Water-Table Elevation and Depth to Water Table

By Roberta Adams

Minnesota Hydrogeology Atlas Series Atlas HG-03

Report

Plate 1, Water-Table Elevation

Plate 2, Depth to Water Table

St. Paul

June 2016

Minnesota Department of Natural Resources

Ecological and Water Resources Division

County Geologic Atlas Program

Contents

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Introduction

This document provides statewide water-table information to help users manage and protect groundwater resources by providing accessible, statewide groundwater data to citizens and all levels of government. Water-table information is considered in land-use programs, surface-water-infiltration planning, and construction projects. These maps provide only a general geographic context for the state. Site investigations should be supplemented with local information that satisfies the exact needs of the project.

This report describes the data sources and methods used in the creation of the maps. The maps are provided in two PDF plates and downloadable digital files. Plate 1 portrays the water-table elevation (above sea level) and Plate 2 the depth (from the land surface) to the water table. The digital data also include the surficial sand units (Figure 1) and are available for use in geographic information systems (GIS). The coverage is continuous statewide and can be used by county, by watershed, or by a specific area defined by the user.

This atlas (HG-03) is the third installment of the Minnesota Hydrogeology Atlas (MHA) series, which provides statewide groundwater information. It builds on the county groundwater atlases initially published for the County Geologic Atlas (CGA) series, updates the previous coverage, and provides new information in areas without existing atlases. This effort is part of the CGA program of the Minnesota Department of Natural Resources (DNR), Ecological and Water Resources Division.

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 geologic units across the state and generally mimics the surface topography. In Minnesota, the surfaces of lakes, streams, and wetlands commonly represent the water-table elevation because these water bodies commonly receive groundwater contributions. The limitations of this assumption are discussed in the Model Limitations section of this report. In Minnesota, the water table is commonly within 10 to 30 feet below the land surface, but can be more than 120 feet below the land surface in upland bluff areas near deeply incised river valleys such as the St. Croix, Root, Minnesota, and Mississippi river valleys.

Surficial Sand and Surficial Sand Aquifers

The textures of surficial geology units play a role in the transmission of water through these materials. Water tends to move easily in materials with larger pore spaces such as sand, making the location of surficial sand bodies important in resource management.

Aquifers form within thick surficial sand units where there is sufficient saturation below the water table. The surficial sand units are shown to indicate where a surficial sand aquifer may be present, though not all surficial sand is a surficial sand aquifer.

Surficial sand aquifers provide significant water resources and play an important role in the pollution sensitivity of deeper aquifers. High-volume groundwater pumping in surficial sand aquifers can lower water levels in adjacent surface water features. Groundwater discharges from surficial sand aquifers maintain lake levels, stream flow, and wetlands. These water bodies are the expression of the water table

at the surface and provide elevation data. The water-table elevation data can be used to identify the regional groundwater flow direction and thus identify the groundwater source areas for these surface-water bodies. Therefore, the location of surficial sand bodies can be used in conjunction with water-table data to make informed groundwater resource management decisions.

Most thick and extensive surficial sand aquifers in Minnesota are contained within sandy glacial deposits that have variable gravel, silt, or clay content depending on the depositional history of the unit. Though surficial sand deposits may not all be aquifers, there can be regional significance to these areas regarding recharge and sensitivity. Figure 1 outlines the extent of surficial sand as determined from the Minnesota Geological Survey (MGS) Geologic Mapping Database (MGS, written communication, 2015).

