Generalized Water-Table Elevation Map of Polk County, Wisconsin

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2000
Miscellaneous Map 48

Introduction

This map is part of the Polk County Groundwater Resource Investigation, a joint project of the Wisconsin Geological and Natural History Survey and the Polk County Board of Supervisors. The purpose of this project was to compile and interpret hydrogeologic data for Polk County. The resulting maps and data can be used by those interested in soil- and water-resource and land-use planning.

An important component of the Polk County study was to identify areas where surface-water features are not directly connected to groundwater; this knowledge is useful to regional lake managers, county planners, and investigators designing site-specific groundwater studies.

The water cycle

Solar energy and gravity play active roles in a continuous water recycling process called the *water cycle* (fig. 1).

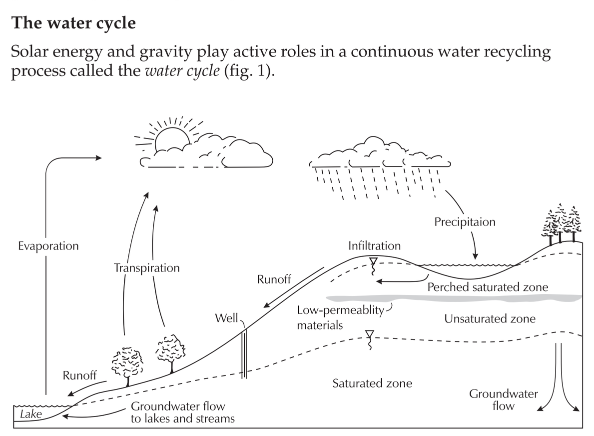


Figure 1. *The water cycle (modified from Dunne and Leopold, 1978).*

Water falling on the land surface can flow downhill as overland runoff, evaporate, transpire through plants, or infiltrate into the ground. As the infiltrating water seeps downward through rock or soil, it travels through pore spaces and open cracks or fractures in the subsurface materials. When these pores and cracks are completely filled with water, the material is said to be *saturated*.

The *water table* marks the top of this saturated zone, where hydraulic pressure in the pores is equal to atmospheric pressure. *Groundwater* is the water contained in the saturated zone below the water table. Above the water table, pores and cracks are partly or completely filled with air and partly filled with water, and the material is said to be *unsaturated*. The amount of infiltrating precipitation is one of the factors that determines the position, or elevation, of the water table, which fluctuates seasonally and from one year to another.

If a zone of saturated material is separated from an underlying main body of saturated material by an unsaturated zone, then the upper groundwater system is said to be *perched*. The upper water table is referred to as a *perched water table*.

Groundwater, under the influence of gravity, moves slowly through pore spaces, eventually discharging to a surface-water body, to the land surface, or to a well. Solar energy causes some water to evaporate, thus returning it to the atmosphere and continuing the water cycle.

In Polk County, the water cycle generally operates with approximately 28 inches of precipitation during an average year, from which about 71 percent (approximately 20 inches) returns to the atmosphere by evaporation and transpiration by plants (Young and Hindall, 1973). The remainder either flows over the land surface and collects in surface-water bodies or infiltrates into the ground as *recharge* to the groundwater system. The ratio of overland runoff to groundwater recharge varies considerably around the state, depending upon factors such as topography, the permeability of the unsaturated materials, vegetative cover, rainfall intensity, and individual farming and general land-use practices.

Movement of groundwater and surface water

A saturated subsurface material that yields sufficient water to a well is called an *aquifer*. *Permeability* is a measure of the relative ease with which water can flow through an aquifer; it is dependent on the nature of the material through which the water is flowing. Large pores or fractures can hold more water than small ones, but for water to flow effectively, these pores or fractures must be connected.

Groundwater can move as rapidly as several feet per day in porous sand and sandstone, or as slowly as inches per year in clay or in unfractured volcanic rock. Sandy soil and sandstone frequently have relatively large pore spaces that are well connected with each other, allowing water to move more easily than it can in clayey soil that has small, poorly connected pores. Rocks such as basalt have low permeability except where they are fractured. If the fractures are well connected, these rocks can transmit water easily; however, if there are just a few poorly connected fractures, these rocks transmit little water.

