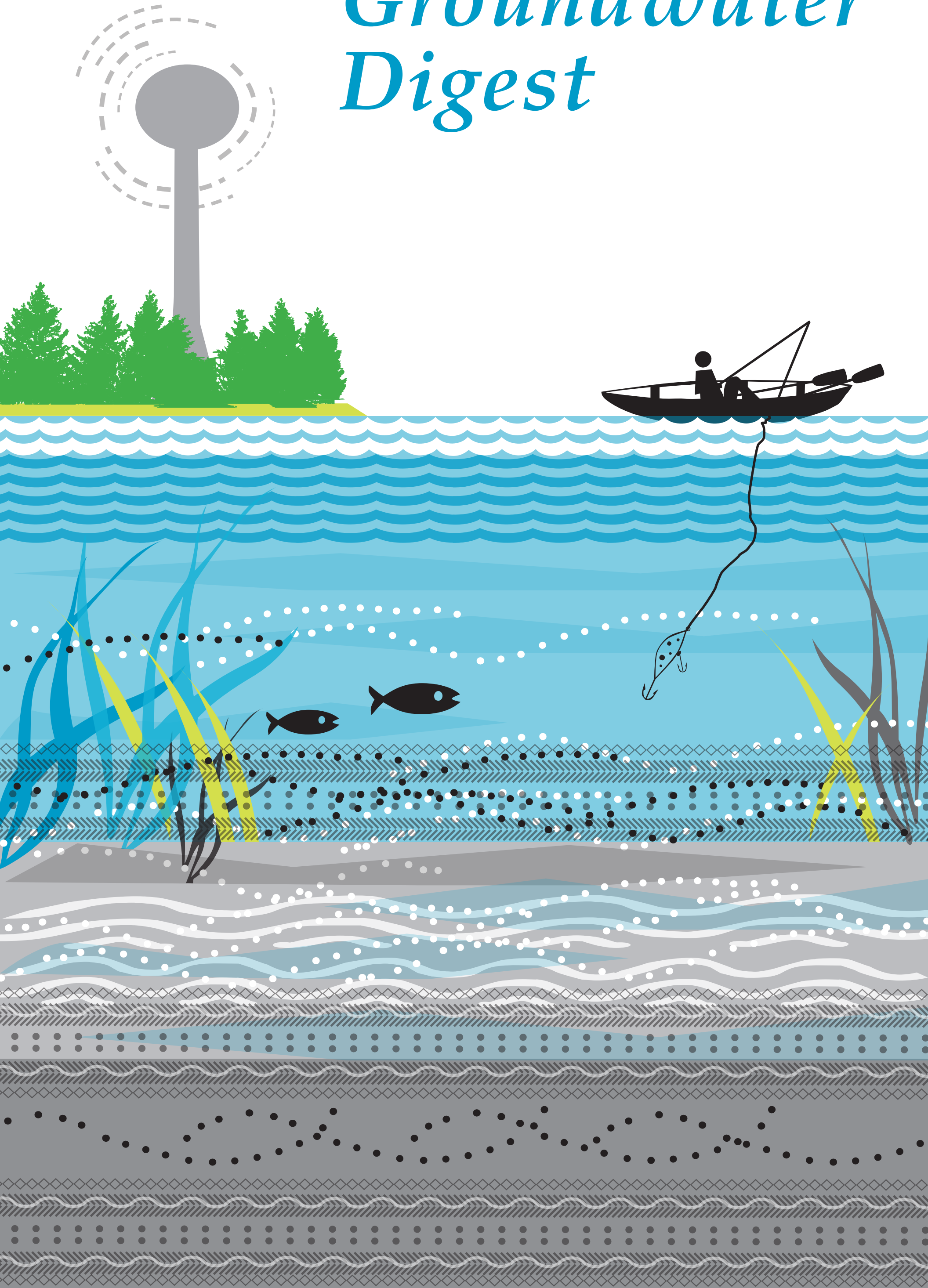
TWIN CITIES METROPOLITAN AREA, MINNESOTA

Groundwater Digest



GROUNDWATER

This Digest Explains How Groundwater "Works" And Why It Is Important To This Region.