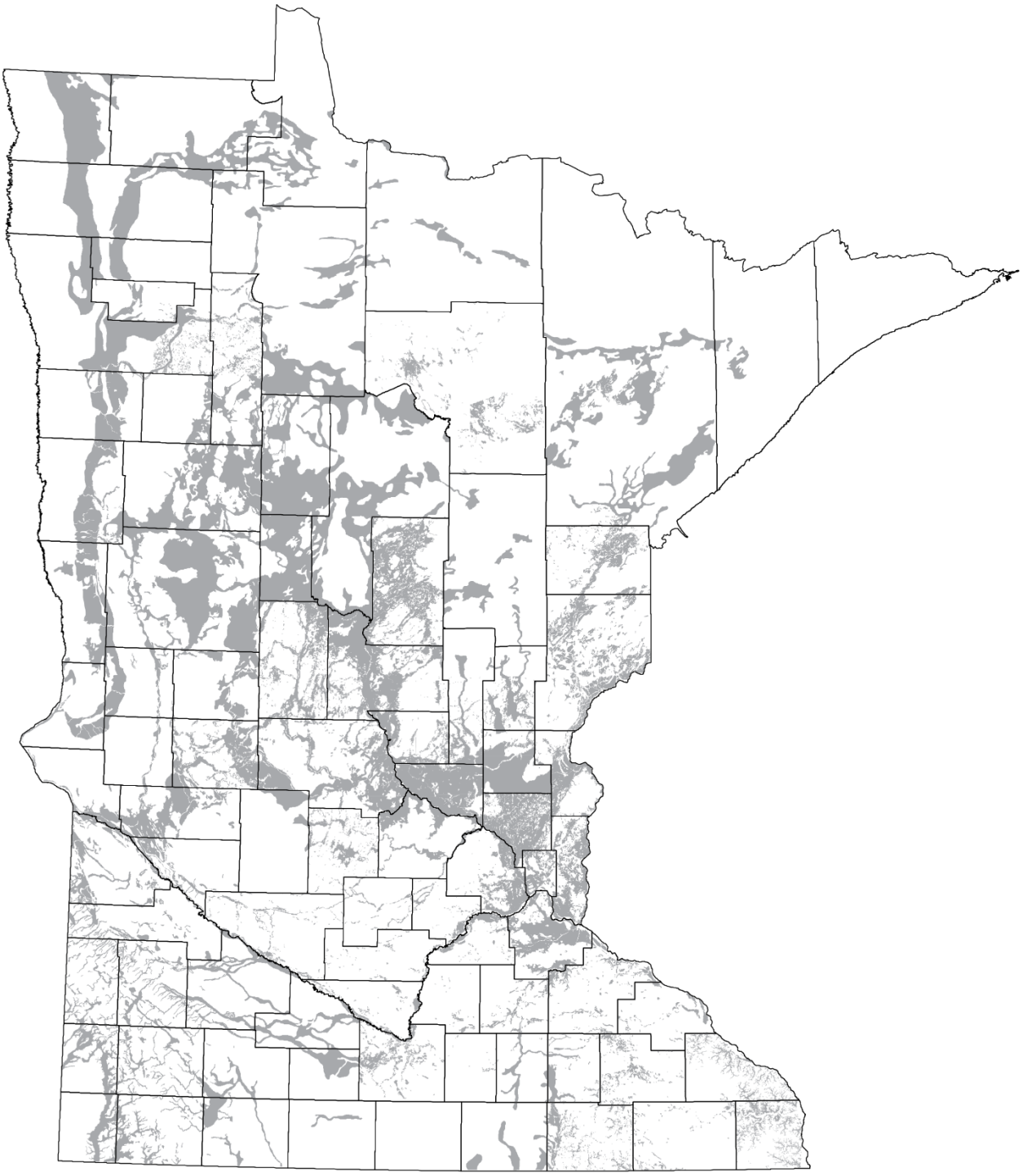

Figure 1: Surficial sand units in Minnesota

The potential extent of surficial sand, determined from geological texture of surficial units from the MGS Geologic Mapping Database (MGS, written communication, 2015). Some areas may be incomplete due to availability of geological maps. Surficial sand aquifers would be found within the surficial sand units.

Methods and Results

Where sufficient well data exist, well records should be used to map the water table within a surficial sand aquifer. However, there are typically a limited number of wells in the aquifer, thus providing few data points. The natural variability of water levels in a given year or season also means that these records do not provide enough data certainty to create a useful statewide water-table map. Therefore, well data are supplemented from Natural Resources Conservation Service (NRCS) soil surveys and surface water features.

