Use of Minnesota's Renewable Water Resources
Moving Toward Sustainability

A report of the Environmental Quality Board and Department of Natural Resources
April 2007

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- 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

Statutory Authority

This document was prepared in response to *Minnesota Statutes*, section 103A.43.

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Executive Summary

Minnesota Statutes, section 103A.43, directs the Environmental Quality Board and Department of Natural Resources to coordinate a biennial assessment of the availability of water to meet the state's long range needs. That is the focus of this report.

The purpose of this report is to help people better understand surface and ground water availability and the demands we place on water. The goal is to help state and local officials manage water resources for the long term future and better plan for development. The project seeks to do this by:

- Bringing attention to what we know and don't know about renewable water resources
- Highlighting the need for evaluation of water resources to help local and state governments make better-educated decisions about future development and water demand

The project evaluated current and future water demand, as well as the quantity of water that could be removed from the system on a long-term, renewable basis without drawing down the resource, all at the county scale. The project worked with published methods describing components of hydrologic systems necessary for generating sustainable supply values, developing five sets of renewable resource estimates. The analysis used the median volume of renewable water resources estimated for each county in making comparisons with water demand for that county. The comparisons were made for reported use in 2005 and estimated use in 2030.

The purpose of this assessment was to evaluate how much of a county's renewable water resource was already in use or likely to be so in the future. But to make a fair comparison, the analysis adjusted appropriations from surface waters coming into a county, since resource estimates on the supply side of the equation did not include such waters. The analysis also removed non-consumptive water uses from the tally, since such waters remain available for people and ecosystems to use.

The 2005 water use values were calculated by averaging each county's per capita demand for the years 1995 to 2005 in order to provide a baseline not artificially affected by a single year's weather. These same use rates were applied in estimating demand in 2030.

The project reached seven conclusions:

1. The label of Minnesota as water rich does not fit as well as once thought. The growth corridor stretching from south of the Twin Cities to St. Cloud already makes significant demands on its renewable water resources, making water supply management a special concern. In the remainder of the state, care also must be taken by local and state officials in planning to meet the demands for and allocation of water.
2. The degree to which renewable water resources are used in any part of the state, today and in the future, should help inform state monitoring and research priorities.
3. Several methods may be used to estimate water availability and sustainable use. Each makes assumptions that introduce uncertainty, a point important to understand when applying the project's results. The report provides information helpful in understanding the extent of water resource use at the county level. However, it does not inform site-specific decision making.

4. The collection and management of resource specific data, including local mapping and evaluation of water resources, can be improved or accelerated to aid in future management.
5. The assessment should help water and land use planners identify where combined use of surface and ground waters may need to be at the top of the list for consideration.
6. Research is needed to:
   - Better define the location and characteristics of ground water resources
   - Understand what volume of water is renewable; that is, how much can be taken for use on a long-term, sustainable basis without drawing down the resource
   - Investigate new means to quantify sustainable supply or ways to build upon existing supply methods
   - Understand the impacts of drainage or other land use practices on rates of recharge, and means to quantify these impacts
   - Understand the impacts of global warming on climate, rates of recharge and water demand
   - Characterize the interactions of surface and ground waters, including the implications of water quality and quantity
   - Quantify the timing, amount and quality of water to better understand ecosystem needs
7. The next assessment of availability should consider:
   - Focusing on geographic areas with supply and demand issues and evaluating resource management options
   - Evaluating how public water suppliers are integrating sustainability into the second generation of water emergency and conservation plans
   - Refining the assessment by analyzing water availability on a seasonal or monthly basis; integrating the concept of imported waters; conducting analyses on a sub-county level where possible; and evaluating the current effect and future risk of water quality degradation on water supply
   - Evaluating water resource monitoring needs, as wells as investigating ecosystem needs
   - Including the results of mass water level measurements covering the period 1955-2008 for the Twin City metro area
   - Evaluating Minnesota’s “safe yield” concept for protection of ground water resources.

Given the complexity of Minnesota’s water resources and the range of people likely to be interested in its outcomes, the next biennial assessment should use both science- and citizen-based advisory committees.

Use of Minnesota's Renewable Water Resources: Moving Toward Sustainability

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Introduction

"The effects of ground water development may require many years to become evident. Thus, there is an unfortunate tendency to forgo the data collection and analysis that is needed to support informed decision making until after problems materialize."[1]

As the quote suggests, the challenge of understanding water supplies, especially during an era of tight budgets in which staff resources are limited, is daunting. Yet, adequate supplies of clean water provide the foundation for a healthy Minnesota economy, healthy ecosystems and a high quality of life. Water provides jobs, supports fish and wildlife, and is the cornerstone of a $10 billion-a-year tourism industry in Minnesota. However, with expected population and economic growth, it is important to understand where water may be sufficient to meet future demands and where it may not. Otherwise, Minnesota's economy, environment and quality of life may be put at risk in the future.

