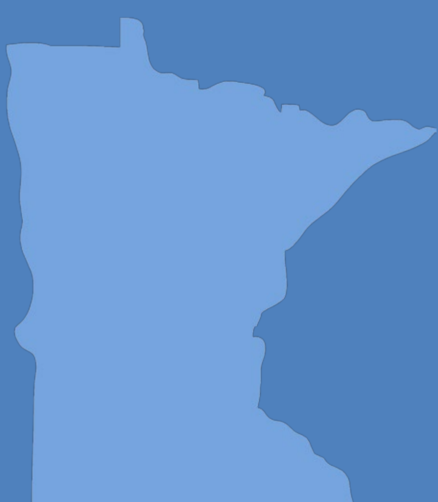
Groundwater Report
Rum River Watershed



Minnesota Pollution Control Agency

November 2016

Authors

Sophia Vaughan

Editing

David Duffey
Andrew Streitz

The MPCA is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audience. Visit our website for more information.

MPCA reports are printed on 100% post-consumer recycled content paper manufactured without chlorine or chlorine derivatives.

Support

Project dollars provided by the Clean Water Fund; from the Clean Water, Land and Legacy Amendment.

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: wq-ws1-11

Contents

Figures

I. Introduction

Groundwater reviews are detailed reports on the condition of groundwater within the boundaries of one of the 81 major surface watersheds in Minnesota. This approach follows the Minnesota Pollution Control Agency's (MPCA) focus on watersheds as the starting point for water quality assessment, planning, implementation and measurement of the watershed's condition. Though groundwater and surface watersheds do not always coincide, this method of investigating the condition of the hydrologic resource as a watershed unit can be usefully applied to groundwater because groundwater and surface water are dynamically linked. This linkage will be explored and explained in this report through the use of the water cycle, tracing the movement of water through the watershed from precipitation to runoff, recharge to withdrawal, and to conclude with evapotranspiration (Figure 1).

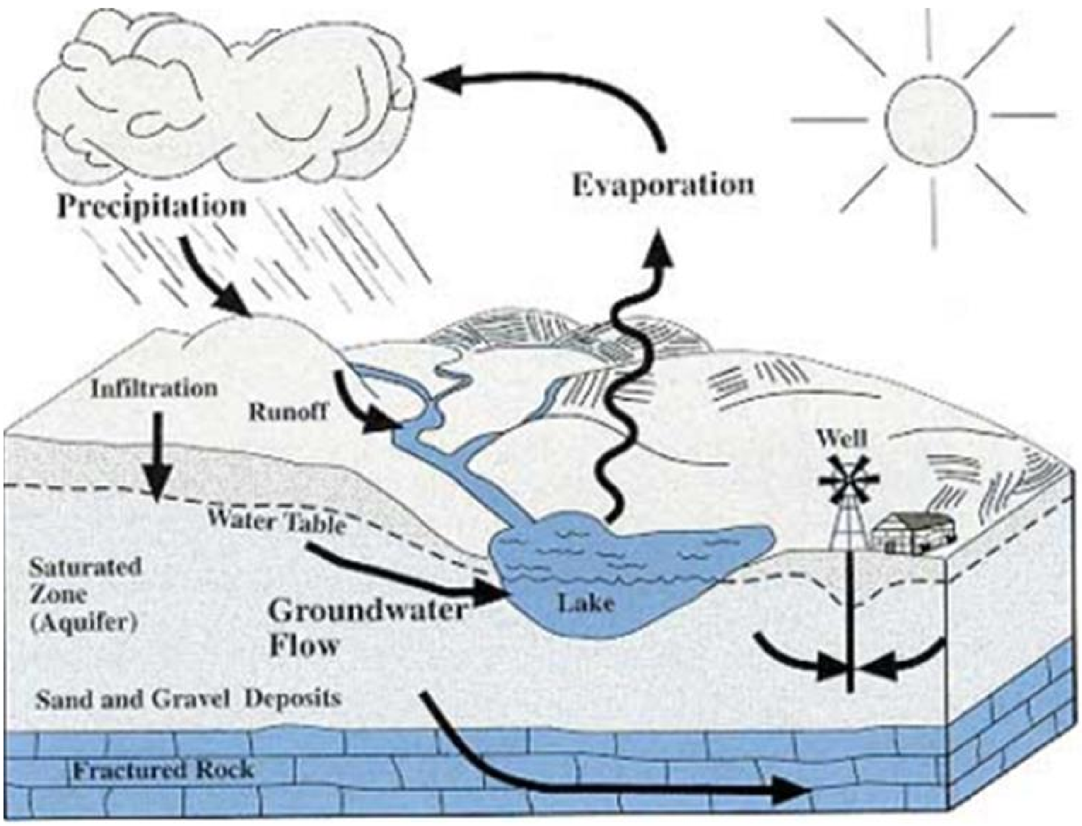


Figure 1: Simplified hydrologic cycle demonstrating the changing states of water above and below the earth's surface

The groundwater reports rely on the analysis of a wide spectrum of hydrologic datasets to provide context for the understanding of groundwater within the hydrologic cycle. The datasets analyzed include precipitation, streamflow, permitted high volume pumping, lake and groundwater elevations, evapotranspiration estimates, water quality samples, contaminant releases, estimates of recharge to surficial aquifers, and hydrogeological maps from local geological atlases.

The watershed monitoring approach

The watershed monitoring approach was adopted by the MPCA as a means to intensively monitor and assess the condition of Minnesota's lakes and streams at a watershed level. This was in compliance with the responsibility of the agency to the Clean Water Legacy Act to "protect, restore and preserve the quality of Minnesota's surface waters" (MPCA, 2009). The approach focused efforts on eight-digit hydrologic unit code (HUC) watersheds during a ten-year cycle for all 81 major watersheds in Minnesota.

The Minnesota Department of Natural Resources (MNDNR), (MNDNR, 2015a) defines surface water and groundwater watersheds as follows:

Surface water watersheds are generally delineated from topographic maps based on land elevations ("height-of-land" method). The MNDNR completed a standard delineation of minor watershed boundaries for Minnesota in 1979. Using U.S. Geological Survey (USGS) quadrangle maps, the MNDNR defined minor watershed outlets and delineated height-of-land minor watershed boundaries for all watersheds greater than five square miles. However, actual boundaries may be different due to map interpretation assumptions or human-induced changes that have occurred since the map was made. Field inspection of areas in question is required to be certain of actual boundaries.

Groundwater watersheds are conceptually similar to surface water watersheds because groundwater flows from high points (divides) to low points (outlets, discharge areas). However, the boundaries of surface water and groundwater watersheds do not always coincide. Groundwater movement occurs in below ground aquifer systems and is subject to 1) hydraulic properties of the aquifer, 2) input to (recharge) and outflow from (discharge) the aquifer system, and 3) geological factors such as formations that block the flow of water and tilted formations that create a flow gradient. Surficial aquifers (the water table) generally mimic surface water watersheds, and their flow usually does not cross surface boundaries. Deeper (confined) aquifers, on the other hand, are less likely to conform to surface features and exhibit watersheds (or basins) determined by geologic factors. As described in the MNDNR website: http://www.dnr.state.mn.us/watersheds/surface_ground.html. For the purposes of this report, groundwater watersheds will be treated as contiguous with surface water watersheds.

Watershed overview

The Rum River Watershed (HUC 07010207) is located in the eastern edge of the Upper Mississippi River Basin, in east central Minnesota. The watershed is a moderately agricultural region within the Northern Lakes and Forests Ecoregion and North Central Hardwoods Forest Ecoregion, draining an area of 1,558 square miles (Figure 2). The Rum River Watershed includes parts of Aitkin (12.7%), Crow Wing (3.4%), Morrison (6.4%), Mille Lacs (36.1%), Kanabec (1.2%), Benton (2.3%), Isanti (23.8%), Chisago (0.3%), Sherburne (3.1%), and Anoka (10.7%) counties (U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The watershed's surface waters include 212 lakes (over 10 acres) and 233 streams segments, or assessment units (AUIDs), throughout the watershed. From its source at Mille Lacs Lake, the Rum River runs south for a total length of 145 miles and confluences with the Mississippi River at Anoka. The watershed elevation ranges from approximately 800 to 1400 feet above sea level, decreasing from north to south (Figure 3).

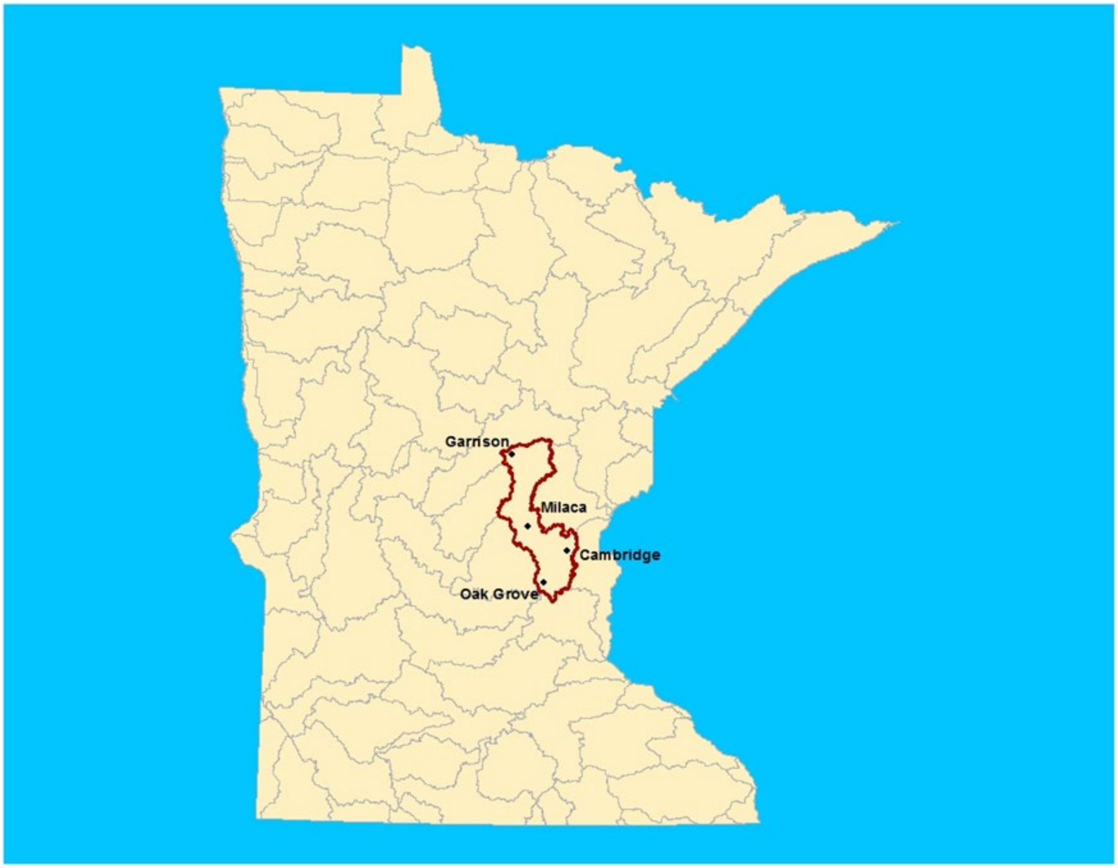


Figure 2: The location of the Rum River Watershed

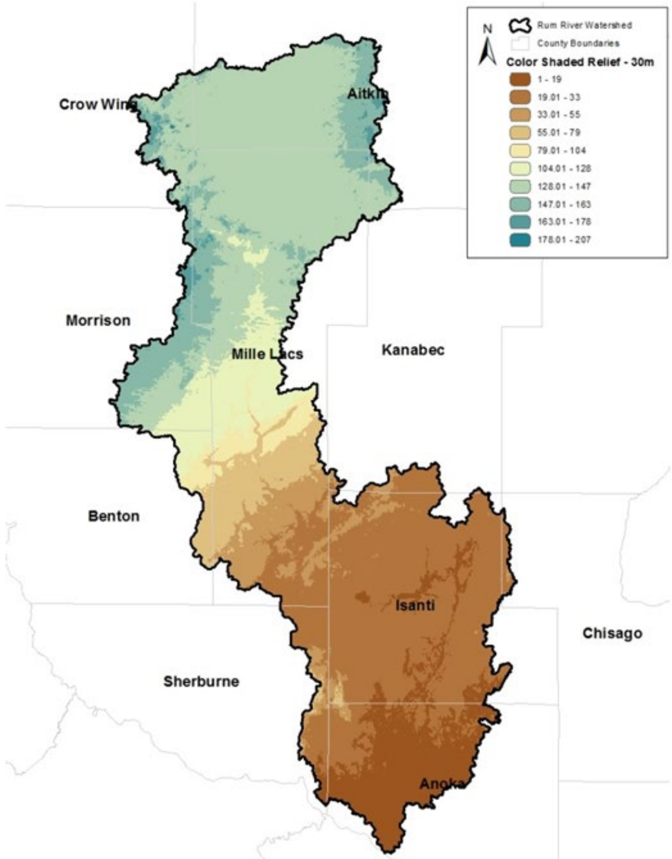


Figure 3: Rum River 8-HUC watershed relief (GIS Source: MNDNR)

Land use

The land is moderately agricultural with 38% utilized for cropland and pasture (USDA, NRCS). The land is owned predominately by private owners (90.6%), while the remaining land is county (0.1%), state (6.5%), other public (0.5%), Tribal (0.2%) and private major (2.0%) (USDA, NRCS). Other land use and cover includes: forest (30.6%), wetlands (10.6%), open water (14.8%), grass/pasture/hay (20.4%), cropland (18.1%) and residential/commercial development (5.3%) (Figure 4) (USDA, NRCS). The total population count of the watershed is 110,366 with an estimated 2,153 farms (USDA, NRCS).

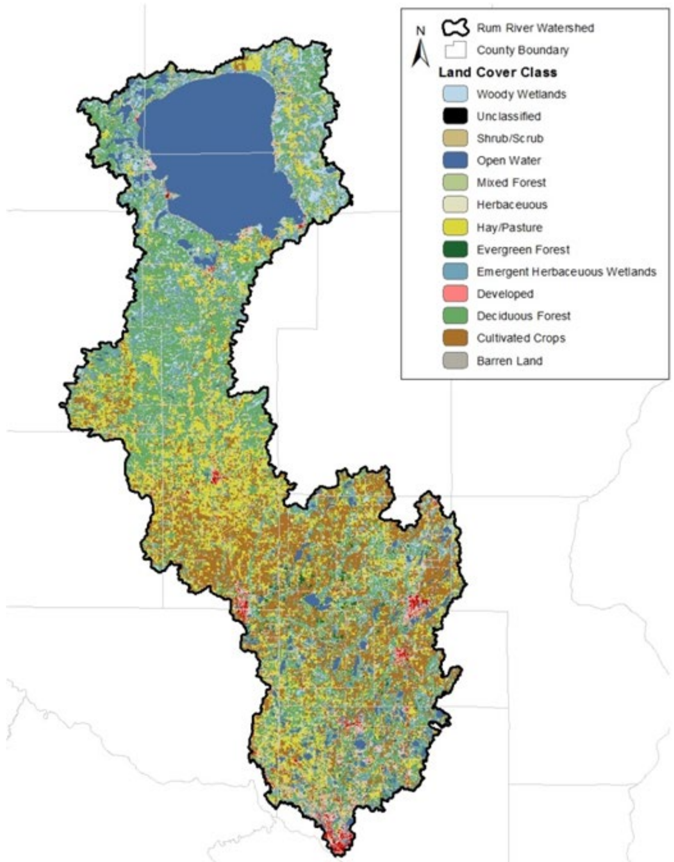


Figure 4: Land cover in the Rum River Watershed (GIS Source: NLCD, 2011)

Ecoregion and soils

The watershed is located within the Northern Lakes and Forests Ecoregion and the North Central Hardwoods Forest Ecoregion. According to the Ecological Classification System (ECS), the Rum River Watershed is located within the Laurentian Mixed Forest Province and the Eastern Broadleaf Forest Province, the Western Superior Uplands Section and the Minnesota and Northeast Iowa Morainal Section. The watershed also lays within the ECS subsections Mille Lacs Uplands (central and north) and the Anoka Sand Plain (south) Subsections (Figure 5).

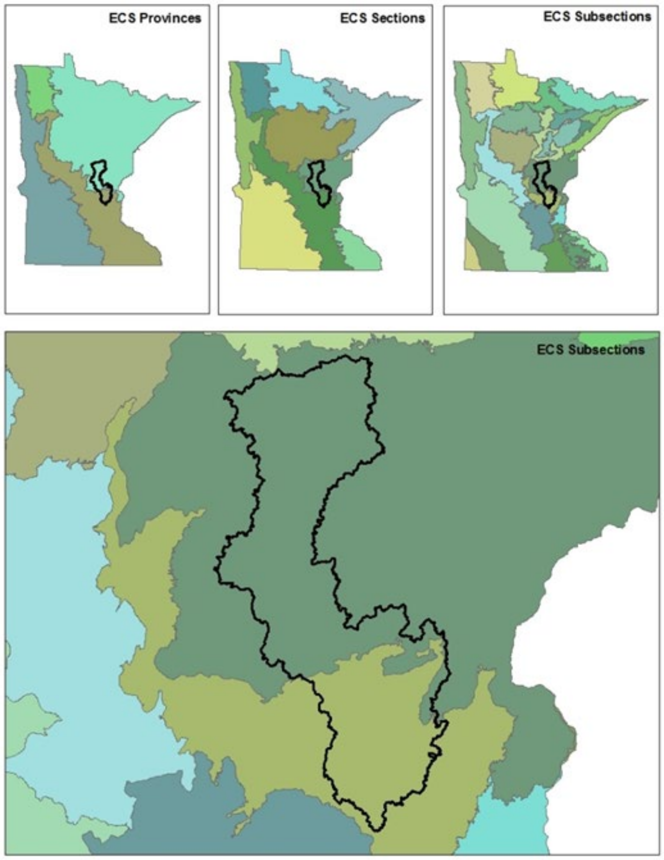


Figure 5: Three levels of Ecological Classification System for the Rum River Watershed

The watershed is comprised of siliceous glacial deposits associated with the Superior Lobe in the north watershed and calcareous glacial deposits associated with the Des Moines Lobe in the south. The agroecosystem is comprised of drumlins and steep poorly drained moraines in the central and northern reaches of the watershed. The southern portion of the watershed is comprised of central till, Anoka sand plains, steep wetter moraines and some alluvium and outwash. Soils in the upper watershed are primarily alfisols mixed with histosols, while those in the lower watershed are primarily entisols (USDA, NRCS). Alfisols are formed from weathering processes under forests or mixed vegetation that contributes to high clay content; making them fertile with a high moisture holding capacity. Histosols are thick, organic-rich soils are associated with wetlands and are often referred to as peats and mucks. Entisols are relatively young soils that are developed from unconsolidated parent material, often found in steep, rocky settings, such as areas where deposition is greater than soil development. A more detailed list of the soil types can be found in Figure 6 (below).

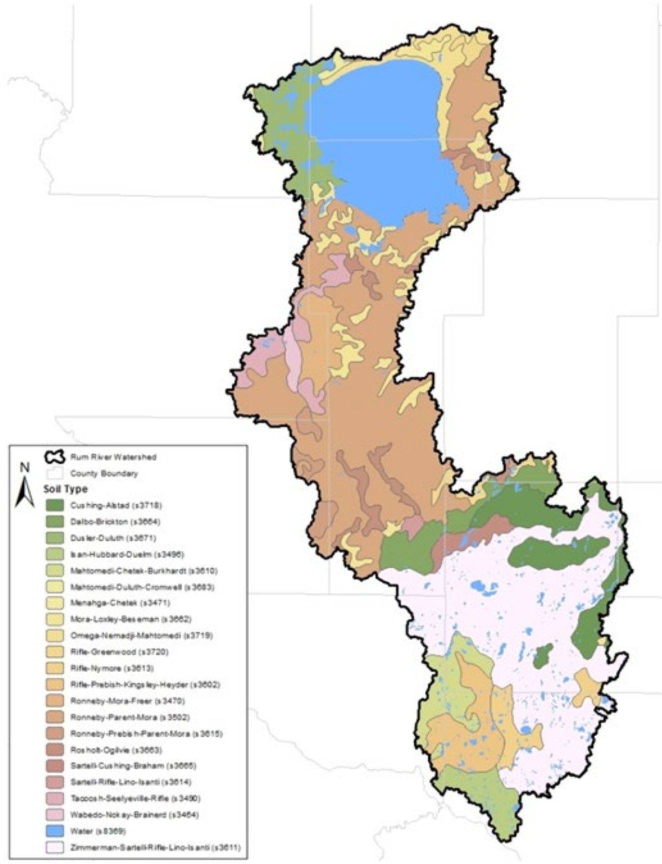


Figure 6: Soil classification for the Rum River Watershed (GIS Source: USDA NRCS, 2006)

II. Climate and precipitation

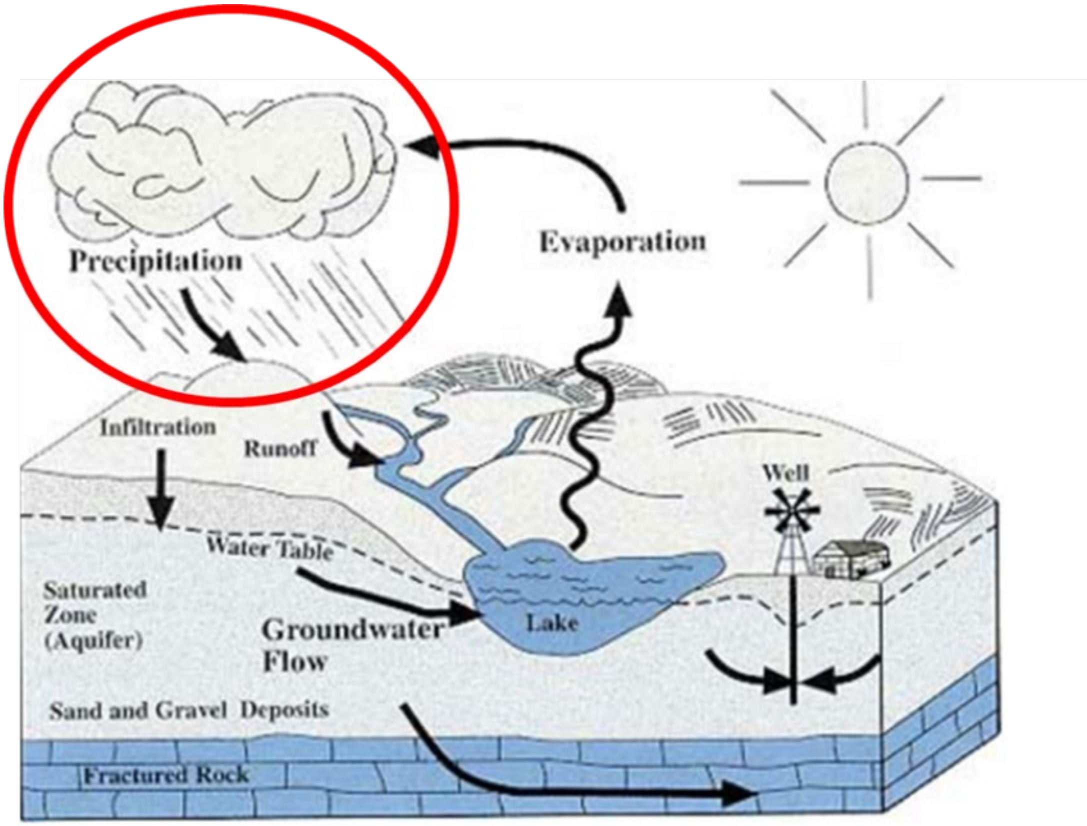


Figure 7: Precipitation within the hydrologic cycle

Minnesota has a continental climate, marked by warm summers and cold winters. The mean annual temperature for Minnesota is 4.6˚C National Oceanic and Atmospheric Administration, 2016); the mean summer temperature for the Rum River Watershed is 18.3˚C and the mean winter temperature is -11.1˚ C (MNDNR: Minnesota State Climatology Office, 2003).

