Methods for Estimating Water-Table Elevation and Depth to Water Table

GW-04

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Contents

Introduction

This document outlines the data and methods used by the Minnesota Department of Natural Resources (DNR) to create maps for the water-table elevation and depth to water table for the County Geologic and Minnesota Hydrogeology atlases.

The water table is defined as the surface between the unsaturated and the saturated zone, where the water pressure equals atmospheric pressure. It occurs in both aquifer and nonaquifer materials across the entire state. In Minnesota, the water table is commonly within 10 to 30 feet of the land surface and generally follows the surface topography. The water table can be more than 120 feet below land surface in bluff areas that are near deeply incised river valleys such as the St. Croix, Root, Minnesota, and Mississippi river valleys. Water-table elevation varies seasonally and annually and is correlated with precipitation cycles. This data variability creates some uncertainty in the water-table elevations and depth to water table shown on these maps.

Using ArcGIS 10.2.2, a regional water-table map is created through interpolation of water-table elevation data using the Topo to Raster tool. Interpolation is used to estimate the water-table elevation between known data points using a modified spline technique.

Data Sources

The water-table elevation is estimated (interpolated) from several sources of data:

- The Natural Resources Conservation Service (NRCS) county soil survey (estimates of wet soil conditions from polygon shapefiles and associated tabular data)
- The elevation of surface water bodies (rivers, perennial streams, and lakes), and water levels in wells constructed in surficial sand aquifers
- The static water level data in wells obtained from well records in the County Well Index (CWI). CWI data contain water levels measured under various climatic conditions and over many years.
- A statewide 30-meter digital elevation model (DEM) derived using Light Detection and Ranging (LiDAR) data.

Additional information regarding data sources is available in Table 1.

Table 1: Data required to create maps for water-table elevation and depth to water table.

Data	Source Location
NRCS tabular and spatial data for soils	USDA Natural Resource Conservation Service http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Lake and river GIS files	MNDNR Hydrography • DNR Water Features https://gisdata.mn.gov/dataset/water-dnr-hydrography • Stream Routes with Stream Types https://gisdata.mn.gov/dataset/water-dnr-hydrography National Wetlands Inventory • Circular 39 Classification (2009-2014) https://gisdata.mn.gov/dataset/water-nat-wetlands-inv-2009-2014 • Circular 39 Classification (1980-1986) https://gisdata.mn.gov/dataset/water-nat-wetlands-inventory
Water-table depth measurement from wells with verified locations	County Well Index, accessed through the Minnesota Well Index web mapping application http://www.health.state.mn.us/divs/eh/cwi/
LiDAR land-surface elevation	Digital Surface Model, Minnesota (2006-2012) Statewide 30-meter digital elevation model (DEM) derived using Light Detection and Ranging (LiDAR) data, where LiDAR has been averaged to 30-meter cell size. https://gisdata.mn.gov/dataset/elev-dig-surf-model
Other possible data sources	Minnesota Biological Survey http://www.dnr.state.mn.us/eco/mcbs/maps.html Minnesota Statewide Spring Inventory (in progress) http://www.dnr.state.mn.us/waters/groundwater_section/mapping/springshed.html

Many of these sources are available through the Minnesota GeoSpatial Commons website: https://gisdata.mn.gov/.

Where sufficient well data exist, the water table within a surficial sand aquifer should be mapped using only well records. However, there are typically a limited number of wells constructed in the aquifer, thus providing few data points. Therefore, data from wells are supplemented with data from NRCS soil surveys and maps of surface water features.

Soils Data

The soils data are the most spatially complete data set. Depth-to-wet conditions (apparent water table) from the NRCS "cosoilmoist" tabular data are included in the NRCS Access database for nonperched conditions. The NRCS tabular data lists soil moisture conditions at two or three depth intervals to a depth of approximately 6.5 feet (2 meters) for each soil map unit for each month of the year. If a soil profile lists any combination of wet conditions above moist conditions, the data are interpreted to represent water that is perched. Soils with perched water table are not used in this method.

The tabular soil data are joined with the spatial data, and then the matching records are sampled at 100-meter spacing to create coverage across the county. The depth-to-wet conditions data are subtracted from the surface of the statewide 30-meter DEM derived LiDAR data, to obtain the estimated water-table elevation of the soil data.

Water Features Data

The elevations at or around surface water features are assumed to represent water-table elevations. In GIS these features are represented by polygons or polylines that are converted to points as data input for the interpolation. All counties use NRCS soil data, perennial stream centerlines, and verified locations of water-table wells from the County Well Index.

NWI data are currently the best representation of wetland features. It incorporates hydrographic features that would otherwise be added separately. The data was compiled and is available for the southern portion of the state as of October 2015 (Figure 1). For counties without updated NWI data (the northern portion), the DNR Water Features are used.

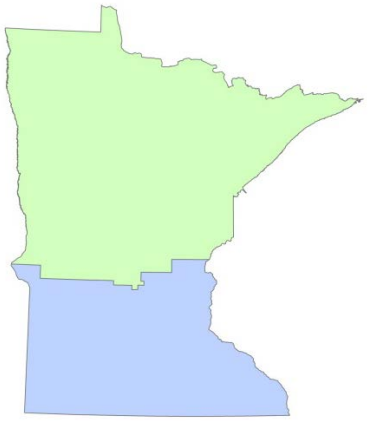

Figure 1: Counties in the northern (green) portion of this map did not have NWI data and used the DNR Water Features GIS layer. Counties in the southern (blue) portion used recent NWI data (as of October 2015).

