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GEOLOGICAL AND NATURAL HISTORY SURVEY
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WATER-TABLE MAP OF THE UPPER BLACK EARTH CREEK WATERSHED

by

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Water-table Map of the Upper Black Earth Creek Watershed
M.A. Muldoon, April 1992
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EXPLANATION

Average elevation of water table in feet. 20-ft contour interval. Datum is mean sea level.

—900— solid where considered accurate within ±0.25 mile on the land surface;

---900--- dashed where considered accurate within ±0.5 mile on the land surface.

➘ general direction of shallow groundwater flow

— — — boundary of the Upper Black Earth Creek surface-water basin (red)

\\\\\\\\\\ regional groundwater divides, approximately located (green)

WATER-LEVEL INFORMATION

Wisconsin Department of Natural Resources well constructors' reports (on file at Wisconsin Geological and Natural History Survey)

● wells where water levels were interpreted as representative of the water table

○ wells where water levels were interpreted as not representative of the water table

Wisconsin Department of Natural Resources and WGNHS monitoring wells and piezometers

\+ water levels are considered representative of the water table

INTRODUCTION

These maps are the result of co-operative funding provided to the Wisconsin Geological and Natural History Survey by the Wisconsin Department of Natural Resources, Dane County Land Conservation Department, City of Middleton, Southern Wisconsin Trout Unlimited, and Badger Flyfisher Association. The purpose of this project was to compile and interpret hydrogeologic data for the Upper Black Earth Creek Basin. The resulting maps can be used as baseline information for future groundwater studies and by local planners, environmental consultants, and developers.

SOURCES OF DATA

These maps were constructed using existing water-well elevations available from

- -Wisconsin Department of Natural Resources well constructor's reports (1936-89),
- -Wisconsin Geological and Natural History Survey published and unpublished geologic logs (1896-1989),
- -Wisconsin Department of Natural Resources monitoring-well data,
- -selected surface-water elevations from United States Geological Survey quadrangles (7.5-minute series, topographic; 1969-82).

In addition, two shallow piezometers were installed along the Highway 14 corridor, Town of Middleton, in order to better define the location of the groundwater divide between the Black Earth Creek basin and the Yahara basin.

THE WATER CYCLE

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

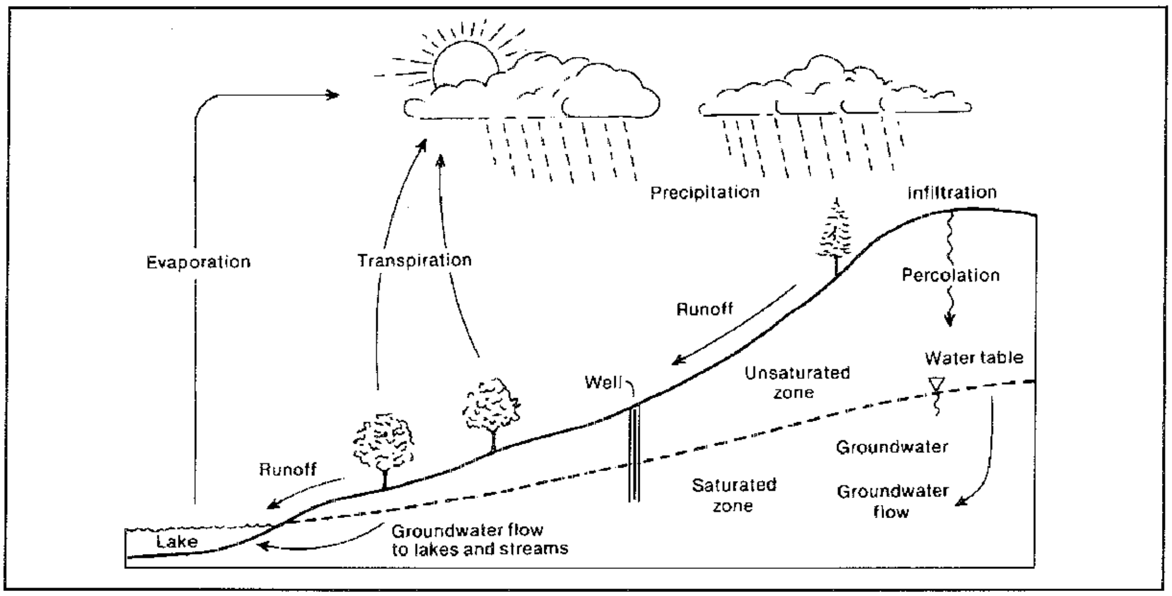

Figure 1. The water cycle.