Precipitation is an important source of water input to a watershed. Figure 8 shows two representations of precipitation for calendar year 2014. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the eastern portion of the state. According to this figure, the Rum River Watershed area primarily received 36 to 40 inches of precipitation in 2014. The display on the right shows the amount those precipitation levels departed from normal. For the Rum River Watershed, the map shows that precipitation ranged from four to ten inches above normal.

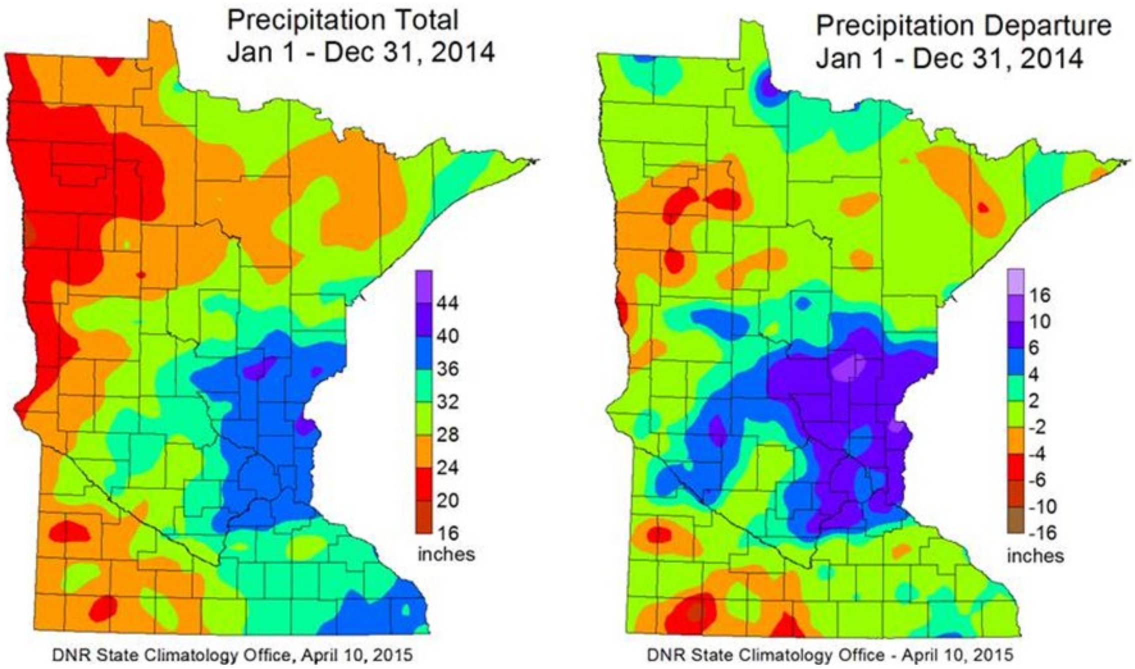


Figure 8: Statewide precipitation levels during 2014 (Source: MNDNR State Climatology Office, 2015)

The Rum River Watershed is located in the East Central precipitation region. Figure 9 and 10 (below) display the areal average representation of precipitation in East Central Minnesota for 20 and 100 years, respectively. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. Though rainfall can vary in intensity and time of year, rainfall totals in the east central region display no significant trend over the last 20 years. However, precipitation in East Central Minnesota exhibits a significant rising trend over the past 100 years (p=0.001). This is a strong trend and matches similar trends throughout Minnesota.

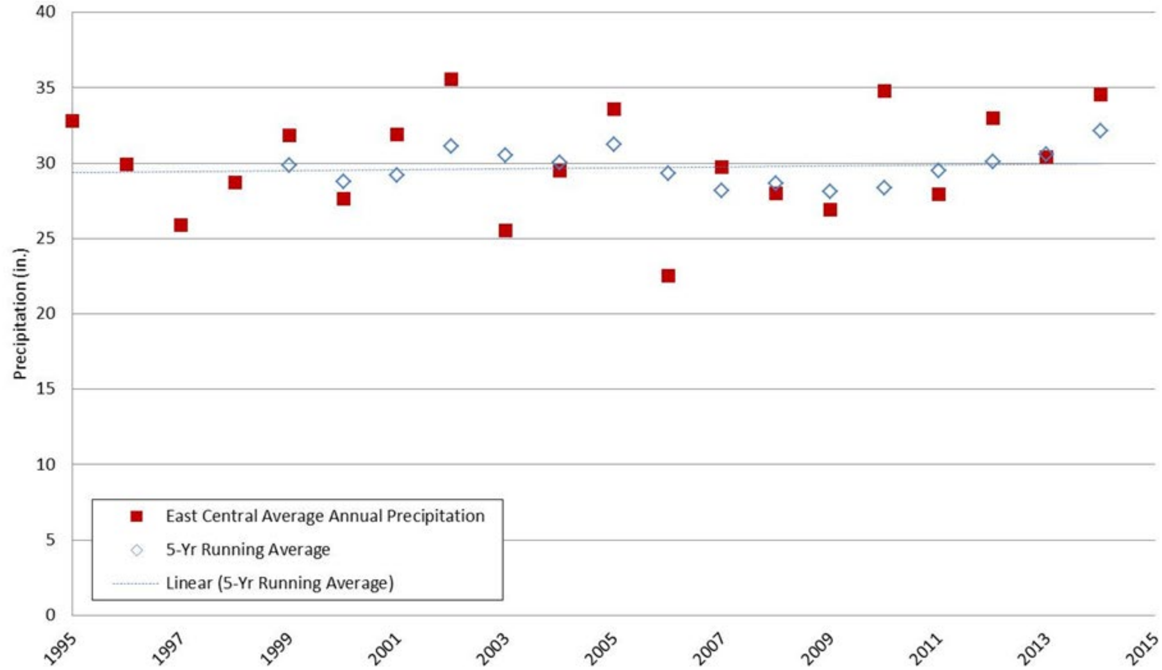


Figure 9: Precipitation trends in East Central Minnesota (1955-2014) with five-year running average

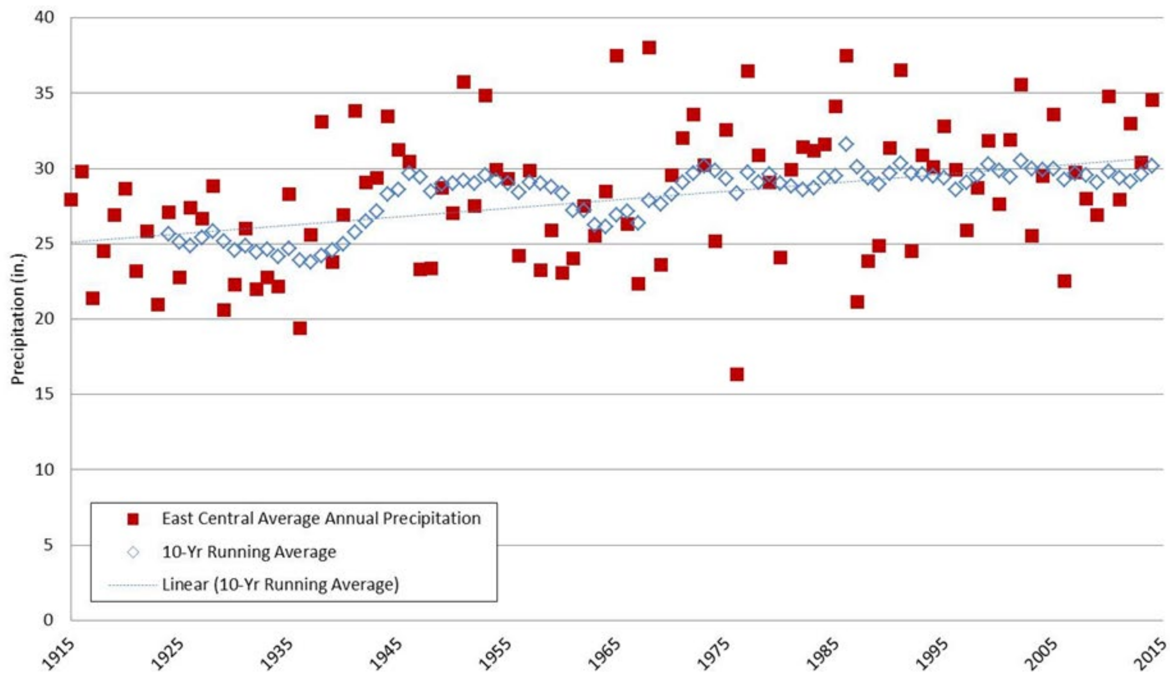


Figure 10: Precipitation trends in East Central Minnesota (1915-2014) with 10-year running average

III. Surface water hydrology

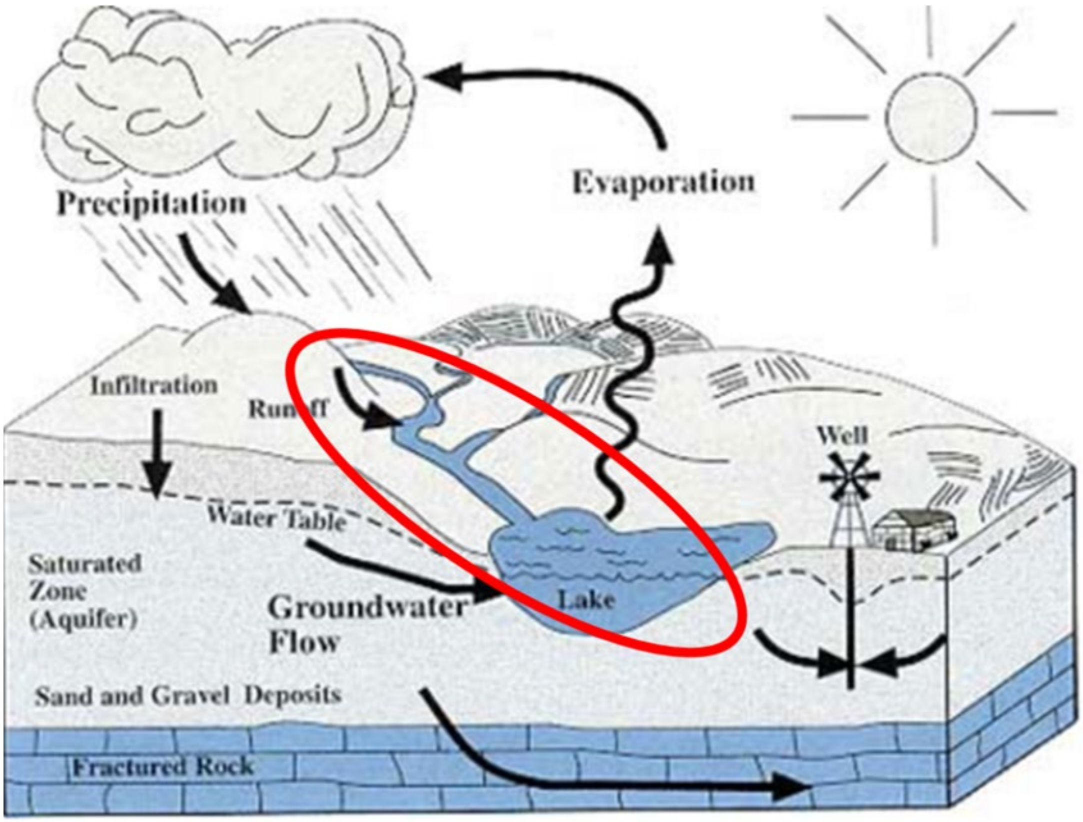


Figure 11: Surface water within the hydrologic cycle

The Rum River Watershed's surface hydrology is comprised of open water (14.8%) and wetlands (10.6%). The watershed has 212 lakes over 10 acres in size, 1,656 stream miles, and 9,912 acres of wetlands (Figure 12) (USDA, NRCS). Its namesake river begins at Mille Lacs Lake, and travels 145 miles south before joining Mississippi River at Anoka (MPCA, 2015a). Other major rivers and creeks in the watershed include Bogus Brook and Mike Drew Brook and major lakes include Mille Lacs, Onamia, and Borden (MPCA, 2015a).

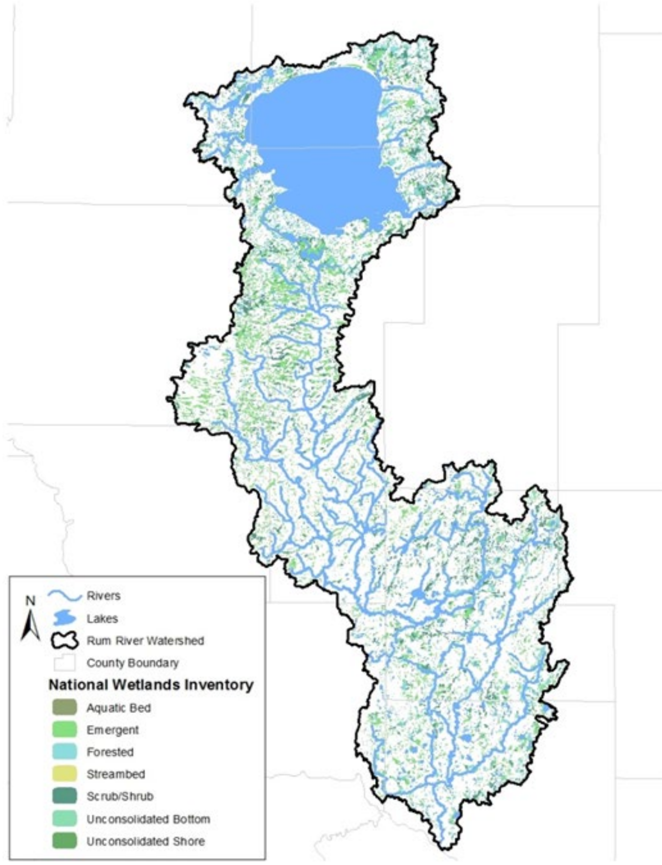


Figure 12: Lakes, wetlands and waterbodies in the Rum River Watershed

Streamflow

Stream flow data from the United States Geological Survey's (USGS) real-time streamflow gaging stations for one river in the Rum River Watershed was analyzed for annual mean discharge and summer monthly mean discharge (July and August). Figure 13 is a display of the annual mean discharge for the Rum River near St. Francis, Minnesota from water years 1995 to 2014. The data shows that although streamflow appears to be slightly increasing, there is no statistically significant trend. Figure 14 displays July and August mean flows for the same time frame, for the same water body. Graphically, the data appears to be increasing in July and August, but neither at a statistically significant rate. By way of comparison at a state level, summer month flows have declined at a statistically significant rate at a majority of streams selected randomly for a study of statewide trends (Streitz, 2011). For additional streamflow data throughout Minnesota, please visit the USGS website: http://waterdata.usgs.gov/mn/nwis/rt.

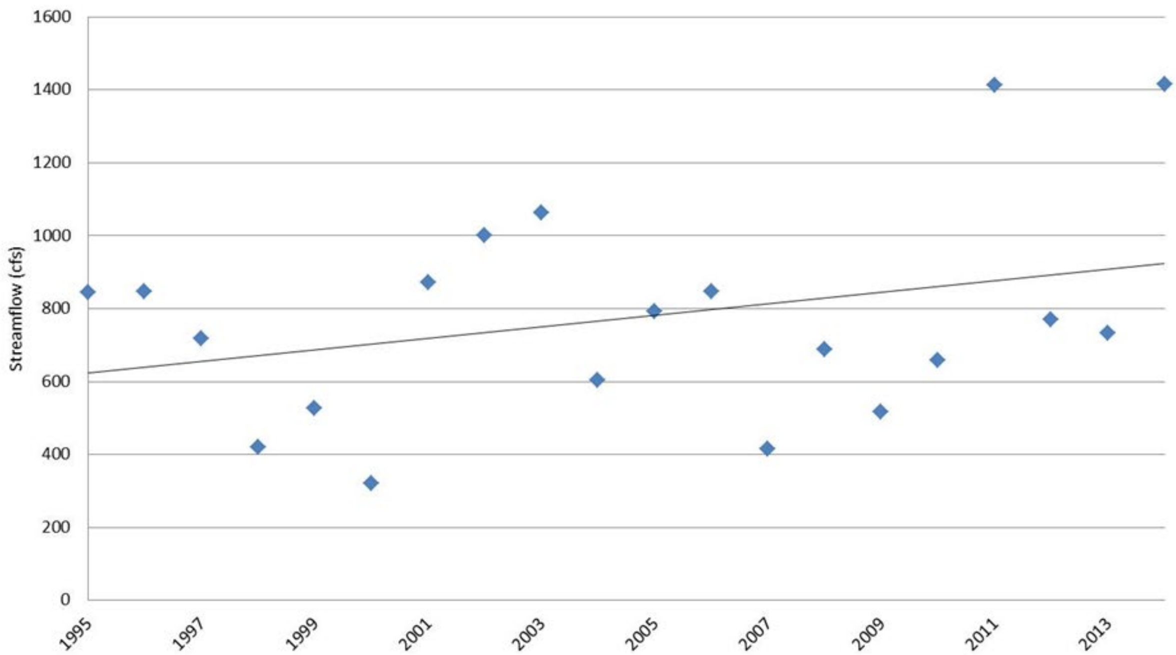


Figure 13: Annual mean discharge for Rum River near St. Francis, Minnesota (1955-2014)

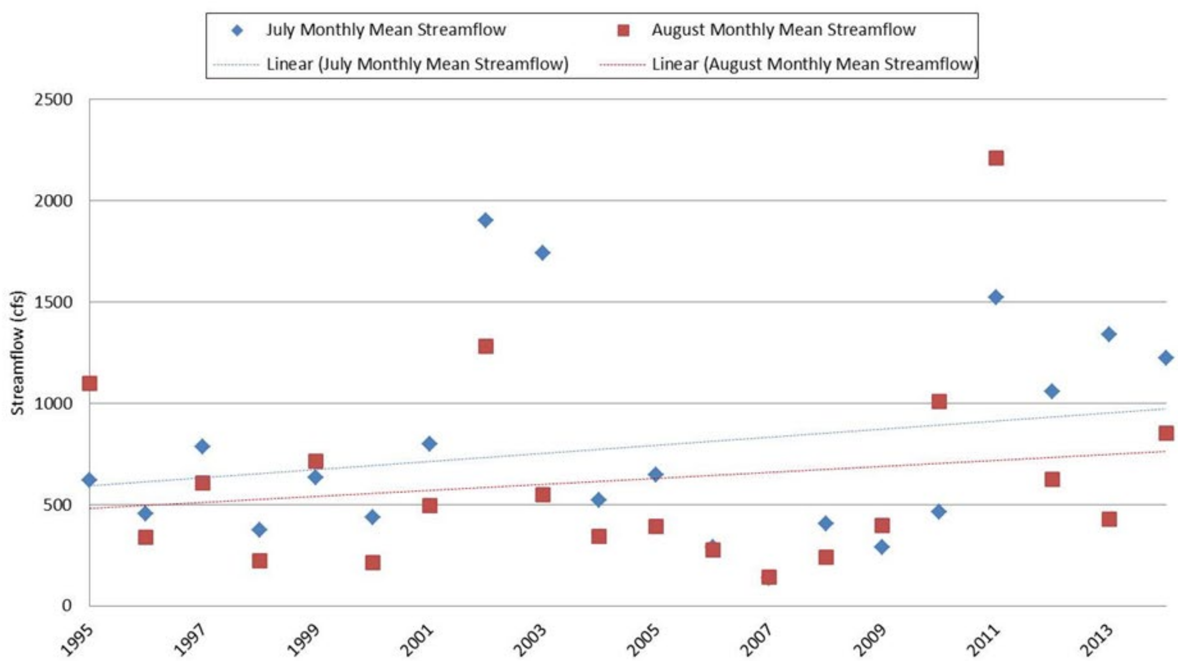


Figure 14: Mean monthly discharge for Rum River near St. Francis, Minnesota (1955-2014)

Lake levels

Shakopee Lake (Inventory Number 48001200) in Mille Lacs County is located near Onamia in the northern area of the watershed (Figure 15). The surface area of the lake is 635 acres with a maximum depth of 15 feet and an average lake water elevation of 1,248.7 feet (MPCA, 2015b). The lake's use classification is 2B, 3C, which is defined as a healthy warm water aquatic community; industrial cooling and materials transport use without a high level of treatment. The overall condition is described as "concentrations of mercury in fish tissue exceed the water quality standard" (MPCA, 2015b).