No matter how rapidly or slowly the groundwater flows, its natural direction of movement is in response to gravity, from upland recharge areas, where water infiltrates into the subsurface, to lowland discharge areas (lakes, rivers, springs, and seeps) where groundwater emerges again. Many surface-water bodies are groundwater-discharge areas, so groundwater quality has a significant impact on the water quality of lakes, streams, and wetlands. Wells are manmade groundwater-discharge points.

A *surface-water divide* is a line of separation, commonly a ridge or a tract of high ground that divides the surface water that flows naturally into one basin from water that flows naturally into a different basin. Several streams and their associated tributaries drain parts of Polk County; these include the Clam River in the northeast, the Trade River and Wolf Creek in the northwest, the Apple River in the central part of the county, and the Willow River in the southeast. All these rivers eventually empty into the St. Croix River, which forms the western boundary of Polk County. However, the drainage network of Polk County is somewhat poorly integrated. Hummocky topography and internal drainage to kettle lakes make determination of surface-water divides complex; consequently, they are not delineated on this map.

A *groundwater divide* is similar to a surface-water divide, in that it is a ridge defined by contours of the water table. Shallow groundwater moves away from the divide toward groundwater-discharge areas. A groundwater divide does not necessarily coincide with a surface-water divide. The groundwater divides in Polk County approximately outline the surface-water basins. A major groundwater divide in the western half of the county separates a region where groundwater discharges either directly to the St. Croix River or to streams that flow into the St. Croix from a region where groundwater discharges to lakes and streams that eventually converge into the Apple River. Minor divides in the northeast and southeast parts of the county separate groundwater that discharges to the basins of the Clam River and the Willow River from that which discharges to the Apple River basin.

This map depicts, in a general way, the direction of shallow groundwater flow, which is primarily away from groundwater divides and perpendicular to lines of equal water-table elevation.

Geology and groundwater availability

The bedrock in Polk County consists of Precambrian basalts overlain by a series of Cambrian and Ordovician rock (Mudrey and others, 1987). The Precambrian basalt, emplaced approximately 1.1 billion years ago and locally known as *traprock*, forms a topographic high that runs from west-central to southern Polk County. The depth to bedrock over this ridge is commonly 50 feet or less, and outcrops are relatively common. During the Cambrian, approximately 523 to 505 million years ago, a series of sandstone and shale was deposited in the area. During the Ordovician, approximately 505 to 468 million years ago, deposition shifted from predominantly sandstone to predominantly limestone and dolomite.

Early glacial advances (perhaps hundreds of thousands to millions of years ago) entered the county from the northwest; however, deposits from those glaciers are present only in the subsurface and are not exposed at the land surface. The modern landscape was largely shaped by glaciers that advanced into the county during the late Pleistocene (between 25,000 and 10,000 years ago). Glaciers entered the county from the northwest and north about 25,000 to 15,000 years ago and deposited a thick sequence of sandy till and outwash across the county. About 12,300 years ago a glacier entered the county from the west and deposited a silty till in the western and northwestern parts of the county (Muldoon and others, 1990; Johnson, 1998). When this glacier was at its maximum extent, it dammed the St. Croix drainageway and formed a large glacial lake in the northwestern part of the county. The last major event to shape the landscape in the study area was the drainage of water from Lake Superior down the St. Croix valley when a glacier was blocking the eastern outlets of Lake Superior. From about 12,000 to 10,000 years ago, water from Lake Superior flowed down the St. Croix drainageway and the St. Croix Dalles were formed (Johnson, 1998).

Over much of the county the glacial deposits are more than 100 feet thick. Although these deposits are variable in composition, they commonly contain enough coarse-grained sand and gravel to provide adequate water supply for domestic wells; about 73 percent of the wells in Polk County receive water from the sand and gravel aquifer.