In this method, the water-table elevation is modeled from the following sources:

Saturated soils. Soil surveys from the NRCS were used to evaluate the elevation of the water table in saturated soils. Water-table elevations that represented perched conditions were excluded.

Surface water. The water-surface elevation of rivers, perennial streams, and lakes were assembled from the statewide 30-meter digital elevation model (DEM) derived using Light Detection and Ranging (LiDAR) data. The extent of surface water bodies were derived from two sources: 1) the National Wetland Inventory (NWI) data in approximately the southern third of Minnesota and 2) the DNR Water Features GIS layer elsewhere (Figure 2).

Well data. Water levels from wells screened in surficial sand aquifers are mostly from the County Well Index (CWI) database. Most water levels in CWI are measured by the well driller when the well is installed.

Figure 2: Surface water bodies source data

The northern portion of Minnesota used DNR Water Features GIS layer because recent NWI data was not available. The southern portion of Minnesota used recent NWI data as of October 2015. See Appendix A for data sources.

The above data were combined and interpolated using the ArcGIS Topo to Raster tool (drainage enforcement is set to “no enforce”) to create a water-table elevation raster with a cell size of 60 meters. Details are available on the methodology and data sources location in the procedures document *Methods for Estimating Water-Table Elevation and Depth to Water Table, GW-04* (DNR, 2016).

The **water-table elevation** map shows the varying elevation of the water table across the state (Figure 3 and Plate 1) which generally follows the topography but is locally affected by geologic conditions. The **depth to water table** map is derived by subtracting the estimated water-table elevation from the land-surface topography using the statewide 30-meter digital elevation model (DEM) derived using Light Detection and Ranging (LiDAR) data (Figure 4 and Plate 2).