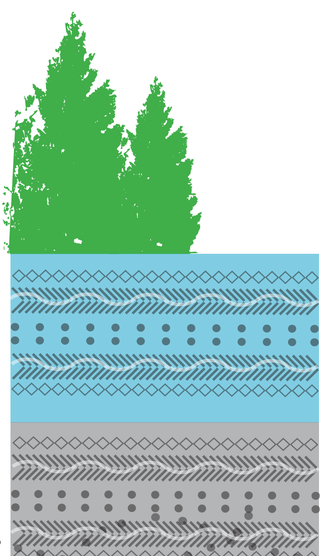
WHAT IS IT AND WHY IS IT IMPORTANT?

Groundwater is water that fills the cracks and pores of rocks and sediments that lie beneath the surface of the earth – much the way water saturates a sponge. In the Twin Cities metropolitan area, this is an abundant but finite and vulnerable resource.

Groundwater is the source of drinking water for 75% of the people in the Twin Cities metropolitan area. Groundwater also flows into many of our lakes and rivers, supporting the recreational parks and natural ecosystems that are so unique and valuable to our metropolitan area.

Current use reflects a long-term shift in the balance between surface water and groundwater, and a growing body of evidence indicates that a "business as usual" approach to groundwater management may not be sustainable:

- Water level and flow records show downward trends in groundwater-connected lakes, wetlands, and trout streams
- Groundwater contamination has been documented in many locations
- Groundwater observation well records show a downward trend at many locations
- Well interference complaints are increasing

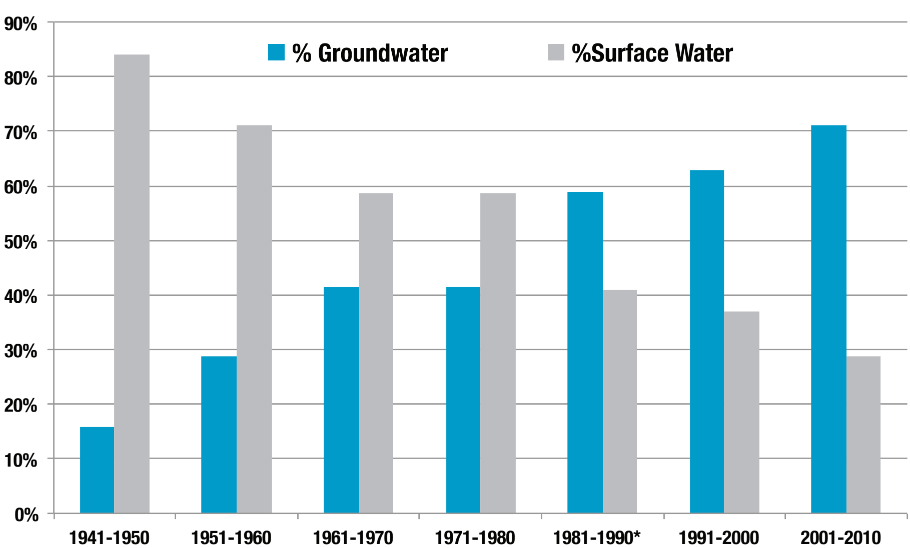


Today, we have a better understanding of the region's groundwater resources than ever before. We can make better decisions that sustain our water supplies into the future.

Groundwater
Water stored in the pore spaces of rocks and unconsolidated deposits found in the saturated zone of an aquifer.

Sustainable Water Use
Use of water that does not harm ecosystems, degrade water quality, or compromise the ability of future generations to meet their own needs.