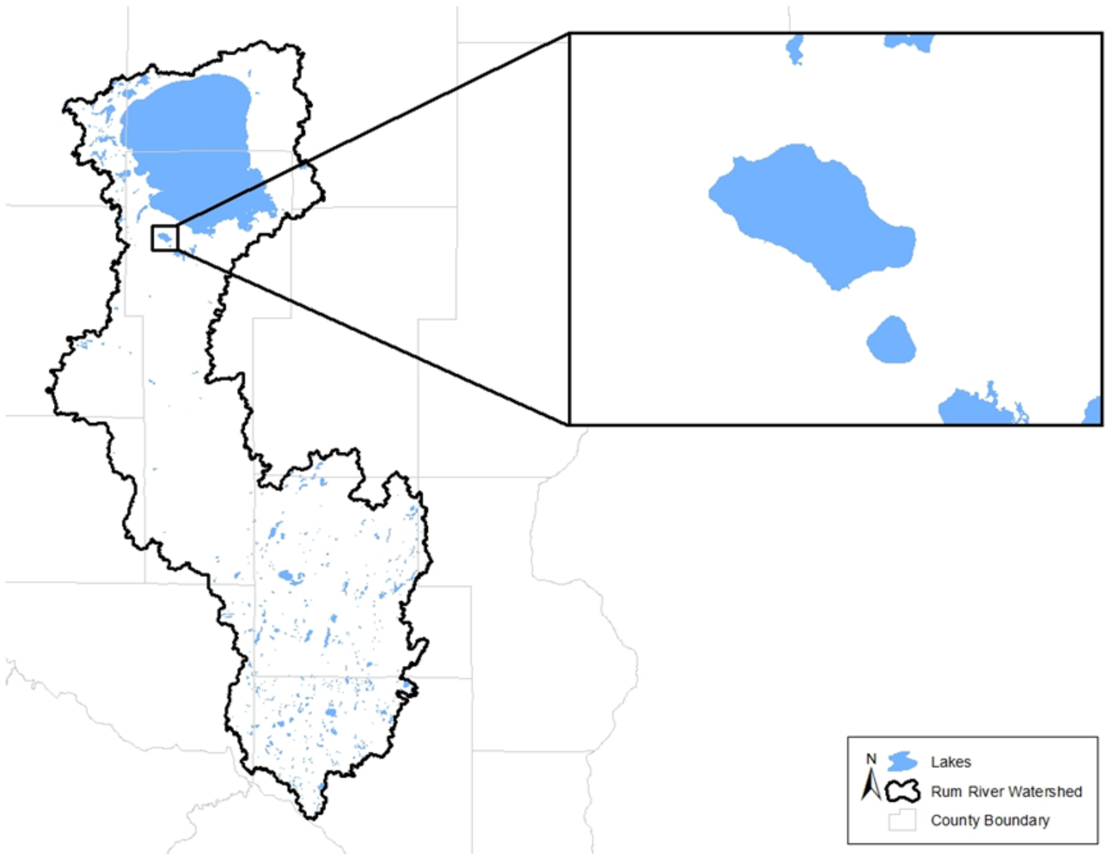


Figure 15: Shakopee Lake within Rum River Watershed

A 2013 survey by the MNDNR determined the dominant bottom substrate of the lake to be sand. The shallow lake has 49 varieties of aquatic plants with dense beds of submergent vegetation, to include flatstem pondweed, northern watermilfoil, coontail, and large-leaved pondweed (MNDNR, 2015b). The average water clarity is 5.5 feet, ranging from 5 to 6 feet (MNDNR, 2015b). Shakopee Lake experiences occasional partial winterkills and low dissolved oxygen levels (MNDNR, 2015b). The MNDNR has maintained fish populations via stocking walleye fry during odd numbered years, but the dominant fish species are northern pike and bullhead (MNDNR, 2015b). In 2007, the MPCA determined the lake to be impaired for aquatic consumption from elevated mercury levels in fish tissue (MPCA, 2015b). Mercury, a neurotoxin, is considered a concern due to the damage it can cause from bioaccumulation to the central nervous system (MPCA, 2007). During the last 20 years, lake level elevation has remained constant, altering for seasonal fluctuations (Figure 16). Lake elevation data can be found from the MNDNR Lake Finder website: http://www.dnr.state.mn.us/lakefind/index.html.

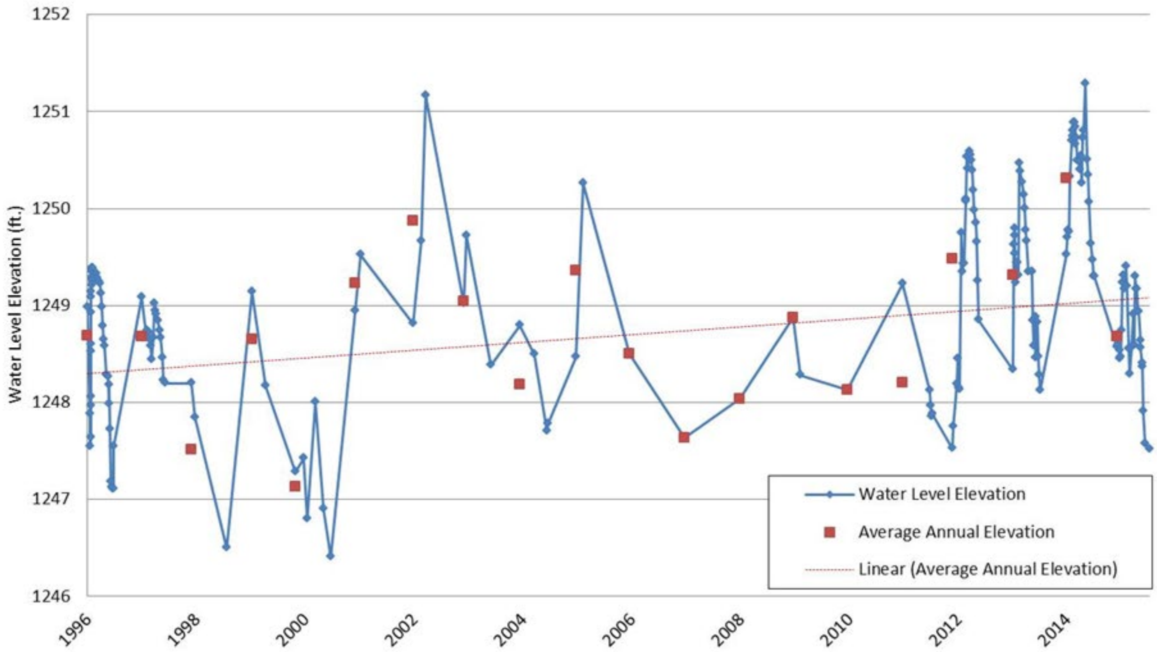


Figure 16: Shakopee Lake water level elevations (1993-2015)

Green Lake (Inventory Number 60013600) in Isanti County is located near Princeton in the south central area of the watershed (Figure 17). The area of the lake is 822 acres with a maximum depth of 28 feet and an average lake water level elevation of 921.3 feet (MPCA, 2015c). The lake's use classification is 2B, 3C; the overall condition is described as "not always suitable for swimming and wading due to low clarity or excessive algae caused by the presence of nutrients, such as phosphorus in the water" (MPCA, 2015c).

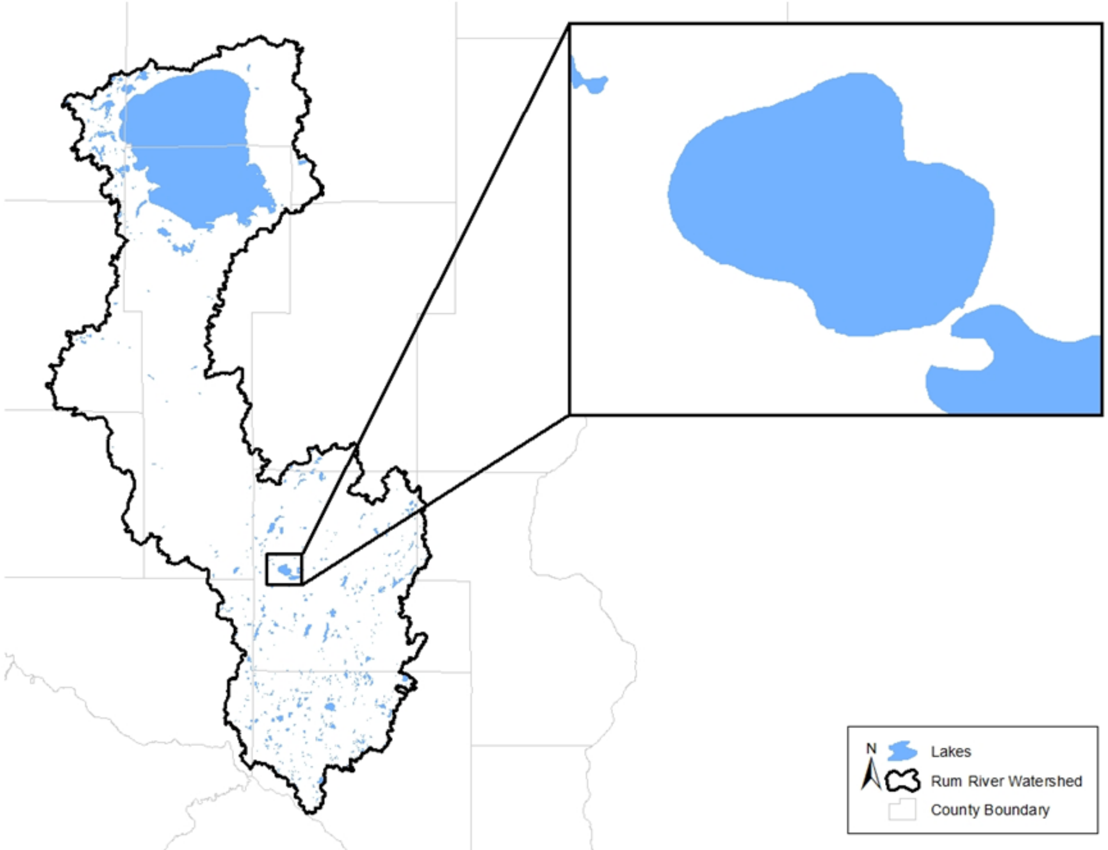


Figure 17: Green Lake within the Rum River Watershed

A 2012, survey by the MNDNR determined that the lake had an average water clarity of 6.9 feet, ranging from 5 to 8.8 feet, and a littoral area of 357 acres (MNDNR, 2015c). The MNDNR primarily manages the lake for walleye and northern pike, stocking the lake with walleye fingerlings and yearlings throughout the last ten years (MNDNR, 2015c). In 2007, the MPCA determined the lake to be impaired for aquatic consumption from elevated mercury and polychlorinated biphenyls (PCBs) levels in fish tissue and for aquatic recreation for nutrient/eutrophication biological indicators (MPCA, 2015b). PCBs are a group of manufactured organic chemicals chlorinated hydrocarbons, which are considered a probable carcinogen (cancer-causing chemical) (U. S. Environmental Protection Agency (EPA), 2016). Although Polychlorinated biphenyls (PCBs) have been banned from production in 1979, PCBs may still be present, to include oil-based products (motor, hydraulic systems, paint), plastics, some electrical equipment, thermal insulation, adhesives and others, as well as in the environment from poorly maintained hazardous waste sites, leak and releases, and improper dumping and disposal of PCB products (US EPA, 2016). Nutrient/eutrophication biological indicators are the reason the overall lake assessment is considered eutrophic and unfit for swimming and wading. Nitrogen and phosphorus are necessary nutrients for lake health, but excess runoff amounts from the landscape can increase lake nutrient levels, triggering algal blooms. These algal blooms decrease light and dissolved oxygen (DO) availability for aquatic plants and organisms, lowering the overall health of the waterbody. During the last 20 years, lake level elevation has remained constant, altering for seasonal fluctuations (Figure 18).

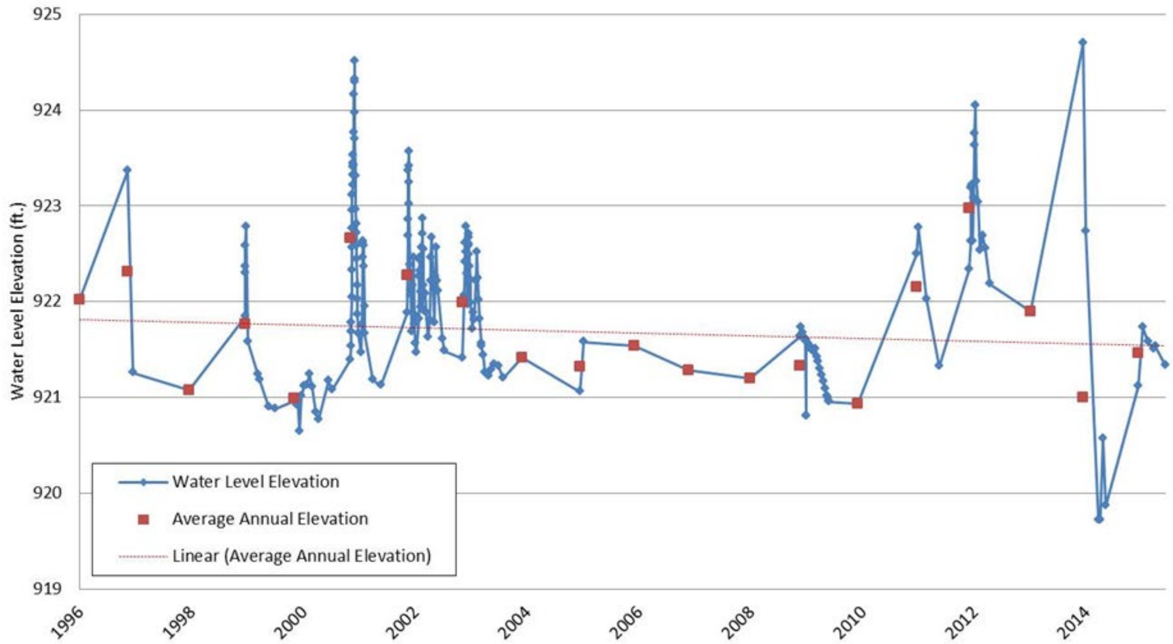


Figure 18: Green Lake water level elevations (1966-2015)

Round Lake (Inventory Number 02008900) in Anoka County is located near Anoka (city) in the southern region of the watershed (Figure 19). The area of the lake is 263 acres with a maximum depth of 15 feet and an average lake water level elevation of 864.9 feet (MPCA, 2015d). The lake's use classification is 2B, 3C; and the overall condition is described as "suitable for swimming and wading, with good clarity and low algae levels throughout the open water season" (MPCA, 2015d).

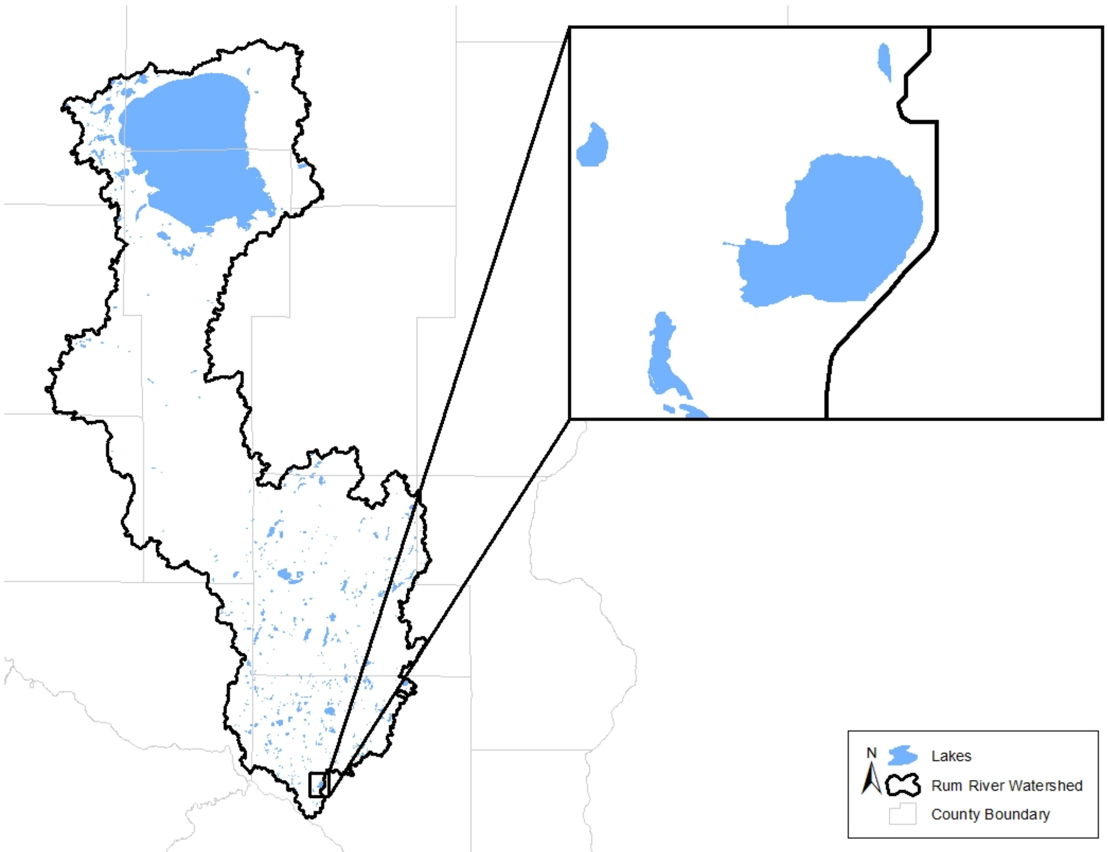


Figure 19: Round Lake within Rum River Watershed

Round Lake is another shallow lake that lacks recent fisheries survey data. Aquatic consumption has not been assessed, and aquatic recreation met all standard for assessed parameters in 2007 (MPCA, 2015d). The water quality is considered between mesotrophic and eutrophic for tropic state index (TSI), transparency, chlorophyll-a, and total phosphorus. Although there are seasonal fluctuations throughout the year, lake level elevation has remained relatively constant during the most recent 20 years (no statistical trend) (Figure 20).

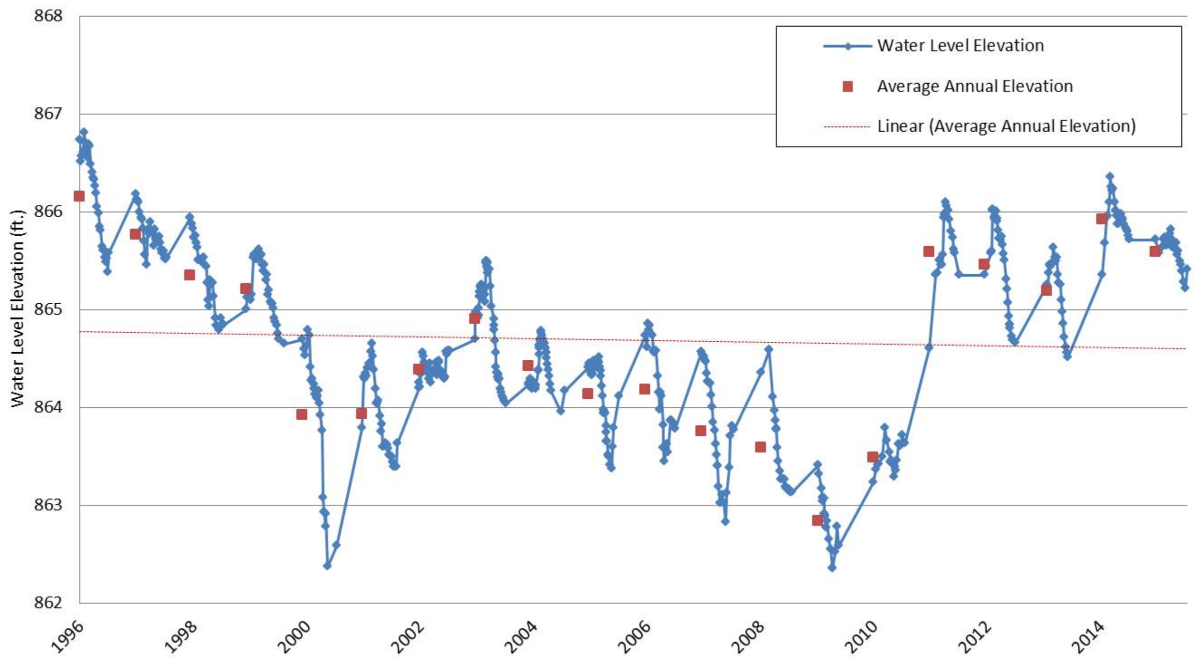


Figure 20: Round Lake water level elevations (1996-2015)

IV. Hydrogeology

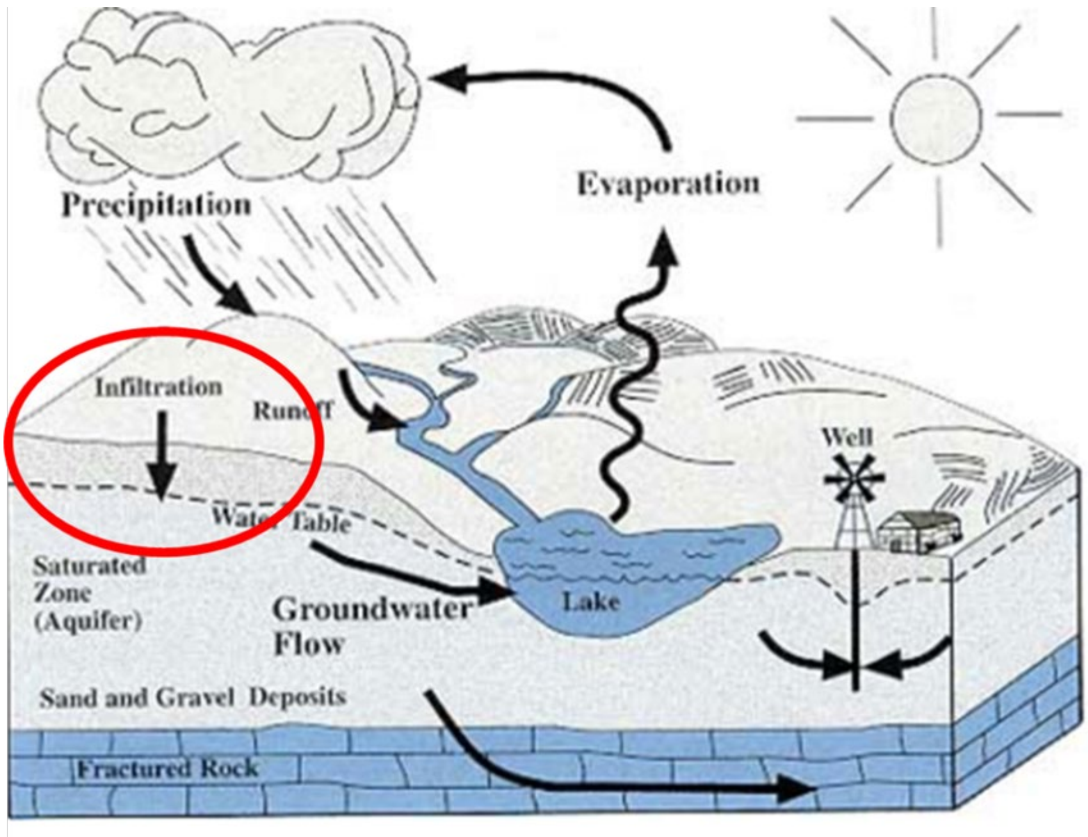


Figure 21: Groundwater within the hydrologic cycle

Hydrogeology is the study of the interaction, distribution and movement of groundwater through the rocks and soil of the earth. The geology of a region strongly influences the quantity of groundwater available, the quality of the water, the sensitivity of the water to pollution and how quickly the water will be able to recharge and replenish the source aquifer. This branch of geology is important to understand as it indicates how to manage groundwater withdrawal and land use and can determine if mitigation is necessary.