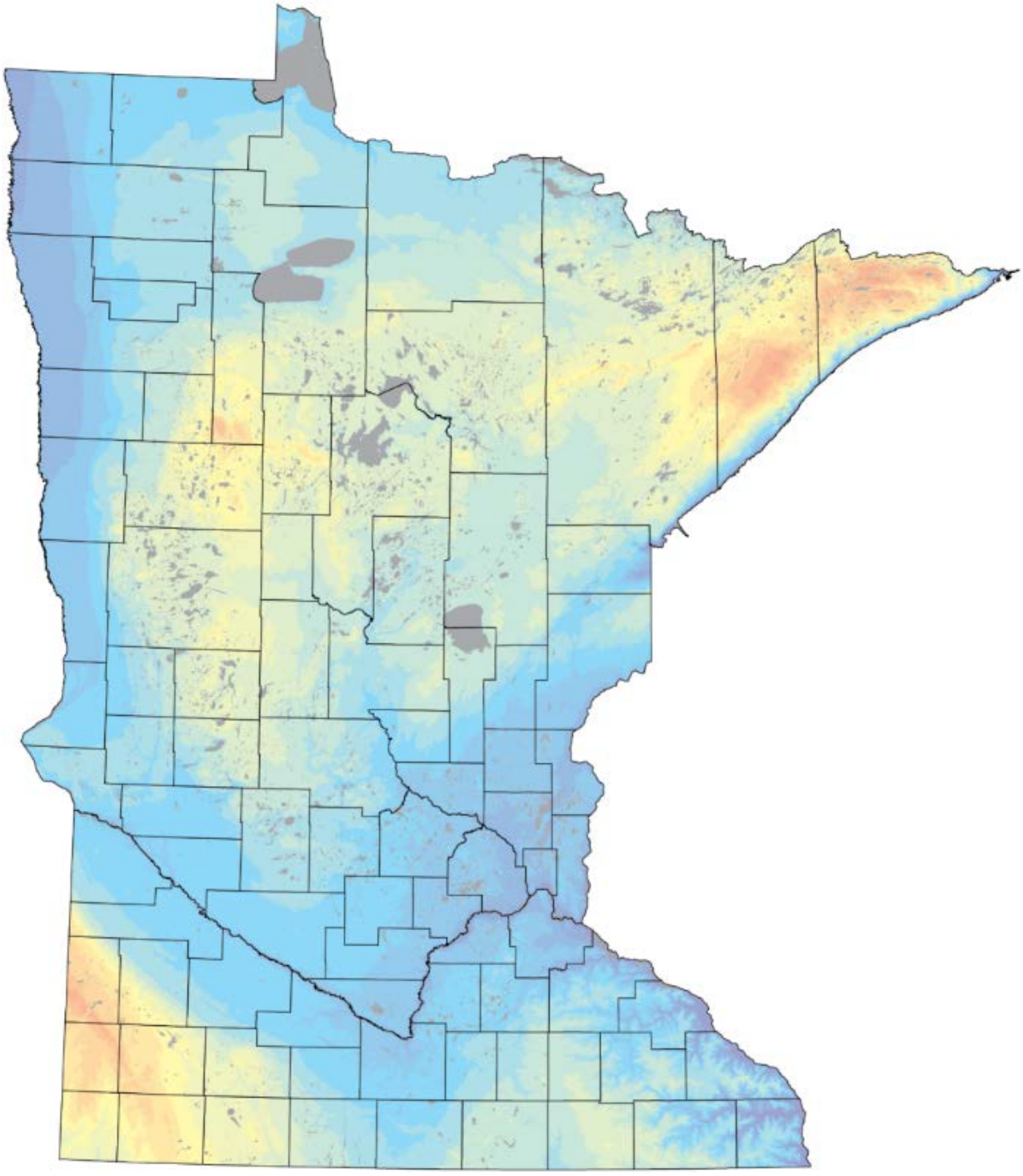

Figure 3: Estimated water-table elevation for Minnesota (preview of Plate 1)

Elevation data were assembled from several sources: water-table elevation in wet soils from the NRCS, the elevation of surface water bodies, and water levels in wells constructed in surficial sand aquifers. Water-table elevation commonly is within 10 to 30 feet of the land surface and follows the land surface topography. Lower water-table elevations are represented by dark blue and higher elevations are represented by orange. Refer to the digital data for detailed analysis.

