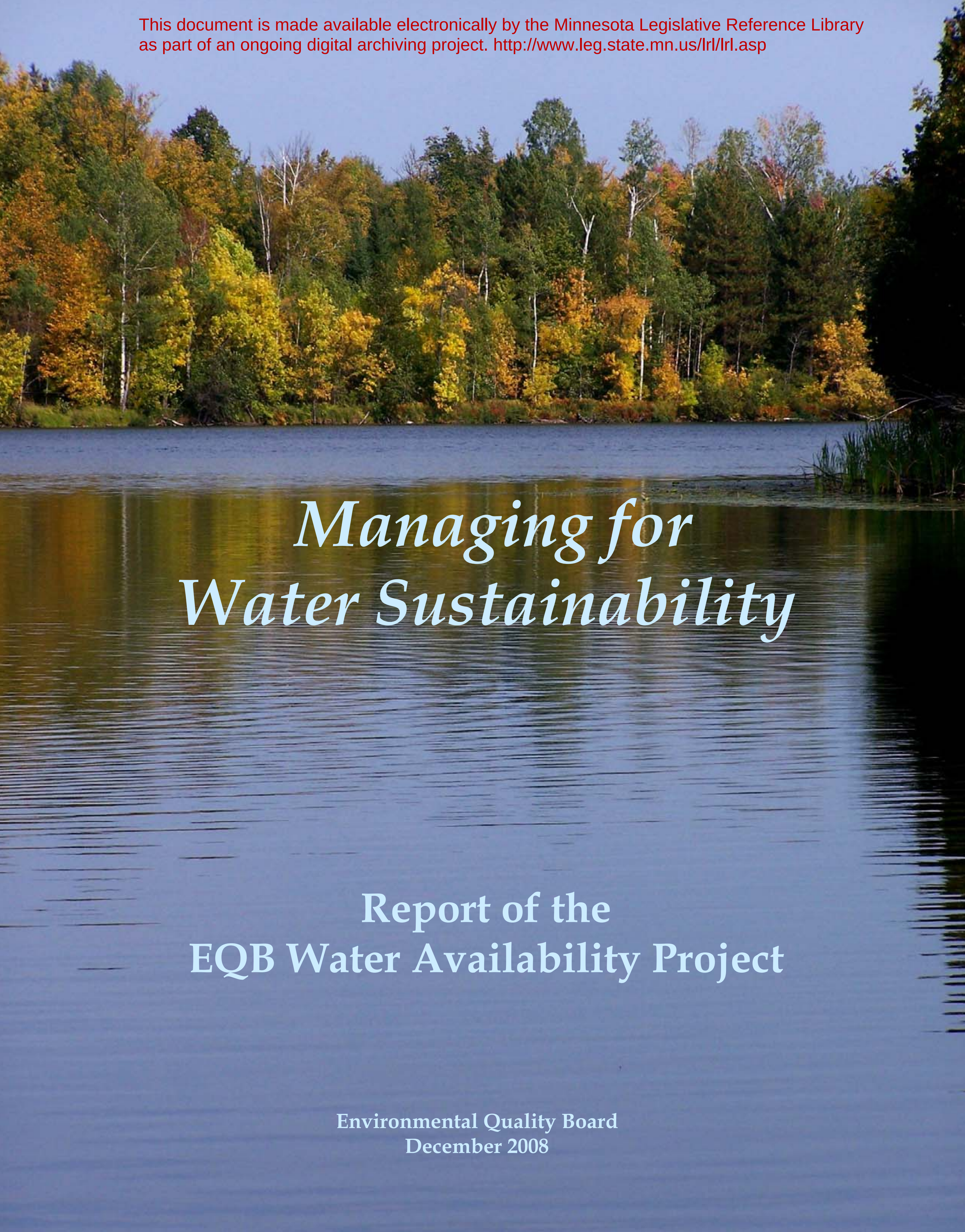

Managing for Water Sustainability

Report of the EQB Water Availability Project

Environmental Quality Board
December 2008

The **Environmental Quality Board** brings together the Governor's Office, five citizens and the heads of nine state agencies in order to develop policy, create long-range plans and review proposed projects that would significantly influence Minnesota's environment and development. *Minnesota Statutes* (see Chapters 103A, 103B, 116C, 116D, and 116G) directs the EQB to:

- Ensure compliance with state environmental policy
- Oversee the environmental review process
- Develop the state water plan and coordinate state water activities
- Coordinate environmental agencies and programs
- Study environmental issues
- Convene environmental congresses
- Advise the Governor and the Legislature

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Upon request, *Managing for Water Sustainability: Report of the EQB Water Availability Project* will be made available in alternate format, such as Braille, large print or audio tape. For TTY, contact Minnesota Relay Service at 800-627-3529 and ask for the Environmental Quality Board.

For more information or for paper copies of *Managing for Water Sustainability: Report of the EQB Water Availability Project*, contact the Environmental Quality Board at:

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December 2008

*Managing for Water Sustainability: Report of the EQB Water Availability Project Sustainability i*s available at the Environmental Quality Board's Internet site: www.eqb.state.mn.us.

Photographs by Princesa VanBuren.

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Managing for Water Sustainability: Report of the EQB Water Availability Project

December 2008

Executive summary

Minnesota has one of the top water management programs in the country, particularly among states that follow the riparian doctrine of water law. Minnesota law governing the allocation of water resources is comprehensive and thorough. And in practice, the state applies this body of law effectively in response to applications for water use. However, the state has only recently begun to consider whether its water supplies are sufficient to meet the long range seasonal requirements of communities, businesses and ecosystems.

To begin to understand this picture and in response to a request from the Minnesota Pollution Control Agency, the Environmental Quality Board resolved at its February 2008 meeting to:

1. *Consider how the state might establish (and/or has established) protective and achievable standards to quantify and address the environmental impacts of proposed water uses;*
2. *Take a broad look at water availability and appropriations, including but not limited to issues specific to the ethanol industry, finding a way to put consideration of proposed water uses into a broader framework and perspective; and*
3. *Summarize need and options for collecting additional data important to comprehensive and timely analysis of proposed water uses*.

In addressing these charges during the last nine months, the EQB convened over a dozen meetings involving over four dozen managers and technical experts. Participants discussed the issues and identified Minnesota's needs both today and long term, and reached a set of 14 inter-related conclusions and 15 recommendations for action or further consideration. These are summarized below under each of the above charges.

Charge One – Achieving protective standards

Minnesota employs commendable water management methods in response to permit requests, but could strengthen these efforts by accelerating the strategic acquisition of hydrologic, hydrogeologic and ecological information and improving the tools it uses to apply this information.

The state should:

1. Establish a long-term strategy for generating and managing the information needed to integrate water sustainability assessment results into regulatory programs on a statewide basis. This strategy must address the legal, financial and security issues that influence public access to this information. Strategy elements also should include:

- Allocation plans by aquifer and watershed
- Continuing efforts to build, maintain and use existing models, such as the Metropolitan Council ground water model
- New efforts to assess regional water availability and sustainability using a variety of methods, models and mapping

2. Maintain and enhance the ambient water quality monitoring network and other monitoring activities to enable more systematic water quality assessment when evaluating water availability and the potential significance for water use, especially for potable water supply.

3. Refine the aquifer protection threshold concept to work in more complicated situations both to protect aquifers and to provide an indication of water sustainability. This should include the development of thresholds for regional systems.

4. Identify defensible criteria for assessing the critical water levels or flow conditions required to support ecosystems. The criteria should consider ecosystem-sensitive practices that protect critical components of the hydrograph, including:

- A habitat- and population-based minimum flow
- A high flow protection standard that protects critical habitat-forming and silt-flushing high flows
- Protections for downstream needs
- Protections for the natural variability of flows over time (hydrograph shape)

Charge Two – Planning for water sustainability

Minnesota is characterized by dramatic spatial and temporal variability of its water resources; the demands people place and will place on these resources; the extent to and manner in which ecosystems depend on water; the interplay between water availability, water quality and land use; and chronic shortages of information, staff and financial resources. Minnesota should consider a number of steps to strengthen planning for water sustainability and increase the likelihood that water will be managed sustainably over the long term.

The state should:

1. Work with local governments, regional development staff and others to plan and manage water systematically at an area-wide scale through designated *water appropriation and use management areas*. It should identify priority areas and priorities for their implementation based upon a system of criteria that includes an assessment of an area's water sustainability limits, the competition for water, water quality concerns, future growth prospects and local interest.

2. Understand how state and local activities and incentives to encourage economic development may affect water availability and sustainability in the areas of interest prior to release of funds or approval of plans.

3. Develop a system of incentives to reward local units of government that incorporate water availability and sustainability considerations into their water and land use plans and decisions.

4. Continue efforts to develop and apply water sustainability models and planning tools, integrating new information and research results, as well as additional social, economic and environmental data. As part of these efforts, the state should establish a water sustainability information system steering committee to consider:

- System users and the questions they need addressed
- Scale and scope implications of user needs
- Available information and database management issues
- Design for easy and continuous information updates
- A long term business management plan

5. Develop Minnesota's resource system planning capability, including efforts to define water sustainability limits; link water management to land use decision-making; seek opportunities for conjunctive surface and ground water management; and consider the use of economic mechanisms in water management.

6. Continue to track and assess the implications of population, economic, climate and land use changes on management practice, sustainability planning and priority setting.

7. Examine opportunities to employ economic policies and incentives in support of sustainable water management. These should include:

- Requiring water users to conduct more aquifer and watershed monitoring and to help support information systems development and analysis
- Providing additional incentives for water conservation and wise management
- Encouraging consideration of alternative water supplies, gray water reuse, conjunctive use and other water saving measures when siting high water uses or designing infrastructure
- Developing methods for making credible estimates of the value of ecosystem services, as well as the economic implications for communities and individuals of water use policies and prospects

Charge Three – Defining water information needs

Although Minnesota's water management program has a strong data collection component, more information is needed to answer today's critical questions. The state does not collect or process sufficient water-related information to know with certainty overall whether it is managing water resources sustainably. State and local governments should work together to address this by: a) developing the information necessary to plan for sustainable resource use, and b) better linking their resource planning efforts. This would help them understand resource limits and vulnerabilities, and plan accordingly.

The state should:
1. Establish a long-term strategy for generating and managing the information needed to integrate water sustainability assessment results into regulatory programs on a statewide basis (See recommendation one under Charge One).

2. Develop a water sustainability data acquisition plan for inclusion in the 2010 state water plan that: a) sets priorities and standards for the next decade of data collection and funding; b) identifies the lead agency for collecting specific data types; c) provides for a routine appraisal of data collection efforts; and d) sets timelines for lead agencies to collect high priority data.

3. Define a strategy for integrating the information needed to assess water sustainability at statewide, regional or county scales. The strategy should: a) define the format for electronic data transfer between state and local agencies; b) set standards for documenting the source and quality of datasets, transferring data to be used in a state geographic information system, and uniquely identifying features such as wells, springs, lakes and rivers to which data are related; c) identify how the state will provide technical support to local governments accessing state data and providing data that is generated through state funding back to the state; and d) provide adequate funding for collecting and maintaining the data and developing applications for sharing the data.

4. Adopt a hydrologic cycle systems approach to monitoring water resources, since an understanding of each aspect of the hydrologic cycle is necessary to managing water sustainably. Priority needs include:

Surface water

- Improved stream gauging coverage to provide better low flow statistics and enhance understanding of ecosystems and ground water
- Collection of water chemistry

Ground and surface water interaction

- Linked monitoring of ground water levels and surface waters
- Compilation of water level and pumping histories for priority aquifers and linkage to relevant surface water resources
- Identification of aquifer and surface water body connections
- Inventory of springs

Ground water

- Statewide coverage of county geologic atlases with improved hydrologic property data
- Accurate information on well locations and real-time monitoring in select locations
- Work to remove backlog of water well logs that have not been scanned or whose location has not been verified and automate verified information
- Collection of water chemistry and age data
- Incorporation of ground water quality and aquifer property information into the County Well Index

Climate

- Temperature
- Precipitation
- Evapotranspiration
- Snow pack

5. Establish technical and stakeholder advisory committees to help Minnesota develop and adopt social, economic and environmental indicators to assess management choices and measure progress toward water sustainability.