In areas where glacial deposits are thin or absent, wells are completed in bedrock. The band of near-surface bedrock that runs from west-central into southern Polk County is underlain by the Precambrian basalt. The basalt is typically very low in yield and is only used when the overlying Pleistocene materials cannot supply adequate water. Only 5 percent of the wells in the county are completed in the basalt. Cambrian sandstone overlies the basalt and forms the uppermost bedrock unit in much of eastern and western Polk County. Approximately 5 percent of wells in the county draw water from the sandstone aquifer. This water quality is generally good; however, some wells completed in the Cambrian sandstone yield water that is high in iron. Younger Ordovician limestone and dolomite overlie the sandstone in the southern part of Polk County and approximately 17 percent of wells draw water from the limestone or a combination of limestone and sandstone.

Contamination of groundwater

Because groundwater originates from precipitation that percolates down from the land surface, any water-soluble material or liquid that is put on or in the ground has the potential to be transported to the saturated zone. The unsaturated zone can serve as a natural filter and may remove many harmful materials from the recharging water by a variety of physical, chemical, and biological processes. In general, thick sequences of fine-grained materials are better able to attenuate contaminants; as a result, areas that have thin or sandy soils over bedrock or thin or sandy soils with a shallow depth to groundwater are especially susceptible to groundwater contamination. Once a contaminant reaches the saturated zone, it has the potential to move with the groundwater and discharge to wells or surface-water bodies. Concentration of contaminants in the saturated zone can be reduced by the processes of dilution, adsorption onto fine-grained particles, and chemical or biological breakdown.

Contamination that occurs today may not become evident for a long time because groundwater can move as slowly as a few inches per year. Once contaminated, groundwater is difficult to purify and may take many years, decades, or centuries to be cleaned.

Data compilation and interpretation

Data were compiled by Kim Cates, Bernie Michaud, Michelle Bridson, and Maureen Muldoon at a scale of 1:24,000, using U.S. Geological Survey quadrangles (7.5-minute series, topographic) as base maps. Selected Wisconsin Geological and Natural History Survey geologic logs were plotted onto these base maps. The Wisconsin Department of Natural Resources well constructor's reports were examined, and those judged to contain the most representative, reliable, and useful data available for each section were plotted. Data density across Polk County ranges from the very few data points on federal, state, or county-owned lands to at least one point per 1 to 2 square miles in the more populated parts of the county. More than 1,000 well data points were used to construct this map.

Surface-water elevations and water elevations in domestic wells are used to compile county water-table maps. Using surface-water elevations to generate a water-table map assumes that the surface-water bodies are not perched and are accurate representations of the water table. Domestic wells are not ideal measuring points for determining water-table elevation. Most wells are open over long intervals and are completed far below the top of the saturated zone. To use water levels in domestic wells, one must assume that groundwater flow is more horizontal than vertical. In addition, well constructor's reports provide measurements taken at different times of the year and in different years. Because of the seasonal variations in water levels and changes in water levels with depth, a water level determined from a well constructor's report was not used as an exact data point. Instead, the water level was considered to represent a range of values.

A previous study of the hydrogeology of Polk County used two office-generated contour maps to identify areas where field studies were needed to accurately define the groundwater flow systems (Muldoon and others, 1990). Comparison of a contour map based on surface-water elevations with one based on water levels in wells identified areas where water levels in wells were more than 50 feet below surface-water elevations (depicted with a green tint in this map). These differences could be caused by a variety of factors, including differing data densities between the two maps, errors in well drillers' records, the existence of complex flow systems or strong vertical gradients in certain areas, or the existence of perched surface-water bodies above a deeper water table. Only relatively large areas where surface-water elevations differ from water levels in wells are depicted on this map; there are also small isolated lakes and wetlands that do not appear to be connected to the groundwater flow system. In areas where surface-water and well-water elevations differ, data points that were not representative of the mapped water table were not used. For example, in the southwest part of the county, the surface-water points from the small upland ponds and wetlands were not used and the points from the larger streams and the wells in the area were retained.

Field investigations

A previous study outlined the Pleistocene geology and hydrogeology of parts of Polk County and suggested that the large discrepancies between surface-water and well-water elevations could be related to geologic settings in the county (Muldoon and others, 1990). These discrepancies may be caused by 1) the existence of small perched lakes in uplands in the southwestern part of the county, 2) steeply mounded water tables under lakes in areas of silty till in the northwest part of the county, and 3) the presence of two distinct saturated zones separated by an unsaturated zone in areas of hummocky sandy till in the northeast part of the county. Data from three field sites described below were collected as part of that investigation.