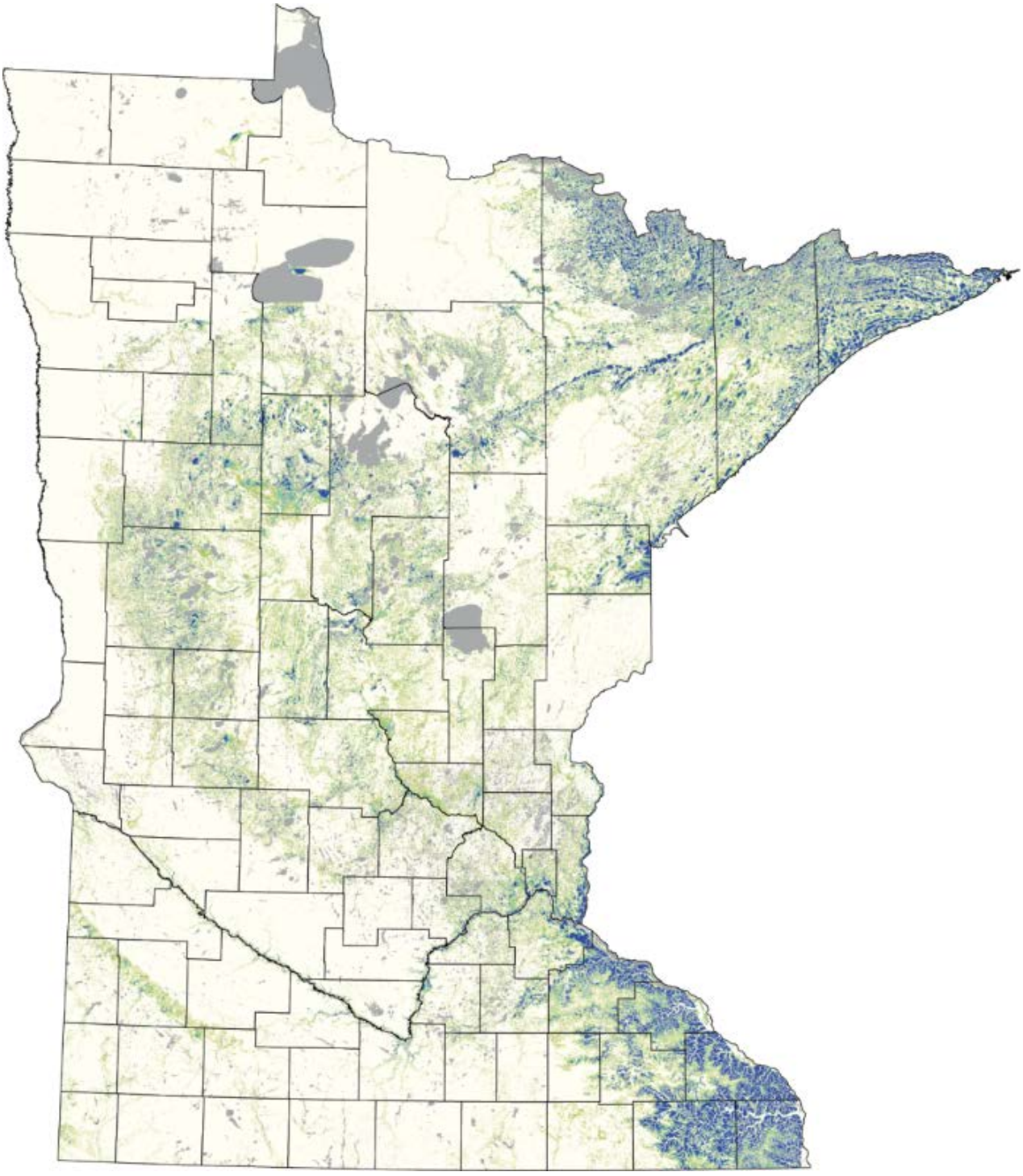

Figure 4: Estimated depth to water table for Minnesota (preview of Plate 2)

Derived by subtracting the estimated water-table elevation from the land-surface topography using the statewide 30-meter DEM derived using LiDAR data. Greater depth is represented by dark blue and lesser depth by yellow. Refer to the digital data for detailed analysis.

Model limitations

There are conditions that cause the water table to fluctuate that will result in local or temporal differences in water-table elevation. This model only represents general conditions. For site specific work, more detailed local data are required. The following factors are important in local areas but are not considered in this statewide model:

- Seasonal or long-term climate effects; short-term weather events

  The well records and other data sources used to estimate groundwater elevation were measured during many different seasons and over many years. These data do not provide a synoptic view of the water table. This creates some uncertainty in the water-table elevations. In areas of surficial sand with a dense network of wells, the water-table elevation is more accurate than in areas where well data are sparse and elevations were estimated using the other sources.

- Practices that affect recharge and drainage (e.g., tile drainage, stormwater drainage, or impervious surfaces)

  The depth to water table may be affected by artificial drainage, stormwater systems, and extensive impervious surfaces. These factors were not included in the water-table elevation modeling process.

- Unmapped details pertaining to the extent and composition of surficial units

  Water-table elevation is affected by the variability in surficial sediment thickness and texture and the nature of the buried bedrock surface. When two tills are the same thickness, the water table will be deeper in a sandy till than in a fine-grained till because of the difference in material texture. In regions of unconfined surficial sand aquifers, water moves readily through the pores in the sand and the water table reacts readily to external forces like pumping and changing climate. However, these details cannot be conveyed in this static statewide model.

- Bedrock geology and regional topography

  The southeastern part of the state has greater depths to the water than other parts of the state (Figure 5). This is an area with deeply incised rivers and thin and variable glacial sediment cover where karst features are present in the bedrock. Water-table conditions are typically deeper along other incised portions of rivers and their tributaries. Data limitations in these high relief river valleys result in poorly constrained water-table elevation and depth to water table modeling.

- Vegetation composition and distribution

  Plants seasonally remove groundwater through evapotranspiration. This occurs throughout the state, especially in wetland, forested, and agricultural areas.