In summary, information is the key ingredient of Minnesota's water allocation program. In one sense, the state's water resources have all been allocated and every use has its purpose, whether for people or the environment. So the manager's task is to understand how much water may be available, the quality of that water, how the water is currently being used, what or who is depending on that source, and what will happen to public interests if a change is made. To complicate the matter, water in the natural environment is anything but constant. In fact, ecosystems depend upon this natural variability for their survival. For people depending on a reliable supply of water or worried about drought or flood flows, variability can be a great concern.

Adequate data is integral to sustainable management because, properly collected and assessed, it allows us to properly understand the resource and answer the questions decision makers and citizens ask. It tells us whether water of sufficient quality can be reliably tapped in a location or a region and whether the use can be sustained over the long run without harming the natural environment, other users, or the prospects of future generations. The Environmental Quality Board's conclusions and recommendations set a course for collecting and applying the information essential to Minnesota's continued progress toward sustainable management of its precious water resources.

Managing for Water Sustainability:
Report of the EQB Water Availability Project
December 2008

Introduction

Minnesota is well known as the land of 10,000 lakes, but people forget that it also is blessed with 92,000 miles of streams, 10 million acres of wetlands and substantial amounts of ground water. While Minnesota's water resource is abundant, it is not evenly distributed across the state or across time. This diversity in abundance brings with it a special responsibility to use, protect and manage the resource wisely and to preserve it for future generations. Unlike other regions of the country and world that have experienced water shortages for years, Minnesota is uniquely poised to proactively manage its water resource in a way that both accommodates sensible growth and preserves natural resources to the lasting benefit of Minnesotans and Minnesota ecosystems.

Understanding this picture and in response to a request from the Minnesota Pollution Control Agency,[1] the Environmental Quality Board resolved at its February 2008 meeting to:

1. *Consider how the state might establish (and/or has established) protective and achievable standards to quantify and address the environmental impacts of proposed water uses;*
2. *Take a broad look at water availability and appropriations, including but not limited to issues specific to the ethanol industry, finding a way to put consideration of proposed water uses into a broader framework and perspective; and*
3. *Summarize need and options for collecting additional data important to comprehensive and timely analysis of proposed water uses.*[2]

In addressing these charges during the last nine months, the EQB convened over a dozen meetings involving over four dozen managers and technical experts.[3] Participants discussed the issues and identified Minnesota's needs both today and long term.

This report summarizes the findings related to the three charges, and suggests recommendations for moving forward around the concept of sustainable water management. Water sustainability is about collecting resource information and using it to understand the environment. It is about applying that understanding through our system of laws, rules and judgments to make decisions that match human needs and goals with environmental protection and long term preservation of our resources. This is the Minnesota framework. The challenge is to communicate to lawmakers and the public how Minnesota's standards make sense, are fair, accommodate economic activity and safeguard the environment for future generations. The challenge requires that participants continually evaluate the framework's utility and performance to define what works well, what needs better information, understanding or tools, and what we must do to make the necessary improvements.

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[1] The original request by the MPCA Board was focused on water availability as it pertains to the growing ethanol industry and high volume water users: "*Specifically, the Board is interested in receiving additional information on the broader issues of water availability and water appropriations related to the growing ethanol industry…. Board members have emphasized the importance of developing data and information on water availability and water appropriations related to the ethanol industry...request the Environmental Quality Board...to discuss this issue and develop options for collecting data and information on water availability and water appropriations in relation to the ethanol industry that will contribute to the comprehensive and timely analysis of individual projects*."

[2] Appendix A. Water Availability Project work plan excerpts

[3] Appendix B. EQB Water Availability Work Group

The report begins with the presentation of information important to understanding the context within which water appropriation decisions are made in Minnesota. This includes information about water use patterns, the hydrologic cycle and its importance to understanding water supply. It also includes a discussion of the concept of water sustainability, including the principles that guide implementation of this concept. The report next describes current water management methods and procedures for addressing the environmental impacts of proposed water uses. This section addresses the Environmental Quality Board's first charge to the work group: achieving protective standards. The next section addresses the Board's second charge: planning for water availability and sustainability. It describes the state's various planning activities and discusses how they can be improved to better contribute to sustainable water management. The final charge focuses on information and collection of the data essential to the success of water management in Minnesota. The appendices contain material that supports the report's responses to each charge.

Water sustainability collaborators

Sustainable water management requires coordination and collaboration by a wide range of participants.

Department of Natural Resources: Water appropriation permitting; water use, climate, hydrologic and hydrogeologic information collection and repository; environmental review and ecosystem management

Metropolitan Council: Metropolitan master water supply planning, metropolitan systems planning, water quality monitoring, local comprehensive plan review

Pollution Control Agency: Water and environmental quality management, pollution prevention, environmental review and environmental education; data repository

Department of Agriculture: Water quality management, integrated pest management and sustainable agriculture; data repository

Department of Health: Regulation of wells and borings, source water and wellhead protection, public drinking water safety, health risk assessment and health risk limits; data repository

Board of Water and Soil Resources: Local government assistance, comprehensive local water planning, wetland management, and local issues forum

Environmental Quality Board: Environmental review oversight, energy and environment strategy development, coordination of public water management and regulation, reports on policy issues, state water plan

Minnesota Geological Survey: Geologic information development; repository of geologic data

University of Minnesota: Hydrologic and hydrogeologic systems research, education and training

U.S. Geological Survey: Hydrologic and hydrogeologic systems expertise and assistance; repository of geologic, hydrologic, water chemistry and climatic data

Local government: Land use, water and comprehensive planning and management

Citizens: Citizen, nongovernmental organization and private sector interests in sustainable water management

Water use in Minnesota

Minnesota water use has increased by 24% over the last 20 years as tracked by the Department of Natural Resources through the water permit program, while population has increased 22%. Since 1990 water use for power generation, public supply systems and industrial processing has steadily increased over time (Figure 1). Water use for irrigation has generally increased but demonstrates variation from year to year.[4]

[4] More detail on water use can be found in the 2007 DNR report, *Water Year Data Summary: 2005 and 2006* , located at: http://www.dnr.state.mn.us/publications/waters/water_year_2005-2006.html.

Power generators and many industries use surface water, returning it to the original source after use with only a minor net loss in volume. Such use is non-consumptive. The water may be warmer or changed somewhat chemically, but it is available for another use downstream. Ground water use is consumptive because the water is not directly returned to its original source. It is for this reason that the study and monitoring of ground water availability and the conservation of ground water is of special concern.

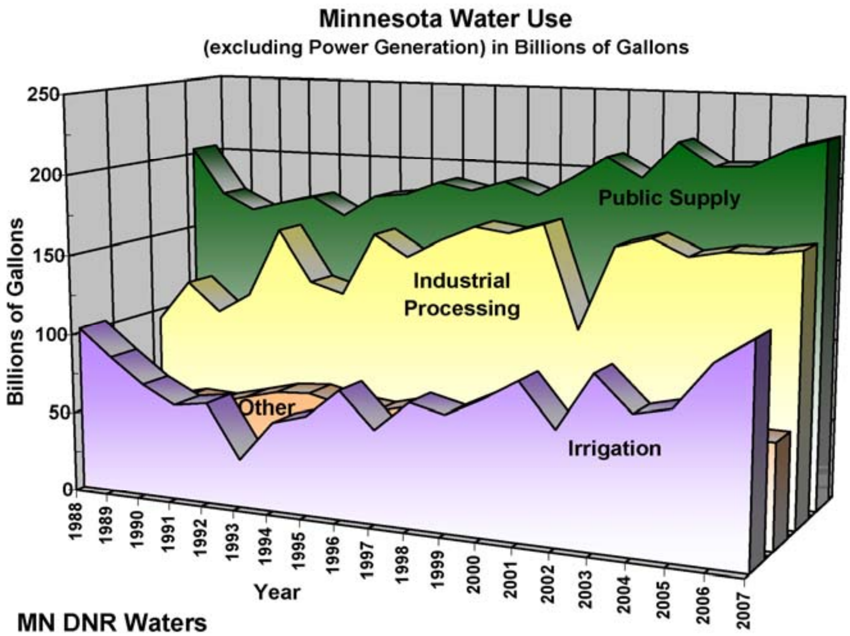


Figure 1. Minnesota water use 1985-2007
Source: Department of Natural Resources

Major water use categories

This section describes the relative statewide significance of Minnesota's major water using industries.

Thermoelectric power generation. Water used to cool power generating plants. This is historically the largest volume use and relies almost entirely on surface water sources. Thermoelectric power generation is primarily a nonconsumptive use in that most of the water withdrawn is returned to its source. Power generation accounted for slightly more than 59% of the total water used in 2007.

Public water supply. Water distributed by community suppliers for domestic, commercial, industrial and public users. This category relies on both surface water and ground water sources. The increase in volume shown over the past 20 years correlates to a growth in population over the same period. Typically, residential water users consume 75 gallons per person per day. Public water supply accounted for approximately 16% of the total water used in 2007. It is estimated that water use from private household wells adds another 27.5 billion gallons to the public water supply annual use, representing slightly less than 2% of the total state water use.

Industrial processing. Water used especially in mining activities, paper mill operations, and food processing, ethanol production, etc. Three-fourths or more of withdrawals are from surface water sources. Industrial processing used 12% of the total state water use for 2007. Based on ethanol facility water withdrawal reports provided to the DNR (1998-2006), Minnesota's ethanol industry achieved a 30% reduction in water demand; improving from an average of almost six gallons to about four gallons of water demand per gallon of ethanol produced. Progress has been made in reducing water use while also increasing the amount of ethanol produced from a bushel of corn.[5]

Irrigation. Water withdrawn from both surface water and ground water sources for major crop and non-crop uses. Nearly all irrigation is considered to be consumptive use. Of 7,000 active water appropriation permits, 73% are for irrigation. Irrigation represented 9% of the total permitted water use in the state, most of which (89%) came from ground water sources.

Other. Large volumes of water withdrawn for activities, including air conditioning, construction dewatering, water level maintenance and pollution confinement. These represent about 4% of Minnesota's 2007 total water use.

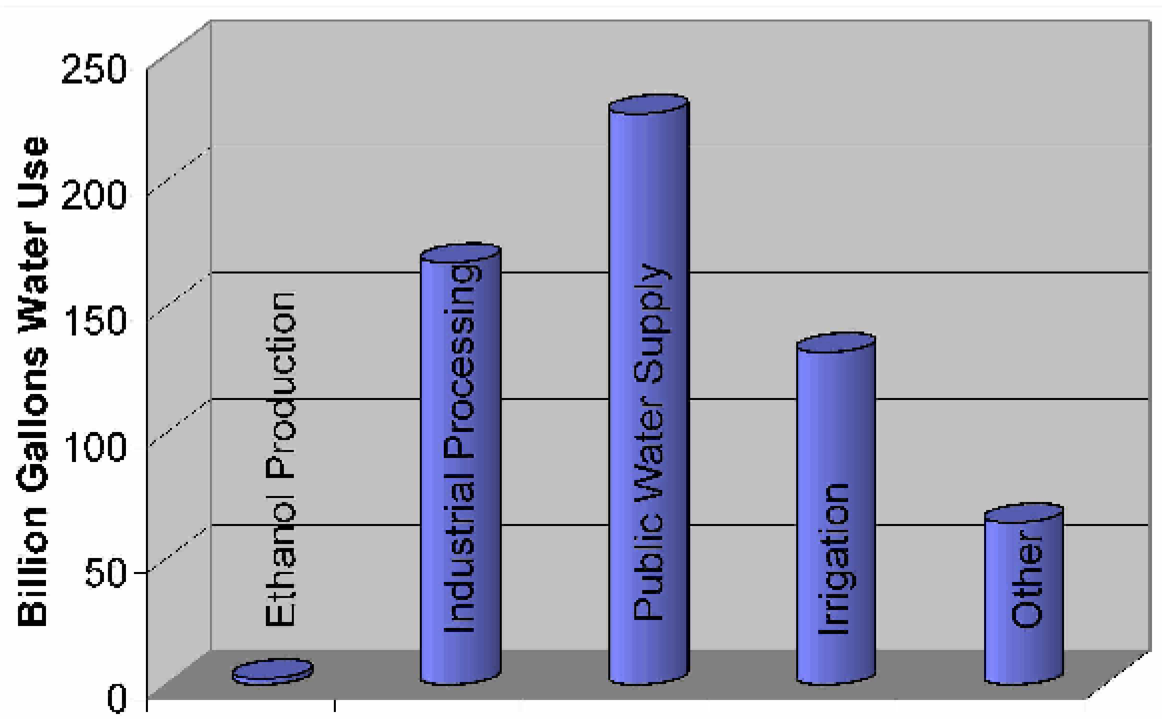


Figure 2. Minnesota water use by sector, excluding power generation
Source: Department of Natural Resources

Minnesota has abundant water but it is not limitless and not always found where needed. When decisions about water allocation are made, location of the use, changes in water demand with the seasons, and volumes of water needed must be considered. Public water suppliers are the largest users of ground water; they are distributed throughout the state and their pattern of water use shows pronounced summer peaks. In contrast, ethanol production uses only about 1% of the ground water used in Minnesota (see Figure 2), but the use occurs at only 15 sites. This use may be significant in those locales because ethanol production facilities use water nearly continuously year-round and water levels in the aquifer remain subject to pumping levels without periods for recovery. A facility producing 47 million gallons of ethanol per year uses as much water as the residential water demand for a city serving 7,000 people. For comparison, an 18-hole Minnesota golf course can use from 250,000 to 500,000 gallons of water per acre per year between mid-April and mid-October; as much water as the residential water demand for a city

[5] See Appendix D for ways in which water use is being reduced in ethanol production.

serving 3,000 people. The “take-home” point is that use of seemingly small volumes of water can have a local impact on available water and on other resources.