MUNICIPAL WATER USE IN SEVEN-COUNTY TWIN CITIES METROPOLITAN AREA



GROUNDWATER TERMS AND CONCEPTS

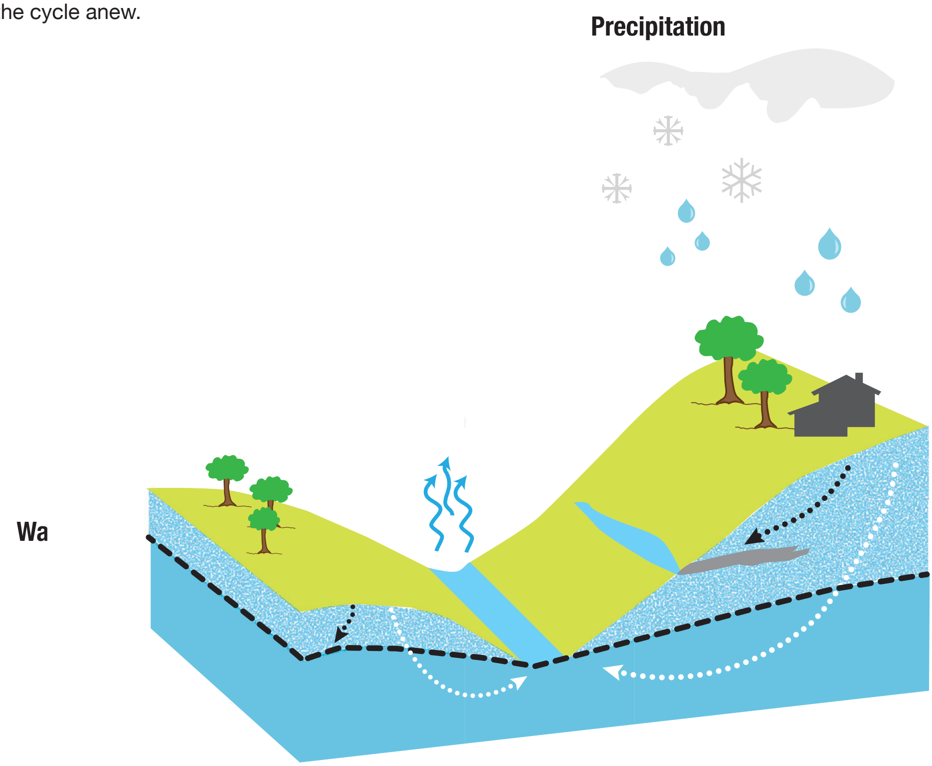
Where is groundwater located?

Groundwater is available nearly everywhere, but the quantity available and the conditions that control the occurrence of groundwater vary from one region to another. Depending on the geology of an area, for example, a person may have to drill only a few feet or may have to drill several hundred feet before reaching the geologic formations that will yield enough groundwater to use.

Where does groundwater come from?

Groundwater, as a part of the water cycle, comes from precipitation – rain and snow – that infiltrates through the soil until it reaches the zone of saturation. This process is called recharge.

Figure 1. Groundwater is part of the water cycle. Precipitation that soaks through our soil is stored in our aquifers until it is pumped out or discharges naturally to surface waters, where it is again able to evaporate and begin the cycle anew.



Where does water reside underground?

The quantity of water a given rock type will hold depends on the rock's porosity – a measure of pore space between the grains of the rock or within cracks in the rock that can be filled with water. However, measurements of porosity do not indicate how well-connected pore spaces are.

How does water move underground?

Permeability is the ability of a geologic formation to transmit groundwater through connected pore spaces. Permeability is controlled by the size, shape, and interconnectedness of the pore spaces of a rock formation. Permeability can range from highly permeable unconsolidated deposits, such as gravels, to impermeable units like shale that block the flow of groundwater.

Geologic Formations
Rocks or unconsolidated deposits that form a unit and may be dominated by a certain type of deposit or rock, or may have some other common feature.

Water Cycle
The path that water takes through its various states – vapor, liquid, solid – as it moves throughout the ocean, atmosphere, groundwater, lakes and streams.

Recharge
Process by which water from rainfall, snowmelt or other sources seeps through the soil into the saturated zone.

Porosity
Volume of open pore space between particles of clay, silt, sand, gravel, cobble or within rock in a geologic formation.

Permeability
Ability of a rock or unconsolidated deposit to transmit water through connected spaces between grains. The size and shape of the spaces controls how easily water flows.

What is the difference between the saturated and unsaturated zones?

The unsaturated zone is the area below the land surface where pores in the soil contain both water and air. Water present in this zone is generally referred to as soil moisture.

The saturated zone is the zone below land surface with only water filling its pore spaces. The upper boundary of the saturated zone, open to atmospheric pressure, is generally known as the water table.

What is an aquifer?

Aquifers are the saturated geologic formations that bear and transmit groundwater. The aquifer is not only a storage reservoir, but also a pathway for water movement underground.

Figure 2. Groundwater is only able to flow through connected open spaces between grains of sediment or in connected fractures in bedrock. When pores are not connected, groundwater cannot move.