Site 1—Osceola Lake, located in the southwestern part of the county, sits at the base of a steep ridge composed of 100 to 150 feet of sand and gravel over bedrock; the ridge is capped by *loess*, silt-sized sediment deposited by the wind during the Pleistocene. Several small lakes on top of the ridge have elevations ranging from 1,040 to 1,050 feet; Osceola Lake has an elevation of 898 feet (fig. 2). Monitoring wells in the area indicate that water-table elevations range from 892 feet near Osceola Lake to 925 feet on top of the ridge. A map of the Pleistocene geology of the County (Johnson, 1998) indicates that the ridge is mainly composed of hummocky till and meltwater-stream sediment. The distribution of these glacial deposits in the southwest part of the county roughly corresponds to the region where there is a large discrepancy between surface- and well-water elevations. On the basis of the data from the Osceola Lake site, Muldoon and others (1990) assumed that the surface-water features in an area south and southwest of Osceola Lake are perched and thus are separated from the underlying aquifers by an unsaturated zone.

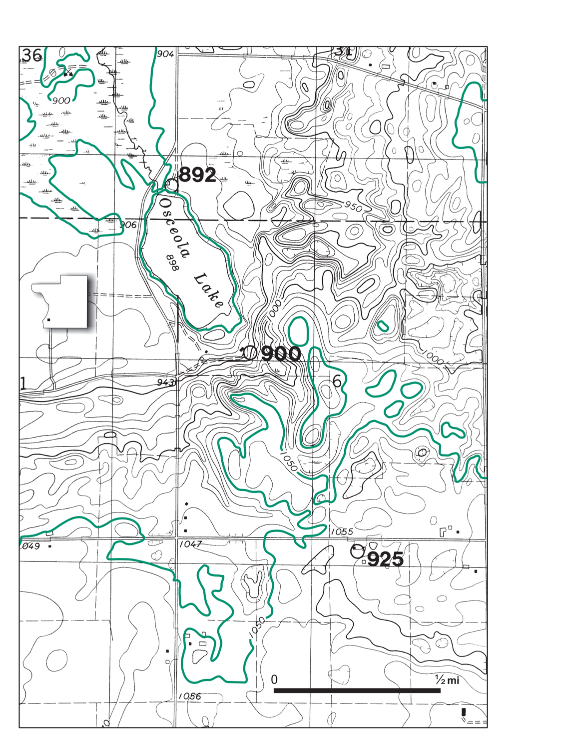


Figure 2. *Part of a topographic map showing the location of Osceola Lake, lake elevation, and water-level elevations from wells (open circles). Contour interval is 10 feet; the 900- and 1,050-foot contour lines are highlighted in green.*

Site 2—Bass Lake, in the northwest part of the county, north of Cushing, is located in a hummocky till plain that contains numerous lakes and wetlands. Surface-water bodies in this area lie at an elevation of approximately 995 feet on the eastern side of the till plain and grade to an elevation of 880 feet on the western edge; water-supply wells in the area have elevations ranging from 925 feet in the east to 860 feet in the west. Figure 3 is a detailed diagram of the Bass Lake site; it shows the location of the line along which a geologic cross section was constructed. Gray, silty till is the surficial unit; it overlies sand and gravel. The till was probably deposited while buried ice was still present in the underlying sand and gravel; as the ice blocks melted, the overlying till collapsed into the resulting depressions. These till-lined ice-block depressions now contain lakes and wetlands.

Five monitoring wells were installed in and around Bass Lake. The wells finished in sand (wells 1 and 3, fig. 3) had water levels much lower than the lake elevation; well 2, completed in the till, had a water level only slightly below lake level. The continuous presence of water in well 5 suggests that Bass Lake is not actually perched, but is instead a steeply mounded lake. The fact that the water level in well 5 was 28 feet below the lake's suggests that strong downward hydraulic gradients exist under Bass Lake, but that continuous saturation exists between the lake bottom and the underlying sand and gravel.