Surficial and bedrock geology

The MNDNR and Minnesota Geological Survey (MGS) have collaborated to develop the County Geologic Atlas Program, with the purpose of eventually developing maps and reports of the geology and hydrogeology for all the counties in Minnesota. Each completed county atlas consists of a Part A (geology by MGS) and Part B (hydrogeology by MNDNR). For the Rum River Watershed, Part A is complete for Crow Wing, Morison, Benton, Sherburne, Anoka and Chisago counties and Part B is complete for Crow Wing, Benton, and Chisago counties. Due to the small fraction of the watershed within the majority of these counties (less than 5%), the county atlases were not used to prepare this report (Figure 22). For more information on the County Geologic Atlases available, please visit: http://www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html.

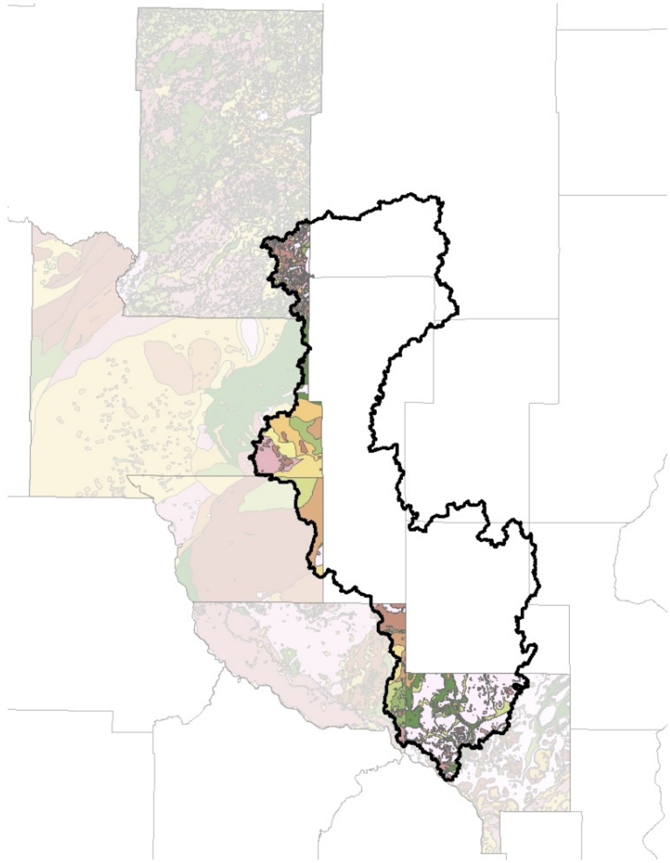


Figure 22: Geologic county atlases, Part A surficial geology for available Rum River Watershed counties

Surficial geology is identified as the earth material located below the topsoil and overlying the bedrock. Glacial sediment is at the surface in much of the Rum River Watershed and is the parent material for the soils that have developed since glaciation. The depth to bedrock ranges from exposed at the surface to 408 feet and is buried by deposits of the various ice lobes that reached this watershed during the last glacial period (Superior and Des Moines lobes), as well as during previous glaciations in the last 2.58 million years. The majority of glacial sediment at the surface is associated with the Superior Lobe in the northern portion and the Des Moines Lobe in the southern portion. The glacial sediments can be grouped by material texture: 1) sand and gravel outwash, 2) calcareous till, 3) non-calcareous till, and 4) peat (Figure 23).

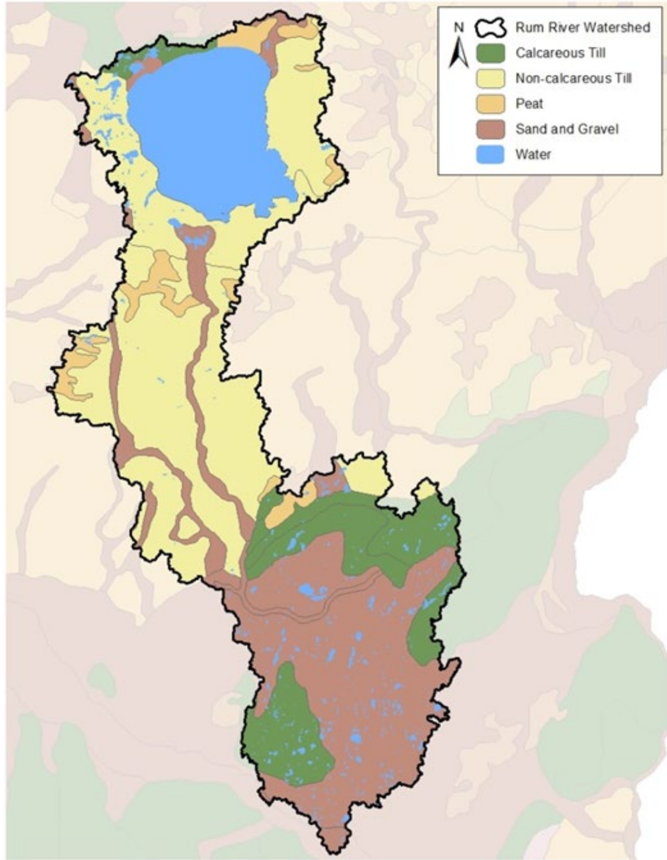


Figure 23: Quaternary geology, glacial sediments within the Rum River Watershed (GIS Source: MGS, 2010)

Bedrock is the main mass of rocks that form the Earth, located underneath the surficial geology and can only be seen in only a few places where weathering has exposed the bedrock. The bedrock geology of the Rum River Watershed region includes Precambrian crystalline rocks in the upper watershed and Precambrian and Paleozoic sedimentary rocks in the lower watershed (Figure 24) (USDA, NRCS). The watershed is divided into two different glacial geologic settings: siliceous and sandy glacial deposits associated with the Superior Lobe in the upper watershed and clay-rich calcareous glacial deposits associated with the Des Moines Lobe in the lower watershed (USDA, NRCS). The Paleozoic bedrock terrane consists of the Wonewoc, Eau Claire and Mount Simon Sandstones (sandstone, siltstone and shale) and the Jordan, St. Lawrence and Tunnel City Group (sandstone, siltstone, shale and dolostone). The Precambrian bedrock covers the extent of the watershed, displaying evidence of volcanic activity. The main terrane groups include East-Central Minnesota batholith (gabbro or granite), Hillman tonalite, Little Falls Formation (greywacke, mudstone, and schist and slate),Mille Lacs and Cuyuna North Range Group (mudstone, quartzite, greywacke, phyllite and graphitic argillite),Mille Lacs Granite, Mille Lacs Group (Dam Lake quartizite and Denham Formation), North, South Range and Mille Lacs Group (mafic metavolcanic and hypabyssal intrusive rocks, argillite, slate, graywacke) and Hinckley, Fond du Lac, Solar Church (sandstone, siltstone, conglomerate). Mafic intrusion with pyroxenite, peridotite, gabbro and lamprophyre is also scattered throughout the central and upper watershed.

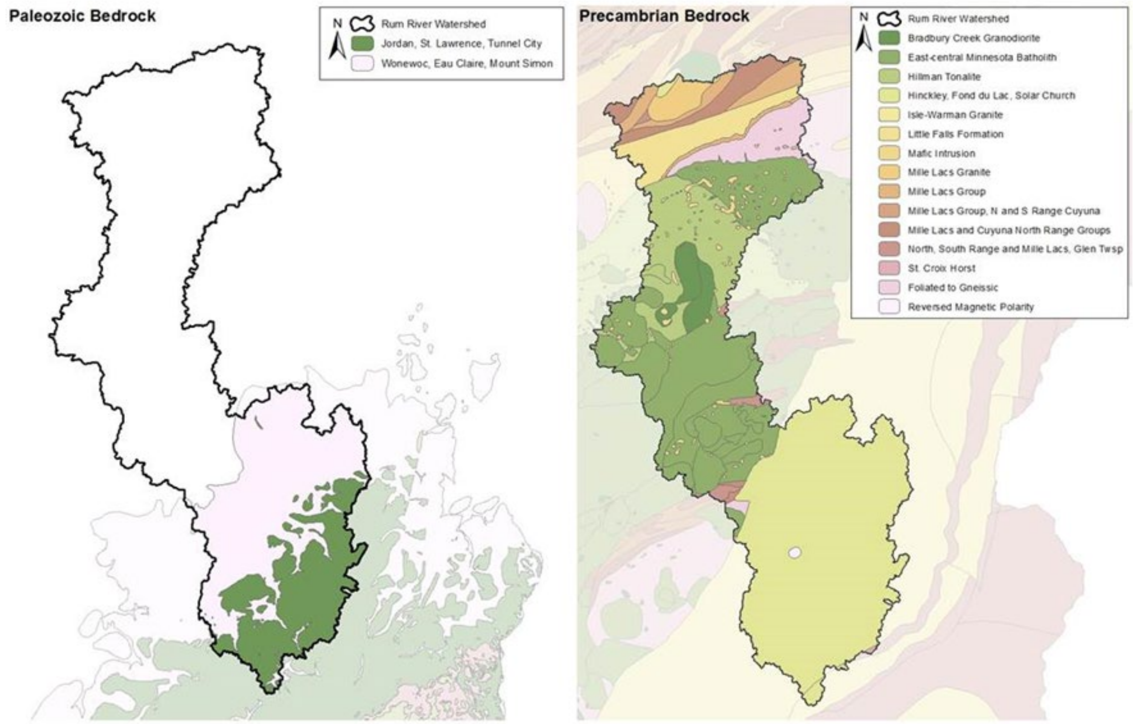


Figure 24: Bedrock geology of the Rum River Watershed: Paleozoic and Precambrian (GIS Source: MGS, 2011)

Groundwater provinces

The Rum River Watershed falls within three of Minnesota's six Groundwater Provinces: The Metro (south), Central (central and north) and Arrowhead (intermittent) Provinces (Figure 25). The majority of the watershed lies within the Central Province which is characterized by "sand aquifers in generally thick sandy and clayey glacial drift overlying Precambrian and Cretaceous bedrock" (MNDNR, 2001). The southern portion of the watershed is within the Metro Province which is characterized by "sand aquifers in generally thick (greater than 100 feet) sandy and clayey glacial drift overlying Precambrian sandstone and Paleozoic sandstone, limestone, and dolostone aquifers" (MNDNR, 2001). The Arrowhead Province is intermittently found within the central portion of the watershed and intermixed with the Central Province. The Arrowhead Province is characterized as "Precambrian rocks exposed at the surface or drift overlying Precambrian rocks is very thin. Groundwater typically found locally in faults and fractures" (MNDNR, 2001).

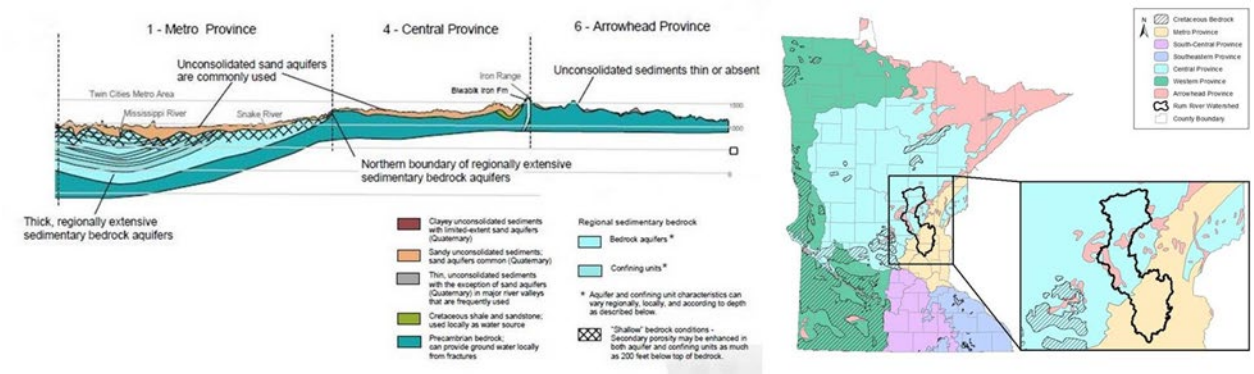


Figure 25: Metro, Central and Arrowhead Province generalized cross section (Source MNDNR, 2001)

Aquifers

Groundwater aquifers are layers of water-bearing units that readily transmit water to wells and springs (USGS, 2015a). As precipitation hits the surface, it infiltrates through the soil zone and into the void spaces within the geologic materials underneath the surface, saturating the material and becoming groundwater (Zhang, 1998). The water table is the uppermost portion of the saturated zone, where the pore-water pressure is equal to local atmospheric pressure. The geologic material determines the permeability and availability of water within the aquifer. Sand and gravel materials are considered highly permeable and are utilized as aquifers, while till layers are less permeable and are considered confining units.

Minnesota's groundwater system is comprised of three types of aquifers: 1) igneous and metamorphic bedrock aquifers, 2) sedimentary rock aquifers, and 3) glacial sand and gravel aquifers (Figure 26). The first group, igneous and metamorphic rock aquifers, is restricted to water available within the fractures of the rock and typically holds limited quantities of water (MPCA, 2005). These aquifers are utilized only when the other two groups are not available, such as in northeastern Minnesota. The second group, sedimentary rock aquifers, consists of sandstone, limestone and shale, which occur primarily in southern and extreme western Minnesota (MPCA, 2005). This type of aquifer contains large quantities of groundwater due to fractures, higher porosity and weathering capabilities of the rocks. The third group is the glacial sand and gravel aquifers. These are shallow aquifers that occur as a result of glacial influences and are found in outwash plains, along river and in old lake beds throughout the state (MPCA, 2005). Also included in this group are deeper, buried glacial aquifers that cover the entire state, except the Arrowhead region and some areas in central and Southwest Minnesota (MPCA, 2005). These aquifers are highly utilized since they contain large and useable quantities of groundwater due to high porosity and permeability and are also less expensive to drill.

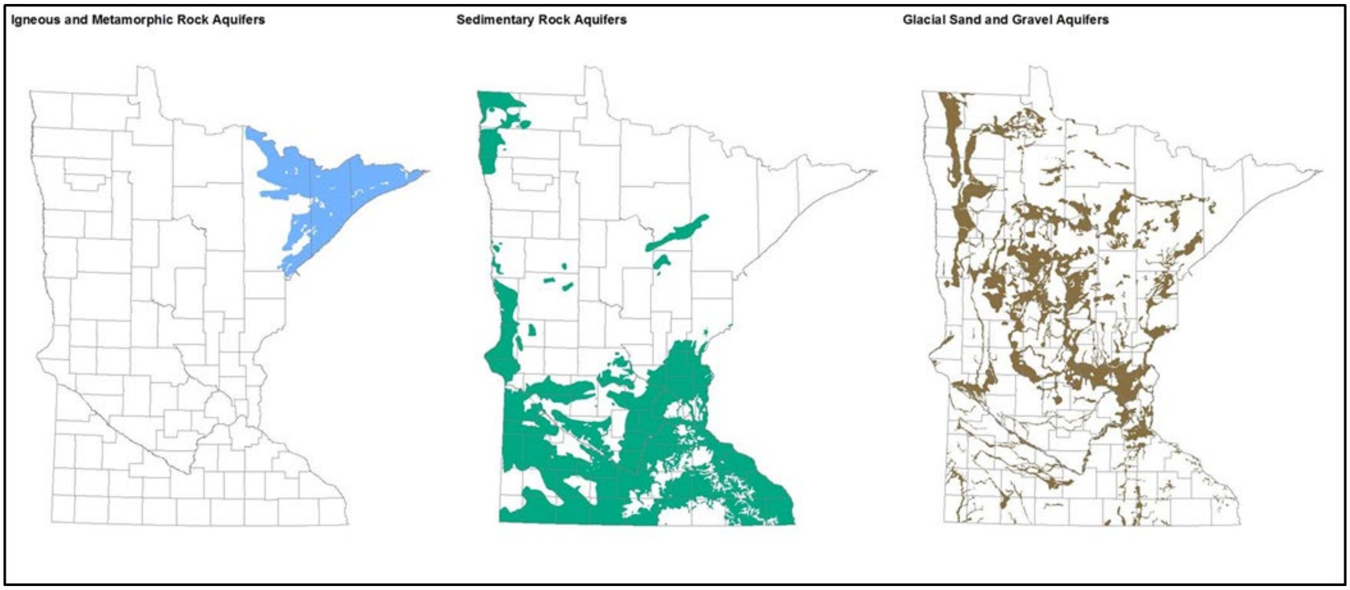


Figure 26: Minnesota's three basic types of aquifers (MPCA, 2005)

The Central Province contains four types of aquifers: surficial and buried aquifers, Cretaceous bedrock (not applicable specifically for the Rum River Watershed), Precambrian bedrock and Biwabik Iron Formation. The Metro Province contains surficial and buried aquifers, the St. Peter aquifer, Prairie du Chien-Jordan, Franconia Ironton-Galesville and Mt. Simon-Hinckley aquifers. The Arrowhead Province includes glacial drift and Precambrian bedrock. The buried sand and gravel aquifers include the Quaternary Buried Artesian Aquifer (QBAA), the Quaternary Buried Unconfined Aquifer (QBUA), and the Quaternary Buried Undifferentiated Aquifer (QBUU). It is from these aquifers that the majority of wells in this region of Minnesota yield the greatest amount of groundwater (MPCA, 1998). Other important sources of groundwater are the surficial sand and gravel aquifers, which consist of well-sorted outwash deposits left behind from the Des Moines Lobe. Two main aquifers included in this category are the Quaternary Water Table Aquifer (QWTA) and the Quaternary Undifferentiated Unconfined Aquifer (QUUU). For the Rum River Watershed, the QWTA and QBAA aquifers are the primary quaternary sources for groundwater withdrawal.

Groundwater pollution sensitivity

When defining and discussing groundwater pollution sensitivity, refer to the MNDNR website: http://www.dnr.state.mn.us/waters/groundwater_section/mapping/sensitivity.html.

> "The MNDNR defines an area as sensitive if natural geologic factors create a significant risk of groundwater degradation through the migration of waterborne contaminants. Migration of contaminants dissolved in water through unsaturated and saturated sediments is affected by many things, including biological degradation, oxidizing or reducing condition and contaminant density. General assumptions include: contaminants move conservatively with water; flow paths are vertical; and permeability of the sediment is the controlling factor.
>
> The pollution sensitivity of buried sand and gravel aquifers and of the first buried bedrock surface represents the approximate time it takes for water to move from land surface to the target (residence time). Groundwater chemistry is used to support hypotheses relating geologic factors to travel time. Dye traces, naturally occurring chemicals, and other human-introduced chemicals are used to date groundwater and better understand flow paths and residence times" (MNDNR, 2015d).

Since bedrock aquifers are typically covered with thick till, they would normally be better protected from contaminant releases at the land surface. It is also less likely that withdrawals from these wells would have a direct and significant impact on local surface water bodies. In contrast, surficial aquifers are typically more likely to 1) be vulnerable to contamination, 2) have direct hydrologic connections to local surface water, and 3) influence the quality and quantity of local surface water. The MNDNR is working on a hydrogeological atlas focused on the pollution sensitivity of the bedrock surface. It is being produced county-by-county, and is not yet completed for those counties within the Rum River Watershed. Until the hydrogeological atlas is finished, a 1989 statewide evaluation of groundwater contamination susceptibility completed by the MPCA is utilized to determine aquifer pollution vulnerability. This display is not intended to be used on a local scale, but as a coarse-scale planning tool. According to this data, the Rum River Watershed is estimated to have primarily low to medium level contamination susceptibility in the central and northern portion of the watershed and high to highest Level contamination susceptibility in the southern region, most likely due to the presence of sand and gravel Quaternary geology (Figure 27) (Porcher, 1989).

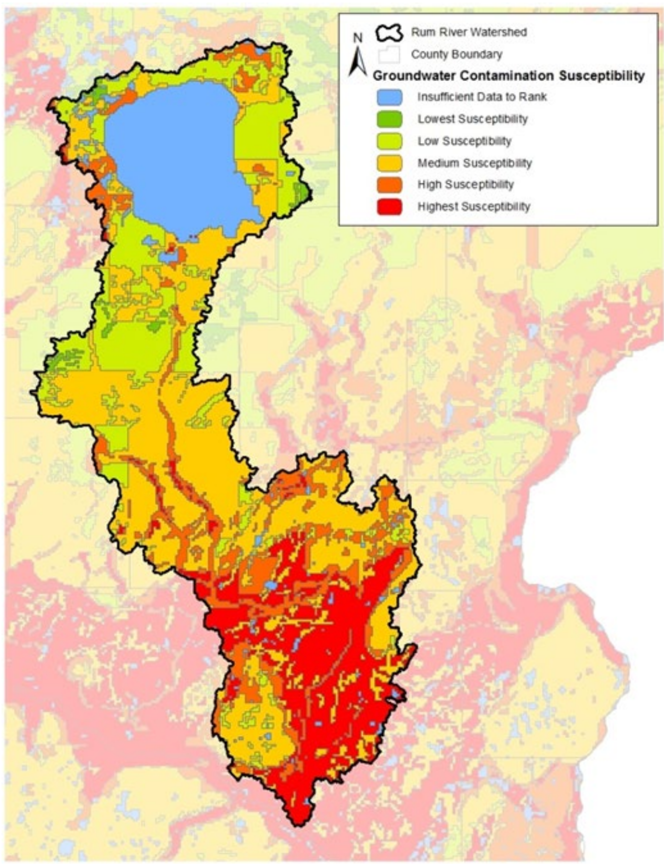


Figure 27: Groundwater contamination susceptibility for the Rum River Watershed (GIS Source: MPCA, 1989)

Groundwater potential recharge

Groundwater recharge is one of the most important parameters in the calculation of water budgets, which are used in general hydrologic assessments, aquifer recharge studies, groundwater models, and water quality protection. Recharge is a highly variable parameter, both spatially and temporally, making accurate estimates at a regional scale difficult to produce. The MPCA contracted the US Geological Survey to develop a statewide estimate of recharge using the SWB – Soil-Water-Balance Code. The result is a gridded data structure of spatially distributed recharge estimates that can be easily integrated into regional groundwater studies. The full report of the project as well as the gridded data files are available at: https://gisdata.mn.gov/dataset/geos-gw-recharge-1996-2010-mean.