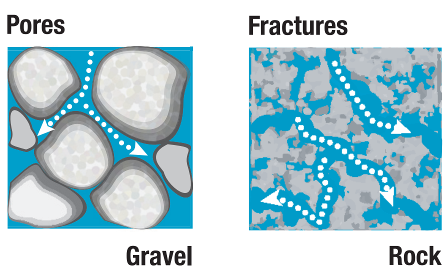
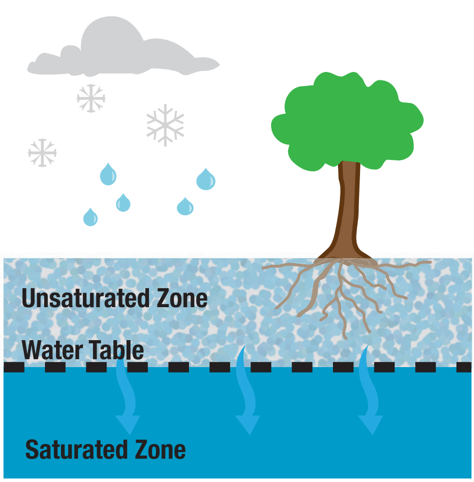


Figure 3. Water flows from the land surface down through the unsaturated zone, where air and water mix, to the saturated zone. The top of the saturated zone is commonly known as the water table.



Confined and unconfined aquifers

Confined aquifer (artesian aquifer): A confined aquifer has an impermeable geologic formation (confining layer) at the top, causing the groundwater to be under pressure. Because of this pressure, the water level in a confined aquifer is above the top of the aquifer and sometimes even above the land surface. The level to which water rises in a well drilled in a confined aquifer is called the pressure head.

Unconfined aquifer (water table aquifer): An unconfined aquifer does not have a confining layer above it. Because groundwater is not under pressure, the water level in an unconfined aquifer can rise or fall freely. There will be a water table in an unconfined aquifer.

Unsaturated Zone
Area below the land surface that contains a mixture of air and water.

Soil Moisture
Moisture contained in the soil above the water table, including water vapor.

Saturated Zone
Zone with only water in the interconnected spaces.

Water Table
The elevation at which the pore water pressure is at atmospheric pressure.

Aquifers
Rock or sediment that is saturated and able to transmit economic quantities of water to wells and surface waters.

Confined Aquifer
Aquifer with a confining layer at the top, causing the groundwater to be under pressure.

Pressure Head
Height of the water column due to aquifer pressurization.

Unconfined Aquifer
Aquifer without a confining layer at the top and a lack of pressure that allows the water level to easily rise and fall.

How does groundwater flow?

Underground, water moves from higher elevations to lower elevations, from locations of higher pressure to location of lower pressure, and from an aquifer's recharge areas to its natural discharge areas at springs, streams, wetlands, and lakes. Water may take from a few days to hundreds of years to reach its natural discharge area. Groundwater movement in gravels and sands is relatively rapid, whereas it is exceedingly slow in clay or in tiny rock fractures. The ability of geologic material to move groundwater is called hydraulic conductivity. It is often measured in feet per day (ft/day).

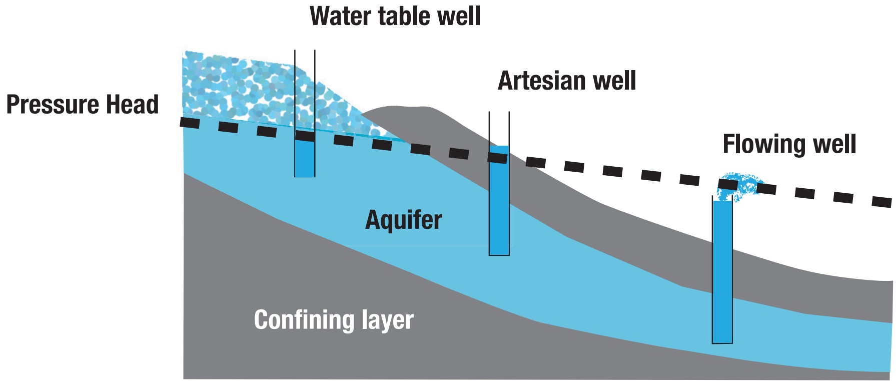
How does land use change groundwater flow?