Bass Lake is located on the northern edge of a large area where differences between surface-water elevations and water levels in wells are in the range of 50 to 100 feet. This region lies entirely within an area where the surficial unit is silty till or silty lake sediment (Johnson, 1998). The extent of the till, however, is greater than the area where water levels do not agree. North of Bass Lake, on the till plain, surface- and well-water elevations are in agreement. A possible explanation is that the till thins to the north, and the lake bottoms may intersect the saturated zone in the underlying sand and gravel.

To the southeast of the Bass Lake area is another area where surface-water elevations differ from water levels in wells. This area is composed of hummocky till, similar to the area in the southwest part of the county where water levels differed. The lack of data in this area makes it difficult to determine the cause of the water-level discrepancy.

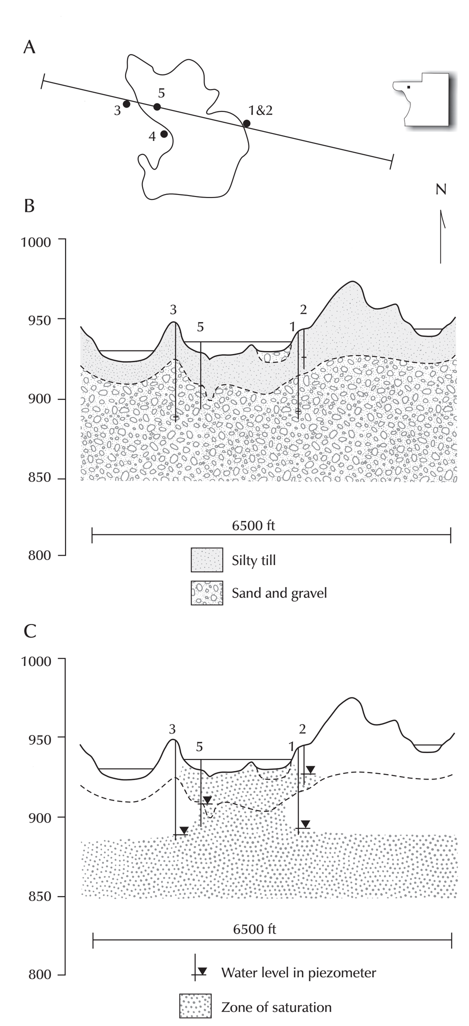


Figure 3. *Hydrogeology of the Bass Lake research site. A. Locations of monitoring wells and the line of geologic cross section; B. geologic cross section; C. water levels in monitoring wells.*

Site 3—The northeast part of the county is characterized by a broad upland plain that contains numerous lakes and wetlands at elevations of 1,250 to 1,300 feet above sea level. Zaporozec (1987) described this area as hydrogeologically complex, where well data are scarce, making hydrogeologic evaluation very difficult. A field site, with hydrogeology that is assumed to be representative of hydrogeologic conditions over the entire upland plain, is just outside Polk County in the northwestern corner of Barron County (fig. 4). The upland area is dissected by a valley that continues east into Barron County, where it contains Upper Waterman, Lower Waterman, Sand, and Beaver Dam Lakes, which range in elevation from 1,212 to 1,231 feet.

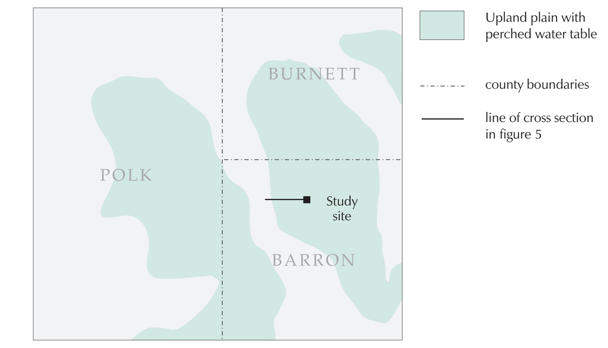


Figure 4. *Map showing location of site 3 in the upland plain that extends over parts of Polk, Barron, and Burnett Counties.*