Water falling on the land surface can flow downhill as overland runoff, evaporate, transpire through plants, or infiltrate into the ground. As this infiltrating water seeps downward through rock or soil, it travels through pore spaces and open cracks or fractures in the subsurface material. 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. The amount of infiltrating precipitation partly determines the position, or elevation, of the water table, which fluctuates seasonally, and from one year to another. 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*.

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

In Wisconsin, the water cycle generally operates with 30 to 32 inches of precipitation during an average year, from which about 75 percent (22 to 26 inches) returns to the atmosphere by evapotranspiration. 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, soil type, vegetative cover, rainfall intensity, and individual farming and general land-use practices.

<u>Movement of Groundwater and Surface Water</u>

A saturated subsurface material that yields sufficient water to a well is called an *aquifer*. *Hydraulic conductivity* 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 in order for water to flow effectively, these pores or fractures must be interconnected.

Groundwater can move as rapidly as several feet per day in porous sand and sandstone, or as slowly as a few inches per year in clay or in unfractured shaley rock. For example, 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 shale have low permeability except where they are fractured. If the fractures are well-connected these rocks can transmit water easily, however, if there 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). Many surface-water bodies are groundwater discharge areas, so groundwater quality has a significant impact on the water quality of lakes, streams, and wetlands. Pumping wells are man-made 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. The boundary of the Upper Black

Earth Creek surface-water basin is shown as a red line on the water-table maps.

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 radially away from the divide. The location of groundwater divides is more uncertain than the location of the surface-water divides because they are defined with less precise data. The groundwater divide between the Upper Black Earth Creek Basin and the Yahara Lakes Basin was primarily determined from shallow piezometer data obtained from DNR monitoring records (HydroSearch, 1991) and two additional piezometers installed by WGNHS. The groundwater divide separating the Black Earth Creek Basin from the Sugar River Basin was determined using water levels in domestic wells. Over much of the Black Earth Creek Basin, the regional groundwater divides correspond with the surface-water divides. However, in southwestern corner of the Town of Middleton, the groundwater divides lies several miles to the south of the surface-water divide. This broad upland area may serve as a significant recharge area for the Upper Black Earth Creek Basin.

DATA COMPILATION

Locations

Data were compiled 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 checked against historical plat books, U. S. Geological Survey ortho-photographs (1987), and maps of subdivision plots in order to determine locations. For some areas, particularly newer subdivisions, the locations of the wells were field checked before they were plotted onto the base maps. Over 800 well construction reports and geologic logs were plotted. Data density varies across the watershed, with fewer data points in the rural portions of the watershed and more data points in the areas of subdivision development. Map accuracy increases in areas of higher data density.

Elevations

Elevations of the wells were determined from U.S. Geological Survey quadrangle maps and the depth to water reported on the constructor's report or geologic log was used to calculate a water-level elevation. The topographic contour interval on the base maps varies from 10 to 20 ft, therefore elevations determined from the maps are assumed to be accurate to within $\pm$ 1/2 the contour interval. In some cases, the "map elevations" did not seem to provide realistic water-level elevations. For those wells, the elevations were field-measured using an altimeter. Altimeter measurements are accurate to within $\pm$ 3 feet. The elevations of 115 wells were measured with the altimeter.

Database

After plotting the data, the locations were digitized and the information from the well constructor's report, or geologic log, was entered into a database.

DATA INTERPRETATION

Using existing file data, such as surface-water elevations and water elevations in domestic wells, to construct water-table maps requires certain assumptions.

Surface-Water Elevations

Using surface-water elevations as data points for a water-table map assumes that the surface-water bodies are accurate representations of the water table. Without detailed field investigations, it is difficult to test this assumption. Over most of the map area, this assumption seemed valid; there were a few areas where water levels in several wells were lower than nearby surface-water elevations. In those areas, the surface-water elevations were not used as data points and the water-table contours do not correspond to the surface-water elevations.