The amount of groundwater recharge in an area depends on climate, topography, soil type, and land use. When land use changes, recharge also changes. Leaking underground storage tanks can pollute recharge, and impervious surfaces like buildings and parking lots can prevent recharge from occurring.

What is the safe yield of an aquifer?

Safe yield is a balance between groundwater pumping and recharge and is expressed as the amount of water that can be safely pumped from an aquifer system without damaging the aquifer. Under confined conditions, safe yield means the amount of water that can be withdrawn without degrading groundwater quality or resulting in a change from artesian to water table conditions. Available head is an informal term to specify the amount of decline in water level that can occur in a confined aquifer before artesian conditions change to water table conditions.

Figure 4. Aquifers may be described as confined or unconfined. Confined aquifers have a low permeability geologic formation above them, causing the groundwater to be under pressure. Unconfined aquifers do not have have such a layer .



Recharge Area
An area where surface water from rainfall, snowmelt or other sources seeps through the soil into the saturated zone.

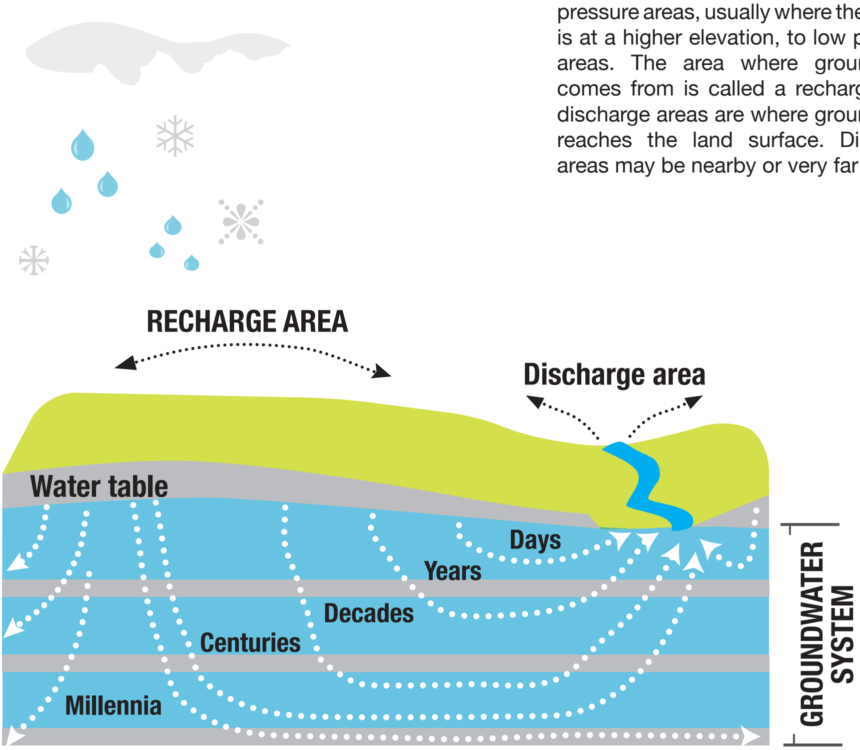
Hydraulic Conductivity
A measure of the permeability of the porous media. It is commonly measured in feet per day (ft/day).

Safe Yield
Amount of groundwater that can be withdrawn from an aquifer system without degrading the quality of the aquifer and without allowing the long-term average withdrawal to exceed the available long-term average recharge to the aquifer system

Recharge
The natural or manmade infiltration of surface water into the zone of saturation.

Available Head
An informal term to specify the amount of decline in water level that can occur in a confined aquifer before artesian conditions change to water table conditions.

Figure 5. Groundwater moves from high pressure areas, usually where the aquifer is at a higher elevation, to low pressure areas. The area where groundwater comes from is called a recharge area; discharge areas are where groundwater reaches the land surface. Discharge areas may be nearby or very far away.



How does groundwater pumping affect the water levels in an aquifer or in lakes and streams?

When groundwater is pumped from a well, the water level is lowered in the surrounding area. A hydraulic gradient or slope is created in the aquifer, which allows water to flow toward the well. The difference between the original water level and the water level during pumping is the drawdown. The greater the yield from the well, the greater the drawdown. The drawdown decreases farther away from the well until a point is reached where the water level is unaffected. The surface of the pumping level is in the form of an inverted cone and is referred to as a cone of depression.