The geology of the upland area consists of thin lake sediment over sandy outwash over red, sandy till (fig. 5); in places there are some finer-grained layers within the till. Although these fine-grained layers do not appear to be common, they seem to control the groundwater flow system. Five monitoring wells were installed at the site, but only three of the five wells contained water (fig. 5). The wells containing water were located in the outwash and the upper part of the till; below a depth of approximately 50 feet (elevation 1,280 feet), the wells were dry. These data suggest that an upper saturated zone is held up by the till; below this, an unsaturated zone exists above a deeper saturated zone. Although no monitoring wells intersected the deeper saturated zone, its elevation has been determined from the elevations of Upper Waterman, Lower Waterman, Sand, and Beaver Dam Lakes as well as from water levels in domestic supply wells. Figure 5 indicates that strong downward hydraulic gradients exist at the site, yet there is no clear discharge point for the upper saturated zone. Muldoon and others (1990) suggested that the precipitation in the upland area must be approximately balanced by evapotranspiration.

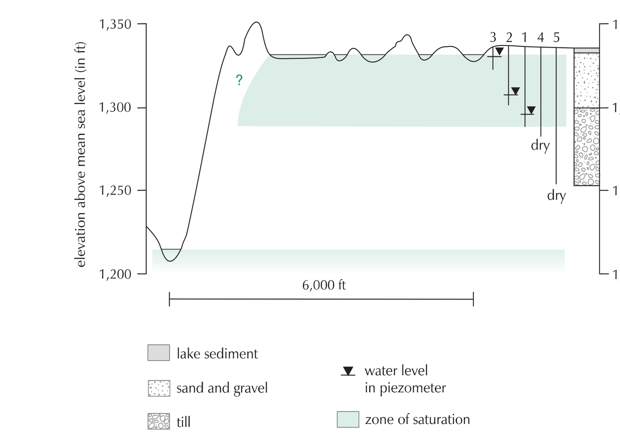
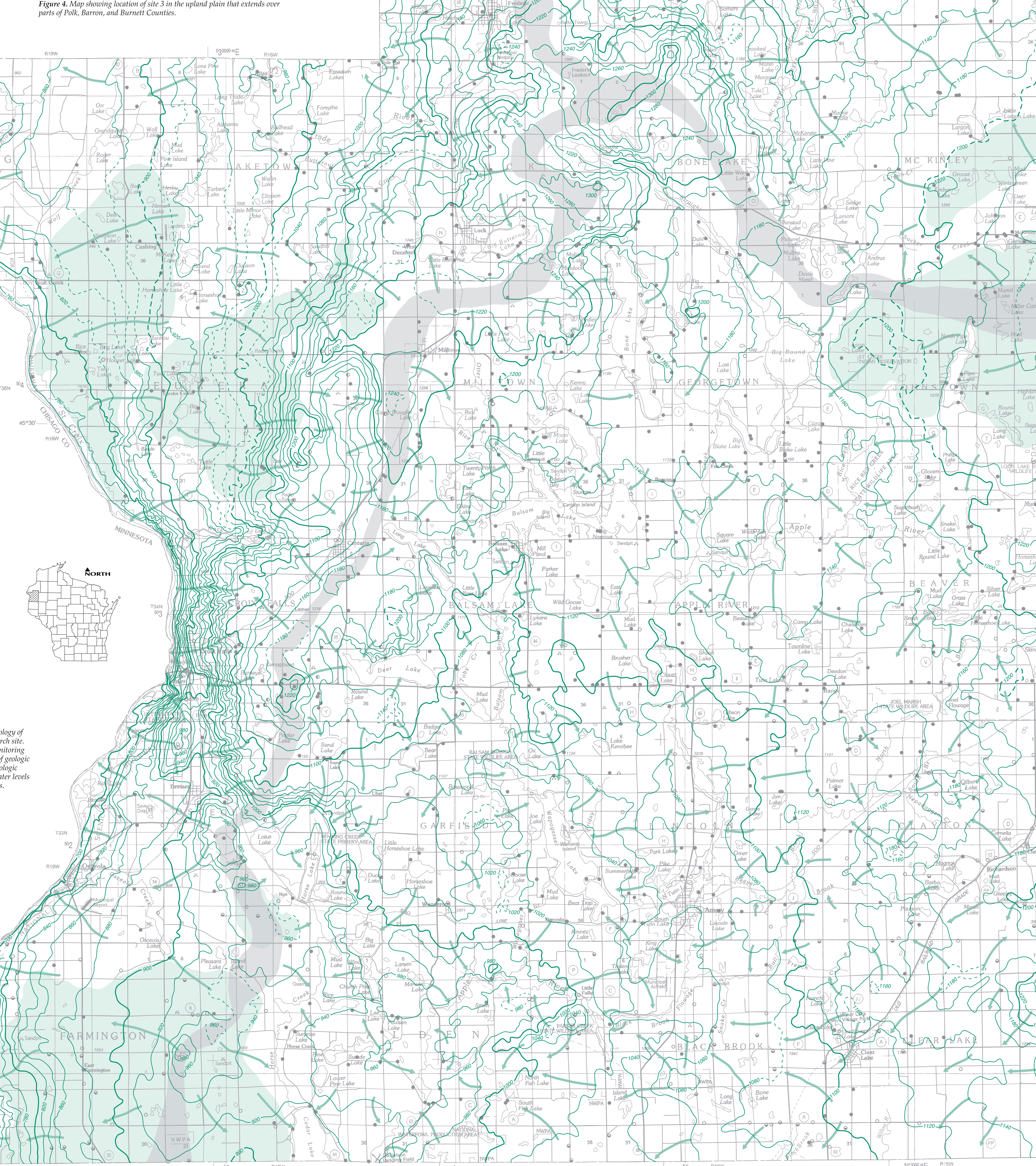