The Minnesota Legislature has established the legal and institutional framework for managing water supplies to meet today's needs while ensuring that future generations can meet their own needs. The Department of Natural Resources regulates the appropriation of water and operates a number of supporting programs to ensure that water supplies meet a variety of economic, social and ecological purposes. *Minnesota Statutes,* section 103G.265, assigns DNR the task of managing 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."

Purpose

Minnesota Statutes, section 103A.43, also directs the Environmental Quality Board and DNR to coordinate a biennial assessment of the availability of water to meet the state's long range needs. That is the focus of this report.

The primary goals of this requirement are to assess how water supply matches up with demand and to consider the implications for planning and policy. The project's assessment, which is detailed in Appendix A, compares present levels of water use, as well as demand projected to the year 2030, with estimates of supply.

The assessment makes the comparison at the county level, a focus chosen for a number of reasons. Unlike statewide or regional analyses, the county level provides a greater likelihood of understanding where water may not be sufficient to meet the demands people and ecosystems place on it. While the county unit does not follow resource boundaries, the county is an entity that citizens know and understand, and that makes important planning and zoning decisions concerning land use, making study findings potentially easier to communicate and implement.

Sustainability defined

The concept of *water sustainability* is an important consideration as well, since it goes to the heart of Minnesota's goals for managing water yet remains unclear to many. *Minnesota Statutes*, section 4A.07, defines *sustainable development* as "development that maintains or enhances economic opportunity and community well-being while protecting and restoring the

[1] Alley, William M. Tracking U.S. Groundwater: Reserves for the Future? Environment, pp 10-25, April 2006

natural environment upon which people and economies depend. Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs." In short, the concept suggests that people need the opportunity to live well while respecting the environment and the needs of future generations.

The DNR adapts the concept of sustainability to water use: "*Sustainable water use* is the use of water to provide for the needs of society, now and in the future, without unacceptable social, economic or environmental consequences."[2] Of course, the meaning of "without unacceptable environmental consequences" must be consistent with "protecting and restoring the natural environment upon which people and economies depend."

Challenges in water management

Managing water among competing demands "without unacceptable consequences" while "protecting and restoring the environment" is a challenge. The need to maintain instream flows – those flow levels necessary for the protection of aquatic communities – demonstrates this. Water availability and use are unevenly distributed across the landscape and time, and the life history of many aquatic organisms depends on this variability.[3] In contrast, people and business often demand certainty.

As the department concludes, "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."[4]

The purpose of this report is to help people better understand surface and ground water availability and the demands we place on water. The goal is to help Minnesotans manage water supplies for the long-term future and to better plan for development. The project seeks to accomplish this through:

- Bringing attention to what we know and don't know about renewable water resources
- Highlighting the need for evaluation of water resources to help local and state governments make better-educated decisions about future development and water demand

Concurrent planning activities

Concurrent with this project, and at the direction of the 2005 Legislature, the Metropolitan Council began accelerated planning activities for addressing the water supply needs of the metropolitan area. The first phase of activities was completed in January 2007 with the issuance of an interim report.[5] The report makes recommendations related to water supply plan review and improving interconnections and physical water system improvements. The second phase of activities includes more in-depth analysis of water availability and development of plans to meet the region's projected growth.[6]

Water Supply

It is difficult to estimate the supply of water available for use in an area on a long-term, sustainable basis. For this report, an assessment applied four methods to generate five recharge estimates. These methods are detailed in Appendix A, including a discussion of the assumptions made.

The project used the *Regional Regression Method, Net Available Precipitation Method, Fractional Precipitation Method*, and *Watershed Characteristics Method,* which generate supply values based on critical components of the

[2] Sustainability of Minnesota's Ground Waters, Department of Natural Resources, 2005

[3] Lytle, D.A., and N.L. Poff. Adaptation to Natural Flow Regimes. 2004. Trends in Ecology & Evolution 9:94-100.

[4] Ibid.

[5] Water Supply Planning in the Twin Cities Metropolitan Area: Report to the 2007 Minnesota State Legislature,

[6] http://www.metrocouncil.org/Environment/WaterSupply/index.htm

Ground Water Resources Vary Across the State of Minnesota

Ground water is everywhere beneath Minnesota's land surface; however, it is not necessarily *available for use* everywhere. The distribution of aquifers in the state is uneven. The varying types and layers of sediment and rock under the land surface in an area determine whether any aquifers are present from which to pump ground water. The types of sediment and rock also determine whether an aquifer is capable of supporting large withdrawals or only able to support limited use. In addition, water quality problems, whether of natural or human origin, can limit the use of supply.

Recharge occurs across the entire landscape, but at varying rates depending on soils, precipitation and other factors. In Minnesota, much of the ground water that is recharged to surficial aquifers flows through and discharges into streams, lakes and wetlands. Confined aquifers are replenished by leakage through the overlying confining layers at much lower rates than recharge to surficial aquifers.

hydrologic system. All but the watershed characteristics method use recharge as a surrogate for sustainable supplies.