Water resources in Minnesota

Ground water is everywhere beneath the surface of Minnesota, but useable amounts are not evenly distributed due to Minnesota’s varying geology. In some areas of Minnesota the location of ground water resources is relatively well known and defined, whereas much more work is needed in other parts of the state to map and describe the resource. Long-term ground water monitoring to assess the response of the resource to climatic fluctuations and withdrawals is crucial to assess the status of the resource and evaluate long-term trends. Additionally, geologic and aquifer maps and monitoring data are essential sources of information for analysis of long-term water sustainability.

Surface water is similarly found in varying amounts throughout Minnesota, providing water for approximately 20% of Minnesota’s water permits. Surface water flows vary more over the seasons than do ground water levels. Conjunctive use of surface- and ground-water sources can be an important component of Minnesota’s sustainable management strategy because a user can draw from surface water while it is abundant, sparing ground water for use during drier periods.

The hydrogeologic information required to model or predict the sustainability of ground water supplies is based upon the geologic framework. That information includes the distribution, size and boundaries of aquifers, the estimated or tested hydrogeologic parameters of hydrogeologic units, the nature of their connection to other aquifers and to the land surface, and current and historic measurements of water levels in those aquifers. Obtaining this information requires a long-term commitment and dedicating the resources needed in data collection.

Understanding Minnesota’s water management framework

Minnesota has a comprehensive framework for sustainable water management. State law, rules and programs provide agencies a solid foundation for the work they do to protect natural resources and meet people’s needs. While the foundation is solid, it is also complex, involving a number of state agencies, levels of government and decision-makers.

Participants in this framework understand its complexity, but those who get engaged in it because of a proposed project or plan may not. Successful projects and successful water management are more likely when all involved understand management goals and how the pieces of the framework fit together. Policy makers and citizens can then build a common understanding of the resources needed to improve the process or manager’s tools.

Water availability and sustainability

Water availability and water sustainability are related, but distinct terms. In this report, the term *water availability* refers to the amounts of useful water in the hydrologic system, but does not consider that less water may be appropriately withdrawn depending upon how a system might respond or the effect a withdrawal might have on connected resources. *Water sustainability* on the other hand does consider these relationships. It also incorporates an understanding of the hydrologic system’s ability to meet people’s needs and safeguard ecosystems for the indefinite future.

A unifying concept. Sustainable water management or "water sustainability" is the underlying goal in Minnesota's management of water resources. Helping people understand what this means is a key to helping them understand the framework.

In practical terms, water use can be considered sustainable if it meets people's needs, safeguards ecosystem functions, preserves water quality, and reserves sufficient water in the system to meet long-term future needs. Depletion or degradation of water resources must be avoided. To do otherwise would harm people or the natural resources that depend on water. For surface water, this means ensuring that seasonally sufficient flows and levels remain to sustain the quality and quantity of natural features and to replenish ground waters. For ground water, it means ensuring that the discharge of good quality water to surface waters continues to sustain the quality and quantity of critical ground water dependent surface features.

Principles. Principles guide decisions and inform priorities in the work agencies do for sustainable water management. These come from Minnesota's laws governing water resources and call for policy, planning and management that:

- Is transparent and easily understood
- Recognizes important interconnections, including the link to land use
- Coordinates interests and integrates views, including those of local governments and citizens
- Collects and interprets the data needed by decision-makers and citizens
- Strives to understand limits to growth, addressing problems in a sustainable way and preventing the emergence of new ones
- Acts in a unified, economical manner
- Communicates the message

Charge One – Achieving protective standards

Consider how the state might establish (and/or has established) protective and achievable standards to quantify and address the environmental impacts of proposed water use.

Minnesota law and rules provide a rigorous framework for protecting water resources. This section examines the standards and procedures used to make water management decisions and considers ways to improve them to better protect the resource. The needs for sustainable resource planning and good information, also important to implementing the framework and achieving the standards, are discussed under Charges Two and Three, respectively.

The Commissioner of Natural Resources is required by *Minnesota Statutes*, section 103G.265 to manage water resources to meet long-range seasonal requirements for domestic, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes. The DNR's water appropriation permit program must balance both development and protection of Minnesota's water resources.

The Minnesota Environmental Policy Act of 1973 established a concurrent process for investigating the environmental impacts of major development projects. The purpose of the review is to provide information about a project's environmental impacts before approvals or necessary permits are issued. Because unanticipated environmental consequences can be very costly to undo and environmentally sensitive areas can be impossible to restore, environmental review creates the opportunity to anticipate and manage any identified problems before a project is built. This section describes important concepts of the water permitting and environmental review programs, which work together in water allocation decisions.

Components of sustainable water resource management

The DNR Water Appropriation Permit Program is the centerpiece of Minnesota's efforts in pursuit of water sustainability. When a permit has been granted, the permittee is required to submit annual reports of water use. The program is developed around the idea that managers can adjust permit requirements based on observed trends in long-term monitoring data. It includes four primary components:

- Overarching standards
- Decision factors that ensure compliance with the standards
- Indicators of measurable progress toward or adherence to the standards
- Adaptive management

Standards. Minnesota law sets standards for non-depletion, reasonable use and non-degradation of water resources in striving to prevent negative impacts. Although the concept is not exhaustively addressed in water law, meeting these standards should ensure sustainability of the resource.

Decision factors. *Minnesota Statutes* and *Rules* identify a number of decision factors that are intended to ensure sustainable water management. Table 1 is a compilation of these factors, which are a key to evaluating permit applications.

Table 1. Decision factors used to determine if a permit may be issued

Proposed use is practical	Efficiency of use has been addressed
Source alternatives have been explored	Water conservation measures will be taken
Return water effects are mitigated	Impacts to water quality are addressed
Capability to sustain use is demonstrated	Impacts to the aquatic system are addressed
Zone of influence and impacts are addressed	Effects on flow, water levels and safe yield are addressed
Effects of use on public values is indicated	Economic benefits of use are balanced with respect to impacts
Link to land use, quality and availability are considered	Collective, long range ecological effects are understood
Effects on public safety and welfare are addressed	Ground water use is limited to protect surface water features
Where data are lacking, uses are conditional	Additional future uses are anticipated
Distribution of use is considered	A monitoring plan has been developed if needed
Proposed use is sustainable	Appropriate stakeholders are included in the process

In essence, each decision factor is the statement of a desired condition of water sustainability. Examples of the kinds of desired conditions suggested by these factors include:

- Use of alternative sources of water reduces exclusive dependence on ground water sources
- Adequate ground water discharge maintains natural flow and temperature regimes in streams
- Ground water contamination is reduced due to wise land use decisions, prevention of spills and nonpoint-source pollution, and effective clean-up efforts
- Conservation and efficient use maintain adequate water supply for public and private users

Indicators. Indicators are measures that present information on trends or resource conditions in a readily understandable way. They provide tools to assess progress toward water sustainability in Minnesota water management. Good indicators reflect the state's water management standards and decision factors, are based on science, and are quantitative, comparable, understandable and measurable over the long term. Examples of surface water, ground water, water use, water sustainability and water quality indicators are presented in Table 2. Note that not every indicator is or can be measured across the state with current levels of data. In addition, Minnesota's indicators also necessarily include elements of social, economic and natural community health. These are yet to be identified.

Table 2. Indicators to measure impacts

Water availability and sustainability assessments employ indicators to measure impacts.

Surface- and ground-water interaction
- Streamflow reach comparisons – are stream reaches gaining or losing?
- Long-term stream flow trends
- Aquifer – surface water impacts
- Aquifer – surface water trends
- Climate – water level trends

Ground water
- Ground water recharge effects – do water withdrawals (including mine dewatering and land drainage) affect recharge?
- Intensity of ground water use – number, capacity and spatial distribution
- Observation well variations – due to seasonal hydrograph or dropping water levels?
- Ground water level – aquifer threshold relationships
- Well interference incidence – do aquifer tests indicate likelihood of interference with existing users?
- Aquifer stress – does the pumped aquifer show risk of stress during tests?

Water use
- Total withdrawals by source (surface- and ground-water) and sector (public supply, domestic, commercial, irrigation, livestock, industrial, mining, thermoelectric power and hydropower)
- Conveyance losses
- Consumptive uses

Water sustainability
- Relative intensity of resource use – past, present and future
- The ratio of water withdrawn or consumed to renewable supply

Water quality
- Water chemistry trends over time
- Physical parameter trends over time
- Tritium
- Stable isotopes
- Chloride and bromide ratios
- Nitrate concentrations

Adaptive management. With an understanding of the hydrologic connections that exist between surface water and ground water, DNR has adopted an approach that addresses the whole hydrologic system (see Figure 3). The culmination of this system is adaptive management: use of long-term data collected about the indicators to identify trends and acting on that knowledge to adjust management practices as appropriate.

For example, a crucial component of managing water resource availability is a network of precipitation gauges, monitoring wells and stream gauges to measure the changes in water levels and stream flows as they occur. Adjustments to withdrawals can then be made in response to changes in ground-water levels and flows.

Adaptive management allows managers to evaluate collective impacts of multiple users in multiple interconnected aquifers over larger areas. The water appropriation permit program is the process used to deliver water resource management. The program is based on adaptive management strategies that can respond to trends observed in long-term monitoring data.

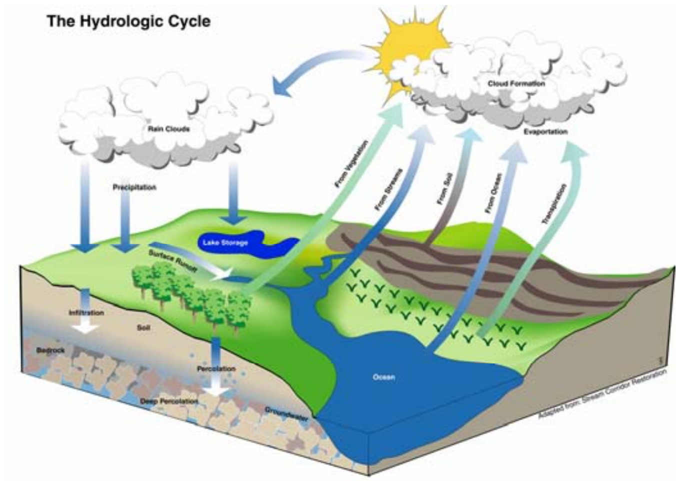


Figure 3. The hydrologic cycle
Source: http://www.buffer.forestry.iastate.edu/Photogallery/illustrations/Images/Hydrologic-Cycle.jpg

Water permitting

Minnesota law generally requires a permit from the DNR Division of Waters for water appropriations in excess of 10,000 gallons per day or 1,000,000 gallons per year.