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock-surficial deposit interface (Figure 28). Typically, recharge rates in unconfined aquifers are estimated at 20 to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS, 2007). For Rum River Watershed, the average annual potential recharge rate to surficial materials ranges from 0.98 to 17.5 inches per year, with an average of 6.4 inches per year (Figure 29). The statewide average potential recharge is estimated to be four inches per year with 85% of all recharge ranging from three to eight inches per year (Figure 30). When compared to the statewide average potential recharge, the Rum River Watershed receives a higher average of potential recharge, most likely attributable to the variability of the surficial sediment distribution of the area.

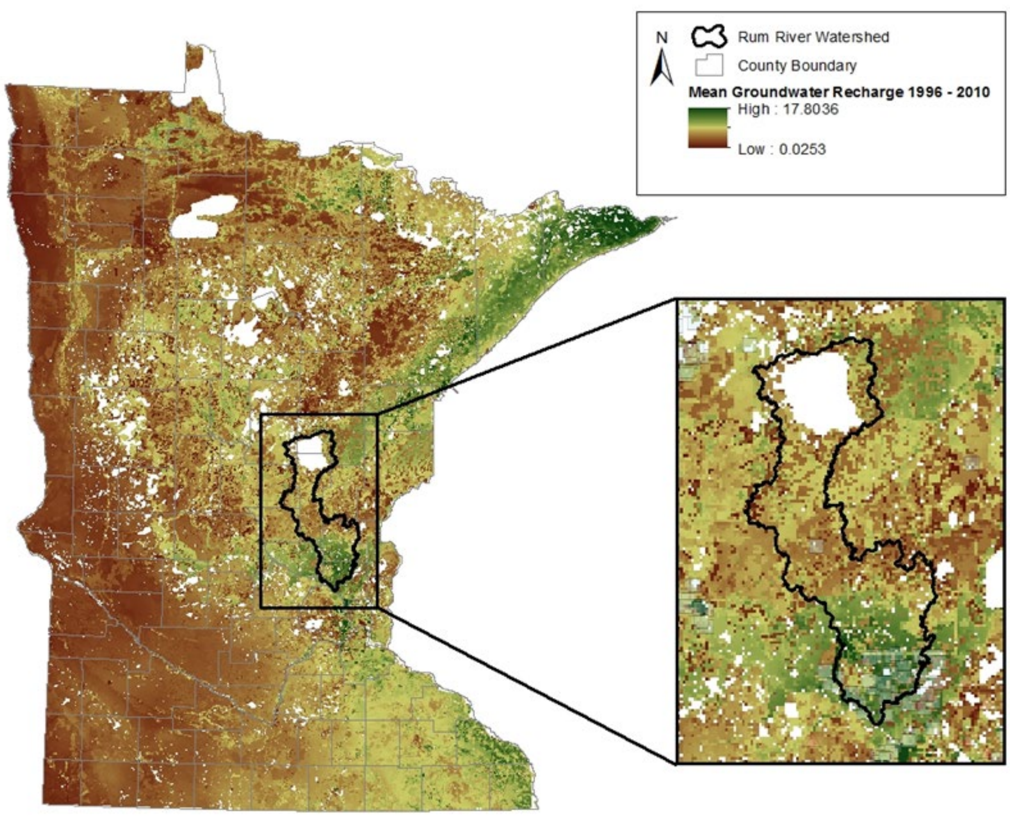


Figure 28: Average annual potential recharge rate to surficial materials in Rum River Watershed (1996-2010)

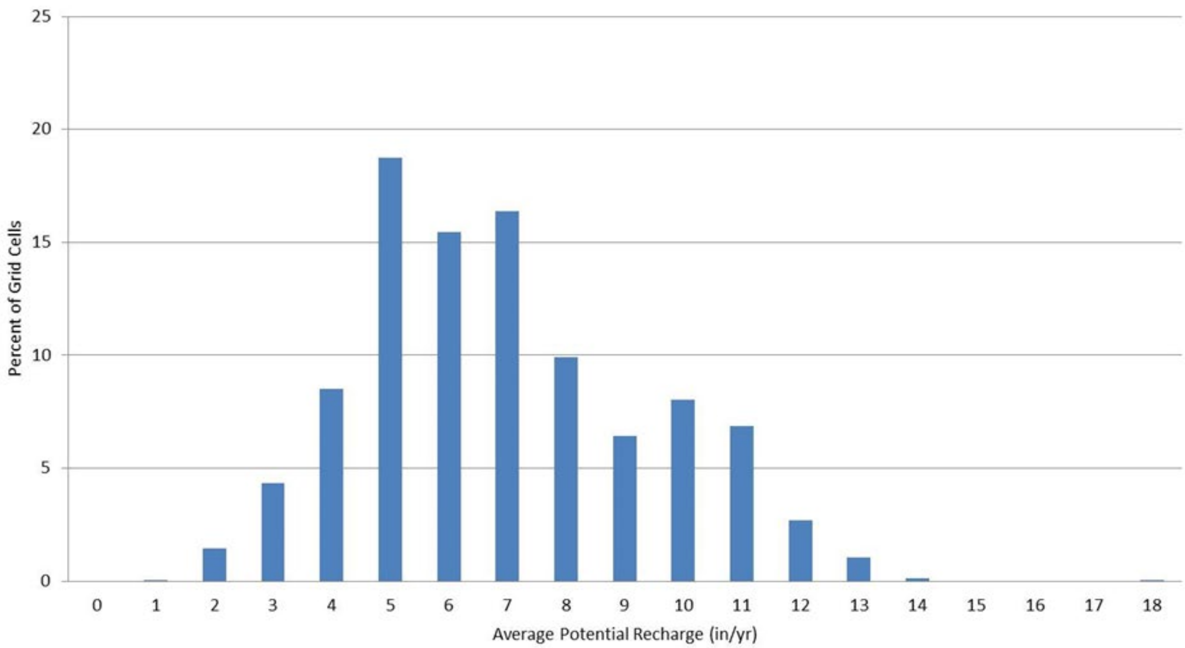


Figure 29: Average annual potential recharge rate percent of grid cells in the Rum River Watershed (1996-2010)

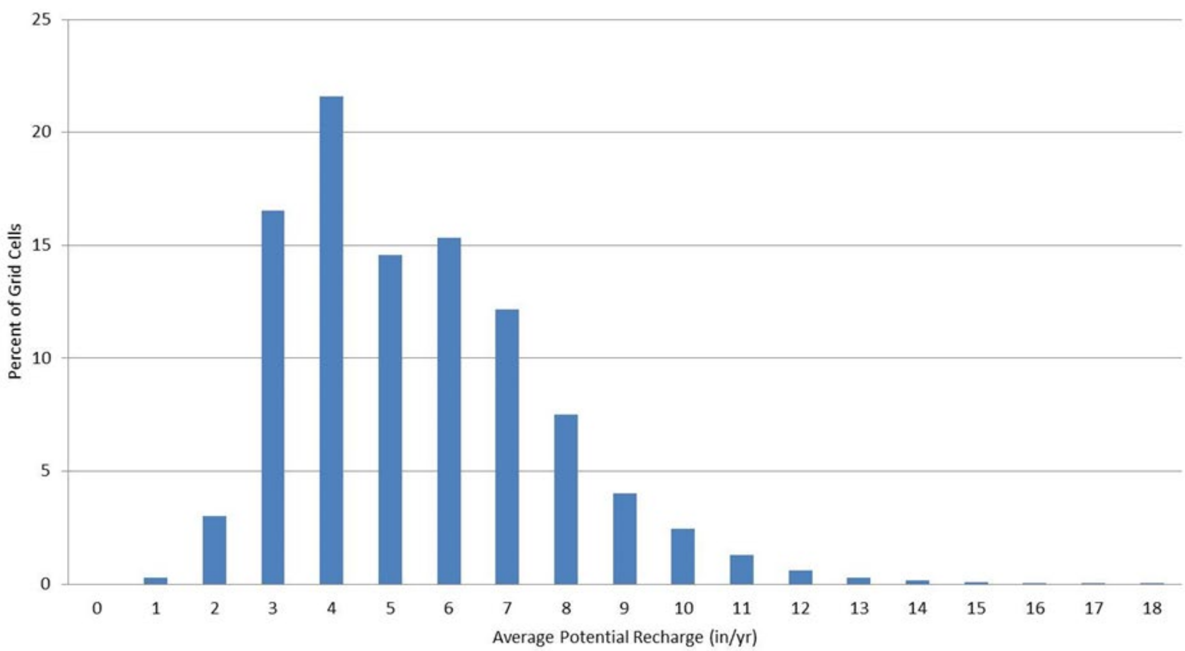


Figure 30: Average annual potential recharge rate percent of grid cells statewide (1996-2010)

V. Groundwater quality

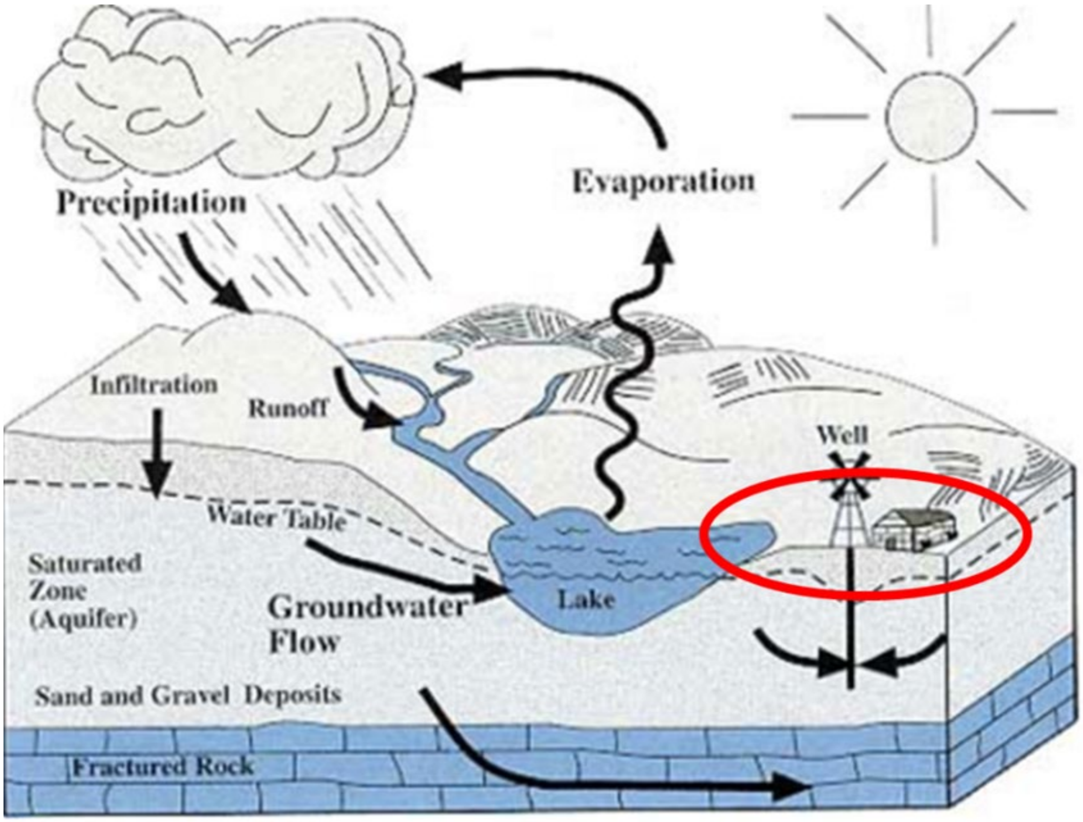


Figure 31: Groundwater quality within the hydrologic cycle

Ambient groundwater network

Approximately 75% of Minnesota's population receives their drinking water from groundwater, undoubtedly indicating that clean groundwater is essential to the health of its residents. The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These ambient wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

There are currently 18 MPCA ambient groundwater monitoring well (17 monitoring, 1 domestic) within the Rum River Watershed. Figure 32 displays the locations of ambient groundwater wells within and around the specified watershed. Data collection ranged from 2004 to 2015; however, the majority of the wells were added in 2010. Therefore, data analysis was conducted on the current MPCA ambient groundwater wells from 2010 to 2015.

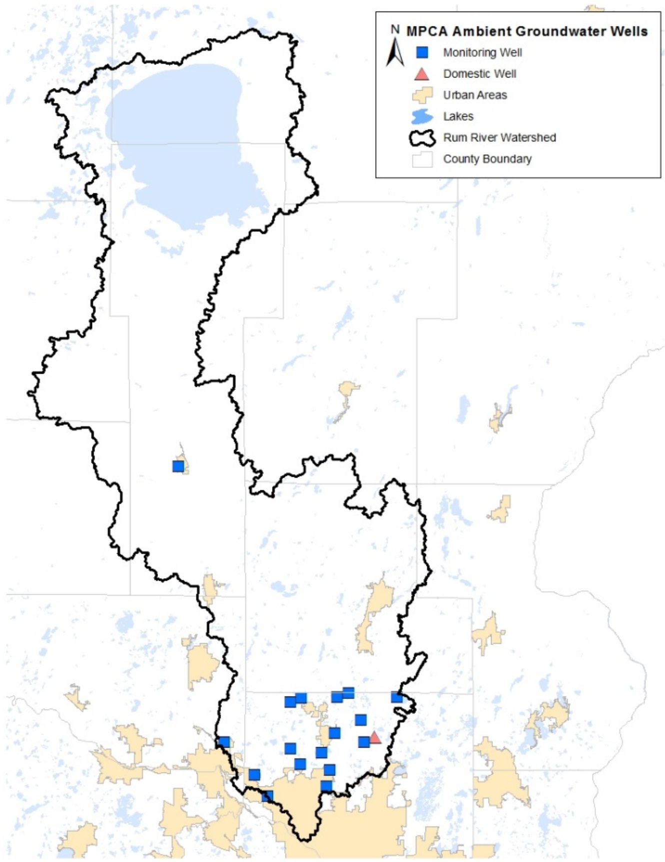


Figure 32: MPCA ambient groundwater monitoring well locations within the Rum River Watershed

The ambient groundwater wells are primarily located within the southern extent of the watershed, with many near urbanized areas (Figure 32). Urbanized areas tend to pose a greater threat for groundwater pollution due to faulty or leaking sewage and septic systems, close vicinity to roads where salt is often used as a deicing agent, and additional emissions from vehicles and infrastructure. Of the 18 wells, 15 are located in residential areas with subsurface sewage treatment systems (SSTS) (also referred as septic systems), two are located in undeveloped areas, and one is within a sewered residential area. In a study of contaminants of emerging concern (CECs) in ambient groundwater in urbanized areas of Minnesota conducted by USGS and MPCA, samples from wells located in sewered residential land use area were identified to have higher percentages of CEC detections when compared to undeveloped or septic residential land uses (SSTS) (Erickson et al., 2014). CECs are predominantly manmade chemicals, although some may be naturally occurring or endocrine active chemicals, and include pharmaceuticals, fire retardants, pesticides, personal-care products, hormones, and detergents (Erickson et al., 2014). The three most commonly occurring CEC detections for the wells sampled within the Rum River Watershed from 2010 to 2014 include sulfadimethoxine (10.3%), isophorone (8.4%), and 2-methylanaphthalene (7.5%).

Chloride has become an increasing concern in developed areas where salt is used as a deicing agent, and where higher chloride concentrations can affect the taste of drinking water (Kroening & Ferrey, 2013). Chloride has a secondary MCL set as 250 milligrams per liter for taste. Chloride detection frequency within the watershed was 93.9% with 10 occurrences exceeding the secondary limit (Figure 33).

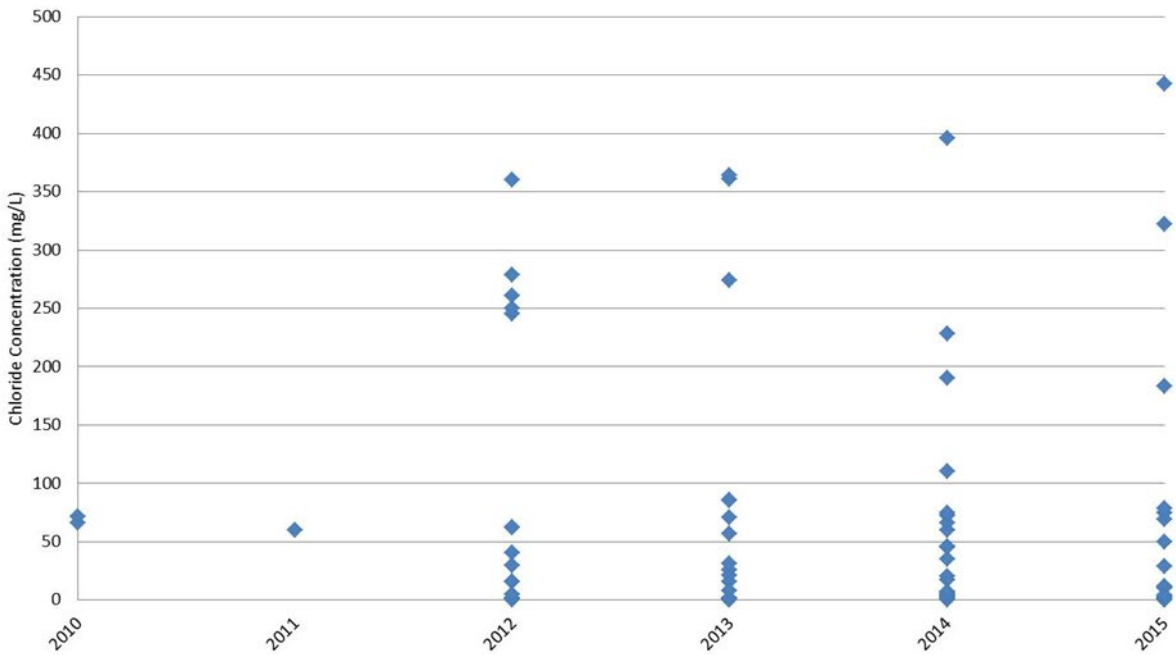


Figure 33: Chloride detections in Ambient Groundwater Samples – Rum River Watershed (2010-2015)

Like chloride, sodium is a naturally occurring chemical that can also be associated with road salt application.There is no drinking water standard for sodium at this time, but high concentrations can be a concern for those with a low-sodium diet. Sodium was detected in these wells at a 98.7% frequency, and concentrations ranging from 1.45 to 201 mg/L (Figure 34).

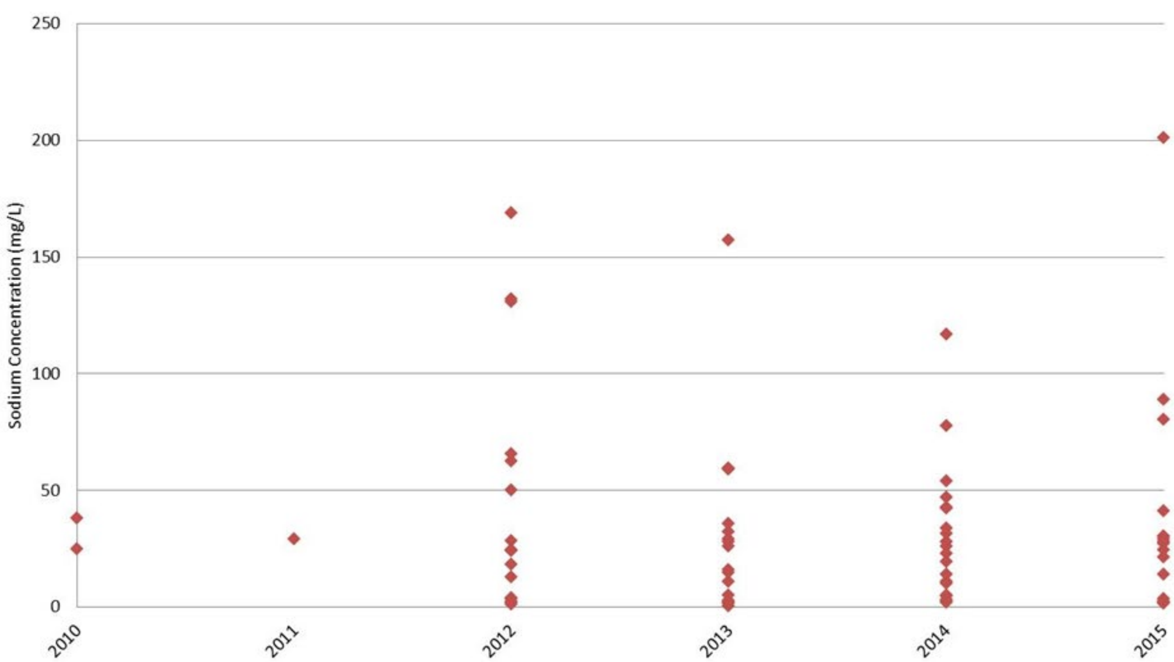


Figure 34: Sodium detections in Ambient Groundwater Samples – Rum River Watershed (2010-2015)

Another chemical of concern is nitrate, a form of nitrogen, which has a MCL of 10 milligrams per liter. This limit is primarily set for the risk of methemoglobinemia (blue-baby syndrome) in infants under the age of six months. Nitrate was detected in 95.2% of the samples, with three exceedances of the MCL (Figure 35). Other common chemical and contaminant detections identified in these wells were sulfate, bromide, aluminum, iron, magnesium, manganese, potassium, strontium, barium, boron and phosphorus.