Figure 5. *Cross section showing hydrogeology of the Waterman Lake area (modified from Muldoon and others, 1990). (Line of cross section is shown in fig. 4.)*



Limitations of the map

This map is a summary of available water-level data for Polk County. The accuracy of the interpretation varies throughout the study area, increasing with greater data density. The contour lines are solid where enough data are available to locate the lines with a reasonable degree of confidence (within ±0.3 mile on the map). The lines are dashed where data are less abundant or where hydrogeologic conditions are more complex and their locations are considered to be accurate to within ±0.7 mile on the map.

It was beyond the resources of this study to field-check the locations and water levels given on the Wisconsin Department of Natural Resources well constructor's reports that were used to construct this map. The map is intended for use at the published scale of 1:100,000 and should *not* be considered definitive for any site-specific applications.

References

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Zaporozec, A., 1987, Hydrogeology of Barron County, Wisconsin in *Atlas of groundwater resources and geology of Barron County, Wisconsin*: Wisconsin Geological and Natural History Survey (scale 1:100,000).

Sources of data

U.S. Geological Survey quadrangles (7.5-minute series, topographic; 1972–83) were used to determine surface-water and well-water elevations.

Water-level observation wells from the Groundwater Level Observation Network, operated and maintained by the U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

Wisconsin Department of Natural Resources well constructor's reports (1936–91).

Wisconsin Geological and Natural History Survey published and unpublished geologic logs (1934–84).

Explanation

800 — Average elevation of water table in feet. 20-feet contour interval. Datum is mean sea level. Solid where considered accurate within ±0.3 mile on the land surface; dashed where considered accurate within ±0.7 mile on the land surface

Groundwater divide, approximately located

General direction of shallow groundwater flow

areas where surface-water elevations are 50 to 100 feet above well-water elevations

Geologic materials contributing water to well (All geologic information is taken from Department of Natural Resources well constructor's reports on file at the Wisconsin Geological and Natural History Survey. Materials contributing water to the well are those units that are saturated and penetrated by the open, or screened, part of the well.)

- sand and/or gravel
- limestone or limestone and sandstone
- sandstone
- basalt

Data have not been field checked. Water-level elevation data were generalized from information collected over a period of approximately 50 years.

Extension
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Base map constructed from U.S. Geological Survey Digital Line Graph files (1990, scale 1:100,000), modified by Wisconsin Department of Natural Resources (1992) and Wisconsin Geological and Natural History Survey (1999).

Scale 1:100,000
KILOMETERS
MILES