Declining Regional Surficial Groundwater and the Effect on Groundwater Dependent Resources

Issue

Ground water is the Watershed District's principal reserve of fresh water and represents much of its potential future water supply. Ground water within the Watershed is a major contributor to flow in Coon Creek and has a strong influence on the health and diversity of plant and animal species in, riparian areas, lakes, and wetlands. It also provides drinking water to individuals and communities within the watershed. Demands for safe drinking water and requirements to maintain healthy ecosystems are increasing (Appendix B, page 11-15; Appendix C, pages 59- 80).

Today, many of the concerns about ground water resources on or adjacent to the Watershed District involve questions about reductions in streamflow, potential loss of ground water-dependent ecosystems such as lakes and wetlands, land subsidence.

Ground water and surface water are interconnected and interdependent in almost all ecosystems in the Anoka Sand Plain. Ground water plays significant roles in sustaining the flow, chemistry, and temperature of streams, lakes, and wetlands, in many settings, while surface waters provide recharge to ground water in other settings. Ground water has a major influence on streambank erosion, and the headward progression of stream channels. In flat terrain, it limits soil compaction and land subsidence. Pumping of ground water can reduce stream flows, lower lake levels, and reduce or eliminate discharges to wetlands. It also can influence the sustainability of drinking-water supplies and maintenance of critical ground water-dependent habitats.

Increasingly, attention is being placed on how to manage ground water (and surface-water) resources in a sustainable manner. The potential for ground water resources to become contaminated from human as well as natural sources is being assessed. Each ground water system and development situation is unique and requires a specific analysis to draw appropriate conclusions.

Declining surficial groundwater levels will affect not only the drinking water supplies, but also resources that may depend on groundwater, such as wetlands, lakes and streams

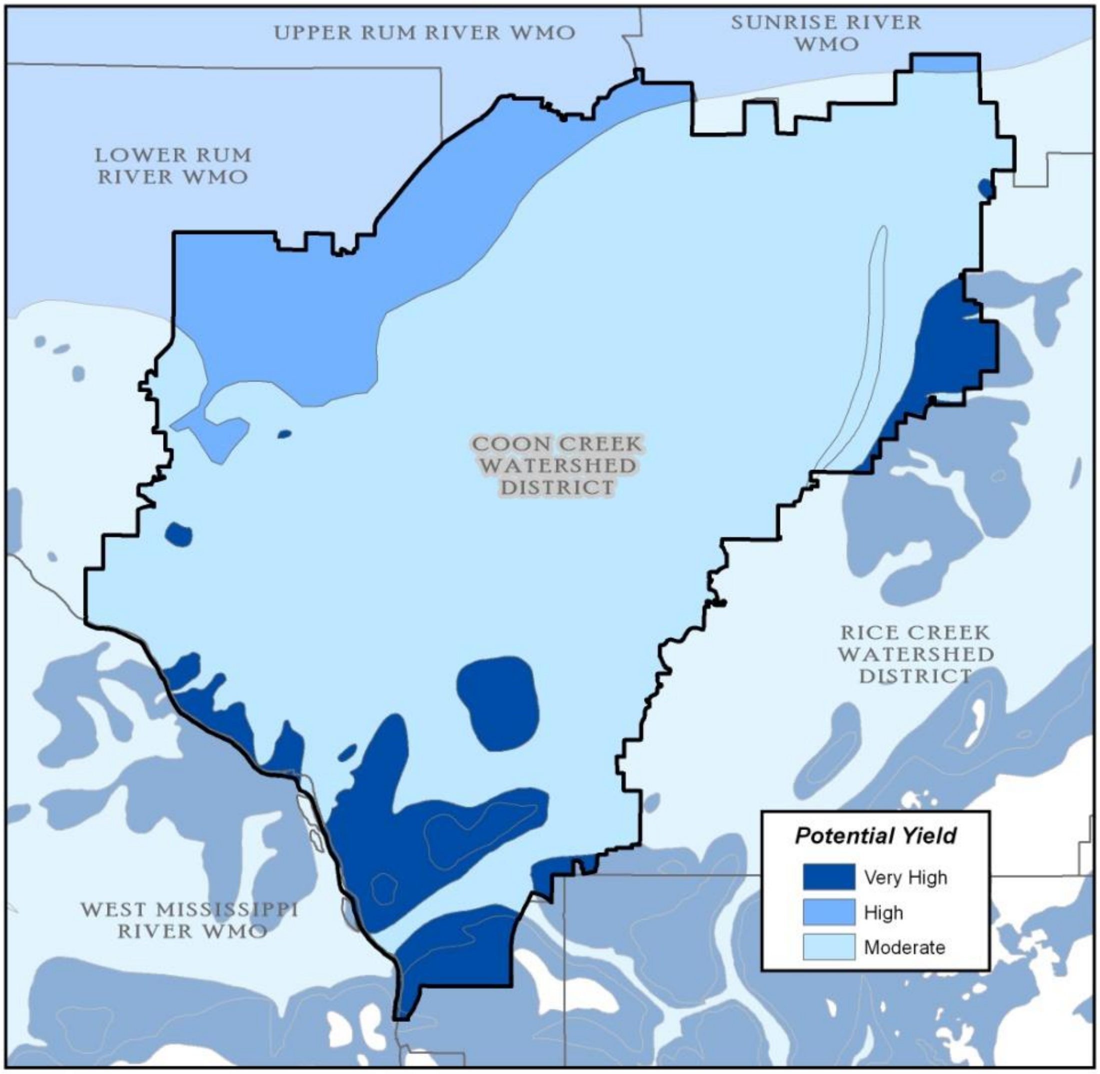
This issue is further complicated by the fact that the dependency of these resources on groundwater is not well understood. In addition, the rates and methods of ground water recharge are not well understood, and vary depending on geologic conditions of the aquifer