If the well is between a groundwater recharge area and the surface water discharge area, groundwater will flow to the well instead of the lake or stream it used to support. If the well is close to the surface water, or if it pumps enough, water may be drawn out of the surface water itself. The greater the drawdown around the well, the more water may be diverted from nearby surface waters.

If the well is near another well and pumps enough, groundwater may flow away from one well to the other. This is called well interference, which occurs when the cone of depression around a wells expands to overlap another.

Hydraulic Gradient
The change in an aquifer's water level elevation over a given distance.

Drawdown
The lowering of the water table in and around a pumping well. It is the difference between the pumping water level and the original water level.

Cone of Depression
A cone-shaped depression of the water table.

Figure 6. Pumping a well causes drawdown in the aquifer's water level, and the resulting slope forms a cone of depression. When cones of depression overlap each other, well interference can occur.

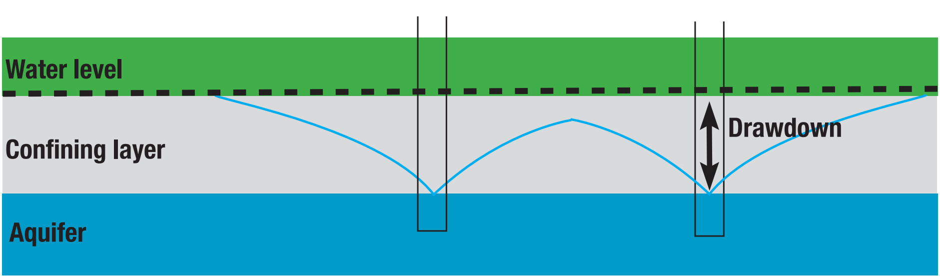


Figure 7. Pumping from aquifers near surface water bodies can diminish those surface waters by capturing some of the groundwater flow that otherwise would have discharged to them, or by inducing flow from surface water into the surrounding aquifer system.

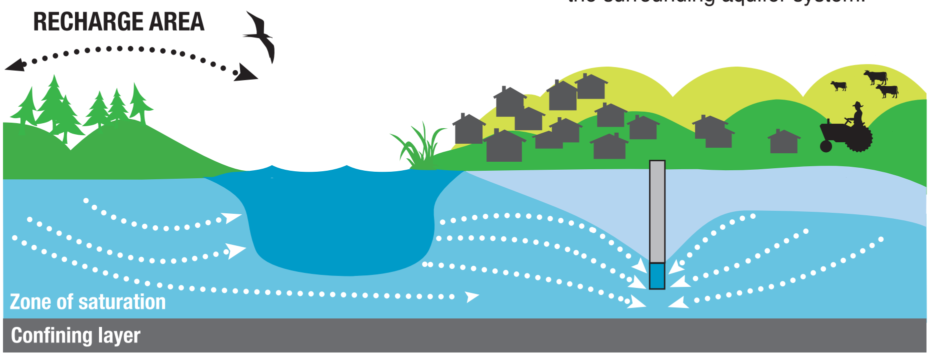
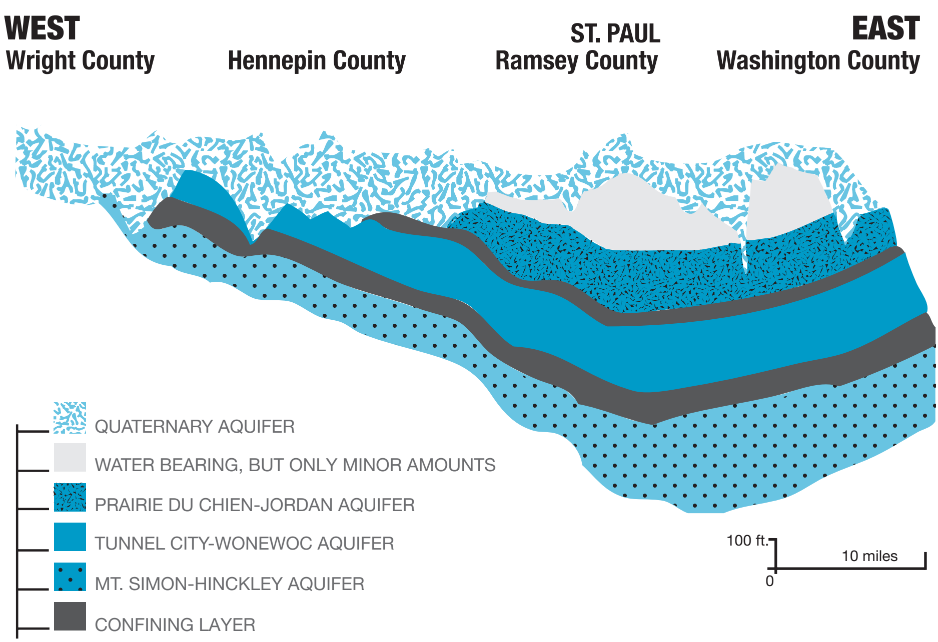
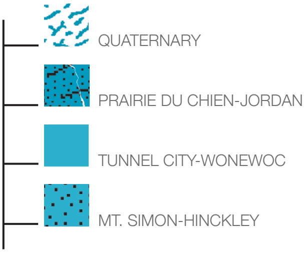


