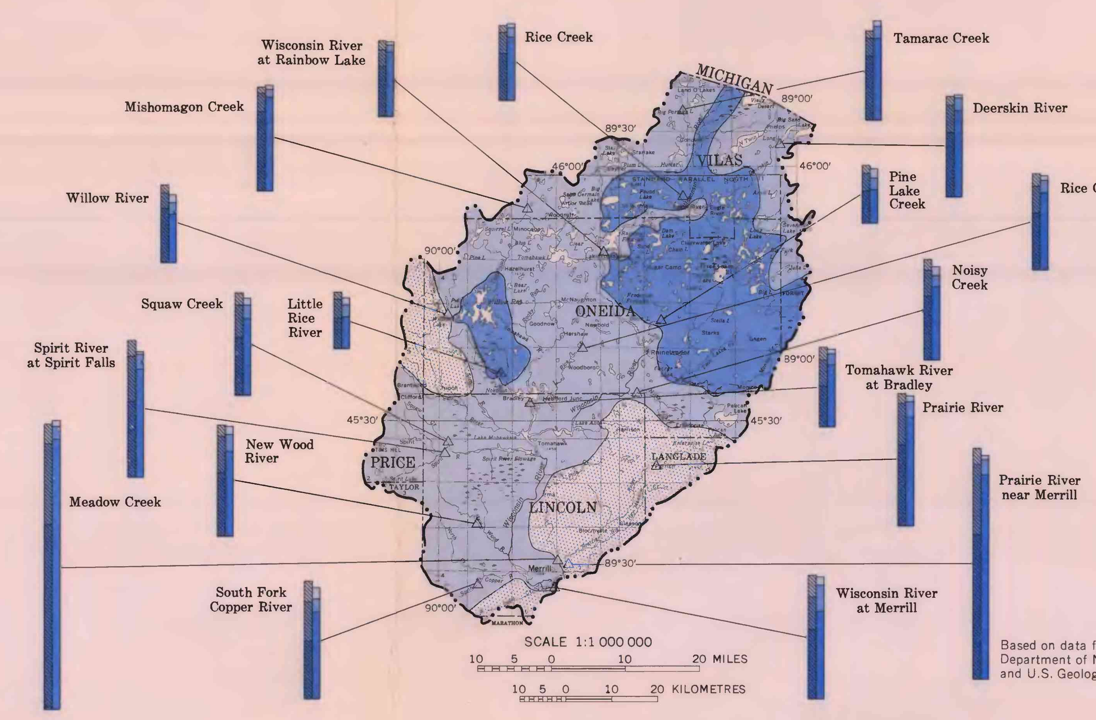
DISTRIBUTION OF BASE-FLOW RUNOFF

Stream discharges at 69 sites during a 4-day period of base flow show the range of runoff from small subbasins. Flow is expressed on the map in cubic feet per second per square mile (cfsm) to eliminate the differences in basin area. Measured base flow ranged from 0.13 to 2.9 cfsm; the average of all subbasins was 1.2 cfsm.

Streamflow during the measurement period was at high base flow, near the 45-percent point on the flow-duration curves of major streams. Although there had been no significant rainfall for the week preceding the measurements, rain was heavy the previous month. As a result, levels in lakes and impoundments were high, the water table was high, and water was standing in marshes. All of these contributed water to streamflow.

The subbasins with low runoff are generally in areas of ground or end moraine, where the permeability of the soil and glacial drift is low and recharge, movement, and discharge of ground water is slow. Subbasins with high runoff are those areas containing highly permeable sand and gravel, where ground-water movement is rapid.

The runoff per square mile was high (averaging 1.8 cfsm for the 13 subbasins measured) in stream reaches where the flow was controlled by release from impoundments.



EXPLANATION

Specific conductance, in micromhos at 25° C		Approximate dissolved solids, in milligrams per litre
Less than 70		Less than 50
70–140		50–100
More than 140		More than 100

Stream sampling site

MILLIEQUIVALENTS PER LITRE: Sodium plus potassium; Magnesium; Calcium; Chloride; Sulfate; Carbonate and bicarbonate

Surface-water divide

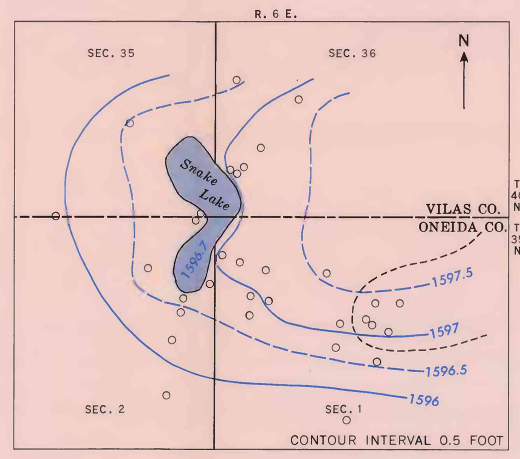
Based on data from Wisconsin Department of Natural Resources and U.S. Geological Survey