The DNR Water Appropriation Permit Program, described in greater detail in Appendix C, aims to balance competing management objectives that include both development and protection of Minnesota's water resources. Permits are permissive only and do not establish a right to appropriation nor a priority of appropriation. When a permit has been granted, the permittee is required to submit annual reports of water use. A permit may be restricted, suspended, amended or cancelled in accordance with applicable laws and rules for any cause for the protection of public interests, or in response to a violation of the provisions of the permit. Management need not wait for scientific certainty or prima facie proof of individual permit impacts before making permit decisions or restricting permits to prevent negative consequences.

To balance competing demands for the development and protection of Minnesota's water resources, it is necessary to understand resource limitations and establish adequate protection measures. Minnesota law calls for the protection of rare surface water features, such as calcareous fens and trout streams. In addition, the law calls for the establishment of protected levels and flows for surface water and safe yields for ground water.

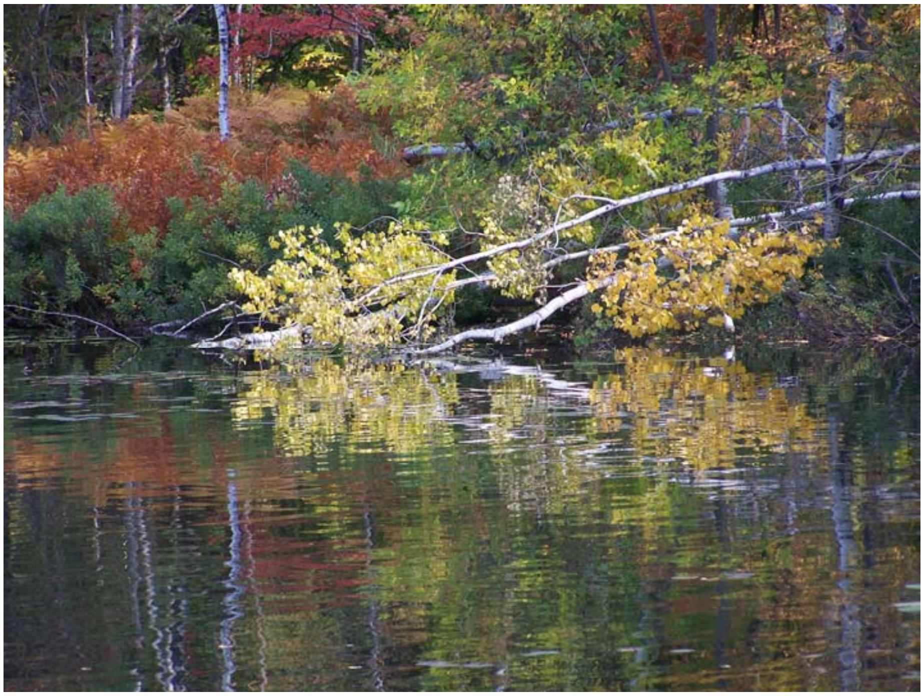
When potential impacts to other users or natural resources are identified, contingency plans are a required component of an appropriation permit. These plans may include identification of potential alternate water supply sources or a statement that the water user agrees in advance to a suspension of withdrawals, if necessary. Although most commonly applied to surface water appropriation, ground water users may be required to have contingency plans if there are potential impacts to other users or uses.

Environmental review[6]

Environmental review is a formal process for investigating the environmental impacts of proposed projects. Major development projects are required to formally undergo environmental review of potential impacts before approvals or necessary permits are issued. The environmental review process aims to evaluate a project's potential environmental effects and provide a forum for public comments. It also informs the public about the project and helps identify ways to protect the environment by providing information that can be incorporated into environmental permits and approvals. In addition to describing

[6] For more detail, see Appendix C.

the project and required approvals, the environmental review document explores a project's potential effects among other things on land use; wildlife and ecologically sensitive resources; cultural resources; traffic, noise, odor and visual impacts; air and water quality; and water resources, generally, including water supply and use.



In analyzing the environmental effects of a proposed project, the responsible governmental unit reviewing the proposal must consider cumulative potential effects as well as direct project effects. To evaluate cumulative potential effects, the RGU should inquire whether a proposed project, which may not individually have the potential to cause significant environmental effects, could have a significant effect when considered with existing and anticipated projects that have been planned or for which a basis of expectation has been laid. The analysis must consider projects located in the surrounding area and that might reasonably be expected to affect the same natural resource as the proposed project.[7] An understanding of cumulative potential effects is important to evaluating projects that need high volumes of water because of the possible impacts to natural resources or other water users.

Standards, practices and regulations. Minnesota's framework for preventing negative impacts on water resources includes standards for non-depletion, reasonable use and non-degradation. The DNR considers non-depletion and reasonable use during water appropriation permitting. Non-degradation is a primary responsibility of the Minnesota Pollution Control Agency, although protection of water quality is explicitly part of the stated goals of water appropriation permitting. In addition, the Minnesota Department of Health establishes standards for contaminant levels in drinking water, which are used to identify where water quality has been degraded to the extent that it can no longer be used for drinking without treatment.

The Department of Health uses several vehicles for addressing water quality degradation. The department establishes drinking water quality standards under health risk limits regulations and prepares health advisories in areas where water contamination has occurred. It administers well construction regulations

[7] The Environmental Quality Board is proposing a rule change to require responsible governmental units to consider the "environmentally relevant" area instead of "surrounding area" in future cumulative effects analyses.

to: a) prevent new wells from using contaminated portions of an aquifer, and b) require the sealing of unused (abandoned) wells that might augment vertical movement of contaminants into an aquifer or between aquifers. The department employs public water supply program regulations to ensure that public water supply wells are monitored for contaminants that may adversely affect public health and that contamination of a public water supply is identified and eliminated in a timely manner. Finally, wellhead protection regulations require public water suppliers to implement measures for reducing the likelihood that their water supply wells will be contaminated to levels that present a public health risk. Wellhead protection provides the opportunity for addressing sustainability at the community level by promoting the coordination of land and water uses to minimize their impacts on drinking water quality.

Ecosystem management strategies. The dominant influence of hydrology in natural aquatic ecosystems suggests that water management should be designed to maintain a natural flow regime despite off-stream and instream water use. A better understanding of how aquatic population dynamics respond to changing flows would support the adoption of more defensible population-based adaptive management measures. Land use practices that maintain natural watershed processes would also protect the critical components of the hydrograph (duration, magnitude, timing, frequency and rate of change). An effective ecosystem management strategy would maintain habitat- and population-based minimum flows, seasonal minimum high flows, and the natural variability of flows over time.

Benefits of a healthy ecosystem

Healthy aquatic ecosystems provide services to humans beyond recreational fishing and power production (Richter et al., 2003). These include: a) a supply of water for drinking, irrigation, manufacturing; b) a supply of fish, waterfowl, mussels; and c) instream benefits, such as, recreation, flood control, pollution dilution, and detoxification (Daily, 1997) and immeasurable societal benefits. Individual communities living along freshwater systems may have different priorities for the derived values listed above and different societal benefits; however, a healthy system can benefit all communities.

The structure and function of river ecosystems are based on five resource components: hydrology, geomorphology, biology, water quality and connectivity (Annear et al. 2004). Management of one component in isolation, such as instream habitat for a single or limited number of species, is typically not wholly effective because each component is in continuous interaction with the other components. As such, a single protected flow level is inadequate to protect instream resources. Poff et al. (1997) describes five components of a flow regime that influence river ecosystems: magnitude, frequency, duration, timing, and rate of change. Alteration of any one component can directly impact physical habitat (e.g. eliminating flood peaks will decrease the streams ability to move sediment) and aquatic organisms (e.g. increasing the rate of change will displace invertebrates and can result in stranding).

Achieving protective standards: Conclusions and recommendations

Minnesota law governing the allocation of water resources has evolved over the past 70 years into today's set of comprehensive management programs. Keeping pace with water management issues through an approach that balances water resource protection within the context of riparian water law has made the state a leader in water management. In practice, the state applies this body of law effectively in response to applications for water use. Information about a project and its surrounding environment is gathered. Investigations are conducted for the resources that would be affected and the collection of additional water resource information may be required in order to better assess potential impacts. For applications to appropriate ground water, the state usually requires users of potentially large quantities of water to conduct an aquifer pumping test. The test is designed to provide quantitative information about local aquifer capacity and to assess any potentially adverse impacts on surface water resources. Such tests may not always accurately predict how long term pumping might impact the ground water system or any connected surface systems. Potential water quality impacts might also be missed. Finally, the state has an opportunity to develop a formalized method for assessing cumulative effects in the environmentally relevant area of projects. None of these challenges is unique to Minnesota; rather, they represent areas where future improvements may be possible.

Charge One Conclusions

1. Minnesota employs commendable water management methods in response to permit requests, but a strategy that would ensure the availability of key hydrologic, hydrogeologic and ecological information in priority areas would improve both the proficiency and efficiency of the system. Continued efforts to develop better tools to use this information also would strengthen water management practice.

2. No single method or activity will solve the state's challenges. Managers need to continue some practices, improve others, develop complementary new approaches, and continually set and reset priorities as they gain new knowledge. The current system, which is based primarily on planned monitoring and the development of contingency plans, should eventually be supplemented by a system where the effects of proposed water uses can be modeled and predicted. In the meantime, the state needs to compile the necessary information to support water management as currently practiced, build a state-of-the-art monitoring network, continue expansion of county geologic atlases, and shift progressively to management informed by improved baseline data, information on hydrologic system limits and state-of-the-art modeling. To accomplish this will not only require additional staff at various levels of government, it will require individuals with the appropriate expertise.

3. The use of aquifer protection thresholds works well in areas where aquifers are limited in areal extent and the appropriators are not numerous. The main drawback is that for many aquifers neither the extent nor the distribution of aquifer properties is known. Data needs are high and direct consideration of indirect collective impacts on related resources is challenging. Nonetheless, where data are available, only a few transient drought-related violations of theoretical (not permit-related) thresholds have occurred.

4. The protection of seasonal requirements of fish and wildlife is a statutory mandate, but more needs to be understood about population responses to changes in levels and flows.

Charge One Recommendations

The state should:

1. Establish a long-term strategy for generating and managing the information needed to integrate water availability assessment results into regulatory programs on a statewide basis. This strategy should address the legal, financial and security issues that affect public access to the information. It also should chart a course for shifting to an emphasis on the application of modeling to evaluate proposed uses and locations as sufficient data are generated. Strategy elements should include:

- Allocation plans by aquifer and watershed
- Continuing efforts to build, maintain and use existing models, such as the Metropolitan Council ground water model
- New efforts to assess regional water availability and sustainability using a variety of methods, models and mapping

2. Maintain and enhance the ambient water quality monitoring network and other monitoring activities to enable more systematic water quality assessment when evaluating water availability and the potential significance for water use, especially for potable water supply.

3. Refine the aquifer protection threshold concept to work in more complicated situations both to protect aquifers and to provide an indication of water sustainability. This should include the development of thresholds for regional systems.

4. Identify defensible criteria for assessing the critical water levels or flow conditions required to support ecosystems. The criteria should consider ecosystem-sensitive practices that protect critical components of the hydrograph, including:

- A habitat- and population-based minimum flow
- A high flow protection standard that protects critical habitat forming and silt flushing high flows
- Protections for down stream needs
- Protections for the natural variability of flows over time (hydrograph shape)

Charge Two – Planning for water sustainability

Take a broad look at water availability and appropriations, including but not limited to issues specific to the ethanol industry, finding a way to put consideration of proposed water uses into a broader framework and perspective.

> **M**innesota is growing …
> But this growth often occurs without thorough consideration of the implications for the environment, particularly water. This priority will ensure that water information and expertise are available to help with growth management decisions. A key element is development of aquifer management plans (determining sustainable yields and resource protection needs) for those aquifers at risk from urban growth. Another key element is providing this information to local governments and helping them build and carry out solid comprehensive plans that incorporate the issues from water plans. Finally, support for preparation of a state investment strategy is also included. The strategy will help focus and integrate state investments and will make the state more responsive in meeting local growth management needs.
> *Minnesota Water Priorities, 2003-2005*, Environmental Quality Board

Water sustainability planning is relatively new to Minnesota. It involves the systematic consideration of future water demand within the capacity of water resource systems to meet that demand without harming ecosystems or degrading water quality. Much of the planning that occurs in Minnesota today addresses one or more pieces of the framework, but the water sustainability component is a work in progress.