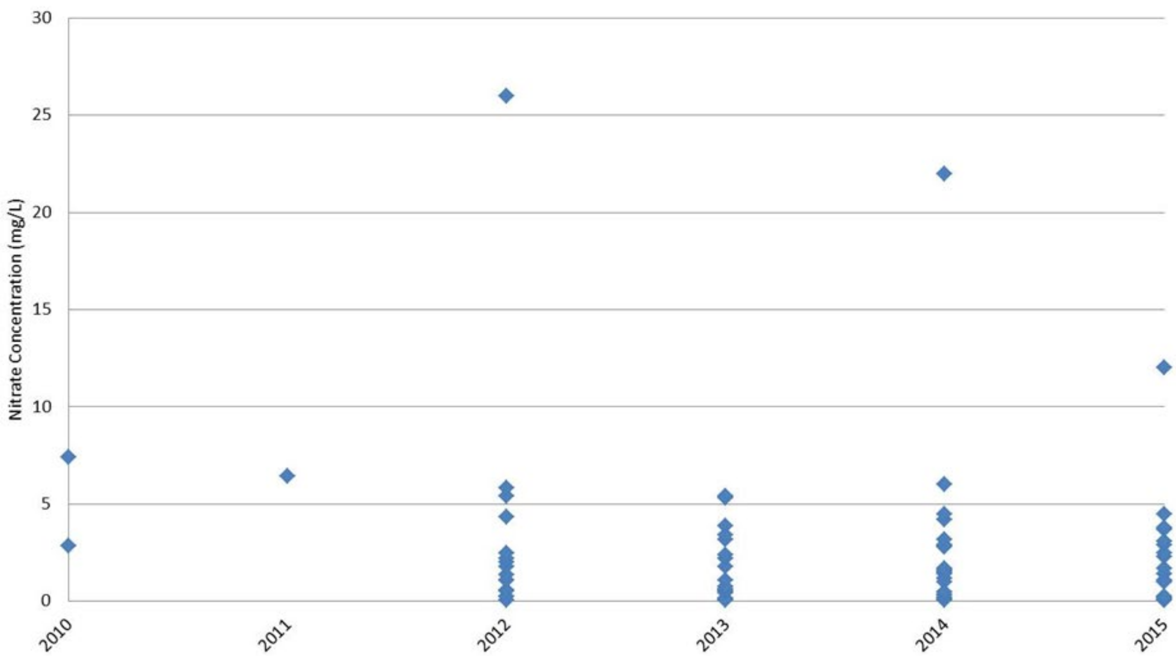


Figure 35: Nitrate detections in Ambient Groundwater Samples – Rum River Watershed (2010-2015)

Regional groundwater quality

From 1992 to 1996, the MPCA conducted baseline water quality sampling and analysis of Minnesota's principal aquifers based on dividing Minnesota into six hydrogeologic regions: Northwest, Northeast, Southwest, Southeast, North Central and Twin Cities Metropolitan Regions. The Rum River Watershed lies primarily within the North Central Hydrogeologic Region, with the northern point in the northeast region and the southern point in the Twin Cities Metropolitan Region (Figure 36). The baseline study determined that the groundwater quality in the North Central Region is considered very good in most aquifers when compared to other areas with similar aquifers. The number of exceedances to drinking criteria for arsenic, beryllium, boron, manganese, nickel, nitrate, selenium, thallium, and vanadium ranged from one to seven, depending on the aquifer (MPCA, 1998). Nitrate was identified as the chemical of greatest concern in this hydrogeologic region, with probable anthropogenic sources contributing to the elevated concentrations. Volatile organic compounds were also detected with the most commonly detected compounds associated with fuel oils, gasoline and well disinfection (MPCA, 1998).

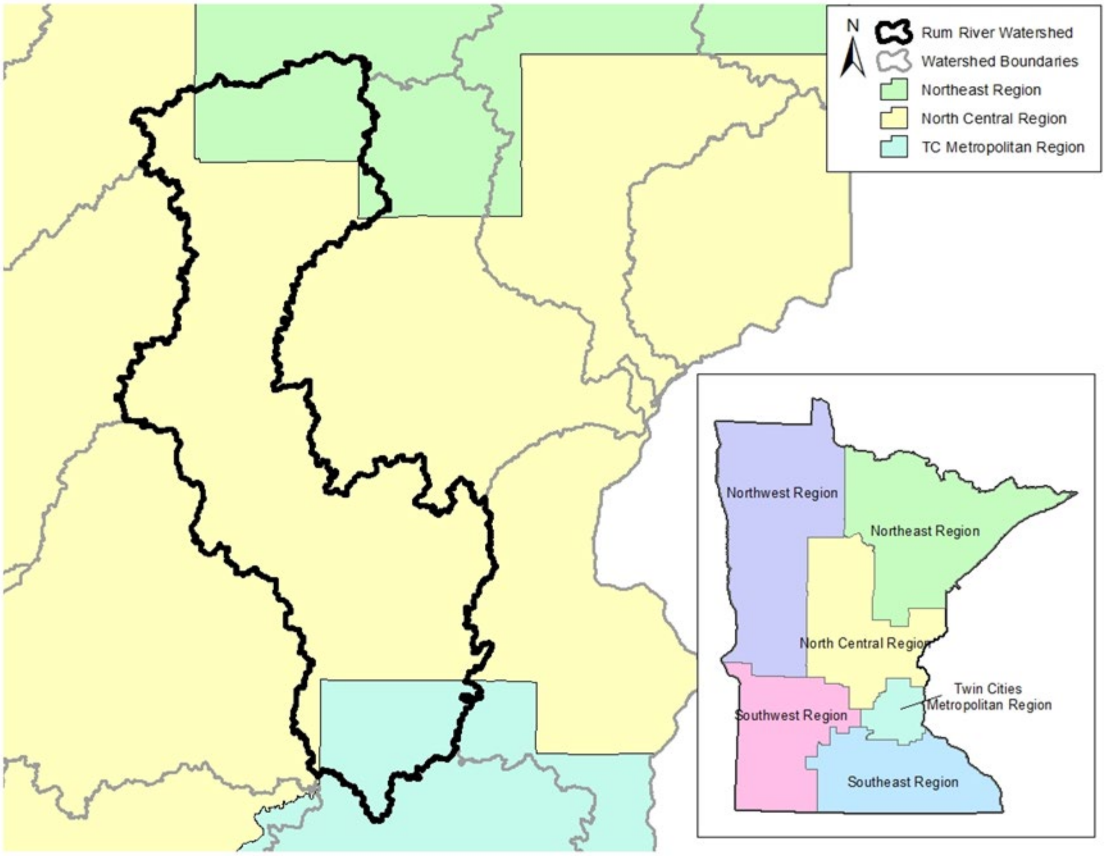


Figure 36: Rum River Watershed within the MPCA hydrogeologic regions

The Minnesota Department of Agriculture (MDA) monitors pesticides and nitrate on an annual basis in groundwater across agricultural areas in the state. The MDA also separates the state into regions, which consist of ten regional water quality monitoring networks that are referred to as Pesticide Monitoring Regions (PMRs). The Rum River Watershed lies primarily within the regional water quality monitoring networks for Region 5 (PMR 5). PMR 5 is also referred to as the East Central Region.

The Monitoring and Assessment Unit (MAU) of the MDA sampled 166 sites throughout Minnesota for pesticides in groundwater in 2015. Although some wells detected up to five common detection pesticides or degradants, which include acetochlor, alachlor, atrazine, metolachlor and metribuzin, no detections exceeded drinking water standards for human consumption (MDA, 2015). Within the Rum River Watershed, the MAU sampled sites in the central area for the presence of pesticides found detections of up to four pesticides per site (Figure 37). When analyzing median trends for long term groundwater sampling for PMR 5, MAU has identified a statistically significant increasing trend in desethylatrazine while a statistically significant decreasing trend in alachlor ESA, metolachlor ESA and metalachlor OXA (MDA, 2015). All other median trend analysis results had no trend or a trend not statistically significant. Detection frequency trend analysis determined statistically significant decreasing trends for alachlor ESA, alachlor OXA, atrazine, and metolachlor ESA; all others did not exhibit trends or statistically significant trends (MDA, 2015).

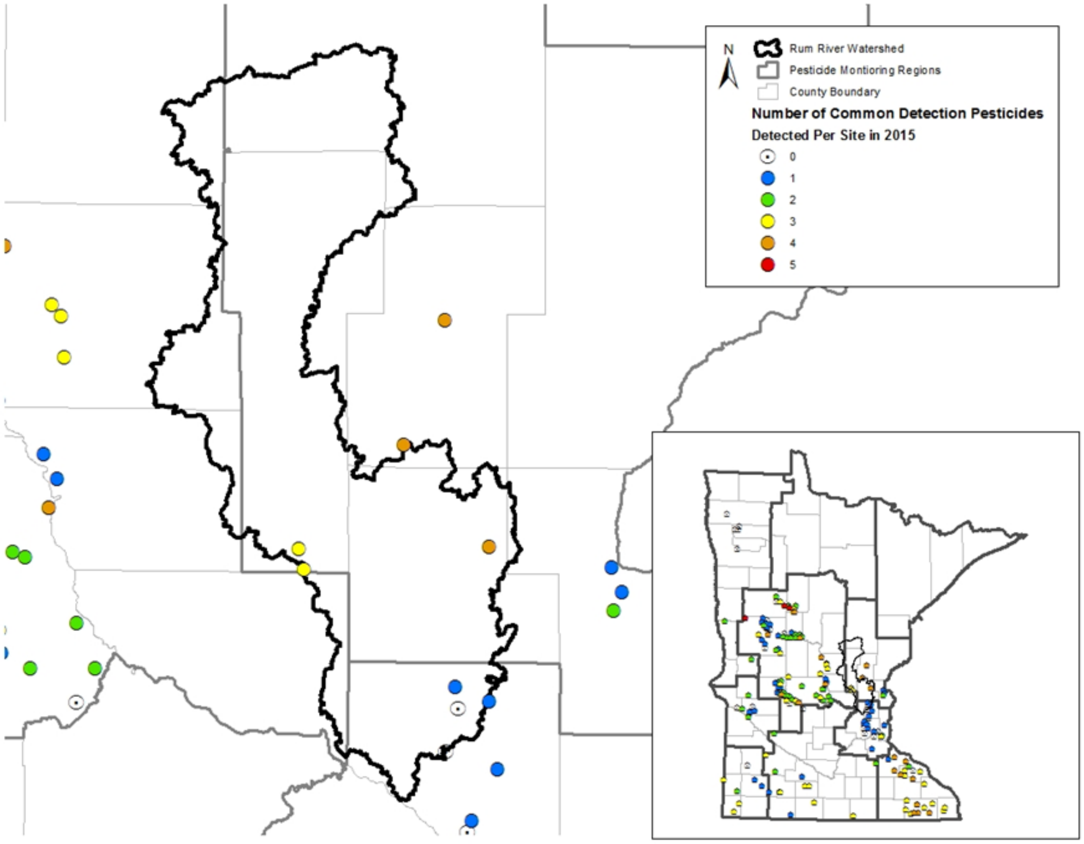


Figure 37: Pesticide detections within the Rum River Watershed (Source: MDA, 2015)

Although there are limited sampling sites specifically within the watershed, PMR 5 displayed high levels of nitrogen-nitrate detections. The 2014 Water Quality Monitoring Report determined that nitrate-nitrogen was detected in 100% of the wells sampled in PMR 5 with a median concentration of 8.27 milligrams per liter (mg/L) (MDA, 2015). Of those samples, 12% were at or below background level of 3.00 mg/L, 44% were within 3.01 and 10.00 mg/L, and 44% were above drinking water standard of 10.00 mg/L (MDA, 2015). Additionally, a MPCA report on the statewide condition of Minnesota's groundwater determined that sand and gravel aquifers have the greatest nitrate concentrations in the state, which also coincides with the location of the sites sampled by the MDA (Kroening & Ferrey, 2013).

Another source of information on groundwater quality comes from the Minnesota Department of Health (MDH). Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that 10.7% of all wells installed from 2008 to 2015 have arsenic levels above the maximum contaminant level (MCL) for drinking water of 10 micrograms per liter (MDH, 2015). In the Rum River Watershed, the majority of new wells are within the water quality standards for arsenic levels, but there are exceedances to the MCL. When observing concentrations of arsenic by percentage of wells that exceed the MCL of 10 micrograms/liter per county, the watershed lays within counties that range from less than 5 to 10% which is considered low. By county, the percentages of wells identified with concentrations exceeding the MCL are as follows: Aitkin (5.8%), Anoka (8.8%), Benton (0.8%), Crow Wing (4.3%), Chisago (3.5%), Isanti (2.6%), Kanabec (2.6%), Mille Lacs (0.6%), Morrison (4.1%), and Sherburne (2.5 %) (MDH, 2015) (Figure 38). For more information on arsenic in private wells, please refer to the MDH's website: http://www.health.state.mn.us/divs/eh/wells/waterquality/arsenic.html.

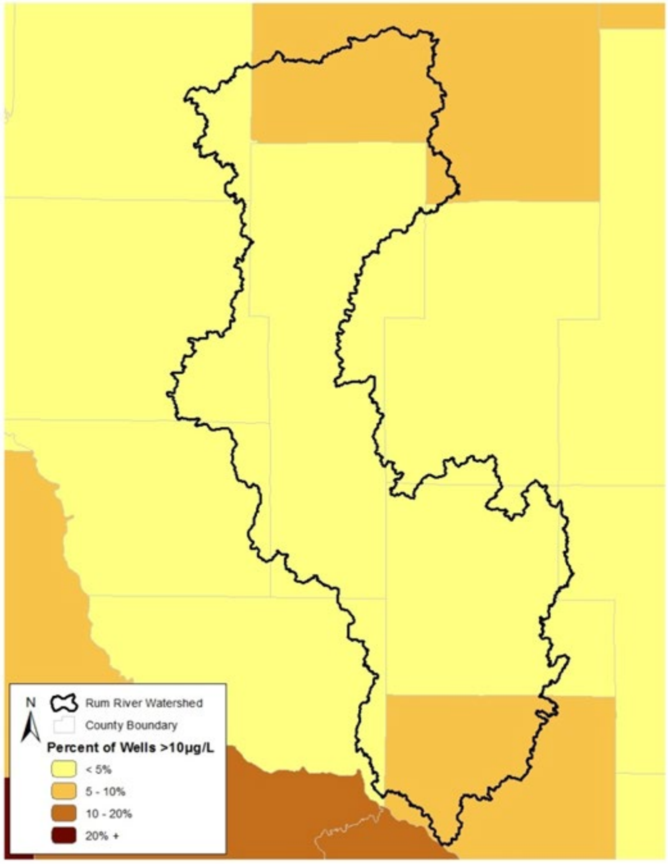


Figure 38: Percent wells with arsenic occurrence greater than the MCL for the Rum River Watershed (2008-20015) Source: MDH, 2015)

A statewide dataset of potentially contaminated sites and facilities with environmental permits and registrations is available at the MPCA's website, through a web-based application called, "What's in My Neighborhood" (WIMN). This MPCA resource provides the public with a method to access a wide variety of environmental information about communities across the state. The data is divided into two groups. The first is potentially contaminated sites, and includes contaminated properties, formerly contaminated sites, and those that are being investigated for suspicion of being contaminated. The second category is made up of businesses that have applied for and received different types of environmental permits and registrations from the MPCA. An example of an environmental permit would be for a business acquiring a permit for a storm water or wastewater discharge, requiring it to operate within limits established by the MPCA. In the Rum River Watershed, there are currently 4,135 sites identified by WIMN: 1,597 water quality sites, 1,086 hazardous waste sites, 261 feedlots sites, 205 investigation and cleanup sites, 52 air quality sites, 22 solid waste sites, 911 tanks and leaks, and (Figure 39). For more information regarding "What's in My Neighborhood", refer to the MPCA webpage at: http://www.pca.state.mn.us/index.php/data/wimn-whats-in-my-neighborhood/whats-in-my-neighborhood.html.

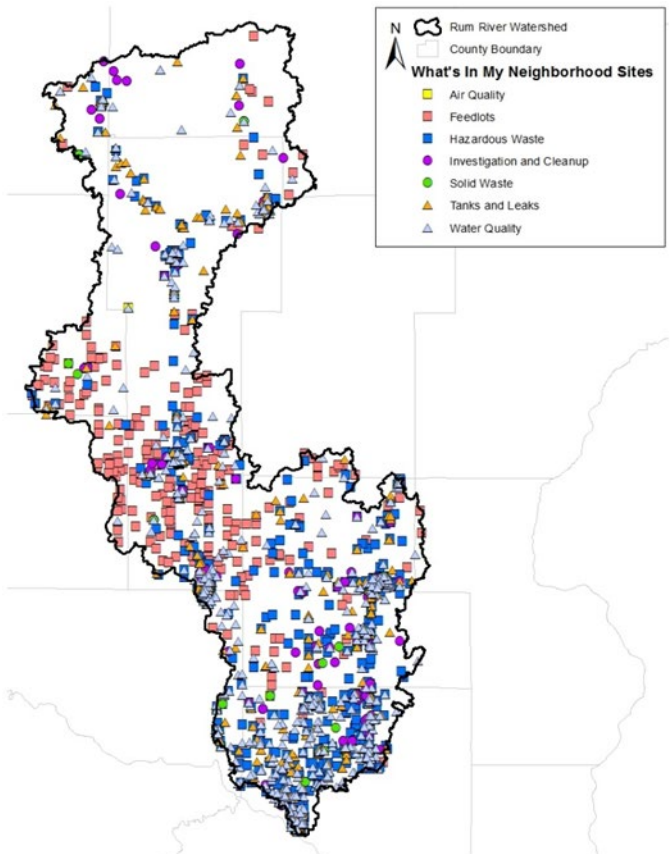


Figure 39: "What's in My Neighborhood" site programs and locations for the Rum River Watershed

VI. Groundwater quantity

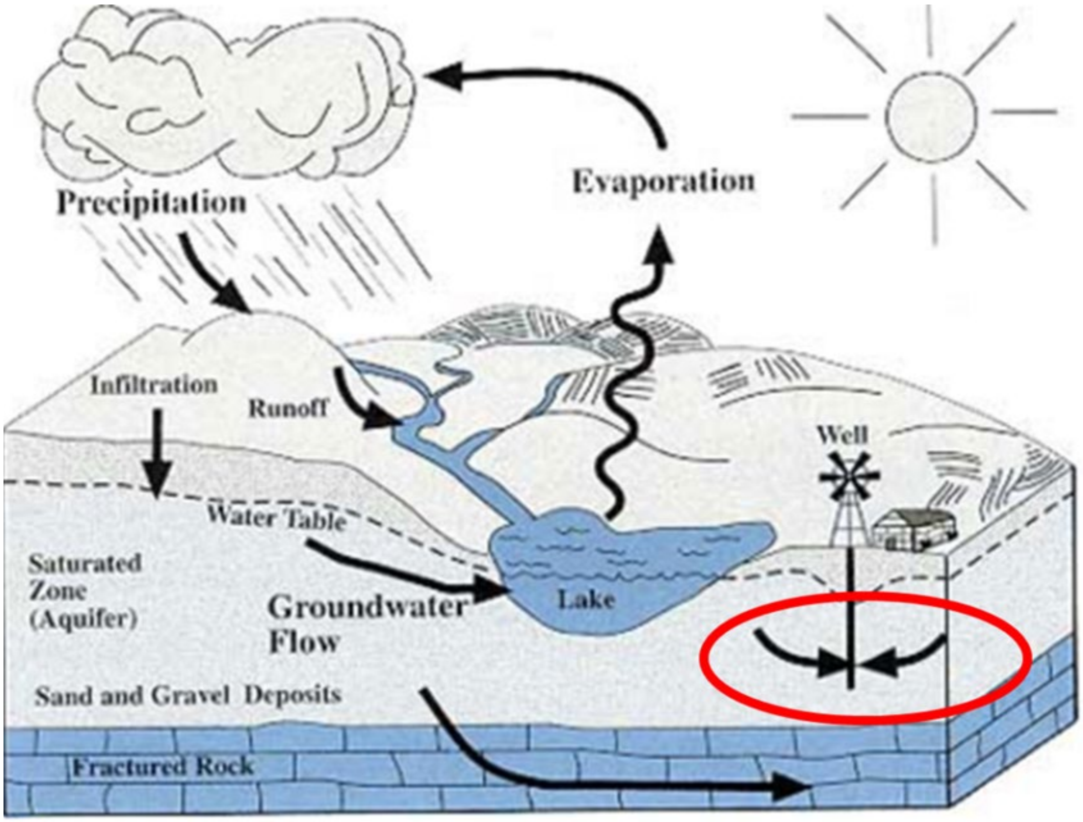


Figure 40: Groundwater quantity within the hydrologic cycle

Groundwater and surface water withdrawals

The MNDNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons per day or one million gallons per year. Permit holders are required to track water use and report back to the MNDNR yearly. The changes in withdrawal volume detailed in this groundwater report are a representation of water use and demand in the watershed and are taken into consideration when the MNDNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

The three largest permitted consumers of water in the state (in order) are power generation, public water supply (municipals), and irrigation (MNDNR, 2015e). According to the most recent USGS site-specific water-use data system (SWUDS), in 2013 the withdrawals within the Rum River Watershed are primarily utilized for water supply (56.6%), such as private or municipal water supply. The remaining withdrawals include: agricultural irrigation (21.9%), non-crop irrigation (10.6%), industrial processing (5.8%), special categories including pollution containment, dust control and livestock watering (4.8%), water level maintenance (0.2%), heating and cooling purposes (0.04%) and power generation (0.01%) (Figure 41). From 1994 to 2013, withdrawals associated with agricultural and non-crop irrigation have increased significantly ($p=0.01$), while water supply, industrial processing, special categories and power generation have not exhibited any statistically significant trends. Heating and cooling and water level maintenance have also increased significantly over this time period (p=0.001 and p=0.01, respectively), but due to the very small percentage of water withdrawn, this is not considered substantial.

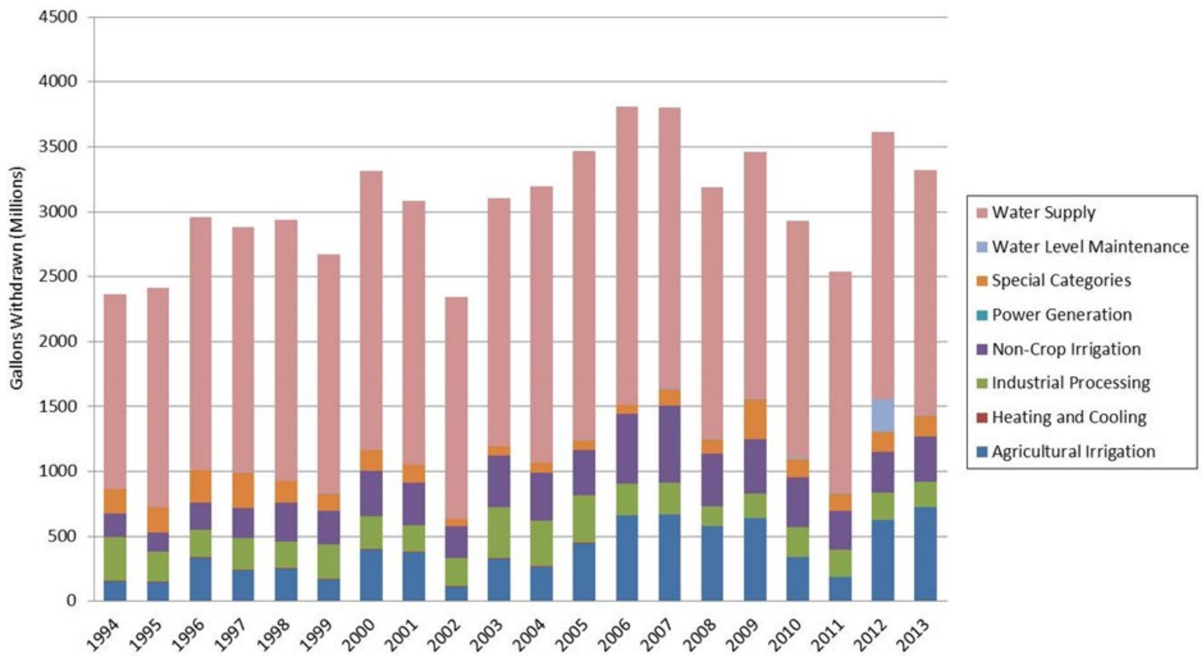


Figure 41: Groundwater and surface water permitted withdrawals by category within the Rum River Watershed (1994-2013)

Figure 42 displays total high capacity withdrawal locations within the watershed with active permit status in 2013. Permitted groundwater withdrawals are displayed below as blue triangles and surface water withdrawals as red squares. During 1994 to 2013, groundwater withdrawals within the Rum River Watershed exhibit a significant increasing withdrawal trend (p=0.05) (Figure 43), while surface water withdrawals does not exhibit a statistically significant trend (Figure 44). Water table (QWTA) withdrawals, which account for approximately 14.8% of all active groundwater withdrawals, do not emulate the overall groundwater withdrawal trend and has no statistically significant trend (Figure 45).