QUALITY OF STREAMFLOW DURING BASE FLOW

Streamflow quality at base flow reflects the quality of water released from surface- and ground-water storage upstream from the sampling point. As with ground water, the quality range is narrow and interpretations are general. As with ground water, the least mineralized surface water is in areas of outwash and ice-contact deposits, and the most mineralized surface water is in areas of ground and end moraine. Also, streams entering Willow Reservoir and those south of it have water of low mineralization, as do streams flowing through the area of shallow bedrock near the east border of the basin.

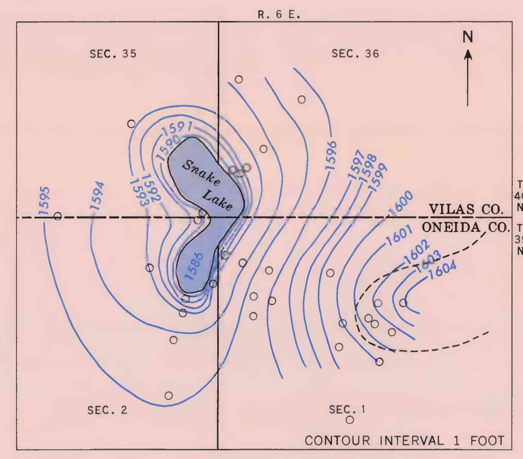
The stream water is a calcium magnesium bicarbonate type. Sodium, sulfate, and chloride concentrations are relatively low. The slightly higher concentrations of these ions from the Wisconsin River at Merrill may be due to upstream additions of waste water.

Specific conductance is related to total mineralization; in this basin an approximate dissolved-solids content can be obtained by multiplying specific conductance by 0.7. The map represents quality during base-flow conditions and illustrates areal differences in stream-water quality.



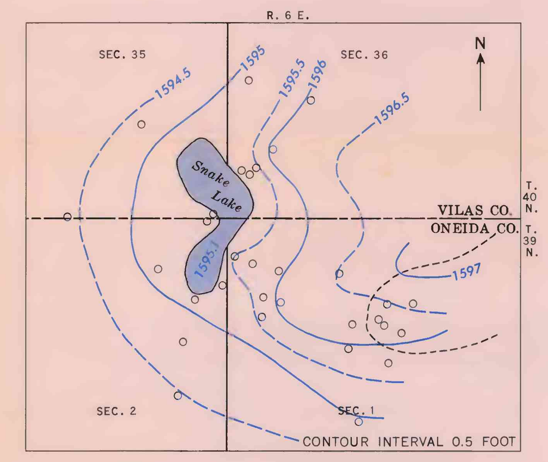
July 9, 1970
Before pumping

Snake Lake, a seepage lake with a manmade outlet and storm-sewer input, is in an area of outwash and is surrounded by a relatively flat water table. The configuration of the water table was determined from water levels in 35 sand-point wells installed in the area. Before any pumping, the water table had a gentle slope to the west, and ground water moved around and through the lake in this direction.



August 26, 1970
After 41 days of pumping

Upon pumping from the lake, the water level was drawn down about 11 feet. A cone of depression was formed that induced ground water to move into the lake from all sides. During a 6-week period, nearly three lake volumes of water were removed by pumping at rates as high as 2,250 gpm. A ground-water mound developed beneath the disposal area to the southeast, where water levels rose 7 feet.



November 21, 1970
After 85 days of recovery

After pumping stopped, the lake level rose, the ground-water mound diminished, and the water table slowly returned to the prepumping configuration. After 44 days, a suggestion of the water-table mounding still remained.

The pumping "flushed" Snake Lake, diluting the lake water with ground water. Dilution was evident from the temperature, color, clarity, and chemical analyses of lake water.

EXPLANATION

Water-table contour
Shows altitude of water table. Contour interval as shown. Datum is mean sea level

Observation wells

Approximate outline of disposal area

After Born and others (written comm., 1972)

CHANGES IN THE WATER TABLE CAUSED BY PUMPING FROM SNAKE LAKE

An example of the close relationship between ground water and surface water was demonstrated by the pumping of Snake Lake in Vilas and Oneida Counties (Born, S. M., and others, 1973).

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

WATER RESOURCES OF WISCONSIN—UPPER WISCONSIN RIVER BASIN

By
E. L. Oakes and R. D. Cotter

1975