Uncertainty in meeting the projected demand in an area generally corresponds to:

- Areas lacking in productive aquifers
- Groundwater/surface water interdependence
- High susceptibility to contamination

Aquifer Productivity

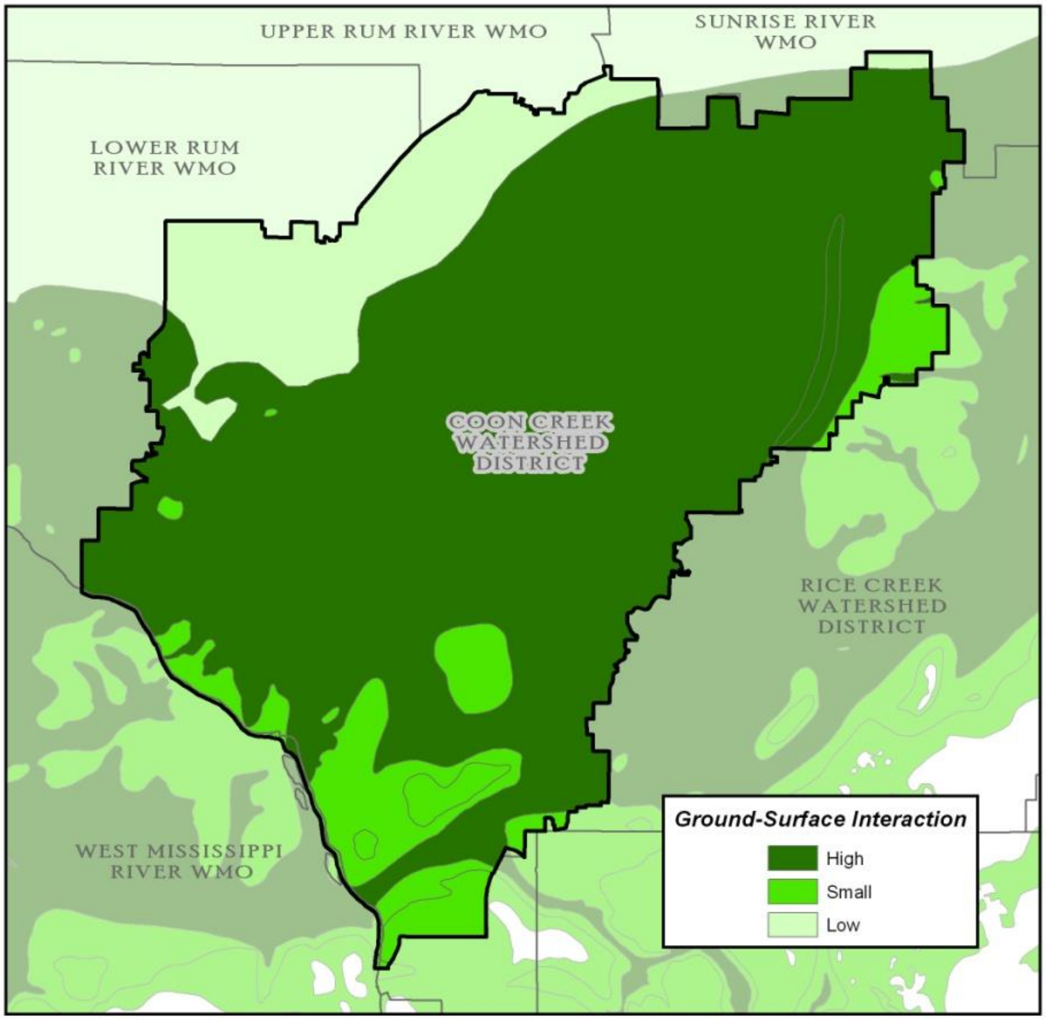
The watershed is fortunate to have a relative abundance of available groundwater. However, productive aquifers are not evenly distributed across the watershed



Groundwater/ Surface Water Interaction

The fresh groundwater in the unconsolidated formations of the watershed is derived largely from precipitation over the outcrop areas. Rainfall lost to evapotranspiration has been estimated at 79 percent. An additional 16 percent is lost to overland flow, leaving 5 percent for recharge.

Since rainfall averages 30 inches per year in the watershed, approximately 1.5 inches per year (23.9 mgy) is potentially available to recharge the surficial groundwater reservoir.



Susceptibility to Contamination The surface, unconsolidated sands can hold a vast quantity of water. Significant pollution sources, actual or potential, include

- septic tanks
- landfills
- chemical spills and dumping
- chemical storage leaks
- Highway deicing
- Agricultural chemicals.

These sources may have immediate local impacts and may also pose long-term, cumulative threats.

Pollutants detected in groundwater that could be harmful to humans or animals should they rise to inappropriate levels include:

- Bacteria
- Chloride,
- Nitrate, and

- Crop protection chemicals

It is estimated that 60,000 people reside in the unsewered portions of the watershed, producing 4.5 mgd of sewage and 6.6 million gallons per year of septage (septic tank pumpage).