The *Regional Regression Method* described by the U.S. Geological Survey was used to estimate a range of annual recharge values to surficial aquifer systems within each county. For this project, the USGS method determined the lower and upper limits of recharge based on the premise that an entire county is quantified by either the lowest or highest rate of recharge demonstrated in the land area. The recharge estimates compiled using the other methods generally fell within the high and low range provided using the USGS method.

On a regional scale in a natural system over time, recharge equals discharge, where recharge is the water going into the system and discharge is the water leaving it. This makes sense, since water would otherwise build up or drain out of an aquifer system.

However, when people remove the water coming into the system, they risk reducing the discharge from the system. A system's discharge provides the flow to streams when it has not rained in weeks. To eliminate such flows would damage the environment Minnesotans so value. But the lesson is to be wary of using recharge alone as a measure of the water that can be safely withdrawn from the system, unless other steps are built in to protect surface features (e.g. calcareous fens or trout habitat) and ecosystem functions.

The project conducts a simple comparison between the water resources recharging each county and those used within it by people and business. However, it is important to note that the natural system is complicated by the local effects of withdrawals, lateral flow into and out of a county, vertical leakage between aquifers, and other factors.

Water Demand

The project evaluated a number of approaches to estimating future demand for water. Analysts recommended that key factors of water demand might be effectively represented by algorithms based on employment figures and projections. This was attempted early on, but found to be unworkable owing to data compatibility issues.[7] After much analysis, the project chose to base estimations of future water demand on the per capita water use experience of Minnesotans by county and utilizing population extrapolations generated by the State Demographer.

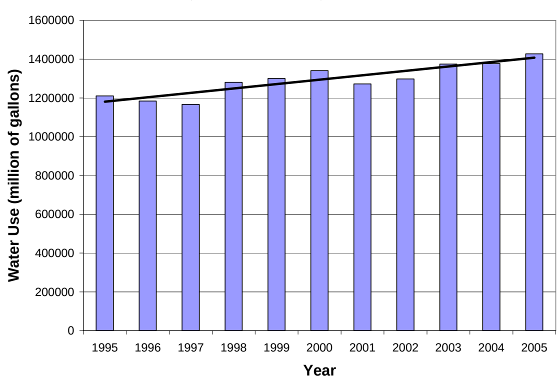
Estimates of future water demand were developed based upon average reported county

[7] DNR organizes its business water use data by different categories than those used by the U.S. Department of Commerce, so that state and federal labor projections, considered the best predictor of future business water demand, could not be used.

per capita water use for the period of 1995-2005, added to estimates of unpermitted uses that do not require a DNR permit. While per capita use increased during this 11-year period, the project assumed that such increases in the future will be negated by expected efficiencies and that per capita use will remain constant to the year 2030.[8] Figure 1 shows the statewide water use experience for 1995-2005, during which total statewide use increased 18 percent, while per capita use increased by 6 percent. (A full page chart of Figure 1 is located in Appendix B, titled Figure 6 and is accompanied by Figure 7, which depicts the increase in per capita consumption.)

Because the average per capita use over the decade integrates behaviors over a range of climatic conditions, the project used that statistic to calculate a climate-normalized use estimate for each county in 2005. These estimates then provided the base for demand projections to 2030. This approach avoids the influence of specific weather conditions in 2005 on water use in that year.[9]

Figure 1. Minnesota Annual Water Use Trends (1995-2005)



Another demand adjustment was made to set up an "apples to apples" comparison with supply estimates. The adjustment was to identify and remove appropriations from water *imported* into a county, which the project defined as surface waters that originate outside a county. Since the project's estimates of sustainable supplies were based on the water generated by rainfall within each county, appropriations made from waters imported into a county were not judged appropriate to include in the analysis.

The extent to which a source of water might be imported was evaluated when the affected uses exceeded 50 million gallons per year. In such cases, use totals were reduced to the extent that their water source originated outside a county. This reduction was established as a ratio of the volume of water originating outside the county to the total volume of water from that source. For example, appropriations by Minneapolis from the Mississippi River were not counted in the Hennepin County assessment because Mississippi River waters were not included in estimates of the county's sustainable supplies.

When assessing how a county's water use compares to its sustainable supply of water, it also is important to take into account whether the water is consumed. If a surface water appropriation is returned to a surface water source in close proximity to its intake and is available for reuse, the use is non-consumptive. The appropriation of ground water is generally consumptive regardless of how it is used, because ground water is usually not discharged back to its source aquifer.

Steam-power cooling is an example of a largely non-consumptive water use. The project assumed that such cooling consumes 2 percent of an appropriation,[10] with 98 percent returned for use by other activities.

Other project steps should be noted: a) water use information was approximated where reported values were lacking; b) water use not requiring a permit is not precisely known, and is, instead, estimated; and c) future water use was estimated based on experience of the years 1995-2005, and thus may not reflect use under drier conditions.

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[8] http://www.unfpa.org/swp/2001/english/ch02.html

[9] However, because Minnesota was relatively wet during the 1995-2005 timeframe used to make the adjustment, the assessment still might underestimate demand.