- The pumping record of large-capacity wells

  The cumulative effects of irrigation and municipal systems can potentially have an effect on water-table elevation, especially seasonally and areas of extensive surficial sand layers and surficial sand aquifers.

Site-specific data should be used to further refine water-table information for local or regional scales.

Summary

The water-table elevation model of Minnesota is based on multiple data sources. Depth to water table is derived by subtracting the water-table elevation from the land-surface elevation as portrayed on the statewide 30-meter resolution DEM derived using LiDAR data. The water table is commonly within 10 to 30 feet of the land surface and mimics surface topography, except in high bluffs along deeply incised valleys where the water table can be up to 120-feet below the surface. Geologic variability and other factors make collecting additional information essential to further refine water-table information for local or regional applications.

This map is meant to supplement previous work done by the County Geologic Atlas program as well as provide valuable hydrologic information for areas not yet mapped. This statewide perspective serves as a base for protection, planning, modeling, and investigations. It should be used in conjunction with more detailed geologic and hydrogeologic information when conducting site-specific investigations.

References

County Well Index, 2016, Database created and maintained by the Minnesota Geological Survey, a department of the University of Minnesota, with the assistance of the Minnesota Department of Health.

DNR, 2015, National Wetlands Inventory Update: Minnesota Department of Natural Resources, accessed April 2015 at <http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html>.

DNR, 2016, Methods for Estimating Water-Table Elevation and Depth to Water Table, GW-04: Minnesota Department of Natural Resources, accessed April 2016 at <http://files.dnr.state.mn.us/waters/groundwater_section/mapping/gw/gw04_wt.pdf>.

ESRI, 2014, ArcGIS Help Resource Center: accessed April 2015 at <http://resources.arcgis.com/EN/HELP/MAIN/10.2/index.html#//009z0000007m000000>.

Glossary

aquifer—an underground layer of water-bearing permeable rock or unconsolidated materials (gravel and sand) from which groundwater can be extracted using a water well.

bedrock—the consolidated rock underlying unconsolidated surface materials such as soil or glacial sediment.

County Well Index (CWI)—a database developed and maintained by the Minnesota Department of Health and Minnesota Geological Survey containing basic information, such as location, depth, and static water level, for wells drilled in Minnesota. The database contains construction and geological information from the well record (well log) for many wells.

discharge—the process by which water leaves the groundwater system.

groundwater—water that collects or flows beneath the earth's surface, filling the porous spaces in soil, sediment, and rocks.

hydrogeology—the study of subsurface water, including its physical and chemical properties, geologic environment, role in geologic processes, natural movement, recovery, contamination, and utilization.

infiltration—the movement of water from the surface of the land into the subsurface under unsaturated conditions in the vadose zone.

karst— a terrain with distinctive landforms and hydrology created primarily from the dissolution of soluble rocks. It is characterized by sinkholes, caves, springs, and underground drainage dominated by rapid conduit flow.

drainage enforcement—the process of removing all sink points in the output DEM that have not been identified as sinks in the input sink feature dataset. The drainage enforcement algorithm attempts to clear spurious sinks by modifying the DEM, inferring drainage lines via the lowest saddle point in the drainage area surrounding each spurious sink. The drainage enforcement can be turned off and the clearing process is ignored.

perched water table—when groundwater forms a lens of saturation within the unsaturated zone above the water table due to an impermeable soil or geologic unit.

recharge—the process by which water enters the groundwater system.

till—unsorted glacial sediment derived from the subglacial erosion and entrainment of rock and sediment over which the glacier has passed and deposited directly by ice. It is no longer till if it has been modified or redeposited.

unconfined—refers to an aquifer which has a water table and implies direct contact of the water table with the atmosphere through an unsaturated layer.

water table—the surface between the unsaturated and saturated zone; where water pressure equals atmospheric pressure.

Appendix A: Spatial Data

Spatial data available for HG-03

The file geodatabase contains the statewide feature class of the water-table elevation and depth to water table, as well as surficial sand overlay. The link to the geodatabase and metadata can be found on the HG-03 page:

http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_wte.html.