Both are available on the Minnesota GeoSpatial Commons website: https://gisdata.mn.gov/.

For the newest information see the National Wetlands Inventory Update: http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html.

Perennial water features such as artificial basins, fish hatchery ponds, lakes, ponds, reservoirs, shallow water, and wetlands, are selected from the DNR Water Features. If a feature was less than 1 US acre, then its centroid was used to represent the water-table elevation. Features greater than 1 US acre have points assigned to the perimeter of the feature at 100-meter intervals to represent the water-table elevation. The water-table elevations are assigned from the statewide 30-meter DEM derived LiDAR data.

Features with a NWI water regime classification of C, F, G, or H are selected from NWI data for use in the water-table elevation model. If a feature was less than 1 US acre, its centroid was used to represent the water-table elevation. Features greater than 1 US acre had points assigned the perimeter of the feature at 100-meter intervals to represent the water-table elevation. Water-table elevation was assigned from the statewide 30-meter DEM derived LiDAR data.

Perennial stream data are converted to points along the centerline at 100-meter spacing, and assigned an elevation based on this statewide 30-meter DEM.

Well Data

The best source of groundwater elevation data are from wells in the surficial sand aquifer. In areas where the well density is low the water-table elevation values are controlled by streams and lake elevations and soil indicators. Query for these wells from the data file Aquifer= 'QWTA' and Swl = 'Y'.

Other Applicable Data

In some counties, additional data may be available for use. Sources may include the Minnesota Biological Survey or spring locations from the Statewide Spring Inventory (Table 1). Whichever data are selected, they must be converted into point feature classes, given elevations with the Extract Values to Points tool in ArcMap 10.2 using the statewide 30-meter DEM derived LiDAR data and saved into the geodatabase.

Estimating Water-Table Elevation and Depth to Water Table

Water-Table Elevation Model

ArcMap 10.2 is used interpolate water elevation data and create a model of the water table. All the point feature classes are merged into one file. With the exception of the soils data, all point files extend beyond the county boundary. This helps prevent artificial sinks along the boundary when running the Topo to Raster process. Point data are converted to raster using the Topo to Raster tool that interpolates all the water elevation data from the various sources and creates a model of the water-table elevation. Rasters can be directly overlain and subtracted efficiently. The raster will be clipped to the county boundary during production. For county maps the raster cell size is set to 30-meters with no drainage enforcement selected in the model. Water-table elevation values that are above the land surface are corrected, using the raster calculator, where any water-table values above the land surface elevation are set to equal the land surface elevation.

Depth to Water Table Model

The raster for Depth to Water Table is calculated by subtracting the water-table elevation raster from the statewide 30-meter DEM derived LiDAR data.

Model Limitations

On average, soil information provides 80–90 percent of data used in the water-table interpolation estimate. Surface water features provide 10 or more percent of data. Static water level measurements from water-table wells typically provide less than 1 percent of data though can be more significant in some counties. This well data could be used exclusively if there is sufficient density of water-table wells in areas of large surficial sand and gravel aquifers.

Conditions that affect the fluctuation of the water table can result in local differences from the maps created by the method described above. Some of these include, but are not limited to, seasonal variability in weather, spatial variability in the extent and composition of surficial geology units, land-use practices, vegetation composition and distribution, and temporal variability in pumping of large capacity wells. The method used to create the Minnesota maps for the water-table elevation and depth to water table therefore does not provide a synoptic view of the water table. The water-table maps provide guidance for many applications; however additional site-specific information should be used to further refine water-table information at local or regional scales.

Water-table elevation varies seasonally and annually and is correlated with precipitation cycles. Because groundwater elevation is measured during different seasons and over many years, the data reflect various climatic conditions; this data variability creates some uncertainty in the water-table elevations shown on maps.

The water table is often affected by artificial drainage; however these effects are not taken into account in the water-table elevation model process.

Surficial Geology and Surficial Aquifers

Differences in the texture of surface sediments affect the water table, where units of coarse sediment, like sand and gravel, have typically lower water-table elevations than fine grained sediments, like clay. Sediment descriptions can be confirmed by looking at the unit descriptions and cross sections provided in Part A of the County Geologic Atlas (CGA).

Geology

Minnesota's surficial geology is spatially highly variable. Large areas of karst and proximity to deep river valleys in the southeast create greater depths to water table as seen in the depth-to-water table map. South-central Minnesota is underlain by relatively thick, flat-laying fine-grained till, commonly producing shallow water-table conditions.

Geomorphological differences across a landscape may create conditions not shown in the model due to the complexity of the internal structure of features. In such cases the Part A CGA should be consulted for details such as the difference between a drumlin field or a moraine from the surrounding landscape. For example, in Todd County the water-table elevation changes between the top of drumlins and the intervening swales. This was accounted for by assuming that the water table on the top of drumlins is

ten feet below land surface. Between drumlins, wet soils and shallow lakes indicate that the water table is close to the land surface.

High Slopes: Bluffs and River Valleys

An exception to the relatively shallow water conditions throughout the state is evident along upland valley edges and terraces of incised river valleys such as the St Croix, Root, Minnesota, and Mississippi rivers and their tributaries. In these areas the depth to water table may be much greater than the estimated shallow conditions for the surrounding areas. There are also limited data along the slopes of high relief river valleys resulting in poorly constrained water-table elevations.

Link and Recommended Citation

DNR, 2016, Methods for estimating water-table elevation and depth to water table: Minnesota Department of Natural Resources, GW-04, accessible at http://files.dnr.state.mn.us/waters/groundwater_section/mapping/gw/gw04_wt.pdf

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