[10] "Measuring and Estimating Consumptive Use of the Great Lakes Water," Great Lakes Commission, 2003

Comparison of Supply and Demand

The project evaluated current and future water demand, as well as the quantity of water that could be removed from the system on a long-term renewable basis without drawing down the resource, all at the county scale. The assessment used the methods for generating sustainable supply values noted in Appendix A, developing five sets of renewable resource estimates. The analysis used the median volume of renewable water resources estimated for each county in making comparisons with demand for that county.

Comparisons of the water Minnesotans used in the year 2005, adjusted as described above, and the water we expect Minnesotans will use in 2030, were made to the median estimate of each county's renewable supply.

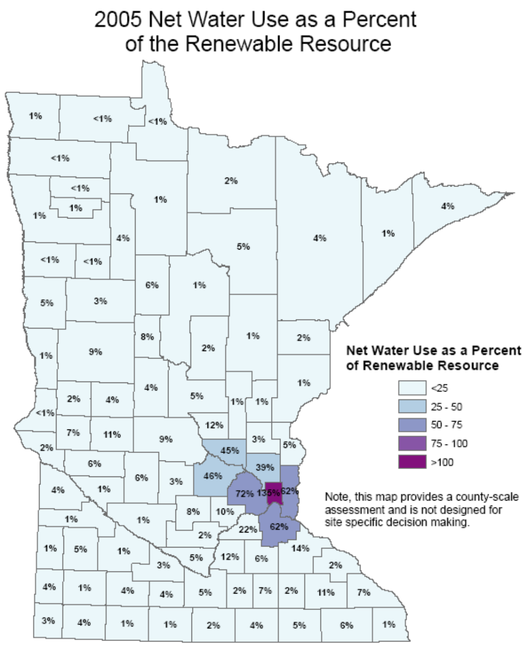
If the water used in a given county is greater than the project's supply estimates, this means *only* that more water is demanded from a county's "home grown" supply than may be available over the long term. This might mean that water users are depleting a county's waters – i.e. pumping reserves faster than they can be replaced – or drawing upon reserves that are imported from another county. It might also mean that ground water appropriations are, or will be, inducing recharge from surface waters at a greater pace than usual, potentially drawing down base stream flows, lake levels or wetlands. Another point to note is that previous work has shown that analysis on an annual basis underestimates the frequency of demand outstripping supply.[11] The uncertainties and assumptions of the assessment notwithstanding, if a county in this position had to rely only on water within its boundaries, it might be well advised to manage its water carefully.

Results

In evaluating the status of water consumption in Minnesota, the project compared the amount of water used in 2005 and the projected water use in 2030 to the amount of water that could be withdrawn on a long-term, sustainable basis. The results are reported as the percentage of renewable resource being used.

The year 2005 was used as the baseline of the assessment since it is the most recent year with a complete data set. The findings of this comparison are listed as a percentage of the renewable resource that is currently in use. Figure 3 reports the 2005 results and is entitled "net" because it reports the results after accounting for imported waters and non-consumptive uses.

Figure 3. 2005 Water Use Results



In 2005, only one county – Ramsey – appeared to use more than 100 percent of its homegrown renewable water resource – reporting 135 percent. This may suggest that Ramsey, a small county with a large population base, draws on the water resources of adjoining counties.

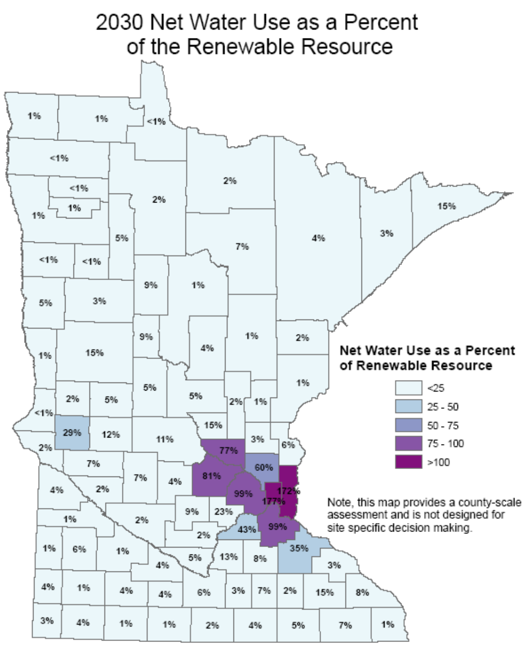
In the seven-county metropolitan area, the net water use of renewable resources ranged from 10 percent in Carver County to 135 percent in Ramsey County. In Greater Minnesota, the range was from less than 1 percent in seven

[11] O'Shea, D. T. 2000. Water Use and Availability in Minnesota. Rivers 7:333-344.

counties to 46 percent in Wright County. Three counties were between 50 and 75 percent and another three were between 25 and 50 percent. The same counties showing higher percents of use in 2005 also showed higher percents in 2030.

A full discussion of the methodology and assumptions is in Appendix A. A full-page map of Figure 3 is in Appendix B. Figure 4 in Appendix B, 2005 Gross Water Use as a Percent of the Renewable Resource, shows this comparison before imported waters and non-consumptive uses have been removed.