State law requires that water appropriation permits must be consistent with state, regional and local water and related land resources management plans. *Minnesota Statutes*, section 103G.271, subd. 2. and *Minnesota Rules* part 6115.0810, also provide for the development of water management plans to implement the elements of any state, regional and local plan relating to water appropriation and use. This section describes current efforts in local, regional and state planning and discusses tools for putting water use in a broader perspective. Appendix E summarizes selected programs and studies regarding Minnesota water resource supply and demand.

Local planning

Local water plans. Local governmental units create and implement plans affecting water although most plans and implementing actions address water quality instead of quantity. Still, a number of county water plans in southwestern and western Minnesota include ground water and supply issues as one of their priority concerns. Local water management planning is authorized under *Minnesota Statutes*, Chapter 103B, and comprehensive or land use plans and official controls under local planning and zoning authority. The main vehicle for water availability planning is found in *Minnesota Statutes*, Chapter 103G and section 473.859 (the latter for communities in the Twin Cities Metropolitan Area).

A potential exists for greater consideration of water availability in comprehensive and land use planning under local planning and zoning authorities. *Minnesota Rules*, Chapter 6115.0810, establishes a process for the preparation and implementation of the elements of any state, regional and local plan relating to water appropriation and use. Local water supply and contingency planning occurs in water supply plans prepared by public water suppliers and the water appropriation permitting process administered by the Department of Natural Resources.

Water availability is sometimes a consideration in local approval processes for development, along with local regulatory standards. For example, a county may require demonstration that an adequate water supply exists before approving a conditional use permit. Additionally, local comprehensive or land use plans could be adapted to include water availability estimates and projections. If suitable water sustainability estimates and projections were available, such information would prove useful for comprehensive or land use planning. Water sustainability related questions in a planning context include:

- Will water supplies be adequate to support existing and anticipated development without adverse impacts on connected resources or water quality?
- In which parts of the planning area are there adequate water supplies for future development? In which parts, if any, are water supplies inadequate?
- What is the likely impact of future water demand upon natural systems, particularly streams, lakes and wetlands (e.g. impacts on base flows, temperatures, water levels, water quality, plant and aquatic life, etc.)?

Contingency plans. Contingency plans are required for surface water permits by *Minnesota Statutes*, section 103G.285, subd. 6. A contingency plan describes the alternatives the applicant will use if further appropriation is restricted due to the flow of the stream or the level of a water basin. A surface water appropriation may not be allowed unless the contingency plan is feasible or the permittee agrees in advance to a suspension of withdrawals, if necessary. For high volume appropriations from ground water, similar statements of use restrictions may be required if it is anticipated that the requested water use may impact surface water features.

Water supply plans. Public water suppliers serving more than 1,000 people are required to have a water supply and contingency plan approved by DNR (*Minnesota Statutes*, section 103G.291). In addition, all communities that provide public water supplies in the Twin Cities Metropolitan Area are required to prepare water supply plan as part of their local comprehensive plans (*Minnesota Statutes*, section 473.859). Water supply plans, first required in 1996, must be updated every ten years. Efforts are underway to work with public water suppliers to develop and approve the second generation of water supply plans, which will incorporate the concept of sustainability. Contingency planning by public water suppliers might include partnering with neighboring communities, using a backup well or surface water source and implementing progressively more restrictive conversation measures.

State and regional planning

Regional and statewide plans provide people with an assessment of broad-scale resources or an overarching perspective. Statewide plans can be helpful during early stages of planning when they present a general idea of water availability issues to be expected when pursuing development in various areas of the state. This may be helpful, for example, in avoiding the siting of a high water use dependent industry within a water poor area. Again, the inclusion of water availability in planning is a vital step toward sustainable development.

Metropolitan Council. The Metropolitan Council is in the third year of work preparing a master plan for meeting the region's long-term water supply needs. It has engaged key stakeholders and developed a region-wide ground water model to guide it in the effort. The plan, which will be completed in early 2009, evaluates future water demands and outlines issues that need to be addressed to meet those demands.[8]

The Council's ground water model was used to evaluate current and future needs across the metropolitan area. Model results were used to develop a water supply profile for each metropolitan area community that lists water supply sources and options available to the community and informs the communities of what issues they may encounter with continued use of their existing water supply sources. The plan also outlines the steps to take to ensure that the sources are developed sustainably. County-specific profiles provide a summary of water supply issues and recommendations relevant to land use planning on a county scale. The profiles are provided as both an appendix of the Master Water Supply Plan Report and as a web application. The interactive web tool provides users access to water supply GIS datasets and offers the ability to create maps. Data provided through this application come from the Minnesota Department of Health, Department of Natural Resources, U.S. Geologic Survey, Minnesota Geologic Survey, and metropolitan area communities and counties.

Department of Natural Resources. At the state level, the DNR examined the issues surrounding ground water sustainability in a 2005 study. The study identified a series of technical, planning, monitoring and regulatory needs. It concluded that "working toward sustainability requires us to monitor and analyze more; to address demands collectively; to use water efficiently; and above all to recognize water's value to our neighborhoods, communities, economy, environment and continued existence on this planet."[9]

Environmental Quality Board. The EQB began its water sustainability work with a 2007 interagency study comparing supply and demand at the county level. Its report, *Use of Minnesota's Renewable Water Resources: Moving toward Sustainability*,[10] compared present levels of water use, as well as demand projected to the year 2030, with estimates of supply. The board concluded that Minnesota may not be as "water rich" as people once thought and that much work is needed to ensure a better understanding of where ground water can be found, and how much can be sustainably and safely consumed over the long run.

Water sustainability planning tools

Sustainable water management requires an interagency, intergovernmental information system that helps people organize, analyze and present information about the hydrologic, economic and ecological environments of concern. While much of the system is in place, housed within member agencies, the state should develop a phased plan to better facilitate data sharing and integration. The state needs an information system that managers and citizens alike can use to support and carry out the Minnesota framework. While the state may lack some desired data, models and trend analyses for a fully comprehensive information system, it has sufficient data to support a preliminary assessment tool.

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[8] See http://www.metrocouncil.org/environment/WaterSupply/index.htm for a current picture of the project's process and outcomes.

[9] The full suite of products from the study can be viewed at http://www.dnr.state.mn.us/waters/groundwater_section/sustainability/index.html.

[10] The board's report can be viewed at http://www.eqb.state.mn.us/documents/UseofMinnesotasRenewableWaterResourcesApril2007.pdf.

A prototype information system. The EQB Water Availability Project developed an information system prototype with the assistance of the Land Management Information Center and with guidance from work group members.[11] The water sustainability planning tool is designed to assist in understanding the opportunities and impacts associated with water use in Minnesota. It also should be useful in strategic water and land use planning. It is not intended to replace or stand alone in lieu of site specific decision-making or permitting. Instead, it supplements these processes. Based on current water permit data, the system helps users understand water use in a county or region and identify adjacent surface waters, protected features, impaired waters, and other water uses.

This tool should be useful for initial screening evaluations of proposed projects or in identifying opportunities for future growth and development. It should be used in combination with information generated through the state water appropriation permit and environmental review processes. The tool is not designed to tell users how much water may be safely appropriated at any one point or how water in an area should be allocated. Rather, it presents information useful in understanding the relative intensity of water use in the context of a region's water and related land resources. The agencies with regulatory authority must still collect and assess the site specific information necessary for regulatory decision-making, but the tool will provide them a picture of the larger system as a backdrop for their decisions.

Planning for water sustainability: Conclusions and recommendations

Minnesota has made important progress in recent years in planning for water sustainability, but should expand the commitment of time and resources it devotes to the task. The state requires city utilities responsible for developing and delivering water supplies to look out ten years to make certain their supplies will be sufficient, which is a good start. In 2005, the Legislature directed the Metropolitan Council to develop a water supply master plan. The draft Council plan looks out to the year 2050 and employs a sophisticated model to understand where ground water resources may be limited. While the region's water supply is adequate to meet projected demand, supplies are not equally available. Withdrawals may result in adverse impacts in some areas, particularly where high growth is projected or sensitive natural resources are present. The Department of Natural Resources in 2000[12] and Environmental Quality Board in 2007[13] conducted regional-level assessments of water sustainability for the entire state, both of which reached the general conclusion that Minnesota is not as water rich as once thought.

Charge Two Conclusions

1. Minnesota is characterized by dramatic spatial and temporal variability of its water resources; the demands people place and will place on these resources; the extent to and manner in which ecosystems depend on water; the interplay between water availability, water quality and land use; and chronic shortages of information, staff and financial resources.

2. Minnesota should consider a number of steps to strengthen planning for water sustainability and increase the likelihood that water will be managed sustainably over the long term. Areas for improvement include funding, technical support, priority setting, coordination, and the linkage between management and planning.

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[11] http://www.eqb.state.mn.us/eqb_w/

[12] O'Shea, D. 2000. Water Use and Availability in Minnesota. *Rivers* 7:333-344

[13] http://www.eqb.state.mn.us/documents/UseofMinnesotasRenewableWaterResourcesApril2007.pdf

3. While progress is being made, the state can do more to automate, integrate and make information more accessible to managers and citizens alike who can use it to support and address water sustainability decisions, whether in planning or management.

4. To understand whether or not today's decisions may be sustainable, people need to consider if they fit within hydrologic and ecological system limits. To make such determinations practicable, tools must be able to:

- Account for basic processes, forces and relationships affecting water resources locally and regionally
- Adjust and adapt as understanding of the system advances, including that related to system capacities and the effects of climate change and land use
- Address the collective and cumulative potential effects of decisions
- Provide for consideration of future growth or change
- Be built on solid data sets and numerical characterization of aquifers and natural systems

5. The policy adopted by the Legislature in 2008 to require local water supply utilities to adopt conservation rate structures is a good first step at incorporating economic incentives as a tool in the pursuit of sustainable water management.

Charge Two Recommendations

The state should:

1. Work with local governments, regional development staff and others to plan and manage water systematically at an area-wide scale through designated *water appropriation and use management areas*. It should identify priority areas and priorities for their implementation based upon a system of criteria that includes an assessment of an area's water sustainability limits, the competition for water, water quality concerns, future growth prospects and local interest.

2. Understand how state and local activities and incentives to encourage economic development may affect water availability and sustainability in the areas of interest prior to release of funds or approval of plans.

3. Develop a system of incentives to reward local units of government that incorporate water availability and sustainability considerations into their water and land use plans and decisions.

4. Continue efforts to develop and apply water sustainability models and planning tools, integrating new information and research results, as well as additional social, economic and environmental data. As part of these efforts, the state should establish a water sustainability information system steering committee to consider:

- System users and the questions they need addressed
- Scale and scope implications of user needs
- Available information and database management issues
- Design for easy and continuous information updates
- A long term business management plan

5. Develop Minnesota's resource system planning capability, including efforts to define water sustainability limits; link water management to land use decision-making; seek opportunities for conjunctive surface and ground water management; and consider the use of economic mechanisms in water management.

6. Continue to track and assess the implications of population, economic, climate and land use changes on management practice, sustainability planning and priority setting.

7. Examine opportunities to employ economic policies and incentives in support of sustainable water management. These should include:

- Requiring water users to conduct more aquifer and watershed monitoring and to help support information systems development and analysis
- Providing additional incentives for water conservation and wise management
- Encouraging consideration of alternative water supplies, gray water reuse, conjunctive use and other water saving measures when siting high water uses or designing infrastructure
- Developing methods for making credible estimates of the value of ecosystem services, as well as the economic implications for communities and individuals of water use policies and prospects

Observations from the project's technical advisors

- Ground water systems can take years to respond to disturbances, thus effects may not be apparent in the short term.
- Watershed and ground water system water budgets can help people understand dynamics of the hydrologic system, an important step in sustainable water management.
- The monitoring of ground water levels should be linked to surface water monitoring to help people understand the interaction of surface waters and ground water.
- The application of economic incentives and mechanisms that recognize the value of water would help encourage sustainable water management.
- What is a "reasonable" use under the state's water law must change as competition for the resource intensifies.
- The state needs to enhance current analysis and monitoring of the collective effects of past and present uses, and build data sets that will allow effective modeling of the impacts of potential future uses.