The increase in groundwater withdrawals can be quantified further by the SWUDS data. In 1994, the number of active permits within the watershed for groundwater sources that reported withdrawal quantities was 149, pumping a reported amount of approximately 2.5 billion gallons of water. In 2013, the number of active permits for groundwater that reported withdrawal quantities was 213, withdrawing 3.3 billion gallons of water. For surface water withdrawals in 1994, the number of reported quantities by active permit holders was 17 and withdrew 89.9 million gallons, while in 2013, the number increased to 18 withdrawing 91.4 million gallons.

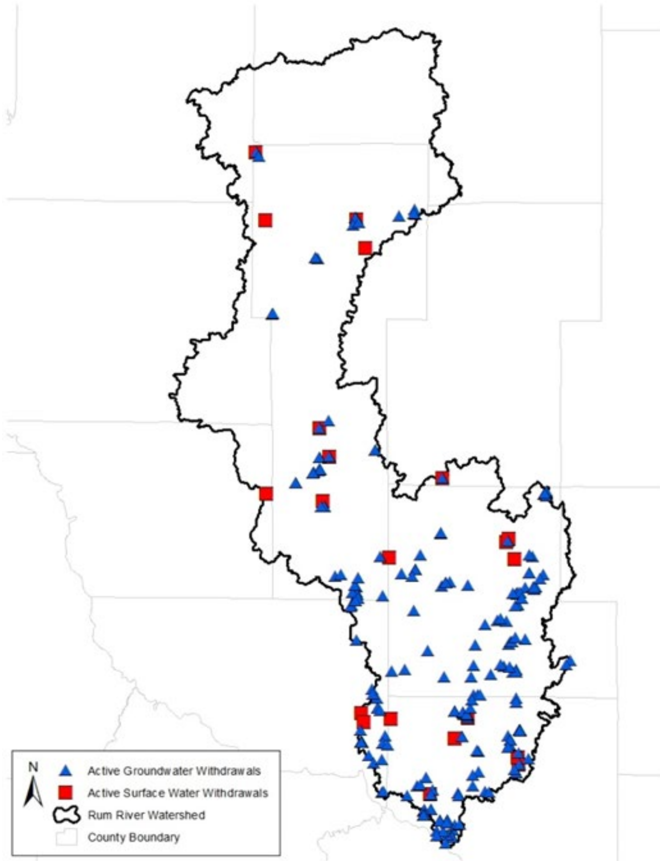


Figure 42: Locations of active status permitted high capacity withdrawals in 2013 within the Rum River Watershed

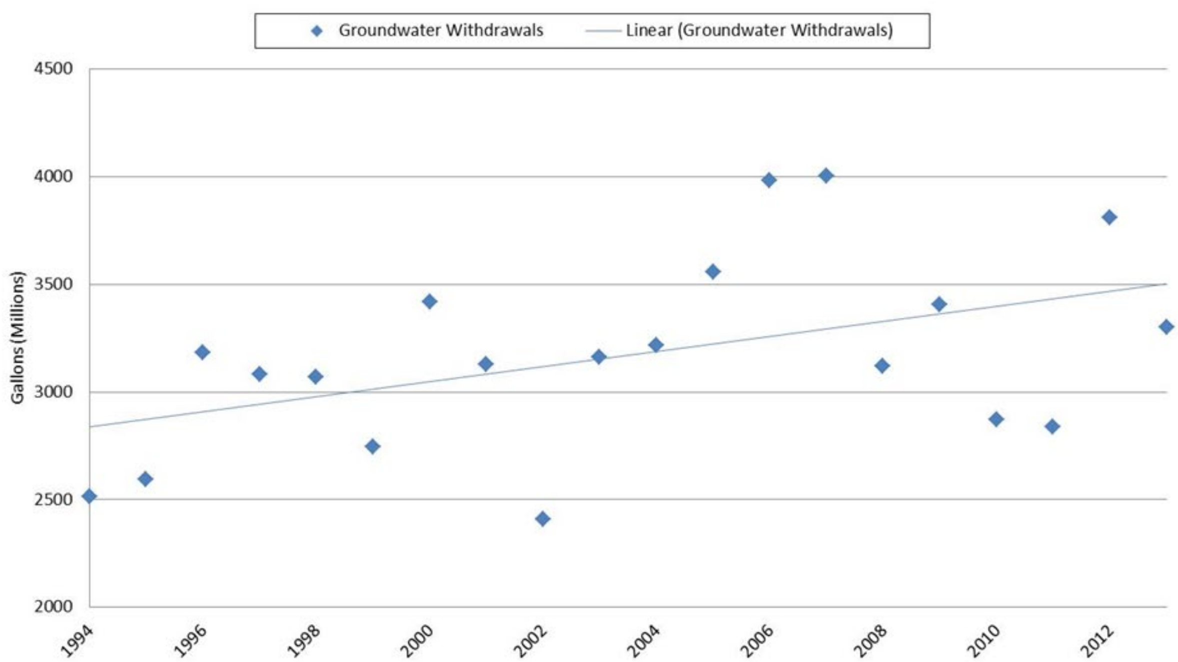


Figure 43: Total annual groundwater withdrawals in the Rum River Watershed (1994-2013)

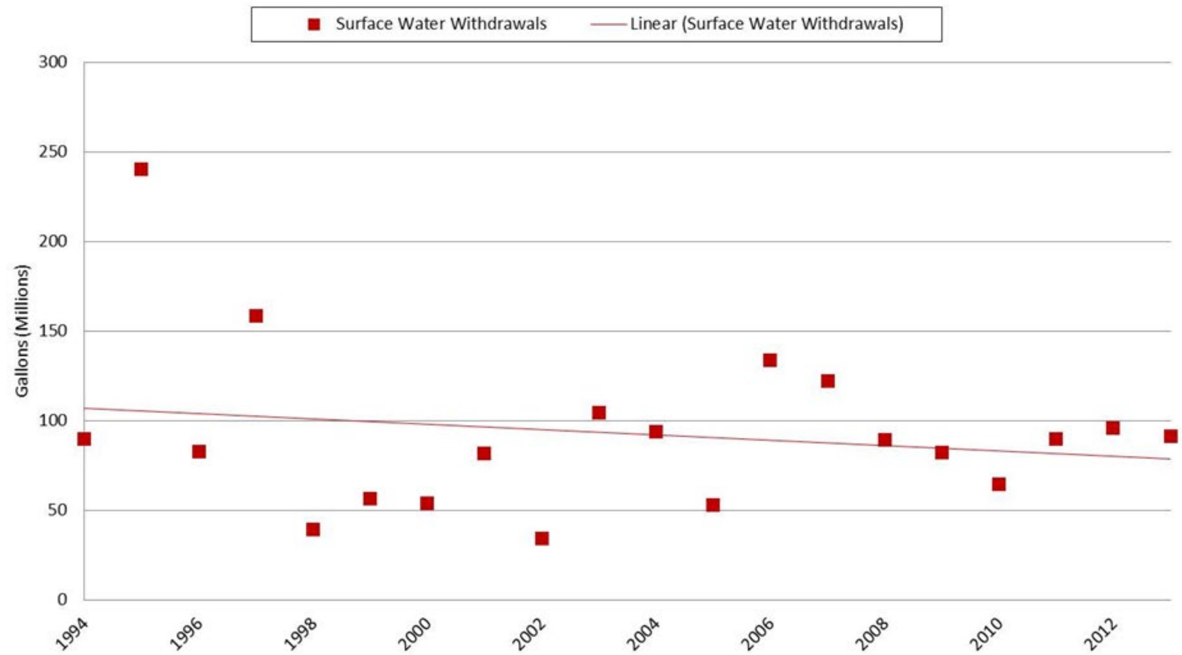


Figure 44: Total annual surface water withdrawals in the Rum River Watershed (1994-2013)

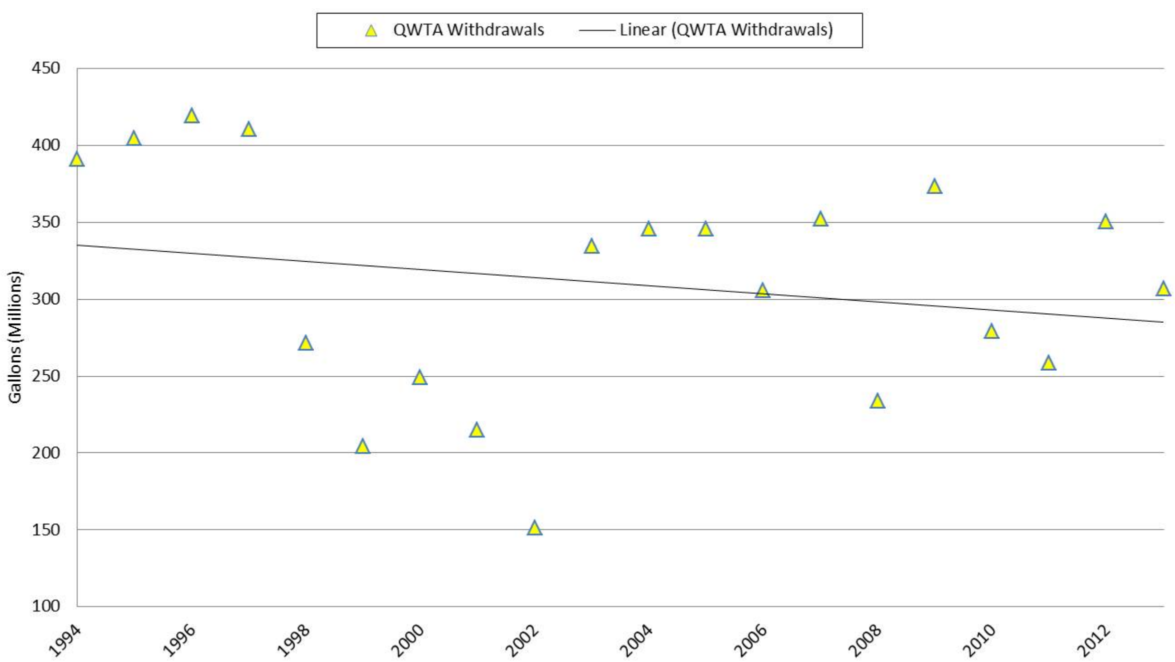


Figure 45: Total annual quaternary water table withdrawals in the Rum River Watershed (1994-2013)

MNDNR observation wells

Monitoring wells from the MNDNR Observation Well Network track the elevation of groundwater across the state. The elevation of groundwater is measured as depth to water in feet and reflects the fluctuation of the water table as it rises and falls with seasonal variations and anthropogenic influences. To access the MNDNR Observation Well Network, please visit http://www.dnr.state.mn.us/waters/cgm/index.html.

Three of the nine MNDNR observation wells (48011, 02025 and 30005) within the Rum River Watershed were chosen based on data availability and geologic location as representative of depth to groundwater throughout the watershed (Figure 46). Depth to Water (DTW) was collected on a monthly basis and the average annual DTW was calculated.

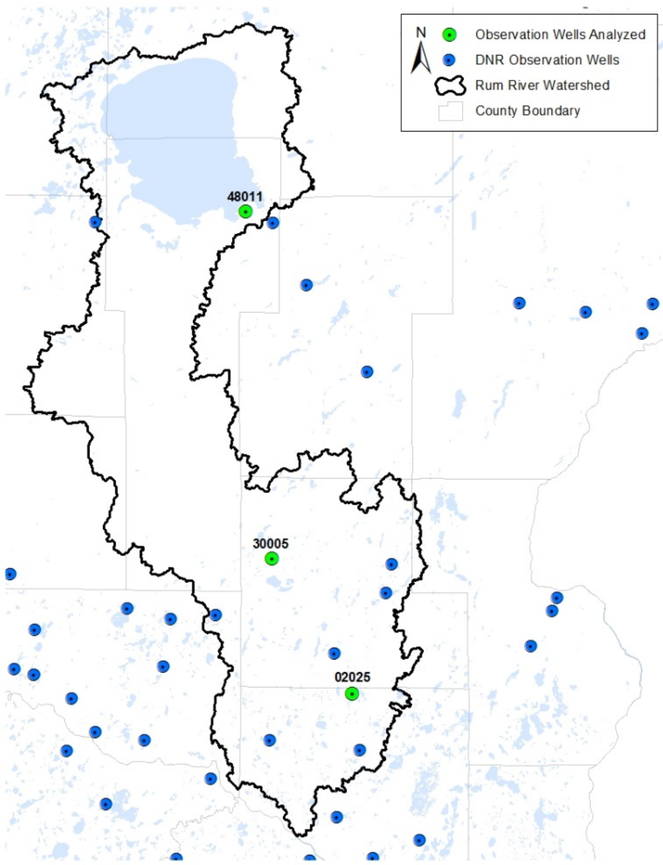


Figure 46: MNDNR quaternary water table observation well locations within the Rum River Watershed

For observation well 48011 located near Wahkon in the northern region of the watershed (Figure 47), observation well 02025 near Bethel in the southern area of the watershed (Figure 48), and observation well 30005 near Princeton in the central region (Figure 49), there is no statistical trend in depth to groundwater on an average annual basis.

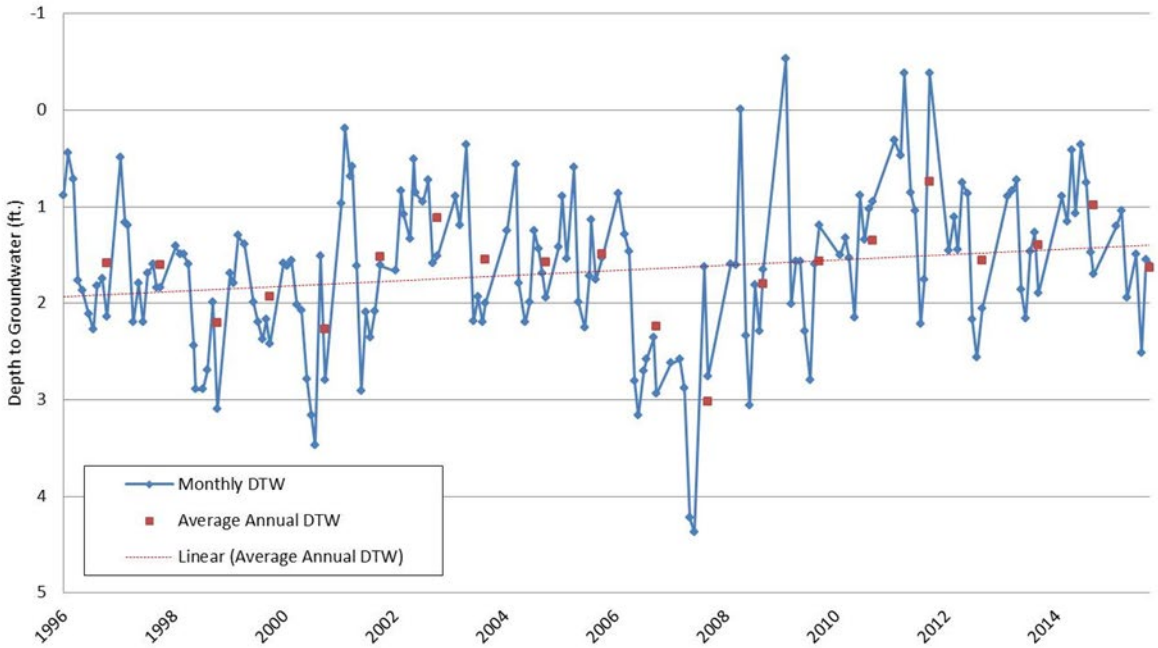


Figure 47: Depth to groundwater for observation well 48011 near Wahkon (1996-2015)

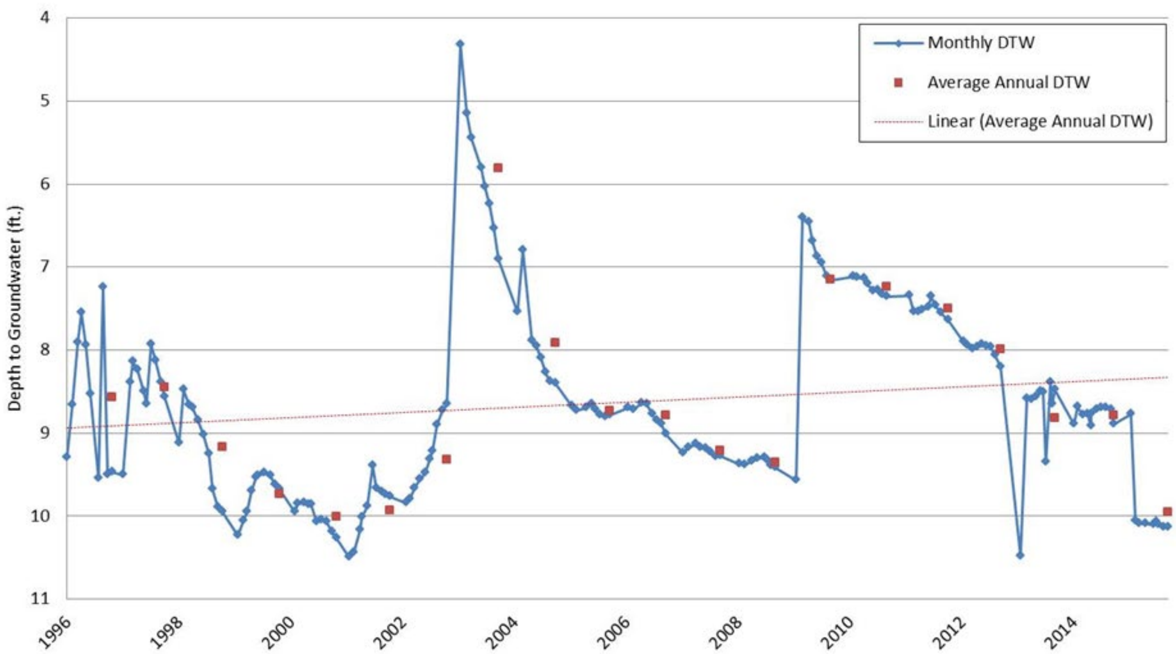


Figure 48: Depth to groundwater for observation well 02025 near Bethel (1996-2015)

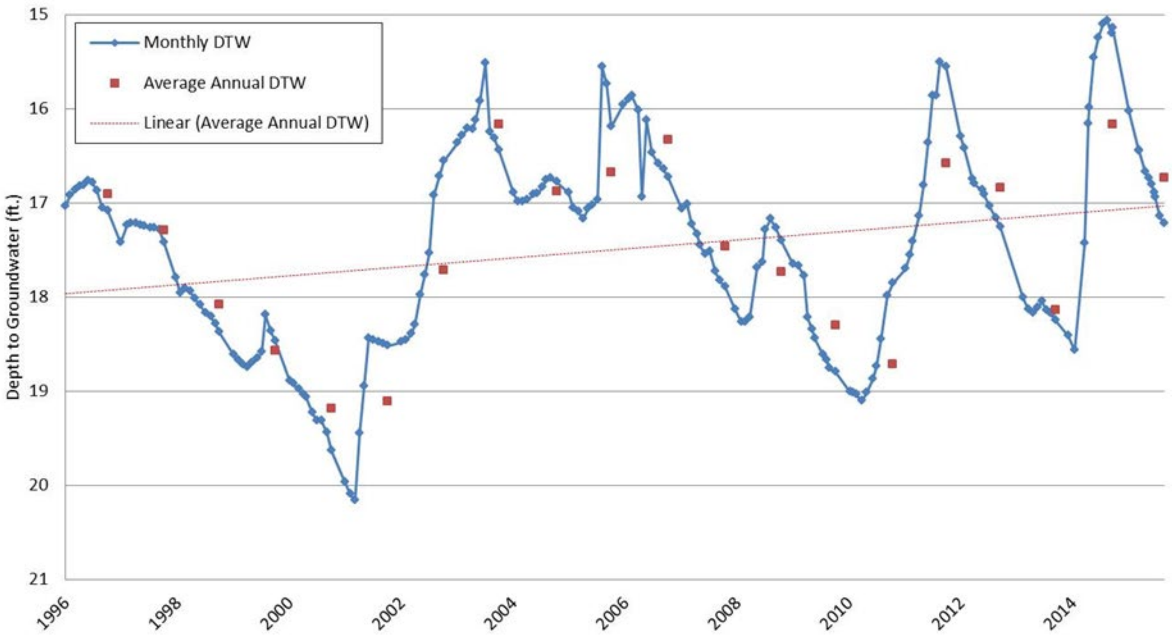


Figure 49: Depth to groundwater for observation well 30005 near Princeton (1996-2015)

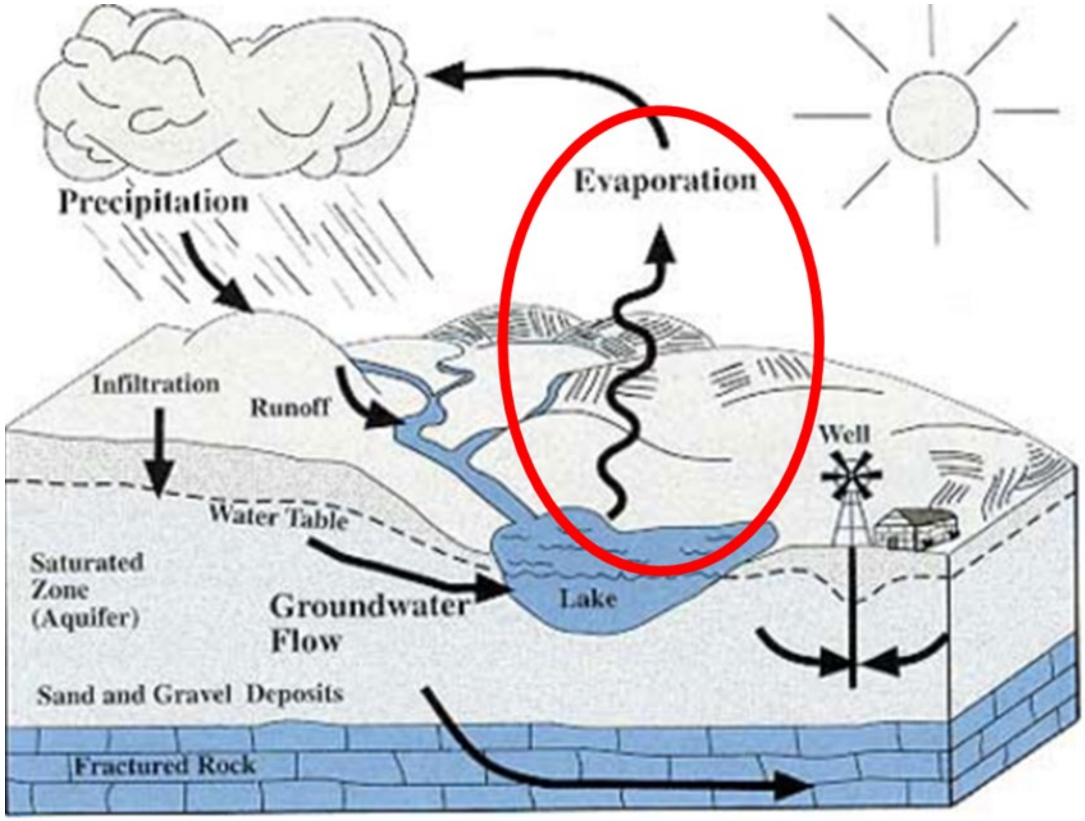


Figure 50: Evapotranspiration within the hydrologic cycle

VII. Evapotranspiration

Evapotranspiration definition

Evapotranspiration (ET) is the sum of evaporation and transpiration. ET can come from surface water bodies, the ground surface, evaporation from the capillary fringe in the near surface water table, and the transpiration of groundwater by plants whose roots draw water from the capillary fringe. Transpiration is mostly derived from the evaporation of water from plant leaves, and accounts for roughly 10% of the moisture in the atmosphere, with the other 90% coming from evaporation from surface water bodies (USGS, 2015b).