Figure 5. 2030 Water Use Results



Future water use was estimated for 2030 based on population extrapolations made by the State Demographer and the Metropolitan Council. The findings, shown in Figure 5, were listed as a percent of the renewable resource expected to be allocated.

In 2030, Ramsey County continued to be above 100 percent, with Washington County's growth also pushing its estimated use above renewable resource levels (177 and 172 percent, respectively). Dakota and Hennepin counties were estimated at 99 percent.

In the seven-county metropolitan area, the 2030 projections, as a percent of renewable resources, ranged from 23 percent in Carver County to 177 percent in Ramsey County, while in Greater Minnesota the range was from less than 1 percent in six counties to 81 percent in Wright County. Four counties ranged between 75 and 100 percent, one county between 50 and 75 percent, and another four between 25 and 50 percent.

A full-page map of Figure 5 is in Appendix B. Figure 6 in Appendix B, 2030 Gross Water Use as a Percent of the Renewable Resource, shows this comparison before imported waters and non-consumptive uses have been removed.

Application of Results

Because the assessment investigated supply and demand at a county scale, it is important to consider how to interpret and use the results. The project's principal conclusion is that the results cannot be used for actual site-specific decisions.

Nevertheless, the results should help foster important conversations. How can a county possibly be using more water today than the system might tolerate long term? How can several other counties already be using a high percentage of their renewable supplies? On the other hand, how can so many counties in which water seems in short supply show up as comfortably within their capacity?

The answers to these questions are complicated, and highlight many issues that still remain. For example, while the assessment and conclusions do not account for surface water entering a county – or even for ground water that may, in effect, be drawn from a neighboring county – they signal an early caution for those concerned about the ability of water resources to sustain development and support ecosystems.

Some ground water experts are not surprised by the project's findings. They note that the vast reserves of ground water underneath the Twin Cities metropolitan area were deposited thousands of years ago, subsequently covered and largely blocked from direct access to recent recharge waters. To what extent is water in these systems essentially a one-time opportunity? The answer is unclear.

This uncertainty makes the call for careful and cautious allocation of water from the state's confined aquifers prudent. It makes better understanding of where ground water can be found, and how much can be sustainably and safely consumed, an obvious state priority. It also makes better knowledge of the connection between ground water and surface water important for a number of reasons. These include:

- The contribution ground water makes to surface flows – low flows are, in fact, ground water discharges
- How these contributions may be put at risk by ground water use
- The need to consider combined use of surface and ground waters
- The influence ground water may have on the quality of surface waters, and vice versa.

Conclusions and Recommendations

1. Not so water rich. The label of Minnesota as water rich does not fit as well as once believed. The growth corridor stretching through the Twin Cities to St. Cloud already makes significant demands on its renewable water resources, making water supply management a special concern. In the remainder of the state, even today, care also must be taken by local and state officials in planning to meet the demand for and allocation of water.

2. An element of priority setting. The degree to which a county uses its renewable resources, now and in the future, should help inform state monitoring and research priorities – whether they involve the addition of monitoring wells and gauging stations, or the commitment to ground and surface water investigations. Table 1 suggests five factors that the state might employ in setting priorities.

3. A screening tool for local planning. The report provides information about renewable water supplies at the county level. While the numbers represent county-wide totals they can be converted into smaller units to illustrate the potential effect of a development on a county's supplies. Table 2 shows the renewable waters estimated to exist in the hypothetical median Minnesota county.

Table 1. Priority-setting factors

1. Extent of existing issues with supply, such as documented water supply declines, special ecosystem needs, or threats to water quality
2. Anticipated population and economic growth
3. Areas and uses with high seasonal demands
4. Areas where surface water resources are dependent on ground water
5. Areas with sustainable alternative supplies

The table illustrates how the renewable water resource estimate generated for a county can be converted into a land-based rate and used to describe the relative commitment a community would make in granting a particular new use or accommodating projected population growth. For example, locating a facility using 750 million gallons in the median county would use 1.4 percent of the county's renewable water resource and the hypothetical equivalent of 10 square miles of the renewable resource.

It is important to note that the hydrogeologic setting of many counties limits the installation of high capacity wells. Despite the fact that a county may only be using a small fraction of its renewable resource, as described in this report, it may still not be able to support a high volume water user.

4. Water use data collection and management. Minnesota has one of the best water use reporting programs in the nation and compliance with reporting requirements is near 100%. Water use and monitoring data are critical for evaluating and managing resource use on a sustainable basis. To streamline data entry and minimize the chances for error, DNR is considering software that enables water users to enter their reports directly online.