Water Source	**Susceptibility**
Drift	Very High
Franconia-Ironton- Galesville	High
Prairie Du Chien-Jordan	Moderately Low
Mt. Simon- Hinckley	Low

Goal

To manage Watershed District water resources for multiple-uses by balancing present and future resource use with domestic water supply needs.

Manage ground water dependent ecosystems under the principles of multiple use and sustainability, while emphasizing protection and improvement of soil, water and vegetation, particularly because of effects upon aquatic and wildlife resources.

Objectives

1. Identify minor sub-watersheds providing water within the drinking water supply Management Area as defined in the City's well-head protection plan or 1 year travel time of municipal and other public wells and water supplies during land management planning.

2. Develop prescriptions on a case-by-case basis to ensure desired multiple-use outputs while recognizing domestic water supply needs.

3. Support Anoka County Geologic Atlas.

4. Show Municipal Water Supply Areas as Special Management Areas.

5. Increase Groundwater Recharge.

6. Decrease Waste of Groundwater.

7. Estimate Groundwater Storage and Supply within the Watershed.

8. Support Proper Abandonment of Unused Wells.

9. Protect the ecological processes and biodiversity of ground water-dependent resources such as lakes and wetlands.

10. Manage ground water-dependent ecosystems to satisfy legal mandates, including, but not limited to, those associated with floodplains, wetlands, water quality and quantity, dredge and fill material, and endangered, threatened and special concern species.

11. To minimize the adverse impacts on groundwater dependent systems by maintaining natural patterns of recharge and discharge.

12. To minimize disruption to groundwater levels critical for sustaining groundwater dependent resources.

Introduction

Ground water-dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes depend on ground water. The following are examples of some ecosystems that may depend on ground water:

- Wetlands in areas of ground water discharge or shallow water table.
- Terrestrial vegetation and fauna, in areas with a shallow water table or in riparian zones.
- Aquatic ecosystems in ground water-fed streams and lakes.
- Aquifer systems.
- Springs and seeps.

Ecological resources include sensitive fish, wildlife, plants, and habitats that are at risk from exposure to ground water contaminants or ground water depletion. Some examples are breeding, spawning, and nesting areas; early life-stage concentration and nursery areas; wintering or migratory areas; rare, threatened, and endangered species locations; and other types of concentrated population or sensitive areas. These areas contain ecological resources that potentially are highly susceptible to permanent or long-term environmental damage from contaminated or depleted ground water.

Ground water-dependent ecosystems vary dramatically in how extensively they depend on ground water, from being entirely dependent to having occasional dependence. Unique ecosystems that depend on ground water, fens for example, can be entirely dependent on ground water, which makes them very vulnerable to local changes in ground water conditions. Ground water extraction by humans modifies the pre-existing hydrologic cycle. It can lower ground water levels and alter the natural variability of these levels. The result can be alteration of the timing, availability, and volume of ground water flow to dependent ecosystems.

Ground water-dependent ecosystems can be threatened by contamination and extraction. Particular threats include urban development, contamination from industry, intensive irrigation or dewatering, clearing of vegetation, mining, and filling or draining of wetlands.

Types of Ground Water-Dependent Resources

Shallow ground water can support terrestrial vegetation, such as forests and woodlands, either permanently or seasonally. Examples occur in riparian areas along streams and in upland areas that support forested wetland environments. Phreatophytes are plants whose roots generally extend downward to the water table and are common in these high-water-table areas. Some fauna depend on this vegetation and therefore indirectly depend on ground water. Terrestrial vegetation may depend to varying degrees on the diffuse discharge of shallow ground water, either to sustain transpiration and growth through a dry season or for the maintenance of perennially lush ecosystems in otherwise arid environments. Ground water-dependent terrestrial plant communities provide habitat for a variety of terrestrial and aquatic animals, which by extension must also be considered ground water dependent.

An additional group of ground water-dependent fauna (including humans) rely on ground water as a source of drinking water. Ground water, as creek baseflow, is an important source of water across much of the watershed, Its significance is greater for larger mammals and birds, as many smaller animals can obtain most of their water requirements from other sources.

Ground water is also used by native fauna. Provision of water has allowed larger populations of both wildlife and pest animals to be sustained than would otherwise be the case. Ground water-dependent vegetation and wetlands may be used by terrestrial fauna as drought refuges. Access to ground water allows the vegetation to maintain its condition and normal phenology (for example, nectar production, new foliage initiation, seeding). Populations of some birds and mammals retreat to these areas during drought and then recolonize drier parts of the landscape following recovery. The long-term survival of such animal populations relies on maintaining the vegetation communities and ensuring that their water requirements are met.

Ecosystems in Streams and Lakes Fed by Ground Water

This category of ecosystem includes many ecosystems that are dependent on ground water-derived baseflow in creeks and streams. Baseflow is that part of streamflow derived from ground water discharge and bank storage. Stream flow is often maintained largely by ground water, which provides baseflow long after rainfall or snow melt runoff ceases. On average, up to 40 percent of the flow of many streams is estimated to be made up of ground water-fed baseflow. The baseflow typically emerges as springs or as diffuse flow from sediments underlying the stream and banks. This water may be crucial for in-stream and near-stream ecosystems. Localized areas of ground water discharge have a largely stable temperature and provide thermal refuges for fish in both winter and summer. Ground water also influences the spawning behavior of some fish. Reducing the baseflow to ground water-fed rivers could reduce upwelling or dry out riffles and reduce spawning success.