Charge Three – Defining water information needs

Summarize need and options for collecting additional data important to comprehensive and timely analysis of proposed water uses.

Sustainable water management requires sound data to support understanding of the various elements of the hydrologic system. This includes high resolution landscape and soils information, precipitation, aquifer recharge, aquifer discharge, aquifer withdrawals, ecosystem services needs, surface water quality, ground water quality, evapotranspiration, surface water and ground water interconnections and flow pathways, among other traits.

Adequate temporal and spatial representation of the data is also needed to support sustainable water management. Minnesota has sufficient water resources to meet foreseeable demands provided they are managed responsibly and the state commits to gathering and assessing the necessary data. A growing base of data better positions the state to act proactively, answering questions and resolving concerns in advance of conflict and shortage. Strategic new data collections should be targeted at highest value and most stressed locations first.

Data integration at large scales

Data must be integrated through an information system or model to provide a broad areawide or regional context for water and ecological resources. Minnesota needs to enhance its hydrologic cycle monitoring system in order to further enable analysts to integrate and assess measurements of temperature, precipitation, evapotranspiration, land use (impervious surfaces, drainage etc.), low flow, surface water levels, ground water levels, and water quality. The goal is to enable managers to evaluate the state of the system and its potential responses to water use, land use and water quality concerns. The system-wide hydrologic cycle view provides the foundation for understanding information system needs of state managers and local officials.

Areas needing accelerated study

Three areas of accelerated study are critical to understanding water availability and sustainability in Minnesota:

- Better hydrograph statistics in streams throughout the state. The recurrence intervals of various flows needed for water supply and to support stream biology need to be determined for watersheds and for specific locations in watersheds throughout the state.
- Enhanced evaluation of water appropriations in aquifers where water availability is of concern including both the impact of the appropriation on surface water features and on the aquifer itself. Expanded monitoring and data collection will improve the accuracy of existing analytic models that are favored for hydrogeologic evaluations. These accepted techniques can then be applied in evaluating the collective impacts of appropriations where water availability is limited or resource impacts are likely to occur.
- Acceleration of existing studies of climate and the geologic, hydrologic and biological processes that affect, or are affected by, changes in water availability. Completion and additional evaluation of existing research is needed to estimate ground water recharge. This work is needed to provide better estimates of recharge and to evaluate differences among methods. Supplemental work also is needed to evaluate and describe requirements for sustainable in-stream flow for aquatic biota. Dynamic variability in precipitation and evapotranspiration resulting from change in climate needs to be better understood.

Finally, better quantification of hydraulic properties of confining beds and leakage to deeper aquifers is needed to supplement information on the water-yielding properties of confined aquifers. Appendix F provides information on the integration of data from the hydrologic cycle.

Better low flow statistics for risk assessment. The recurrence interval of low flows needed for water supply and to support stream biology needs to be determined for watersheds and for specific locations in watersheds throughout the state. A computer application such as the EQB water sustainability planning tool should be used to conduct a statewide assessment of areas where stresses on the resource are likely to increase. This will allow planners and managers to focus their efforts on areas most likely to be in need of attention. A science-based water-withdrawal assessment process could be used in these watersheds to determine whether proposed withdrawals could cause adverse impacts to streamflow, aquatic habitat, lakes and wetlands.

The assessment process and its computer programs could evaluate new or increased high-capacity withdrawals from surface water or ground water. It could identify which withdrawals are likely to cause an adverse impact in a stream. Withdrawals identified as having a greater potential to cause an adverse resource impact could require additional review. The program would use a statewide database of aquifer types and properties in conjunction with a robust analytical equation to identify withdrawals likely to cause an adverse environmental impact.

Accelerate studies of change in water availability. Completion and additional evaluation of existing research is needed to estimate ground water recharge to both confined and unconfined aquifers. This work is needed to provide better estimates of recharge and to evaluate differences among methods. Supplemental work also is needed to evaluate and describe requirements for sustainable instream flow for aquatic biota. The dynamic variability in precipitation and evapotranspiration resulting from change in climate needs to be better understood. Finally, better quantification of the hydraulic properties of confining beds and leakage to deeper aquifers is needed as part of the County Geologic Atlas Series. This would provide additional important information on the water-yielding properties of confined aquifers.

Understanding the effects of pumping ground water
Water table aquifers

The key to understanding the potential impact of a pumping well on streamflow is to recognize the source of water to wells. When a water table (unconfined) well is pumped, water is removed from storage in the aquifer, and the water table near the well is reduced. Once the water level in the aquifer near the well is reduced, flow is induced toward the well, creating a cone of depression around it. This cone of depression continues to expand until the pumping can be balanced by (a) an increase in recharge to the system, (b) a decrease in the discharge from the aquifer, or (c) a combination of increased recharge and decreased discharge. The sum of increased recharge and decreased discharge is called capture. If the well cannot capture enough water to balance pumping, water levels will continue to decline until pumping cannot continue at the initial rate. The capture of a pumping well does not depend on the initial recharge rate; rather it depends on the change in aquifer recharge and discharge induced by pumping.

Defining water information needs: Conclusions and recommendations

> We can't manage what we don't measure.
> *Minnesota Water Priorities, 2003-2005*
> Environmental Quality Board

Information is the key ingredient of any water allocation program. Minnesota's water resources have all been allocated and every use has its purpose, whether for people or the environment. So the manager's task is to understand how much water may be available, the quality of that water, how the water is currently being used, what or who is depending on that source, and what will happen to public interests if a change is made. To complicate the matter, water in the natural environment is anything but constant. In fact, ecosystems depend upon this natural variability for their survival. For people depending on a reliable supply of water or worried about drought or flood flows, variability can be a great concern.

Adequate data is integral to sustainable management because, properly collected and assessed, it allows us to answer these questions. It tells us whether water of sufficient quality can be reliably tapped in a location or a region and whether the use can be sustained over the long run without harming the natural environment, other users, or the prospects of future generations.

Charge Three Conclusions

1. Although Minnesota's water management program has a strong data collection component, more information is needed to answer today's critical questions. The state does not collect or process sufficient water-related information to know with certainty overall whether it is managing water resources sustainably.

2. Despite information shortages, the state employs commendable water management methods in response to permit requests, requiring permittees to collect additional information when necessary.

3. State and local governments should complement current efforts by developing the information necessary to plan for sustainable resource use and link their resource planning efforts. This would help them understand resource limits and vulnerabilities and how they might better work together.

4. The systematic acquisition of hydrologic, hydrogeologic and ecological information in advance of permit requests and continued efforts to develop better tools to use this information would strengthen the state's management of water and increase efficiency in the permitting process.

5. State and local governments need to advance the use of indicators to track status and trends in water availability, water quality, water chemistry and land use. The goal is to help people understand the short-term effects and long-term implications of the demands we place or may be expected to place on the resource. This understanding would inform citizens whether planning and management activities are working to ensure water sustainability.

***Charge Three Recommendations*[14]**

The state should:

1. Establish a long-term strategy for generating and managing the information needed to integrate water sustainability assessment results into regulatory programs on a statewide basis. In addition, this strategy must address the legal, financial and security issues that influence public access to this information. Strategy elements should include:
   - Allocation plans by aquifer and watershed
   - Continuing efforts to build, maintain and use existing models, such as the Metropolitan Council ground water model
   - New efforts to assess regional water availability and sustainability using a variety of methods, models and mapping

2. Develop a water sustainability data acquisition plan for inclusion in the 2010 state water plan that: a) sets priorities and standards for the next decade of data collection and funding; b) identifies the lead agency for collecting specific data types; c) provides for a routine appraisal of data collection efforts; and d) sets timelines for lead agencies to collect high priority data.

3. Define a strategy for integrating the information needed to assess water sustainability at statewide, regional or county scales. The strategy should: a) define the format for electronic data transfer between state and local agencies; b) set standards for documenting the source and quality of datasets, transferring data to be used in a state geographic information system, and uniquely identifying features such as wells, springs, lakes and rivers to which data are related; c) identify how the state will provide technical support to local governments accessing state data and providing data that is generated through state funding back to the state; and d) provide adequate funding for collecting and maintaining the data and developing applications for sharing the data.

4. Adopt a hydrologic cycle systems approach to monitoring water resources, since an understanding of each aspect of the hydrologic cycle is necessary to managing water sustainably. Priority needs include:

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[14] The information system improvements required to store, process, integrate and assess the implications of this information are described under the second charge.

Surface water

- Improved stream gauging coverage to provide better low flow statistics and enhance understanding of ecosystems and ground water
- Collection of water chemistry

Ground and surface water interaction

- Linked monitoring of ground water levels and surface waters
- Compilation of water level and pumping histories for priority aquifers and linkage to relevant surface water resources
- Identification of aquifer and surface water body connections
- Inventory of springs

Ground water

- Statewide coverage of county geologic atlases with improved hydrologic property data
- Accurate information on well locations and real-time monitoring in select locations
- Work to remove backlog of water well logs that have not been scanned or whose location has not been verified and automate verified information
- Collection of water chemistry and age data
- Incorporation of ground water quality and aquifer property information into the County Well Index

Climate

- Temperature
- Precipitation
- Evapotranspiration
- Snow pack

5. Establish technical and stakeholder advisory committees to help Minnesota develop and adopt social, economic and environmental indicators to assess management choices and measure progress toward water sustainability.

Conclusions

The EQB Water Availability Project brought together dozens of interests and experts around an apparently straightforward question: *What does Minnesota need to do to ensure that its water resources are managed in a sustainable manner?* The project's answer is a set of 14 inter-related conclusions and 15 recommendations for action or further consideration. When it adopted a work plan in February 2008 to guide the project's development, the Board anticipated this work to be the beginning of a sustained effort to improve water management in Minnesota. This report is the first step of that effort.

APPENDIX A. Water Availability Project work plan excerpts

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Water Availability Project
Environmental Quality Board
Work Plan[15]
February 21, 2008

The charge

The EQB charge includes three components:

- Take a broad look at water availability and appropriations, including but not limited to issues specific to the ethanol industry, finding a way to put consideration of proposed water uses into a broader framework and perspective
- Consider how the state might establish (and/or has established) protective and achievable standards to quantify and address the environmental impacts of proposed water uses
- Summarize need and options for collecting additional data important to comprehensive and timely analysis of proposed water uses

Assumptions

Four assumptions define the project's scope:

- The project should be completed in six months.
- The project should address the charge based upon existing data.
- There is a need to provide better information to the public about our understanding of water availability and sustainability.
- Today's decisions would benefit from an understanding of the context of future needs.

Questions

To understand the broad issues related to water resources in Minnesota, the project should aim to answer the following questions:

- What do and don't we know about Minnesota's ground water resources?
- Can we make any estimates on water availability in a broad sense?
- What's our water resources management strategy?
- Do we have a sustainable planning strategy? What is it?
- What do we want to know from a resource management and planning perspective?
- Can we identify the data gaps and develop tools that would improve our understanding in any of the areas we'd like to know more about?

[15] Adopted by the Environmental Quality Board on February 21, 2008

Outcomes sought

People understand:

- The steps followed and data used in the evaluation and permitting process, and how that process determines water availability and appropriations specific to large-water use permits
- The standards used or needed to quantify and address the environmental impacts of ethanol plants and other water users, and how they protect Minnesota's water resources and environmental quality
- What we know and don't know about ground water resources, the effects of a proposed new user, and long-term cumulative effects of water and land use
- The need and urgency of additional information and research, improving data, information management and communications, and securing necessary funding and staffing needed to satisfy growing concerns about water availability
- The links between water availability and other water-related environmental concerns
- How today's water permitting, availability and policy decisions fit with the long term view, including population and land development changes, commercial and industrial expansion, and climate change that might be reasonably expected in the future

APPENDIX B. EQB Water Availability Work Group

The Environmental Quality Board convened monthly meetings of the EQB Water Availability Work Group, beginning with adoption of the work plan on February 21’ 2008. In addition to EQB staff, this diverse group represented the following agencies:

Board of Water and Soil Resources	Department of Agriculture
Department of Commerce	Department of Health
Department of Natural Resources	Metropolitan Council
Minnesota Geological Survey	Pollution Control Agency
U.S. Geological Survey	University of Minnesota

Technical focus group

A technical committee of the EQB Water Availability Work Group was also convened. This group assisted with the evaluation of past, ongoing and future projects and approaches in the area of water availability and sustainability. Members represented the following organizations:

Barr Engineering	Board of Water and Soil Resources
Department of Health	Department of Natural Resources
Department of Natural Resources Iowa	Hennepin County
Landmark Environmental	Metropolitan Council
Minnesota Geological Survey	Pollution Control Agency
USGS	University of Minnesota

Web-based communication

The project developed a strong web-based communication system for work group use. This facilitated rapid transfer of information and maintained a strong means to share progress with group members.