Table 2. Water use in a typical county

What does an average Minnesota county look like? Using median values, the middle-of-the-road county is characterized by:

- An area of 716 square miles
- Renewable water resource of 54,722 million gallons a year
- Gross water use of 2,111 MGY
- Net water use (after removing imported waters and non-consumptive water use) of 1,823 MGY
- 2005 use at 3.3% of the county's renewable water resource

What happens if a high water-using industry is added to the county? Adding an industry that uses 750 million gallons of water per year would be equivalent to:

- 1.4% of the county's supply
- 36% of the county's current gross water use (41% of the net use)
- 10 square miles of renewable water

This summary assumes that the water supply is evenly distributed over the county, which is unrealistic. However, it does provide a basic tool for putting in perspective a proposed new water use.

5. Planning for use of surface and ground water. As demand for limited supplies grows, the combined use of surface and ground waters will become more common. The 2030 assessment should help water and land use planners identify where combined use may need to be at the top of the list for consideration.

6. Research needed to move forward.
Research is needed to:

- Better define the location and characteristics of ground water resources
- Understand how much water is renewable; that is, how much can be taken for use on a long-term, sustainable basis without drawing down the resource
- Investigate new means to quantify sustainable supply or ways to build upon existing supply methods
- Understand the impacts of drainage or other land use practices on rates of recharge and means to quantify the impacts
- Understand the impacts of global warming on climate, rates of recharge and water demand
- Characterize the interactions of surface and ground waters, including the implications of water quality and quantity
- Quantify the timing, amount and quality of water to better understand ecosystem needs

7. The next edition. The next assessment of availability should consider:

- Focusing on geographic areas with supply and demand issues and evaluating resource management options
- Evaluating how public water suppliers are integrating sustainability into the second generation of water emergency and conservation plans
- Refining the assessment by analyzing water availability on a seasonal or monthly basis; integrating the concept of imported waters; conducting analyses on a sub-county level where possible; and evaluating the current effect and future risk of water quality degradation on water supply
- Evaluating water resource monitoring needs, as well as investigating ecosystem needs
- Including the results of mass water level measurements covering the period 1955-2008 for the Twin City metro area
- Evaluating Minnesota's "safe yield" concept for protecting ground water resources.

Given the complexity of such analyses and the range of people likely to be interested in their outcomes, the next biennial assessment should use both science- and citizen-based advisory committees.

Appendix A

Project Assessment Methods

The assessment evaluated current and future water demand, as well as an estimate of available water resources, all at the county scale. The assessment worked with published methods describing recharge to the water table system and used these as surrogates for generating sustainable supply values, developing five sets of renewable resource estimates. The analysis used the median amount of renewable water resources estimated for each county in making comparisons with demand for that county. The comparisons were made for reported and permitted use in 2005, and estimated use in 2030. In addition, the analysis adjusted appropriations from surface waters coming into a county, since resource estimates did not include such waters. It also removed non-consumptive water uses from the tally. The 2005 water use values were calculated by averaging each county's per capita demand for the years 1995 to 2005 in order to provide a baseline not artificially affected by a single year's climate. These same use rates were applied in estimating demand in 2030.

In 2005, only one county – Ramsey – appeared to use more than 100 percent of its renewable water resource, reporting in at 135 percent. In the seven-county metropolitan area, the range was from 10 percent in Carver County to 135 percent in Ramsey County. In Greater Minnesota, the range was from less than 1 percent in seven counties to 46 percent in Wright County. Three counties ranged between 50 and 75 percent and another three between 25 and 50 percent.

By 2030, the percent use of seven-county metropolitan area renewable resources ranged from 23 percent in Carver County to 177 percent in Ramsey County, while in Greater Minnesota the range was from less than 1 percent in six counties to 81 percent in Wright County. Four counties ranged between 75 and 100 percent, one county between 50 and 75 percent, and another four between 25 and 50 percent.

For this report, the USGS determined the upper and lower limits of recharge based on the premise that the entire county is quantified by either the lowest or highest rate of recharge demonstrated in the land area. For this reason, the values serve as the high and low bars of the report's supply estimates. The remaining three methods produce results that generally fall within these county ranges. They presumably are closer to the amounts that might be sustainably tapped in a given area because they consider characteristics of the entire county; not simply a county's high and low thresholds.

Regional regression recharge method. The USGS has estimated the average annual recharge to surficial aquifers for practically all locations in Minnesota.[12] The regional regression recharge method is based on a regression analysis of recharge estimates with climate and soils data from regions within Minnesota. The analysis evaluated a variety of recharge methods at local to regional scales and over a series of temporal scales. The regional regression recharge method relies on a number of different soil and climatic variables, finding strong dependence on precipitation, potential evapotranspiration and specific yield. These findings were then scaled up to a regional level using general soils association information. The result is a characterization of Minnesota's regional recharge values, providing a range of values for each county. This report selected the high and low recharge values for each county as a way to bracket the range of recharge.

[12] Lorenz, D.L. and G.N. Delin, A Regression Model to Estimate Regional Ground-Water Recharge in Minnesota: Ground Water, v. 45, no. 2, doi: 10.111/j.1745-6584.2006.00273.x.