The ambient ground water flux is likely to be the key attribute influencing a surface-water ecosystem's dependency on ground water. The ground water level in riverine aquifers is important for maintaining a hydraulic gradient towards the stream that supports the necessary discharge flux. Sufficient discharge of ground water is needed to maintain the level of flow required by the various ecosystem components. Contamination of riverine aquifers by nutrients, pesticides, or other contaminants may adversely affect dependent ecosystems in baseflow-dominated streams.

Lakes, both natural and human made, can have complex ground water flow systems. Lakes interact with ground water in one of three basic ways:

1. Some receive ground water inflow throughout their entire bed;
2. Some have seepage loss to ground water throughout their entire bed
3. Others, perhaps most, receive ground water inflow through part of their bed and have seepage loss to ground water through other parts.

Changes in flow patterns to lakes as a result of pumping may alter the natural fluxes to lakes of key constituents, such as nutrients. As a result, the distribution and composition of lake biota may be altered.

The chemistry of ground water and the direction and magnitude of exchange with surface water significantly affect the input of dissolved chemicals to lakes. In fact, ground water can be the principal source of dissolved chemicals to a lake, even in cases where ground water discharge is a small component of a lake's water budget.

The transport of nutrients by ground water can be a significant source of water-quality degradation in lakes. Major sources of nutrient enrichment are inadequately designed and maintained household septic systems and nonpoint pollution sources, such as construction-project and agricultural runoff.

Hyporheic and Hypolentic Zones

The interface between saturated ground water and surface water in streams is a zone of active mixing and interchange between the two and is known as the hyporheic zone. The hyporheic zone is generally confined to the near stream area; however, in large alluvial or glacial outwash areas this zone may extend hundreds of feet away from the river channel. Hyporheic zones can be important for aquatic life. In both gaining and losing streams, water and dissolved chemicals can move repeatedly over short distances between the stream and the shallow subsurface below the streambed. The spawning success of fish may be greater where flow from the stream brings oxygen into contact with eggs that were deposited within the coarse bottom sediment or where stream temperatures are controlled by ground water inflow. Upwelling of ground water provides stream organisms with nutrients, while downwelling stream water provides dissolved oxygen and organic matter to microbes and invertebrates in the hyporheic zone. This exchange zone is an important habitat for many invertebrates and a refuge for some vertebrates during droughts and floods.

A similar mixing zone, called the hypolentic zone, occurs at the interface between saturated ground water and surface water in lakes and wetlands. In many lakes, the most active portion of the hypolentic zone is located in the littoral zone in close proximity to the shoreline. Distinct vegetation and aquatic communities are likely to be associated with focused and diffuse discharge of ground water.

Springs

Springs typically are present where the water table intersects the land surface. Springs are important sources of water to streams and other surface-water features. They also may be important cultural and aesthetic features. The constant source of water at springs leads to the abundant growth of plants, and many times to unique habitats for endemic species like spring snails. Ground water development can reduce spring flow, change springs from perennial to intermittent, or eliminate springs altogether. Springs typically represent points on the landscape where ground water flow paths from different sources converge. Ground water development may affect the amount of flow from these different sources to varying extents, thus affecting the chemical composition of the spring water.

Wetlands

Wetlands occur in widely diverse settings from organic flats to depressions and floodplains. Similar to streams and lakes, wetlands can receive inflow from ground water, recharge ground water, or do both. The persistence, size, and function of wetlands are controlled by hydrologic processes active at each site. For example, the persistence of wetness for many wetlands depends on a relatively stable influx of ground water throughout seasonal and annual climatic cycles. Characterizing ground water discharge to wetlands and its relation to environmental factors such as moisture content and chemistry in the root zone of wetland plants is a critical but highly challenging aspect of wetlands hydrology.

Wetlands can be quite sensitive to the effects of ground water pumping. This pumping can affect wetlands not only by lowering the water table, but also by increasing seasonal changes in the elevation of the water table and exposing accumulated organic and inorganic material to oxidation. Some peat-forming wetlands are highly stable environments that may contain fossil material that provides insights into past environments. Over extraction of water, like the draining of wetlands for agriculture and other development, can destroy this valuable source of scientific data.

Fens are peat-forming wetlands that receive recharge and nutrients almost exclusively from ground water. The water table is at or just below the ground surface. Water moves into fens from upslope mineral soils, and flows through the fen at a low gradient. Fens differ from other peatlands because they are less acidic and have higher nutrient levels; therefore, they are able to support a much more diverse plant and animal community. Grasses, sedges, rushes, and wildflowers often cover these systems. Over time, peat may build up and separate the fen from its ground water supply. When this happens, the fen receives fewer nutrients and may become a bog. Patterned fens are characterized by a distribution of narrow, shrub-dominated ridges separated by wet depressions.

Fens, and ground water driven wetlands are common in the Anoka Sand Plain and the Coon Creek Watershed. Low temperatures and short growing seasons slow decomposition of organic matter and allow peat to accumulate. Fens provide important benefits in a watershed, including preventing or reducing the risk of floods, improving water quality, and providing habitat for unique plant and animal communities. Like most peatlands, fens have experienced a decline in acreage, mostly from mining and draining for cropland, fuel, and fertilizer. Because of the large historical loss of this ecosystem type, remaining fens are rare, and it is crucial to protect them. While mining and draining these ecosystems provide resources for people, up to 10,000 years are required to form a fen naturally.