Sources for spatial data used in creating water-table maps

Statewide 30-meter DEM derived using LiDAR data
https://gisdata.mn.gov/dataset/elev-dig-surf-model

National Resources Conservation Service soil data
http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

County Well Index
http://mdh-agua.health.state.mn.us/cwi/cwiViewer.htm

National Wetland Inventory
https://gisdata.mn.gov/dataset/water-nat-wetlands-inv-2009-2014
Status of upcoming counties: http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html

DNR water features, DNR 24k perennial stream centerlines, and DNR 24k lakes and open water
https://gisdata.mn.gov/dataset/water-dnr-hydrography

Appendix B: Previous Available Water-Table Maps

Table 1: Atlas History

This table describes the water-table data available for previously published atlases. County Geologic Atlases not included in this table are either in process at time of publication or have not been completed. Future atlases will include water-table elevation and depth to water table maps, and associated spatial data.

More information can be found at:
http://www.dnr.state.mn.us/waters/groundwater_section/mapping/status.html.

CGA #	County	Water-Table Elevation Map	Depth to Water Table Map	Spatial Data
C-03	Olmsted	N/A	N/A	N/A
C-04	Hennepin	N/A	N/A	N/A
C-05	Washington	N/A	N/A	N/A
C-06	Dakota	N/A	N/A	N/A
C-07	Ramsey	N/A	N/A	N/A
C-08	Fillmore	N/A	N/A	N/A
C-09	Rice	Yes		Elevation
C-10	Stearns	N/A	N/A	Elevation
C-11	Mower	N/A	N/A	No data
C-12	Goodhue		Yes	Depth
C-13	Pine	N/A	N/A	No data
C-14	Wabasha		Yes	Both elevation and depth
C-15	Pope	Yes	Yes	Both elevation and depth
C-16	Crow Wing	N/A	N/A	Both elevation and depth
C-17	Scott	No Part B, some data available from MGS		
C-18	Todd	Yes		Elevation
C-19	Carlton	Yes	Yes	Both elevation and depth
C-20	McLeod	Yes		Elevation
C-21	Carver	Yes		Elevation
C-22	Chisago	Yes		Both elevation and depth
C-23	Benton	Yes		Elevation
C-26	Blue Earth	Yes	Yes	Both elevation and depth

Appendix C: Technical Reference

Maps

Maps were compiled and generated in a geographic information system (GIS). Digital data products are available from the Department of Natural Resources (DNR), Ecological and Water Resources Division.

Maps were prepared from DNR and other publicly available information. Every reasonable effort has been made to ensure the accuracy of the factual data on which the report and map interpretations were based. However, the DNR does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information; sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Every effort has been made to ensure the interpretations conform to sound hydrogeologic and cartographic principles. These maps should not be used to establish legal title, boundaries, locations of improvements, or other site-specific decisions.

Universal Transverse Mercator projection, zone 15N, North American Datum of 1983. North American Vertical Datum of 1988. GIS and cartography by Roberta Adams and Holly Johnson. Edited by Carrie Jennings and Ruth MacDonald.

Conversion Factors

1 foot = 0.3048 meters

Link

This report, Plates 1 and 2, the GIS files, and the metadata can be downloaded from:
http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_wte.html.

Recommended citation

Adams, R., 2016, Water-table elevation and depth to water table: Minnesota Department of Natural Resources, Minnesota Hydrogeology Atlas Series HG-03, report and 2 plates, accessible at http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_wte.html.

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Acknowledgements

I'd like to thank the following people for their comments on this report and contributions from staff of the County Geologic Atlas program of the Minnesota Department of Natural Resources (DNR), Ecological and Water Resources Division: Jim Berg, Todd Petersen, Jan Falteisek, Ruth MacDonald, Carrie Jennings, Holly Johnson, John Barry, and Steve Thompson.

Funding for this project was provided by the
Minnesota Environment and Natural Resources Trust Fund
and the Clean Water Fund.

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This information is available in alternative format on request.