Watershed characteristics method. In this method, researchers at the University of Minnesota estimate the amount of water that might be tapped on a sustainable basis based on measurements of stream runoff characteristics and their association with landscape components defined as the geology, hydrogeology, stream network system, relief, soils, vegetation and climate; for example, the minimal monthly stream runoff (or minimal monthly base flow) was used for assessment of sustainable ground water supply. This methodology allows estimating water availability on a sustainable basis for human and ecological needs throughout a region. The approach is based on the principal that water is a single resource, whether it shows up at any point in time as ground water or surface water. This method was used in 2001 to quantify ground water sustainability in the metropolitan region.[13]

The method examines the temporal and spatial variability of stream flow characteristics across Minnesota's three ecoregions (Laurentian Mixed Forest, Eastern Broadleaf Forest and Prairie Parkland) and five hydrogeological subdivisions. It uses a principal component and factor analysis of annual rates of stream runoff and minimum monthly rates for each region based upon a lengthy period of record (from 1918 to 1967).

The analysis estimates the amount that might be safely pumped from ground water based upon long-term minimum flows in the month of lowest stream flow over the period from 1935 to 1981. Since in Minnesota the lowest flows tend to occur in February, the method averaged the lowest flow recorded each February from 1935 to 1981. These flows represent the sustainable ground water resource.

The method estimates the volume that might be pumped from surface waters by subtracting those long-term minimum flows from each month's average flow calculated over the same period. The method also quantifies the characteristics of water balance components for the natural landscape framework, making it possible to assign sustainable use values to the land area or a parcel of land. The method quantifies sustainable water supply values for the entire freshwater system.

Net available precipitation method. This method recognizes that the amount of water ultimately available in a given location is determined by the amount of precipitation in the area minus losses to evapotranspiration, plus a portion of the water imported to the area. If one assumes that the combination of upstream or up-gradient water users and instream ecosystem users fully "appropriate" that imported water, then the sustainable level that users in a downstream area might appropriate is the net available precipitation.

Fractional precipitation method. Recharge to unconfined aquifers in Minnesota typically equals 20-25 percent of annual average precipitation[14]. This report estimated county-level recharge using 20 percent of average annual precipitation as a simplified analysis to compliment the other more rigorous estimation methods. Precipitation data[15] was downloaded for each weather station in Minnesota, yielding average annual precipitation for the period 1971-2000. Each weather station within a county was averaged to generate a county-wide precipitation value. Twenty percent of this precipitation value is taken to be an estimation of recharge.

Challenges in Assessing Water Demand

Assessing water demand on a county basis is a challenging proposition, but through the DNR permit process, as well as the Minnesota Department of Health municipal supply records, a log of historic use is

[13] Ruhl et al, Estimates of Recharge to Unconfined Aquifers and Leakage to Confined Aquifers in the Seven-County Metropolitan Area of Minneapolis-St. Paul, Minnesota, USGS, 2002

[14] USGS Fact Sheet 2007-3002, Ground-Water Recharge in Minnesota, 2007, in press, 6p.

[15] Midwest Regional Climate Center, http://mcc.sws.uiuc.edu/climate_midwest/maps/mn_mapselector.htm

available that documents the volume of consumption and water use trends. These numbers form the base of current demand totals, with the challenge being to extrapolate these values to future consumption. Some specific questions to be addressed by a water sustainability analysis include:

- How will fluctuations in weather patterns impact water use?
- How will per capita water use change in the future?
- In which counties will high water-using industries expand?
- What will be the impact of improved water technologies and the EPA and AWWA water efficiency initiatives?
- What impact might bioenergy plants have on the water landscape?
- Do the current DNR and MDH reporting requirements provide the level of detail necessary for adequately quantifying water use?
- How can we accurately document use in Minnesota that does not require permits, and is it a significant contribution not only to water use but to consumption?
- What is the long-term impact of expanded water treatment facilities discharging to surface waters versus private systems recharging onsite?
- How can we better quantify the fluctuating amounts of water that ecosystems need to flourish?
- How do we best allocate and manage use of available supplies among competing uses?

Limitations in Quantifying Supply

Water is taken from both ground and surface water sources in Minnesota. However, aquifers have not been well defined throughout the glacial region, and the available supplies held within them are not well understood. More research is needed in this area and in evaluating how aquifers respond to withdrawal stress on the system.