Evapotranspiration variation across Minnesota

Regarding evapotranspiration in Minnesota, the MNDNR describes this process as:

> The presence of moist versus dry air masses also helps to determine the atmosphere's ability to absorb water vapor evaporating from soil and open-water surfaces, or transpiring from leaf surfaces. Western Minnesota, more frequently under the influence of dry air masses, has higher evapotranspiration rates than the eastern half of the state. Temperature plays an important role in determining the amount of energy available for evapotranspiration. Because spatial temperature

patterns are determined mainly by latitude, southern Minnesota experiences more evapotranspiration than in the north.

Due to its position in the continent, Minnesota is located on the boundary between the semi-humid climate regime of the eastern U.S., and the semi-arid regime to the west. Semi-humid climates are areas where average annual precipitation exceeds average annual evapotranspiration, leading to a net surplus of water. In semi-arid areas, evapotranspiration exceeds precipitation on average, creating a water deficit. In Minnesota, the boundary between the climate regimes cuts the state roughly into east-west halves, as seen in an analysis of the difference between annual precipitation and evapotranspiration in Figure 51 (MNDNR, 2015f).

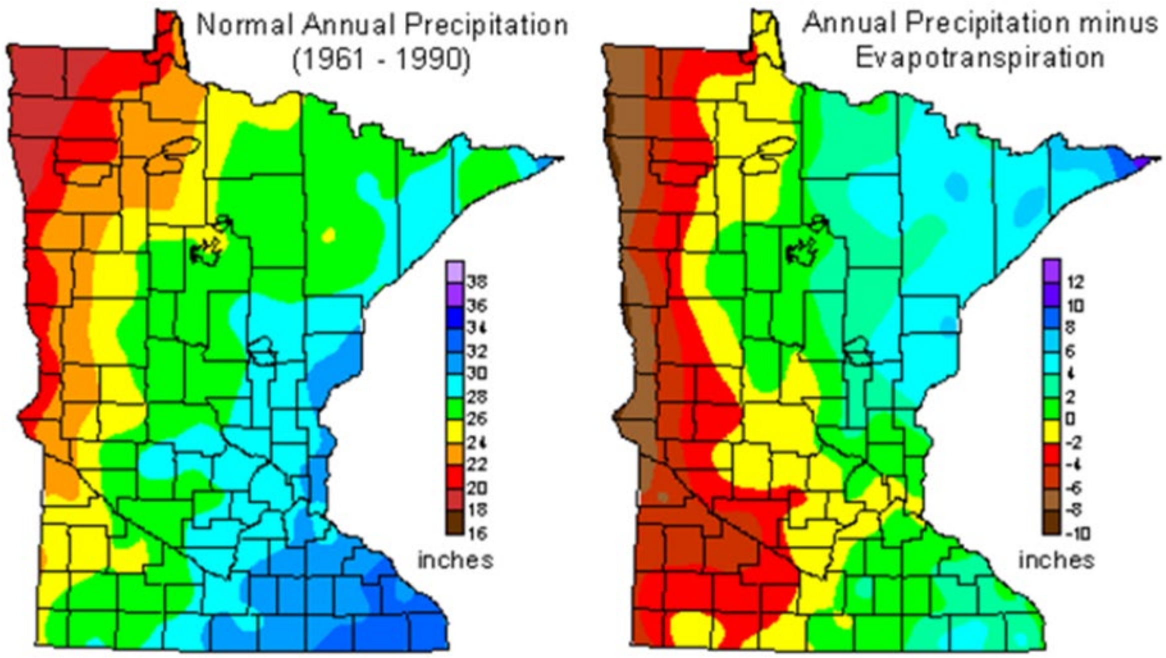


Figure 51: Minnesota annual precipitation and precipitation minus evapotranspiration (1961-1990)

VIII. Conclusion: Statement of groundwater condition

The principle concerns for this report are surface water quality and groundwater protection. According to the USDA NRCS, the County Soil and Water Conservation Districts within the Rum River Watershed identified and listed issues they believe should be considered as top priority for conservation and cost sharing efforts (USDA NRCS). Those issues include: soil quality and surface water quality-excessive sheet and rill erosion, nutrient/animal waste management, stormwater management, sediment and erosion control, groundwater protection (quality and quantity), and protection of shoreland/riparian areas.

Surface water quality

Surface water quality can be degraded by a number of different factors, including, but not limited to, atmospheric deposition, sedimentation from eroded soils, excess nutrients from runoff from nearby farm fields or impervious surfaces from urban areas, flow alteration or variability, point and nonpoint sources, septic systems and landfill disposal. According to the MPCA's surface water impairment list, the Rum River Watershed included a total of 32 impairments, with 18 stream reaches and 13 lakes (one lake had three impairments) (MPCA, 2015e). The primary impairment is mercury in fish tissue (62.5%), followed by insufficient DO levels (18.7%), nutrient/eutrophication biological indicators (15.6%), and PCB in fish tissue (3.1%). For more information impaired waters, please refer to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface waters for the Determination of Impairment, 305(b) Report and 303(d) List: https://www.pca.state.mn.us/sites/default/files/tmdl-guidancemanual04.pdf.

Mercury has been a rising issue for human consumption of fish due to the bioaccumulation of this element and its associated compounds which can cause damage to the central nervous system (MPCA, 2007). Research has identified that 70% of mercury deposition in Minnesota is anthropogenic while 30% is natural from atmospheric deposition (MPCA, 2007). In 2007, the U.S Environmental Protection Agency approved the Minnesota's Statewide Mercury Total Maximum Daily Load study, which allocated reduction shares to 90% federal and 10% state. The state is working on the long term goal to reduce the mercury concentration in water bodies by reducing state emissions by 93% (MPCA, 2007).

Although nutrients, such as nitrogen and phosphorus, are necessary for stream health, excess levels can cause algal blooms, which decrease the amount of light and dissolved oxygen available for aquatic plants and organisms. DO, a function of atmospheric pressure, water temperature, and dissolved substances in the water, is a vital constituent for aquatic health and water quality. Two primary sources for depleted oxygen levels include excess nutrient runoff and soil erosion (causing turbidity) from agricultural landscapes into nearby waterbodies. The total number of acres treated within the Rum River Watershed with one or more chemicals, including insecticides, herbicides, wormicides and fruiticides is 136,674 acres, or approximately 13.7% of the watershed (USDA NRCS). This is a small percentage of the watershed, but should be monitored and mitigated due to the number of impaired stream reaches. Turbidity is caused from suspended sediments in the water column, often from soil erosion, that can block light and limit the photosynthesis process.

Groundwater protection

Groundwater protection is a function of both quantity and quality. One simple measure of groundwater quantity is the difference between the amount of groundwater withdrawn versus the amount of water being recharged to the aquifer. Groundwater withdrawals in the watershed have increased from 2.5 billion gallons in 1994 to 3.3 billion gallons in 2013. Part of this rising demand is for agriculture, which has increased the demand for irrigation, which has increased statistically (p=0.01) over this time

Figure 52: Aerial view of agricultural fields near Princeton, Minnesota

period. Also, population increase has created more urbanization and development. It is estimated that the development pressure is moderate to considerable in some parts of the watershed where land is converted from farms, timberland and lakeshore into home development (USDA NRCS). This increase in development is also seen with an increase in municipal water supply, which has significantly increased (p=0.001) from 1994 to 2013. Increases in agricultural practices and development causes fragmentation of the landscape, resulting in increased sediment and pollutant loading (Figure 52) (USDA, NRCS).

While the amount of water being withdrawn from aquifers has increased greatly over time, there is no statistical evidence of a groundwater table drawdown from the MNDNR observation wells. There are fluctuations due to seasonal variations, but long term changes have not been observed from this data. This may be due to a higher rate of potential groundwater recharge to surficial materials throughout the watershed (Figure 53). When comparing the location of the permitted groundwater withdrawals, they are primarily correlated with areas of higher potential recharge, which ranged as high as 17.5 inches per

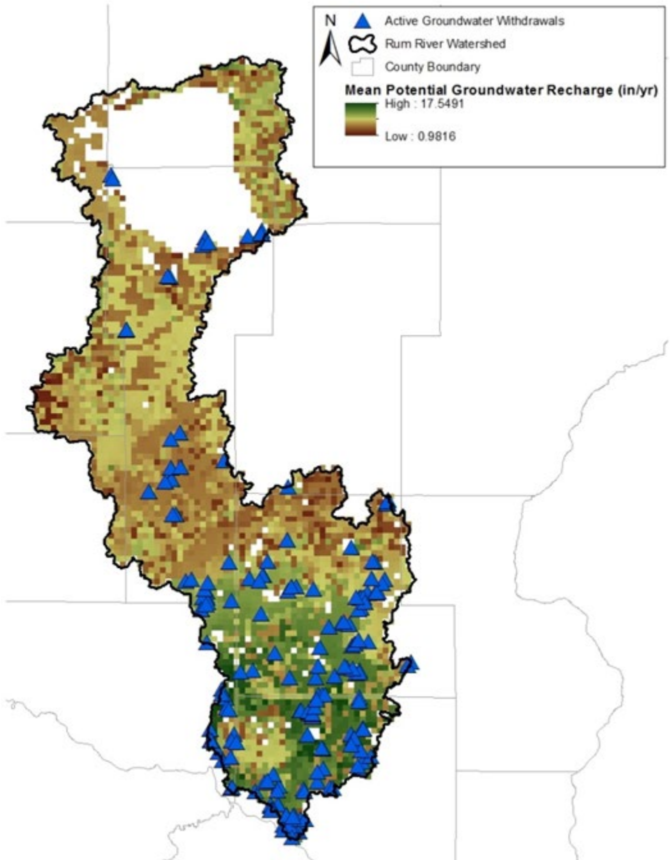


Figure 53: Mean potential groundwater recharge and groundwater permit locations in the Rum River Watershed

year. However, if water usage continues to increase at its current rate, the probability of the water table being drawn downwards also increases. It is for this reason that the MNDNR monitors and takes precautions when permitting water use appropriations.

The watershed is located primarily within the North Central Hydrogeologic Region, with the northern tip in the Northeast Region, and the southern tip within the Twin Cities Metropolitan Region. During the MPCA's baseline study, the groundwater quality in the southwest region was determined to be poor, while the North Central Region groundwater quality was considered very good. Although exceedances were found for many different constituents within the regions, the primary contaminant of concern was nitrate. Nitrate was detected in 100% of the wells in the Pesticide Monitoring Region 5, with 44% above the drinking water standard. Up to four different pesticides were found in some of the sites sampled in the watershed, though none at a level of concern. Chloride is a concern for this watershed, due to highly developed land use within the southern part of the watershed. Arsenic monitoring conducted by the MDH, determined that concentrations exceeded the water quality standard of 10 micrograms per liter in less than 10% of the private wells in all of the watershed counties.

The groundwater quality of the watershed appears to be good, despite the exceedances of MCLs. The MPCA monitors 18 wells within the watershed to investigate the background chemistry and impact of chemicals on the groundwater. Statistical analysis was completed on these wells for 117 different constituents and parameters to determine concentration, frequency and possible trends. Chloride, Sodium and nitrate detection frequency for 2010 to 2014 was 93.9, 98.7 and 95.2% of wells, respectively. Chloride exceeded the secondary MCL in ten instances and nitrate exceeded the MCL in three instances. CECs were also detected with the three most common detections being sulfadimethoxine, isophorone and 2-methylanaphythalene. Frequently detected compounds in these wells included sulfate, bromide, aluminum, iron, magnesium, manganese, potassium, strontium, barium, boron and phosphorus.

Groundwater quality is based on the sensitivity of the aquifers and the effects of naturally occurring and anthropogenic constituents found in the water. Factors affecting aquifer sensitivity include: 1) whether the aquifer is shallow or deep, 2) whether the aquifer is unconfined or confined, 3) the material of the aquifer, and 4) groundwater recharge rates. Typically, aquifers that are shallow, unconfined, have low clay content with cobbles and gravel materials, and high recharge tend to have greater sensitivity to contamination. Sources of contamination can be naturally occurring, such as atmospheric deposition or weathering processes, or anthropogenic influences, such as leaking storage tanks, septic systems, landfills, uncontrolled hazardous waste, and chemical applications to agricultural landscapes or for deicing roads, parking lots, or sidewalks. Although the ambient groundwater quality data appears to be good, the MPCA's WIMN program has identified a number of potentially contaminated sites and facilities within the Rum River Watershed. These types of sites include feedlots, hazardous waste, investigation and cleanup, solid waste, and tanks and leaks sites that have been identified as a potential, current or past contamination site or a site that is not a contamination risk, but required an

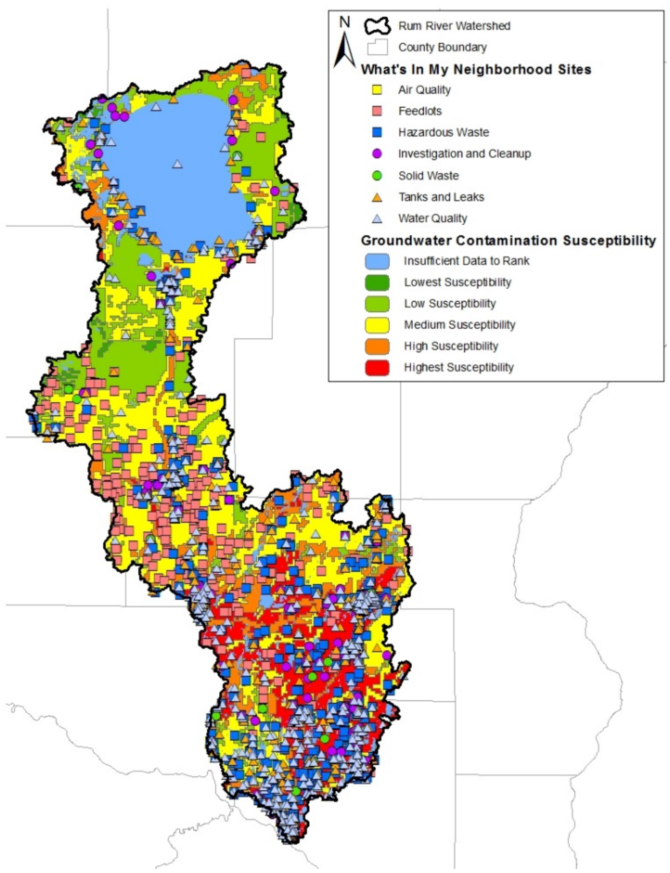


Figure 54: Rum River Watershed groundwater contamination susceptibility and WIMN sites

environmental permit or registration from the MPCA (Figure 54). Due to the higher levels of groundwater contamination susceptibility throughout the watershed, it is important to continue to monitor these potentially harmful sites in order to inhibit possible water pollution.

Recommendations

Overall, the groundwater quality of the watershed appears to be healthy, with few exceedances of chemicals and contaminants of interest and concern. Additional and continued monitoring will increase the understanding of the health of the watershed and its groundwater resources and aid in identifying the extent of the issues present and risk associated. Increased localized monitoring efforts will help accurately define the risks and extent of any issues within the watershed. Adoption of best management practices will benefit both surface and groundwater. These practices, such as planting cover crops, replacing aging septic systems, and controlling feedlot runoff and chemical application, will help prevent and mitigate negative impacts in the future.

As population and development grows, so too do irrigation and water supply demands. The MNDNR permits and tracks water use by permit holder and rising demand suggests that the department be cautious in granting future permits. Another factor to consider is climate change. Climate change is stimulating changes in precipitation, seasonal length, and droughts, which all can contribute to alterations in groundwater availability. The current state of the Rum River Watershed may be able to maintain the current demand, but with changes in demand and climate, the status quo may not be sustainable.

IX. References

Erickson, M.L., Langer, S.K., Roth, J.L, and Kroening, S.E. (2014), Contaminants of Emerging Concern in Ambient Groundwater in Urbanized Areas of Minnesota, 2009-12 (ver. 1.2): U.S. Geological Survey Scientific Investigations Report 2014-5096. Retrieved from http://pubs.usgs.gov/sir/2014/5096/pdf/sir2014-5096.pdf.

Kroening, S. and Ferrey, M. (2013), The Condition of Minnesota's Groundwater, 2007-2011. Document number: wq-am1-06

Minnesota Department of Agriculture: Pesticide and Fertilizer Management (2015), 2014 Water quality Monitoring Report. MAU-15-101.

Minnesota Department of Health (2015), Private Wells - Arsenic. Retrieved from https://apps.health.state.mn.us/mndata/webmap/wells.html.

Minnesota Department of Natural Resources (2001), Figure 1: Minnesota Ground Water Provinces. Retrieved from http://files.dnr.state.mn.us/natural_resources/water/groundwater/provinces/gwprov.pdf.

Minnesota Department of Natural Resources: State Climatology Office (2003), Climate. Retrieved from http://www.dnr.state.mn.us/faq/mnfacts/climate.html.

Minnesota Department of Natural Resources: State Climatology Office (2015), Annual Precipitation Maps. Retrieved from http://climate.umn.edu/doc/annual_pre_maps.htm.

Minnesota Department of Natural Resources (2015a), Surface-water watersheds vs. ground-water watersheds. Retrieved from http://www.dnr.state.mn.us/watersheds/surface_ground.html

Minnesota Department of Natural Resources (2015b), Fisheries Lake Survey: Shakopee. Retrieved from http://www.dnr.state.mn.us/lakefind/showreport.html?downum=48001200.

Minnesota Department of Natural Resources (2015c), Fisheries Lake Survey: Green. Retrieved from http://www.dnr.state.mn.us/lakefind/showreport.html?downum=30013600.

Minnesota Department of Natural Resources (2015d), Groundwater Pollution Sensitivity. Retrieved from http://www.dnr.state.mn.us/waters/groundwater_section/mapping/sensitivity.html.

Minnesota Department of Natural Resources (2015e), Water use- Water Appropriations Permit Program. Retrieved from http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html.

Minnesota Department of Natural Resources (2015f), Climate's Impact on Water Availability; evapotranspiration. Retrieved from http://www.dnr.state.mn.us/climate/water_availability.html.

Minnesota Pollution Control Agency (1998), Baseline Water Quality of Minnesota's Principal Aquifers: Region 2, North Central Minnesota.

Minnesota Pollution Control Agency (2005), Minnesota's Ground Water [PowerPoint slides]. Retrieved from https://www.pca.state.mn.us/sites/default/files/pp-mngroundwater.pdf.

Minnesota Pollution Control Agency (2009), Watershed Approach to Condition Monitoring and Assessment. Document number: wq-s1-27.

Minnesota Pollution Control Agency (2015a), Rum River Watershed. Retrieved from https://www.pca.state.mn.us/water/watersheds/rum-river.

Minnesota Pollution Control Agency (2015b), Shakopee: 4 MI NW of Onamia (Lake). Retrieved from http://cf.pca.state.mn.us/water/watershedweb/wdip/waterunit.cfm?wid=48-0012-00.

Minnesota Pollution Control Agency (2015c), Green: 8 MI E of Princeton (Lake). Retrieved from http://cf.pca.state.mn.us/water/watershedweb/wdip/waterunit.cfm?wid=30-0136-00.

Minnesota Pollution Control Agency (2015d), Round: 1 MI NE of Anoka (Lake). Retrieved from http://cf.pca.state.mn.us/water/watershedweb/wdip/waterunit.cfm?wid=02-0089-00.

Minnesota Pollution Control Agency (2015e), Minnesota's Impaired Waters List. Retrieved from https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list.

Porcher, E. (1989), Ground Water Contamination Susceptibility in Minnesota (revised edition), Minnesota Pollution Control Agency, St. Paul, MN, 29 p.

Streitz, A. (2011), Minnesota Pollution Control Agency. Retrieved from http://www.mgwa.org/newsletter/mgwa2011-4.pdf

United States Environmental Protection Agency (2016), Polychlorinated Biphenyls (PCBs). Retrieved from https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs.

United States Department of Agriculture, Natural Resources Conservation Service (No Date), Rapid Watershed Assessment: Rum River (Wahkon) (MN) HUC: 07010207. Retrieved from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022268.pdf.

United States Geological Survey (2007), Ground Water Recharge in Minnesota. Retrieved from http://pubs.usgs.gov/fs/2007/3002/pdf/FS2007-3002_web.pdf.

United States Geological Survey (2015a), Aquifers and Groundwater. Retrieved from http://water.usgs.gov/edu/earthgwaquifer.html.

United States Geological Survey (2015b), Evapotranspiration, The Water Cycle. Retrieved from http://water.usgs.gov/edu/watercycleevapotranspiration.html.

Zhang, H. (1998), Geologic Atlas of Stearns County, Minnesota: Hydrogeology of the Quaternary Water Table System. County Atlas Series, Atlas C-10, part B, Plate 8 of 10, Hydrogeology of the Quaternary Water-table System.