Current Situation

Many of the outer suburbs of the Twin Cities area draw on groundwater aquifers for their primary drinking water supply. There is a growing concern that these aquifers are being depleted because municipalities are drawing water out faster than the water can be recharged. The Master Water Supply Plan by the Metropolitan Council indicates the potential for a significant decline in aquifer water levels, up to a 50% decline in available head by 2030.

Implications

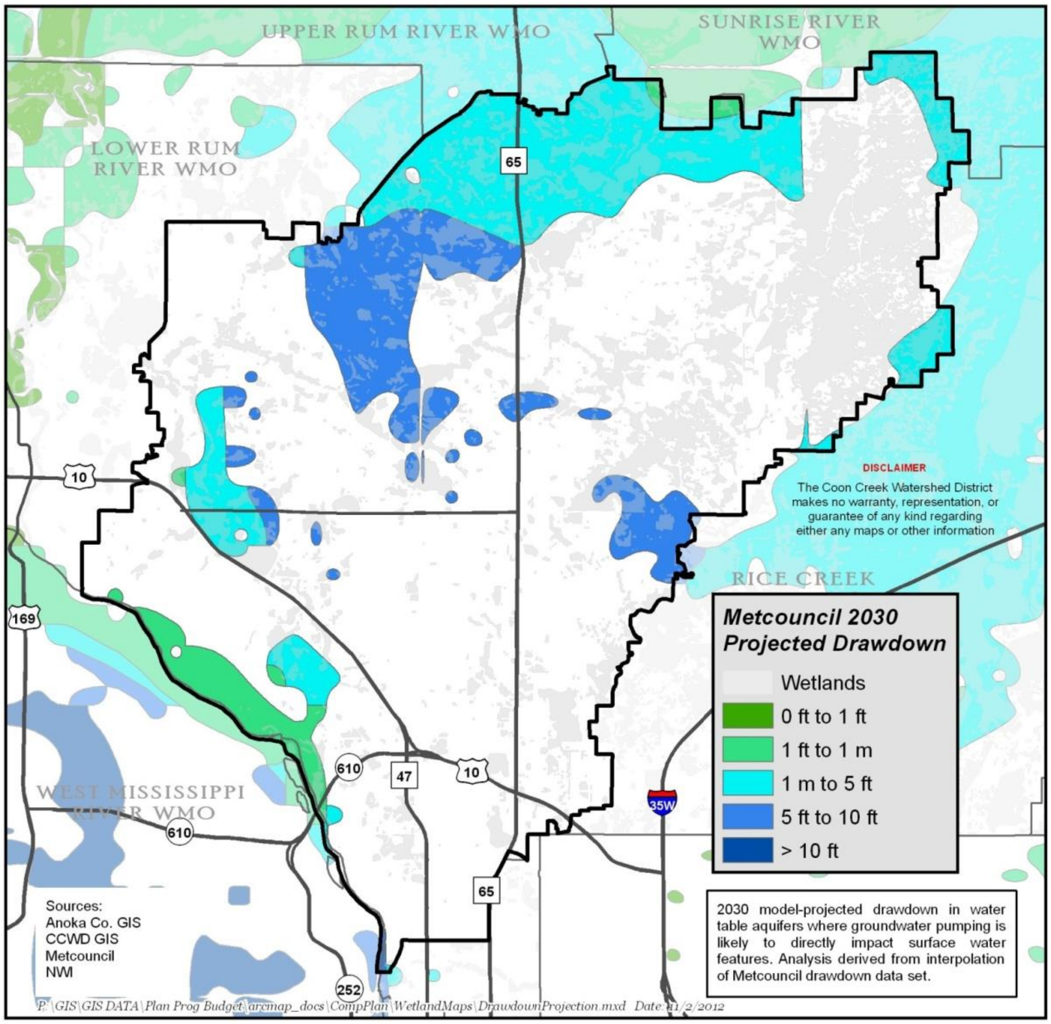
Adequate water supplies are necessity for any home or city. The source must provide quality water at a constant and dependable rate. Groundwater is the source for 100 per cent of public drinking water within the watershed for both domestic use and livestock and wildlife watering.

Loss of Groundwater Driven Surface Water Features

If surficial groundwater levels continue to fall between 2013 and 2023, surficial water features, such as

a. Lakes (decline of 50% surface area)
b. Wetlands (8,375 acres)
c. Base Flow

will be difficult to protect and sustain in the areas shown below:



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2030 model-projected drawdown in water table aquifers where groundwater pumping is likely to directly impact surface water features. Analysis derived from interpolation of Metcouncil drawdown data set.

Sources:
Anoka Co. GIS
CCWD GIS
Metcouncil
NWI

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Blaine "Uncertainty"

The Met Council study indicates that the 'uncertainty in meeting the projected demand in an area generally corresponds to:

- Areas lacking in productive aquifers
- Groundwater/surface water interdependence

- High susceptibility to contamination

Potential Impacts on Surface Water Contribute to Drinking Water Uncertainty in Certain Areas

If the Metropolitan Council projections are correct, the watershed will experience a loss of almost 52% (8,400 acres) of surficial water and related land resources by 2030.