- Water Availability Project
  http://www.eqb.state.mn.us/project.html?Id=19502
- Water Availability Work Group Discussion Board
  http://www.eqb.state.mn.us/resource.html?Id=19501
- Technical Focus Group Resources
  http://www.eqb.state.mn.us/resource.html?Id=19614

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APPENDIX C. Environmental review and permitting

The Minnesota Environmental Policy Act of 1973 established a formal process for investigating the environmental impacts of major development projects. The purpose of the review is to provide information about a project's environmental impacts before approvals or necessary permits are issued. Because unanticipated environmental consequences can be very costly to undo and environmentally sensitive areas can be impossible to restore, environmental review creates the opportunity to anticipate and manage these problems before projects are built.

The environmental review process aims to evaluate a project's potential environmental effects and provide a forum for public comments. It also informs the public about the project, and helps identify ways to protect the environment by providing information that can be incorporated into environmental permits and approvals. In addition to describing the project and its purpose, and identifying the required permits and approvals, the environmental review document also explores the effects of the proposed project (among other things) on land use; wildlife and ecologically sensitive resources; cultural resources; traffic, noise, odor, and visual impacts; air and water quality; and impacts on water resources, including water supply and use.

In analyzing the environmental effects of a proposed project, the RGU must consider the cumulative potential effects as well as the direct effects of the project. To evaluate cumulative potential effects, the RGU should inquire whether a proposed project, which may not individually have the potential to cause significant environmental effects, could have a significant effect when considered along with other projects that are already in existence, as well as any anticipated future projects that have been planned or for which a basis of expectation has been laid; are located in the surrounding area; and might reasonably be expected to affect the same natural resource as the proposed project. An understanding of cumulative potential effects is important to evaluating projects that need high volumes of water. In addition, the criteria for assessing such effects could contribute potentially important elements to a policy framework. More detail of guidance given RGUs is contained in the following section.

The Minnesota Supreme Court provided the above-stated meaning for cumulative potential effects in the 2006 case Citizens Advocating Responsible Development vs. Kandiyohi County Board of Commissioners and Duininck Brothers, Inc. Units of government are still learning how to consider cumulative potential effects in the review of specific projects in light of this court case. The EQB has developed rule amendments incorporating guidance on how to handle cumulative potential effects based on the case. EQB staff recommends using the proposed amendments as guidance, pending completion of the administrative rulemaking process. EQB's guidance includes the following principles:

- The "surrounding area" should be considered as the area in which the various impacts from the project could overlap or interact with the impacts from other existing and future projects. In its rule amendments, the EQB proposes to substitute the term "environmentally relevant area" for "surrounding area."
- In determining if a basis of expectation has been laid for a project, an RGU should determine whether a project is reasonably likely to occur and, if so, whether sufficiently detailed information is available about a project to contribute to the understanding of cumulative potential effects.
- In making these determinations the RGU should consider: whether any applications for permits have been filed with any units of government; whether detailed plans and specifications have been prepared for a project; whether future development is indicated by adopted comprehensive plans or zoning or other ordinances; whether future development is indicated by historic or forecasted trends; and any other relevant factors.

- In deciding whether a project requires an EIS because it has the potential for significant environmental effects based on the EAW record, the RGU should consider the following factors with respect to cumulative potential effects:
  - Whether the cumulative potential effect is significant
  - Whether the contribution from the project is significant when viewed in connection with other contributions to the cumulative potential effect
  - The degree to which the project complies with approved mitigation measures specifically designed to address the cumulative potential effect
  - Efforts of the proposer to minimize the contributions from the project

Even with this detailed guidance, there still remains a need for more information to support the work of planners and regulators. While the environmental review rules serve as an important tool for evaluating the environmental effects of projects, a broader framework is still needed to inform local and state agencies of activities that affect the planning and management of growth.

Water appropriation permitting. *Minnesota Statutes*, section 103G.265 requires the Department of Natural Resources to manage water resources to ensure an adequate supply to meet long-range seasonal requirements for domestic, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes. Permits from the DNR Division of Waters are required for water appropriations in excess of 10,000 gallons per day or 1,000,000 gallons per year with some exceptions. The DNR Water Appropriation Permit Program aims to balance competing management objectives that include both development and protection of Minnesota's water resources. All permitted water users are required to submit annual reports of water use.

Permit applicants may be required to conduct an aquifer test when DNR needs more information in order to assess whether the source aquifer is capable of supporting the proposed request, whether there could be impacts to natural resources, or whether there could be impacts to other water users. If an aquifer test is required, DNR works with applicants to design a test that will determine aquifer characteristics such as transmissivity, storage coefficient, boundary conditions, and potential impacts to ground water and surface water such as changes in physical or chemical parameters that may impact the ecology. DNR has developed a generic letter detailing the aquifer test requirements including data collection requirements, typical data collection schedules, and the water appropriation permitting process for large volume users (over 100 million gallons per year).

The basic aquifer test and subsequent analyses include the following considerations and processes:

- Pretest data collection by the project proposer within a minimum 1.5-mile radius of the production well including the location and detailed construction data on all wells, and water levels and location of surface water features.
- Development of geologic cross-sections and maps of the area showing static water levels of the various aquifers and surface water bodies. These help determine which wells or surface water features should be monitored during the aquifer test and whether additional observation wells are needed.
- Establishment of a preliminary monitoring network prior to the aquifer test to gather background data.
- Determination by the DNR of which wells and surface water bodies will be monitored during the test. These selections are based on the distance from the production well, depth of well, pumping rate, discharge point and known aquifer characteristics.
- Determination by the DNR of the length of the aquifer test and water level recovery period. DNR collects static water levels prior to pumping phase start-up and after shutdown. The length of an aquifer test is dependent on the rate of appropriation, proposed annual volume, previous aquifer test results for the area of interest, anticipated ecologic impacts and geologic conditions. An aquifer test is broken into two separate components, the pumping cycle and the water level recovery period. Aquifer tests for agricultural irrigation are limited to three days (M.S. 103G.295 subd. 4), while tests for other

large volume appropriations last from seven to 30-days. The project proposer and the DNR remain in communication as the test is conducted, making modifications as needed.

- After the aquifer test is completed, the project proposer provides DNR with a formal report documenting the aquifer test parameters, aquifer characteristics, and impacts to water supply wells or surface water features. A Professional Geologist must complete the report.

DNR uses all the data collected for an evaluation of potential impacts of a proposed appropriation. Aquifer test results are used to assess whether the aquifer can sustain the requested appropriation for the life of the project, provide base flows for surface water features, allow for future use of the aquifer for both ecological and human needs, and establish a recharge/discharge equilibrium that does not result in a declining trend in water levels.

Large volume water appropriation permits typically require collection of long-term water level readings from the water supply source and any potentially connected resources. The monitoring data is submitted on a quarterly or annual basis. Many water appropriation permits require the permittee to install one or more observation wells to monitor water level readings in the source aquifer. The installation of an observation well may be required between the production well and a surface water body such as a calcareous fen, lake or stream to ensure the appropriation does not violate a permit threshold for aquifer level, surface water level or base flow.

Water appropriation permits can include the establishment of thresholds to protect the source aquifer, adjoining aquifers, or surface water features such as lakes, wetlands or streams. Thresholds are tied to a specified static water elevation for an aquifer or to a protected elevation in another resource of concern (e.g. lake or wetland). For projects that may impact watercourses, stream flow monitoring stations upstream and downstream of the project may be required in addition to the required observation well(s). Comparison of flow volumes between the two surface monitoring sites will determine if surface water is infiltrating into the aquifer as a result of the water appropriation.

Contingency plans are required (*Minnesota Statutes*, section 103G.285, subd. 6) for use of surface waters. A contingency plan describes the alternatives the applicant will use if further appropriation is restricted due to the flow of the stream or the level of a water basin. A surface water appropriation may not be allowed unless the contingency plan is feasible or the permittee agrees to withstand the results of not being able to appropriate water. For high volume appropriations from ground water, similar statements may be required if it is anticipated that the requested water use may impact resource features.

Resolution of water issues. *Minnesota Statutes*, section 103G.265 directs the DNR to develop and manage water resources to assure an adequate supply to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes from waters of the state. Minnesota's statutes and rules provide several options for prevention and resolution of water use issues.

Water appropriation permits. *Minnesota Statutes*, Chapter 103G and *Minnesota Rules*, Chapter 6115 refer to applicable aspects of the water appropriation permitting process, which are detailed elsewhere in this report; however, it is important to remember that permits are permissive only and do not establish any rights or priority of appropriation. A permit may be restricted, suspended, amended or cancelled in accordance with applicable laws and rules for any cause for the protection of public interests, or for violation of the provisions of the permit. Rare surface water features such as calcareous fens and trout streams are accorded special protection under these statutes and rules. In addition, resource protection limits, including protection elevations and protected flows for surface water and safe yields for groundwater are defined.

Well interference. *Minnesota Rules*, part 6115.0730 describe that a well interference occurs when a high capacity well impacts a domestic or public water supply well by lowering water levels below the reach of those wells. For instance, a well interference may happen if a domestic well is drilled and a pump installed only in a partial thickness of an aquifer. Nearby high capacity pumping may cause the water level to drop below the depth of the domestic well's pump. Sufficient water may still be available in the aquifer for both users; however, the domestic well's construction, depth of well or pump, no longer enables water to be pumped. If the DNR anticipates before a permit is issued that a well interference is likely, the permit applicant will be required to investigate the impact of the proposed appropriation. If a well interference occurs after a permit is issued, the affected well owner must submit an account of the problem and have the problem documented by a licensed well driller. The DNR will then investigate and, if justified, require the responsible permittee to negotiate a reasonable agreement with the affected well owner. In the example scenario, some possible resolutions are lowering the pump in the domestic well to below the new water level, drilling a deeper domestic well, providing an alternative water supply, or altering the high capacity pumping rate or timing.

Water use conflicts. (*Minnesota Rules*, part 6115.0740). Water use conflicts occur where the available supply of waters of the state in a given area are limited to the extent that there are competing demands among existing and proposed users which exceed the reasonably available waters. For example, under certain low flow conditions consumptive appropriations of surface water are limited (*Minnesota Statutes*, section 103G.285, subd. 2) such as during extended dry periods when stream flows are low. In order to protect in stream and down stream high priority uses, water appropriation permits may be suspended resulting in implementation of Contingency Plans, discussed elsewhere in this report. Permits are reinstated when stream flows exceed the minimum protected flow plus the total draft from all appropriators within the watershed. Water use conflicts could also occur even in a highly productive aquifer after a period of low precipitation and recharge if there are multiple high capacity users who are pumping simultaneously for an extended time. The water level in the aquifer may drop to the point that there is not sufficient water available for all users at the rate and amount desired. Water use conflicts can be addressed with local allocation plans and/or permit modifications to assure resource protection and distribution of water to the highest priority water uses defined in *Minnesota Statutes*, section103G.261.

Water supply plans. (*Minnesota Statutes*, section 103G.291). Public water suppliers serving more than 1,000 people must prepare and submit a Water Supply Plan to the DNR every ten years. These Water Supply Plans, which are also discussed elsewhere in this report, must address supply and demand reduction measures and allocation priorities, and must identify alternative sources of water for use in an emergency. Second generation plans are currently being developed and have a focus on resource sustainability and monitoring.

Management plans. (*Minnesota Rules*, part 6115.0810). A comprehensive water appropriation management plan may be prepared by DNR in cooperation with other state and federal agencies, regional commissions and authorities, local governments and citizens. Because the availability, distribution and utilization of waters of the state and the character and use of related land resources vary considerably throughout the state, these plans need to be prepared for a definable area. That area must be of sufficient size and areal extent so the geohydrologic and climatic factors can be defined and managed in relation to the hydrologic and physical characteristics of the water and related land resources. General requirements and contents of plans need to include an evaluation of the hydrologic systems and adequacy of information, an evaluation of data on water quality for all the elements of the hydrologic cycle, an evaluation of present and anticipated future use of waters and lands and the amounts and distribution of use within the area, an evaluation of the problems and concerns relating to use of the waters within the area, water conservation alternatives and methods and procedures for dealing with water shortages or excesses, and considerations of the relationship of the water appropriation and use management plan to other water resources programs of the state.

