Generalized Water-Table Elevation Map of Burnett County, Wisconsin

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1998
Miscellaneous Map 45

Introduction

This map is part of the Burnett County Groundwater Resource Investigation, a joint project of the Wisconsin Geological and Natural History Survey and the Burnett County Board of Supervisors. The purpose of this project was to compile and interpret hydrogeologic data for Burnett 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 Burnett County study was to identify areas where surface-water features are not directly connected to groundwater. In the southeastern part of the county, complex glacial stratigraphy has resulted in areas that have two discrete saturated zones (Muldoon and others, 1990). This knowledge is useful to regional lake managers, county planners, and investigators designing site-specific groundwater studies.

The water cycle

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

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 the land surface, to a well, or to a surface-water body. Solar energy causes some water to evaporate, thus returning it to the atmosphere and continuing the water cycle.

In northwestern Wisconsin, the water cycle generally operates with approximately 28 inches of precipitation during an average year, from which about 70 percent (about 20 inches) returns to the atmosphere by evapotranspiration (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.

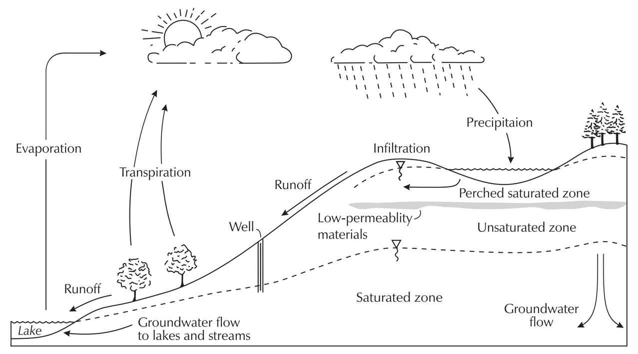

Figure 1. *The water cycle (modified from Dunne and Leopold, 1978).*

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 narrow tract of high ground that divides the surface waters that flow naturally into one basin from those that flow naturally into a different basin. There are no major surface-water divides in Burnett County. All streams and rivers in Burnett County flow toward the St. Croix River, which forms the western boundary of the county.

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 in different (often opposite) directions. A groundwater divide does not necessarily coincide with a surface-water divide. However, there are also no major groundwater divides in Burnett County. Over much of the county, groundwater flows along short flow paths and discharges to lakes and streams that then flow toward the St. Croix River.

Geology of Burnett County

The bedrock of Burnett County consists of Precambrian basalt overlain by a series of Precambrian sandstone and shales and Cambrian sandstone (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 Polk County into southern Burnett County. The depth to bedrock over this ridge is commonly 50 ft or less and rock outcrops are relatively common. During the Cambrian, approximately 523 to 505 million years ago, several types of sandstone were deposited in the area.

Glaciers entered the county from the northwest and north about 25,000 to 15,000 years ago. These glaciers deposited a thick sequence of sandy till and sand and gravel across the county. About 12,300 years ago a glacier entered the county from the west and deposited a silty till in the western parts of the county (Muldoon and others, 1990). When this glacier was at its maximum extent, it dammed the St. Croix drainageway and formed a large glacial lake in the central part of the county. The last major event to shape the landscape in the study area (approximately 10,000 to 12,000 years ago) was the drainage of water from Lake Superior down the St. Croix valley when a glacier was blocking the eastern outlets of Lake Superior.

Over much of the county the glacial deposits are more than 100 ft 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; 97 percent of the wells in Burnett County receive water from the sand and gravel aquifer. In areas where glacial deposits are thin or absent, wells are completed in the bedrock. The band of near-surface bedrock that runs from west-central Polk County into southern Burnett County is underlain by the Precambrian basalt and some Cambrian sandstone. Water quality from the sandstone and basalt is generally good; however, some wells completed in the Cambrian sandstone yield water that is high in iron. The sandstone aquifer usually provides dependable water supplies (2% of the wells), but the basalt is typically a very low-yielding aquifer that is only used when the overlying Pleistocene materials cannot supply adequate yield. Only 1 percent of the wells in the county are completed in the basalt.

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 with 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, M.V. Dahl, Bernie Michud, Wendy Anderson, Michelle Bridson, and M.A. Muldoon at a scale of 1:24,000, using U.S. Geological Survey quadrangles (7.5-minute series, topographic) as base maps. All available 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 reports for a given area were compared with each other. Those judged to contain the most representative, reliable, and useful data available for each section were plotted. Data density across Burnett County ranges from the very few data points on federal, state, or county-owned lands (for example, the St. Croix National Scenic Riverway, Crex Meadows, and county forest land) to at least one point per 1 to 2 square miles in the more populated parts of the county. More than 700 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.

For the Burnett County water-table map, we used two office-generated contour maps to identify areas where field studies were needed to accurately define the groundwater flow systems. By comparing a contour map based on surface-water elevations with one based on well water levels in wells, we identified an area in the southeast part of the county where water levels in wells were more than 50 ft below surface-water elevations (Muldoon and others, 1990). Data from the study site (described below) suggest that groundwater flow systems in the southeast part of Burnett County can be complex; however, regional groundwater flow patterns can be estimated using the existing office data. In areas where perched groundwater flow systems exist (depicted with green tint in this map), the surface-water and well-water points that were not representative of the mapped water table were not used. For example, in the southeast part of the county, the surface-water points from the upland lakes and wetlands were not used and the points representing the valley lakes and the wells in the area were retained.