Water Levels in Wells

In order to use water elevations in domestic wells as data points for a water-table map, one must assume that vertical hydraulic gradients are negligible. This assumption is necessary because most domestic wells are open over long intervals and are completed far below the top of the saturated zone. In order to evaluate whether vertical gradients were significant, the elevation of the open interval for each well was determined. Over much of the area, wells completed at very different depths had similar water levels, however, in some areas, vertical gradients seemed significant. In those areas, the wells with shallow open intervals were assumed to provide the closest estimate of the elevation of the water-table and data from the deeper wells were not used.

The areas of significant downward hydraulic gradients are typically the recharge areas of groundwater flow systems and the areas where groundwater divides occur. As noted above, domestic wells are not ideal measuring points for determining the elevation of the water table in these areas, as a result, the final maps represent an interpretation of the existing data, not exact maps of the water-table surface.

DISCUSSION

Water-level Trends with Time

There has been interest in whether groundwater levels are being lowered due to increased pumping in the Upper Black Earth Creek Basin, particularly in the Middleton area. Over much of the watershed, a comparison of water-levels from wells drilled in the 1940's-1950's and wells drilled in the late 1980's (with similar construction) indicates little to no change over time.

In the Middleton area, it is difficult to use the existing data to adequately answer this question. The shallow wells in this area were drilled prior to significant development and so the reported water levels can provide an historic measure of groundwater levels. As Middleton has grown, individual domestic wells have become less common as homes are connected to public water supply. The newer wells in the area are thus deep public-supply wells, or high-capacity wells for industry. These deeper wells do not provide adequate measuring points for determining the elevation of the water table.

Some data suggest that groundwater levels have not yet been significantly lowered in Upper Black Earth Creek Basin. Water levels from shallow monitoring wells along the Highway 14 corridor (sections 9 & 10, Town of Middleton) indicate that the groundwater elevations are similar to nearby surface-water elevations which suggests that groundwater levels have not been significantly lowered due to pumping. In order to better assess the effects of the high capacity wells on shallow groundwater levels, water-levels should be measured in nearby shallow domestic wells that may not have been abandoned and in shallow monitoring wells in the area.

Seasonal Variations

Well constructor's reports provide water-level measurements taken at different times of the year and in different years. Using these data to produce a water-table map ignores any seasonal variations in water levels as well as any trends in water levels over time. Seasonal variations in water levels are not likely to change the configuration of the water-table maps since these variations tend to be small relative to the 20-ft contour interval that is used for the maps. Water levels in WGNHS monitoring wells near Mt. Horeb, (which is a similar hydrogeologic setting) fluctuated approximately 3 to 5 ft over a year of monitoring (Bradbury and McGrath, 1992). Similar fluctuations have been observed in DNR monitoring wells near Refuse Hideaway (HydroSearch, 1991).

LIMITATIONS OF THE MAPS

These maps depict, in a general way, the direction of shallow groundwater flow, which is assumed to be perpendicular to lines of equal potentiometric-surface 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 $\pm$0.25 mile on the maps). 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 $\pm$0.5 mile on the maps.

It was beyond the resources of this study to field-check the locations and water levels given on all of the Department of Natural Resources well constructor's reports that were used to construct these maps. These maps are a summary of available water-level data for Polk County. It is intended for use at the scale of 1:24,000 and should *not* be considered definitive for site-specific applications.

REFERENCES

Bradbury, K.R. and McGrath, R.W., 1992. *Field Study of Atrazine Contamination of Groundwater in Dane County, Wisconsin:* Final Administrative Report to Wisconsin Department of Agriculture, Trade and Consumer Protection and Wisconsin Department of Natural Resources in fulfillment of contract No. 133-P531. Wisconsin Geological and Natural History Survey, 71 p.

HydroSearch, 1991. *Ground-water Monitoring Study at the Refuse Hideaway Landfill, Middleton, Wisconsin, Volumes I & II.* Submitted to the Wisconsin Department of Natural Resources, 6/24/91.