Figure 8. The aquifers of the Twin Cities Metropolitan Area consist of unconsolidated glacial deposits and underlying bedrock layers. They form a bowl shape called the Twin Cities Basin when viewed in cross section from west to east.



HYDROGEOLOGIC CHARACTERIZATION OF THE TWIN

While many geologic units exist in the Twin Cities Metropolitan area, the primary aquifers include:



Quaternary Aquifer

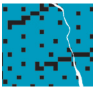
Extent: Variable across the metro

Geologic Material: Discontinuous and complex bodies of silt, sand, and gravel

Yield: Moderate to high. Reported pumping capacity of metropolitan area municipal wells: 100 to 3,800 gallons per minute (average of 1,185)

Management Concerns:

- Challenging to identify the location of the most productive sand and gravel layers
- First aquifer to be recharged
- Vulnerable to contamination
- Water quantity and quality varies



PRAIRIE DU CHIEN-JORDAN AQUIFER

Extent: Not present across entire metro

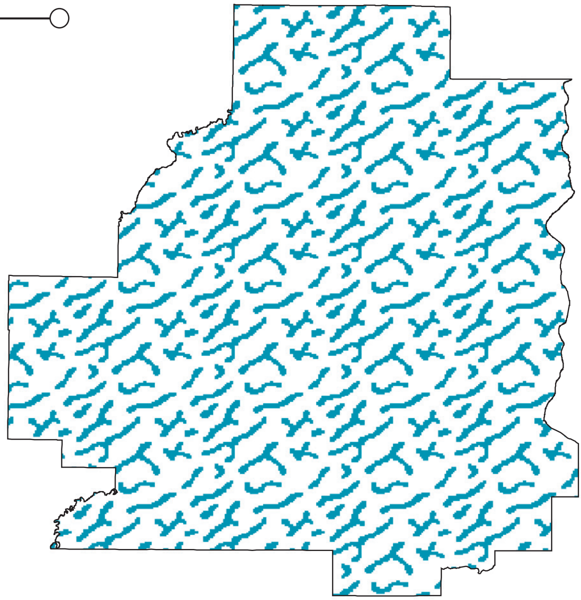
Geologic Material: Carbonate rocks and sandstone

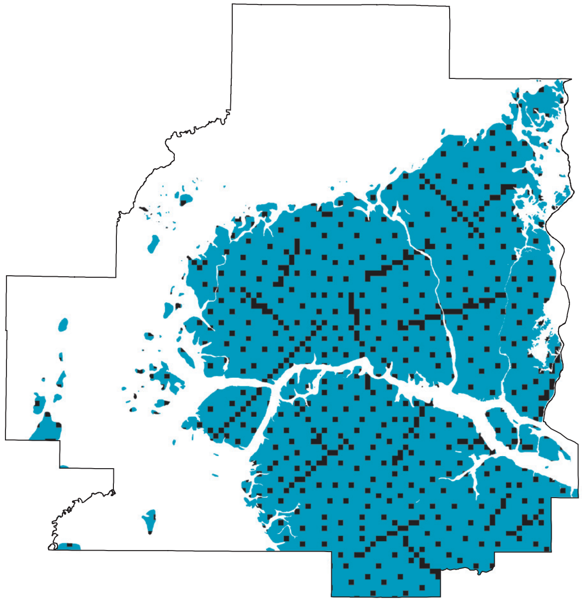
Yield: High. Reported pumping capacity of metropolitan area municipal wells: 120 to 4,100 gallons per minute (average of 1,270)