The District estimates that there will be an additional impact (either through conversion of wetland type or lower lake levels) to an additional 2,000 acres (approximately 12%).

Management Considerations

The Watershed District ground water policy is specifically designed to protect ground water-dependent ecosystems so that, wherever possible, the ecological processes and biodiversity of their dependent ecosystems are maintained, or restored, for the benefit of present and future generations. The general level of understanding of the role of ground water in maintaining ecosystems is very low. Ground water resource managers and investigators tend to underestimate ecosystem vulnerability to ground water development, pollution, and land-use change. Planners must recognize ecosystem dependence on ground water and related processes. Perhaps such recognition can be best achieved by incorporating ground water resource inventory, monitoring, and protection into management plans.

The initial step in protecting ground water-dependent ecosystems is developing an inventory of those systems within the watershed. Identify and describe their locations, ecological values, and degrees of dependence on ground water. Land management plans should then be reviewed and revised as necessary to incorporate ground water-level, ground water extraction-rate, ground water recharge-rate targets or other management rules that minimize localized impacts on dependent ecosystems. The degree of protection will vary according to the characteristics and dynamics of each ground water system and the significance of the ground water-dependent ecosystems. Protection may range from minimal where the aquifer is deep and has little connection to the surface, to significant where the connection is strong and the conservation value of dependent ecosystems is high. More localized measures for protecting ground water-dependent ecosystems may include the following steps:

- Establishing buffer zones around dependent ecosystems, within which ground water extraction is excluded or limited.

- Establishing maximum limits to which water levels can be drawn down at a specified distance from a dependent ecosystem.
- Establish a minimum distance from a connected creek or other dependent ecosystem from which a well could be sited.
- Protecting ground water quality in areas that provide recharge to dependent ecosystems by limiting the types of activities that can take place there.

The social and economic costs of the recommended management prescriptions and protections, as well as the costs related to impacts from use, also need to be considered. Ground water extractions should be managed within the sustainable yield of aquifer systems so that the ecological processes and biodiversity of their dependent ecosystems are maintained or restored. In this process, threshold levels that are critical for ecosystem health should be estimated and considered. Planning, approval, and management of developments and land uses should aim to minimize adverse impacts on ground water systems by maintaining natural patterns of recharge and discharge, and by minimizing disruption to ground water levels that are critical for ecosystems.

Activities That Affect Ground Water

This section describes some of the activities that commonly cause ground water problems within the watershed.

Ground Water Pumping

As surface water resources become fully developed and appropriated, ground water commonly offers the only available source for new development. In many areas of the watershed, however, pumping of ground water has resulted in significant depletion of ground water storage. These ground water depletions can result in lowered water levels in wells, hydraulic interference between pumping wells, reduced surface water discharge, land subsidence, and adverse changes in water quality.

Declining Water Levels

It is useful to consider three terms that have long been associated with ground water sustainability:

1. Safe yield
2. Ground water mining
3. Overdraft.

The term “safe yield” commonly is used in efforts to quantify sustainable ground water development. The term should be used with respect to specific effects of pumping, such as water-level declines, reduced streamflow, and degradation of water quality. The consequences of pumping should be assessed for each level of development, and safe yield should be taken as the maximum pumpage for which the consequences are considered acceptable.

The term “ground water mining” typically refers to a prolonged, progressive, and, in many cases, permanent decrease in the amount of water stored in a ground water system. This phenomenon may occur, for example, in heavily pumped aquifers in arid and semiarid regions. Ground water mining is a hydrologic term without connotations about water-management practices.

The term “overdraft” refers to withdrawals of ground water from an aquifer at rates considered to be excessive and therefore carries the value judgment of overdevelopment. Thus, overdraft may refer to ground water mining that is considered excessive as well as to other undesirable effects of ground water withdrawals

Pumping ground water from a well always causes:

1. A decline in ground water levels at and near the well;
2. A diversion of ground water to the pumping well that was moving slowly to its natural, possibly distant, area of discharge (fig. 19).

Pumping of a single low-capacity well typically has a local effect on the ground water flow system. Pumping of high-capacity wells or many wells (sometimes hundreds or thousands of wells) in large areas can have regionally significant effects on ground water systems. Where a new pumping well is installed near an existing pumping well and both are tapping the same aquifer, overlapping cones of depression (well interference) can result (Fetter 2000).

The effect on the existing well from pumping the new well is lowered water levels, an increased rate of decline, and reduced yield. In addition, changes in water chemistry at the existing well can result. The new well likewise has a lower yield than if it had been placed farther from the existing pumping well.

Ground water heads respond to pumping to markedly different degrees in unconfined and confined aquifers. Pumping the same quantity of water from wells in confined and in unconfined aquifers initially results in much larger declines in heads over much larger areas for the confined aquifers. This is because less water is available from confined aquifers for a given loss of head compared to similar unconfined aquifers.

As might be expected, declines in heads and associated reductions in storage in response to pumping can be large compared to changes in unstressed ground water systems. For example, declines in heads as a result of intense pumping can reach several hundred feet in some hydrogeological settings. Drawdown is typically larger in confined aquifers. Widespread pumping that is sufficient to cause regional declines in aquifer heads can result in several unwanted effects:

Substantially decreased aquifer storage, particularly in unconfined aquifers;

1. Dried up wells in places because the lowered heads are below the screened or open intervals of these wells;
2. Decreased pumping efficiency and increased pumping costs because the vertical distance that ground water must be lifted to the land surface increases;
3. Changed rates of movement of low quality or contaminated ground water and increased likelihood that the low quality or contaminated ground water will be intercepted by a pumping well;
4. Land subsidence or intrusion of saline ground water may result in some hydrogeologic settings.