APPENDIX D. Industry efforts to reduce water demand for ethanol production

Based on ethanol facility water withdrawal reports provided to the DNR (1998-2006), Minnesota's ethanol industry achieved a 30% reduction in water demand; improving from an average of almost six gallons to about four gallons of water demand per gallon of ethanol produced.

- Approximately 30% of the water for dry-mill ethanol facilities is used for the production process. It is primarily either used as steam to cook corn mash or directly added to milled corn to make slurry.
- The remaining 70% of water demand does not come into contact with the product. This non-contact water is primarily used for energy related needs of cooling tower and boiler systems.

Reducing demand for production process water

Due to advances made in industry practices, there is little or no wastewater discharge from the production process. The evaporation of water from drying distillers grains is the primary source of water loss. The evaporation of water from drying digester grains represents the largest loss of product-contact water.

Reducing the amount of product-contact water appropriated is being achieved through improvements to aid the fermentation process. Specifically:

- Through fractionating or separating the fermentable from the non-fermentable parts of the corn kernel;
- By improvements in the enzymes used in the hydrolysis process, particularly for cold mash preparation, and;
- In improving the yeasts used in the fermentation process.

All three strategies result in less water required for the fermentation process while increasing the percentage of alcohol resulting from it. Over the last 20 years, there has been an 8% increase in the amount of ethanol produced from a bushel of corn.

Reuse of product-contact water for the production process is being achieved though:

- No-contact, steam systems using coils to heat mash versus injecting steam directly into mash. Although more expensive than steam injection, the steam-coil systems allow condensate to be returned to the boiler for reuse;
- Anaerobic digestion of wet distillers grains retaining water investment while producing biomethane for process heating needs.
- High efficiency ring dryers, as opposed to rotary, which allow for effective capture of evaporated water from drying distillers grains and reuse as cooling tower makeup water.
- Biomethanators to process waste water and remove organic contaminants which allow for the reuse of process water, and an anaerobic process that produces biomethane to off-set some natural gas use.
- High efficiency stillage systems concentrating solids residue from the distillation process are 15% more efficient than conventional evaporator systems, and reduce water loss due to distillers grain drying while reducing net energy use.

Reducing demand for non-contact water

Non-contact water loss is primarily related to energy production, specifically cooling tower and boiler systems. Make-up water needed for cooling towers represents about 68% of the total, with boiler and process makeup water the remaining 32%. Technologies that reduce demand for non-contact water continue to improve. Recent examples include:

- High efficiency cooling towers using 20% less water than conventional systems.
- Fan-driven air-cooling towers, although using more electricity than water cooled towers, can provide significant water saving potential.

- Membrane separation systems can increase the concentration to ethanol from the beer column reducing the need for boiler water used for distillation. For example, 3M's membrane-solvent extraction process is increasing beer-well ethanol from 12% to 70% reducing water needs for distillation process by 40%.

Zero discharge
Systems which treat non-contact waste water so that it may be reused in the plant, eliminating wastewater discharges and associated fees are becoming viable options. Two plants in Minnesota are moving forward with zero discharge installations at this time.

Summary
The ethanol industry has made measureable and significant progress in reducing the amount of water used per gallon of ethanol, while also increasing the amount of ethanol produced from a bushel of corn. The actions cited above represent near-term options to reduce water demand by the industry. However, even though pay back periods may be attractive, large investments in capital are needed for implementation. The availability of capital to upgrade to best available technologies is a key to realizing these benefits. Due to the cost of these capital improvements and recent record prices for energy, steel and corn, it has become more difficult for Minnesota producers to finance desirable projects.

APPENDIX E. Comparison of programs and studies regarding Minnesota water resource supply and demand

	Evaluation criteria			
	Description of program/study and its application	**Methods**	**Underlying Data Sets, Main Factor(s)**	**Scale/ resolution**
Water supply planning and permitting				
Water Supply Plans (MS 103G.291)	Identification of potential resource issues and water supply alternatives to address existing and future needs	Sustainability and availability assessments using water levels and other data	Geologic mapping (where available), monitoring data and resource specific modeling	Local (public water supplier) covering the area of influence
DNR Water Appropriation Permit Program (MS 103G.271)	The evaluation of water appropriation requests. Water use data to evaluate resource impacts. Structure for adaptive management	Aquifer tests and resource monitoring	Well construction, water level and aquifer test data. Geological mapping (where available) and resource specific modeling.	Site based with aquifer and watershed considerations
Hydrogeologic mapping/GIS modeling				
DNR/MGS County Atlas Program	Local land use planning; qualitative analysis of pollution sensitivity and ground water recharge for shallow to medium depth aquifers	Geologic and hydrogeologic mapping/GIS 3D spatial analysis	Surface and subsurface geologic mapping, geochemistry, County Well Index water levels	Variable, typically 1:100,000
Comparison of local to regional scale estimates of ground-water recharge in MN, USGS 2006	Construct and calibrate ground water flow models for large areas	Algorithm/GIS	Precipitation, growing degree days, soil type	100 km^2/order of magnitude soil hydraulic conductivity
DNR 2008 Aquifer Mapping (LCCMR in progress) and 2009 proposal	Physical and qualitative recharge characteristics of Mt. Simon aquifer along its western and northwestern edge	Geologic and hydrogeologic mapping, water level analysis	Surface and subsurface geologic mapping, geochemistry, water levels	Regional
Hydrogeologic mapping with quantitative aquifer computer modeling				
Metro Ground Water Model 2.0	Predictive tool for estimating quantitative effects of large ground water withdrawals or climate change	3D steady- state computer model	Stream flow, surface and subsurface geologic mapping, CWI water levels, aquifer test and precipitation data	Regional and sub-regional
USGS Aquifer Studies	Predictive tool for estimating quantitative effects of ground water withdrawals or climate change	Water level, aquifer test, and precipitation analysis, aquifer computer modeling	Surface and subsurface geologic mapping, water level, aquifer test, geochemical and precipitation data	Local and county

Wellhead Protection Studies	Predictive tool for estimating recharge and potential contaminant capture zone of community well or well field.	Water level, aquifer test and precipitation. analysis, aquifer computer modeling	Surface and subsurface geologic mapping, water level, aquifer test, and geochemical data.	Local
Water sustainability planning tools and studies				
Watershed Assessment Tool, DNR	Quick access to resource information (land, water, infrastructure) on a web-based GIS platform	Compilation of published data presented within a 5 component resource framework to assess watershed health	Five Components: Hydrology, Geomorphology, Biology, Connectivity, and Water Quality are assessed through approximately 45 GIS base layers	Watershed
Water Sustainability Planning Tool (WSPT), EQB 2008	Provide broad qualitative and quantitative perspective for new and future water uses; support local land use planning	GIS, regional water balance, compilation of published quantity and quality data	Recharge data, precipitation data, land use, impaired waters, CWI, DNR permit data	1300 km^2
Use of Minnesota's Renewable Water Resources: Moving Toward Sustainability, EQB 2007	Provide county-wide perspective on water use and estimated sustainable supply	Compared supply and demand at the county scale for the years 2005 and 2030	Recharge and discharge data, precipitation data, climate-adjusted water use, population and water demand projections	County
Water Resource Sustainability, U of MN 2007 (LCCMR in progress)	Quantification and regionalization of sustainable (renewable) water supply for comparison with human and ecological needs at a multiple scales	Multidimensional statistical models relating watershed water balance component fluxes to watershed geophysical properties.	Selected stream flow data, and earth geophysical data including: geological, hydrogeological, soil, vegetative cover, land use, stream network, topography, and climate.	County, regional, state, national, continental, global
Future of Energy and Minnesota Water Resources, U of MN 2007 (LCCMR in progress)	To explore systemic linkages between energy and water in Minnesota; to identify regions of the state that may be water limited in future under different scenarios	Algorithms, GIS, system dynamics modeling	Water stocks and flows (atmosphere, land surface, aquifers), water consumption by human systems, energy production, climate change	100 km^2

APPENDIX F. Principal types of data and data compilations required for analysis of ground water systems

Data type or data compilation	Status in Minnesota (scale dependent)				
	Generally Adequate	**Limited Adequacy**	**Generally not Adequate**	**Data Access**	**Comments**
Physical Framework					
Topographic maps showing the stream drainage network, surface-water bodies, landforms, cultural features, and locations of structures and activities related to water	**X**			Good	
Geologic maps of surficial deposits and bedrock		**X**		Good	1:100,000 scale or more detail is necessary; County Geologic Atlas Program is primary source
Hydrogeologic maps showing extent and boundaries of aquifers and confining units		**X**		Good	1:100,000 scale or more detail is necessary; County Geologic Atlas Program is primary source. Mapping of buried glacial aquifers is relatively new and needs attention.
Maps of tops and bottoms of aquifers and confining units		**X**		Good	Mostly available for bedrock aquifers, and very recent County Geologic Atlases
Saturated-thickness maps of unconfined (water-table) and confined aquifers		**X**		Fair	Some older maps need digitizing
Average hydraulic conductivity maps for aquifers and confining units and transmissivity maps for aquifers			**X**	Poor	
Maps showing variations in storage coefficient for aquifers			**X**	Poor	
Estimates of age of ground water at selected locations in aquifers		**X**		Good	
Hydrologic Budgets and Stresses					
Precipitation data	**X**			Good	
Evaporation data		**X**	**X**	Fair	Evapotranspiration data also needed
Streamflow data, including measurements of gain and loss of streamflow between gauging stations	**X**	**X**		Good	Good coverage of streamflow, but not necessarily unregulated streamflow, particularly in the central and eastern parts of the state. Good coverage of gaining and losing streams limited.

Maps of the stream drainage network showing extent of normally perennial flow, normally dry channels and normally seasonal flow	**X**	**X**		Good	
Estimates of total ground-water discharge to streams		**X**	**X**	Fair	
Measurements of spring discharge		**X**	**X**	Fair	
Measurements of surface-water diversions and return flows	**X**			Fair	
Quantities and locations of interbasin diversions	**X**			Fair	
History and spatial distribution of pumping rates in aquifers	**X**	**X**		Fair	
Amount of ground water consumed for each type of use and spatial distribution of return flows	**X**	**X**		Good/Fair	
Well hydrographs and historical head (water-level) maps for aquifers	**X**	**X**		Good/ Fair	Some historical maps are not very accessible. Some areas lack compiled historical information. Poor coverage of hydrographs suitable for estimating recharge.
Location of recharge areas (areal recharge from precipitation, losing streams, irrigated areas, recharge basins and recharge wells) and estimates of recharge		**X**	**X**	Fair	
Chemical Framework					
Geochemical characteristics of earth materials and naturally occurring ground water in aquifers and confining units		**X**	**X**	Fair	
Spatial distribution of water quality in aquifers, both aerially and with depth		**X**	**X**	Good/Fair	
Temporal changes in water quality, particularly for contaminated or potentially vulnerable unconfined aquifers		**X**	**X**	Fair/Poor	
Sources and types of potential contaminants	**X**	**X**		Good/Fair	
Chemical characteristics of artificially introduced waters or waste liquids		**X**		---	
Maps of land cover/land use at different scales, depending on study needs	**X**			Good	
Streamflow quality (water-quality sampling in space and time) particularly during periods of low flow		**X**		Fair	
Modified from USGS Circular 1186, Table 2, p. 69.					
Note: "Generally adequate" implies data suitable for multiple scales; "Limited adequacy" implies data partially limited by scale, geographic extent, or completeness; "Generally not adequate" indicates data usability very limited due to completeness, geographic coverage, lack of historical information, or other restrictions.					
Note: For "Data Access" Column, "Good" indicates data on-line in useable format; "Fair" lacking one or both of "good" criteria, perhaps only available in published documents in paper format; "Poor" indicates "papers in a shoebox": either data not collected, in unpublished paper form only, or not readily accessible.					

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