Management Concerns:

- Not available to some growing communities
- As the most heavily used aquifer in parts of the region, greater likelihood of water use conflict
- Connected to some protected surface waters
- Vulnerable to contamination, particularly where fractures exist and where bedrock above it has been eroded

CITIES METROPOLITAN AREA





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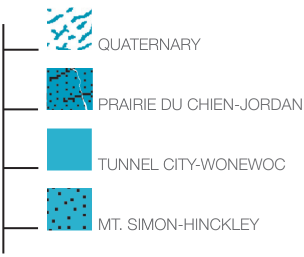


TUNNEL CITY-WONEWOC AQUIFER

(formerly known as the Franconia-Ironton-Galesville Aquifer)

Extent: Not present across entire metro

Geologic Material: Sandstone and carbonate

Yield: Moderate to low. Reported pumping capacity of metropolitan area municipal wells: 115 to 1,600 gallons per minute (average of 700)

Management Concerns:

- Productivity varies greatly across the region and is highest where it is fractured or weathered
- Connected to some protected surface waters
- Vulnerable to contamination where fractured and where bedrock above it has been eroded

MT. SIMON-HINCKLEY AQUIFER

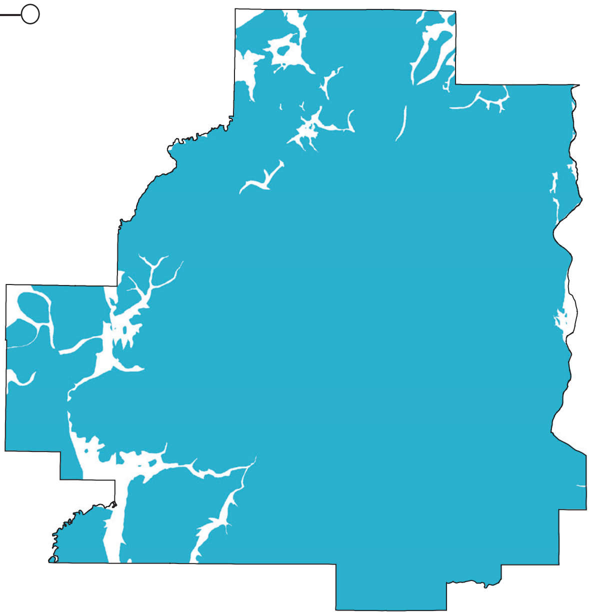
Extent: Throughout metro

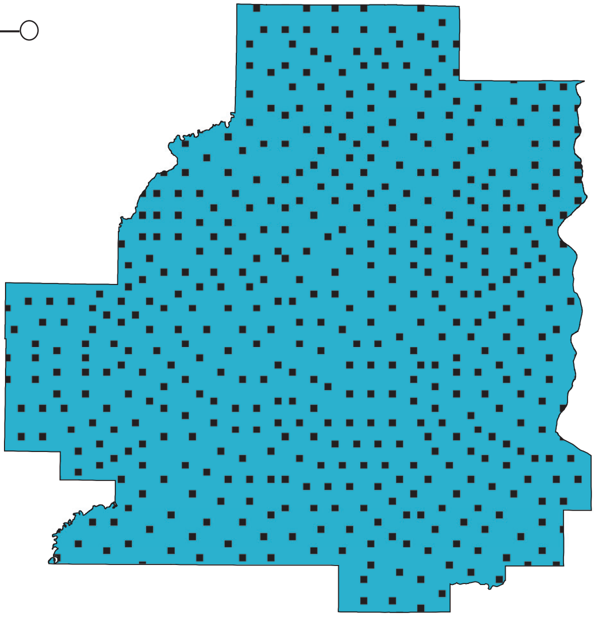
Geologic Material: Sandstone

Yield: High to moderate. Reported pumping capacity of metropolitan area municipal wells: 230 to 2,300 gallons per minute (average of 930)

Management Concerns:

- Use restricted by Minnesota law
- Very slow recharge rate
- Significant groundwater mining has occurred historically, creating a regional cone of depression
- Relatively low vulnerability to contamination





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