Perennially flowing springs can be adversely affected by too much water well pumping. Flows may diminish or cease if too much pumping occurs in an aquifer where a hydrologic connection exists between a spring and a well. Many examples of this phenomenon can be found in the Metropolitan Area and Anoka County. The same holds true for surface streamflows, especially during baseflow periods and in times of drought when all of the streamflow comes from ground water discharge.

Depletion of ground water also can lower water levels in lakes, ponds, wetlands, and riparian areas. Water temperatures can rise from solar heating of smaller volumes of water and depletion of cooler ground water inflows. In turn, geochemical reaction rates may increase and affect the organisms in those waters, possibly to their detriment. Algae blooms are more likely in these lakes, ponds, and reservoirs, and when the algae die, fall to the bottom, and decompose, dissolved oxygen is consumed in the water body, causing stress to or killing fish and other aquatic species.

Where the depletion of ground water causes a decline in surface water or even total stream dewatering, terrestrial species may be adversely affected similarly to aquatic species. If any species so affected are listed under the Endangered Species Act, the Watershed District has a duty to consult with the appropriate agency responsible for administering that act and implement its recommendations for species protection or recovery. Recommendations can include modifying or canceling an authorization for water extraction.

Land Subsidence

Land subsidence is a gradual settling or sudden sinking of the Earth's surface because of subsurface movement of earth materials. More than 80 percent of the identified subsidence in the United States is a consequence of human impact on subsurface water. This effect is an often-overlooked environmental consequence of our water-use practices. Impacts from land subsidence include damage to manmade structures, such as buildings and roads, as well as irrecoverable damage to aquifers.

In some areas, excessive pumping can cause the collapse of the framework of aquifer materials. The result is aquifer compaction and subsidence at the land surface. This compaction results in the permanent loss of aquifer storage, even if the water table should later recover when pumping stops. Although the water table may recover to prepumping levels, resumption of pumping will result in rapid drawdown because of the loss of aquifer storage capacity. In some parts of the Watershed, the lowering of the water table from pumping has resulted in drainage of organic soils and wetland areas, and such changes can adversely affect wetland ecosystems. Subsidence also can severely damage building foundations, roads, and buried pipelines, and can increase the frequency of flooding in low-lying areas.

A time lag often occurs between the dewatering of an aquifer and subsidence because much of the compaction results from the slow draining of water from confining units adjacent to the aquifer This phenomenon is called “hydrodynamic consolidation.” It is also responsible for residual compaction, which may continue long after water levels are initially lowered or even after pumping stops.

Two distinct processes account for most water-related subsidence in the Watershed:

(1) Compaction of aquifer systems
(2) Drainage and subsequent oxidation of organic soils.

Impacts of Subsidence

Localized surface impacts of subsidence include earth fissures and sinkholes. Earth fissures occur as a result of ground failure in areas of uneven or differential compaction. Most fissures occur near the margins of alluvial basins or near exposed or shallow buried bedrock in regions where differential land subsidence has occurred. They tend to be concentrated where the thickness of alluvium changes markedly. When they first open, fissures are usually narrow vertical cracks, less than an inch wide and up to hundreds of feet long. They can subsequently lengthen to many thousands of feet and widen to more than 10 feet as a result of erosion and collapse. Vertical offset along the fissure is usually no more than a few inches.

The large-scale and differential settling of the ground surface that accompanies subsidence can have a profound impact on manmade structures. The cost of damage caused by subsidence is estimated to be millions of dollars each year. Types of potential damage to manmade structures caused by subsidence include the following:

- Damaged roads.
- Broken foundations.
- Severed utilities and pipelines.

- Damaged underground and above-ground storage tanks.
- Damaged storage and treatment ponds.
- Broken well casings and damaged pumps.
- Damaged railroad tracks, bridges and tunnels.
- Flood damage in low-lying areas
- Damage to irrigated fields.

Effects of Vegetation Management on Ground Water

Manipulation of vegetation, including both trees and shrubs, can directly and indirectly affect ground water. Vegetation influences the water budget through its effects on water inputs to the basin and more directly through plant water use. By intercepting rain and snow, the vegetation canopy can facilitate water loss to sublimation and evaporation. This interception loss may affect the amount of water available for ground water recharge. By shading ground and water surfaces, vegetation can also influence the rate and timing of snowmelt and evaporation from those surfaces. Plants with access to ground water (phreatophytes) also influence ground water quantity. They take up ground water directly for transpiration. Management activities that intentionally or unintentionally influence the density, structure, and species composition of vegetation may have measurable effects on the quantity and quality of ground water.