Field investigations

A previous study outlined the Pleistocene geology and hydrogeology of parts of the Waterman Lake area, an area that has two separate groundwater flow systems and that extends over parts of southeastern Burnett, northeastern Polk, and northwestern Barron Counties (Muldoon and others, 1990). This area is characterized by a broad upland plain that contains numerous lakes and wetlands at elevations of 1,320 to 1,340 ft above sea level. The upland area is dissected by a valley that contains Upper Waterman, Lower Waterman, Sand, and Beaver Dam Lakes, which range in elevation from 1,212 to 1,231 ft.

A field site, with hydrogeology that is assumed to be representative of hydrogeologic conditions over the entire upland plain, is located just outside Burnett County in northwestern Barron County (fig. 2). Zaporozec (1987) characterized this region as hydrogeologically complex. The geology of the upland area consists of thin lake sediments over sandy sand and gravel over red, sandy till (fig. 3, Muldoon and others, 1990). 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 piezometers were installed at the site, but only three of the five piezometers contained water (fig. 3; Muldoon and others, 1990). The piezometers containing water were located in the sand and gravel and the upper part of the till; below a depth of approximately 50 ft (elevation 1,280 ft), the piezometers were dry. These data suggest that there is an upper saturated zone that is held up by the till; below this, an unsaturated zone exists above a deeper saturated zone. Although no piezometers 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 3 indicates that strong downward hydraulic gradients exist at the site, yet there is no clear discharge point for the upper saturated zone. We believe that the precipitation in the upland area must be approximately balanced by evapotranspiration.

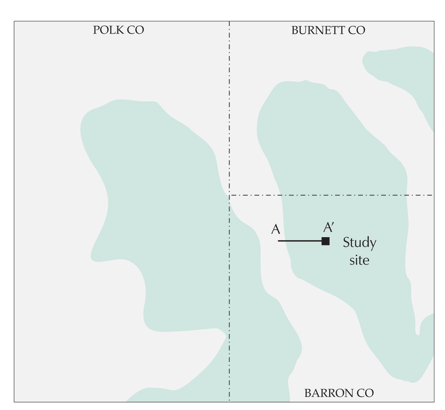

Figure 2. *Location of field site in Barron County, Wisconsin.*

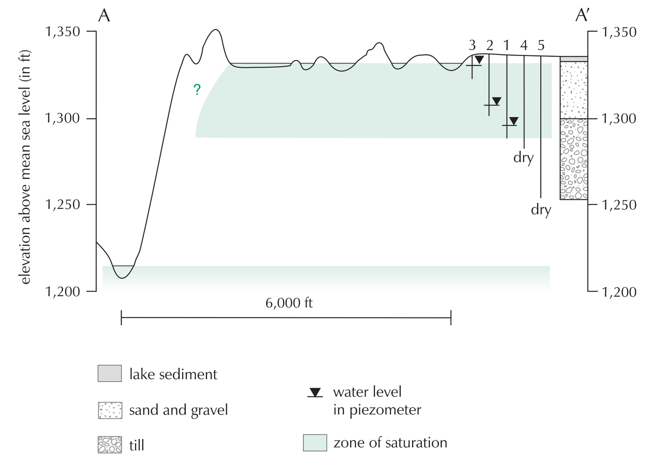

Figure 3. *Cross section showing hydrogeology of the Waterman Lake area (modified from Muldoon and others, 1990).*

Limitations of the map

This map depicts, in a general way, the direction of shallow groundwater flow, which is primarily perpendicular to lines of equal water-table elevation. 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. This map is a summary of available water-level data for Burnett County. It is intended for use at the published scale of 1:100,000 and should *not* be considered definitive for site-specific applications.

References

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Young, H.L., and Hindall, S.M., 1973, Water resources of Wisconsin, St. Croix River Basin: U.S. Geological Survey Hydrologic Investigations, Atlas HA-451.

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Sources of data

U.S. Geological Survey quadrangles (7.5-minute series, topographic; 1982–83) 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 (1937–90).

Wisconsin Geological and Natural History Survey published and unpublished geologic logs (1953–89).

Water-level data from U.S. Geological Survey piezometers at Crex Meadows (Patterson, 1990).

This map is an interpretation of the data available at the time of preparation. Every reasonable effort has been made to ensure that this interpretation conforms to sound scientific and cartographic principles; however, the map should not be used to guide site-specific decisions without verification. Proper use of the map is the sole responsibility of the user.

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Explanation

Average elevation of water table in feet. 20-ft contour interval, with supplemental 10-ft contours. 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

general direction of shallow groundwater flow

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

federal, state, or county-owned land

Geologic materials contributing water to well (All geologic information is taken from Wisconsin Department of Natural Resources well constructor's reports on file at the Wisconsin Geological and Natural History Survey.)

- ● sand and/or gravel
- ○ sandstone and sandstone with shale
- ◐ basalt or granite
- ? unknown

Data have not been field checked. Water-level elevation data were generalized from information collected over a period of approximately 55 years.