Phreatophyte Management

Plants growing along creek and ditch margins generally have better access to water than plants growing in upland areas. Although most phreatophytic plants utilize soil water when available, phreatophytes primarily use ground water. This use may cause quite dramatic diurnal fluctuations in shallow alluvial aquifers in areas near streams. Because of higher water availability in areas adjacent to stream channels and on floodplains, plants growing in these areas generally transpire at higher rates than vegetation in uplands where water is limiting. As a consequence of these high rates of water use by plants with access to ground water, attempts have been made to estimate potential water salvage through the removal of phreatophytes. Although the volumes of salvaged water proposed in these studies are often quite impressive, very few studies have actually demonstrated that removal of even extensive areas of vegetation have resulted in measurable increases in streamflow. Most studies have indicated that clearing of phreatophytes results in no measurable change in streamflow. Removal of phreatophytes, however, does often result in increases in water table elevations in shallow aquifers and destabilization of streambanks. Water salvage from removing such vegetation is often significantly less than expected and sometimes results in higher water loss from an area than before removal. Depending on the depth from the soil surface to the water table, an elevated water table may result in increased evaporative losses from the site if the capillary fringe comes into contact with the atmosphere. Furthermore, water is used by the vegetation that replaces the phreatophytes.

Evapotranspiration in stands dominated by phreatophytes has been estimated to be from 1.1 to 9 acre-feet of water per acre per year in arid areas. Robinson reported that annual savings in areas of dense vegetation may amount to 2 to 3 feet of water, depending on depth to the water table. The benefits of riparian vegetation to fish, wildlife, and humans are now recognized and far fewer projects to eliminate them are being undertaken. The recent drought, however, has stimulated an interest in controlling phreatophytes such as willow (*Salix spp.)* or Box elder (*Acer negundo*).

The presence, density, and composition of phreatophytes can affect the quality of ground water through uptake of nutrients and pollutants. Phreatophytic vegetation has been used for bioremediation of soil and ground water toxicity caused by mining and solid waste disposal. Certain species can take up and store particular ions, heavy metals, and other pollutants. Phreatophytic vegetation may be very effective in removing nitrate from ground water as well as phosphorous and other nutrients.

Upland Forest Management

Removal of the forest canopy affects the amount of interception of snow and rain by the canopy, as well as the infiltration rate of the precipitation that reaches the forest floor. Both of these processes can affect ground water recharge and the rate of ground water movement at a local scale. MPCA has estimated that interception in Minnesota ranges from 30% to 40% in natural to developed areas. Intercepted water is not available for ground water recharge; however, if the forest canopy is reduced or removed, this water can become available as long as the forest floor has not been compacted by heavy machinery or removed by erosion. Under certain conditions, forest fires can form impermeable layers (hydrophobicity), which hinder or even prevent infiltration of water on the forest floor, limiting water on the ground surface from recharging shallow aquifers. Slow drainage of soil moisture in the range of field capacity is the source of a large proportion of the baseflow of forested headwaters streams, where organic matter content of soils tends to be high.

The Developing Fringe

Residential and commercial development has been rapid within the Watershed. As dewatering occurs and water supplies become stressed, land managers will be pressured to permit additional municipal drinking-water wells. In the future, ground water management is likely to evolve toward total aquifer management. Protection measures such as limitations on activities in recharge areas, reservation of some areas for production of high quality water, and protection of unique ground water-dependent ecosystems will be incorporated into land management plans. It will no longer be sufficient to manage for operators and users. Managers must recognize that ground water serves diverse functions, some of which are ecological.

In unincorporated areas, residential growth is characterized by the use of individual domestic wells and individual sewage treatment systems (ISTS; also known as septic systems). In the settings typical of much of the watershed, proper siting and design of an ISTS is problematic. The traditional ISTS; design is appropriate for installation in areas underlain by sufficient soil thickness and porous media aquifers.

Strategies to Achieve the Goal	Strategies to help reduce the effects of unusual or prolonged environmental conditions include:
Development Regulation	Streamline and develop consistent permitting process between the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, Cities, and Watershed Districts. One-stop shopping is the objective with consistent requirements. Maintain natural drainage patterns of recharge and discharge, and minimize disruption of ground water levels that are critical to groundwater dependent resources. Prevent pollution or significant changes to ground water quality. Give preferential consideration to ground water-dependent resources when conflicts among land-uses activities occur. Delineate and evaluate both ground water itself and ground water-dependent ecosystems before approving any project with the potential to adversely affect those resources. Establish maximum limits to which water levels can be drawn down as a specified distance from a ground water-dependent ecosystem in order to protect the character and function of that ecosystem. Establish a minimum distance from a connected stream, wetland, lake or other ground water-dependent ecosystem from which ground water withdrawal may be sited.
Planning, Programming and Budgeting	The District anticipates addressing this issue through ground water studies, particularly support of the County Geologic Atlas, both through those completed by the District and by others. As more information becomes available, the District may revise its rules to incorporate the new knowledge. Evaluate adopting a policy that, in all state and water management district funding programs, quantifiable water conservation best management

	practices are considered an “alternative water supply” and are equally as eligible as capital facility expansion projects for grants and financial assistance. Encourage the development of region wide plans for the distribution, interconnection, and use of reclaimed water. Encourage a dedicated source of state funding for alternative water supply development projects. Evaluate the minimum flows and levels needed to protect water supply needs of natural systems before determining the availability of surface water for water supply. Plan and implement to minimize adverse impacts on ground water-dependent ecosystems. Evaluate, plan and implement a program to pursue rehabilitation of degraded ground water systems, where possible.
Public & Governmental Relations	Cities must anticipate, plan for and adapt to the potential effects of climate change.
Research & Data Collection	Support research to develop Sand Plain-specific climate change models to foster a sustainability/vulnerability analysis handbook on climate change impacts.

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