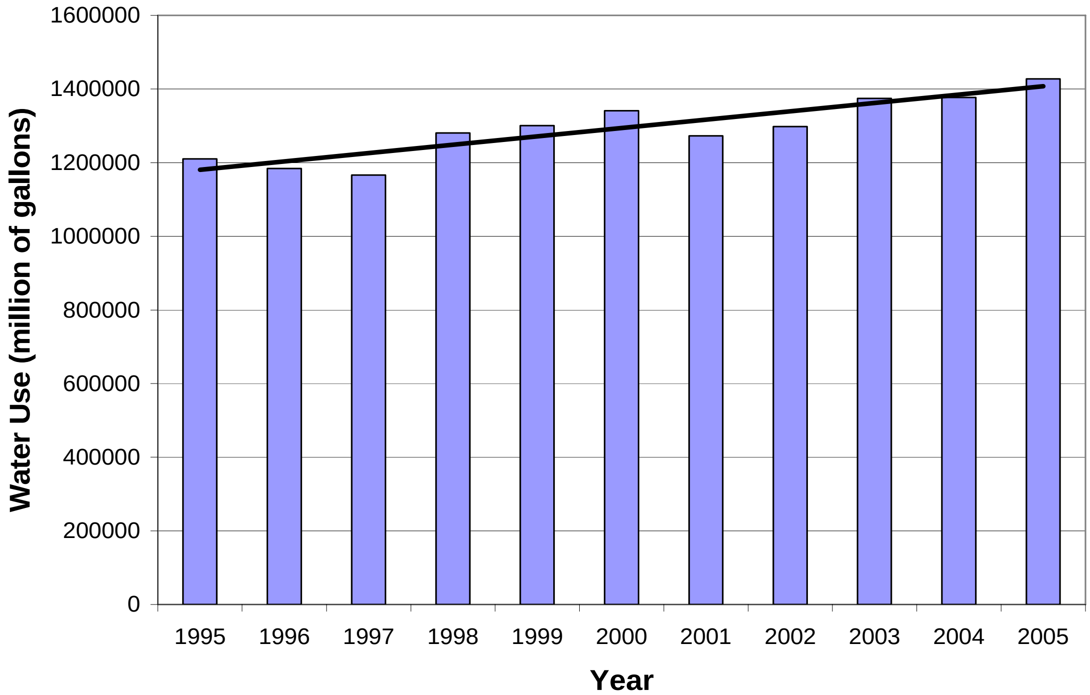
Additionally, appropriated ground water is generally discharged to surface water features. Anything that can be done to maximize use of surface waters and minimize ground water use will help preserve ground water reserves. Questions that need to be addressed include:

- How do we assess sustainable supply?
- How might we better define the extent of ground water aquifers in Minnesota?
- How can we best preserve surface water features that are sustained by ground water sources?
- What impact does ground water quality have on quantity?
- What effect does ground water have on surface water quality?
- Neither ground nor surface water sources follow county boundaries; thus, how can we best assess these features on a county basis?
- How does recharge in a dynamic aquifer system respond to water withdrawals?

Appendix B

Results
Water Use as a Percent of Minnesota's Renewable Water Resource

Figure 1. Minnesota Annual Water Use Trends (1995 – 2005)



During the period examined, 1995-2005, per capita water use in Minnesota showed an increase of 6%. This increased rate of consumption, coupled with a population increase of 26% by 2030 demonstrates the need for planning and assessments, such as this.

Figure 2. Per Capita Water Use Trends (1995 – 2005)

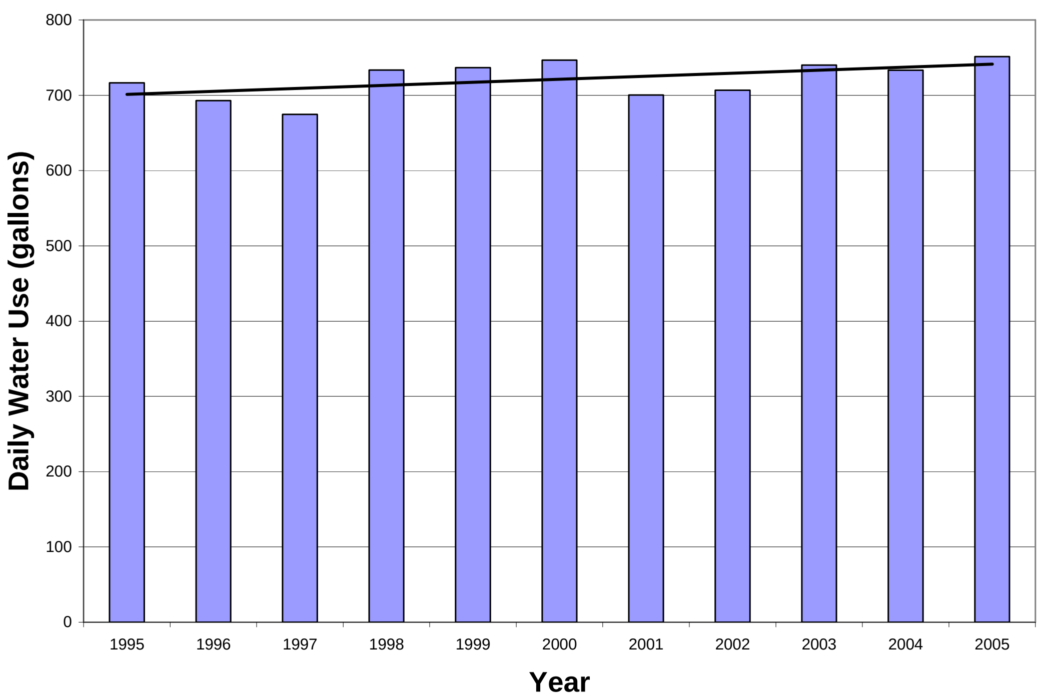
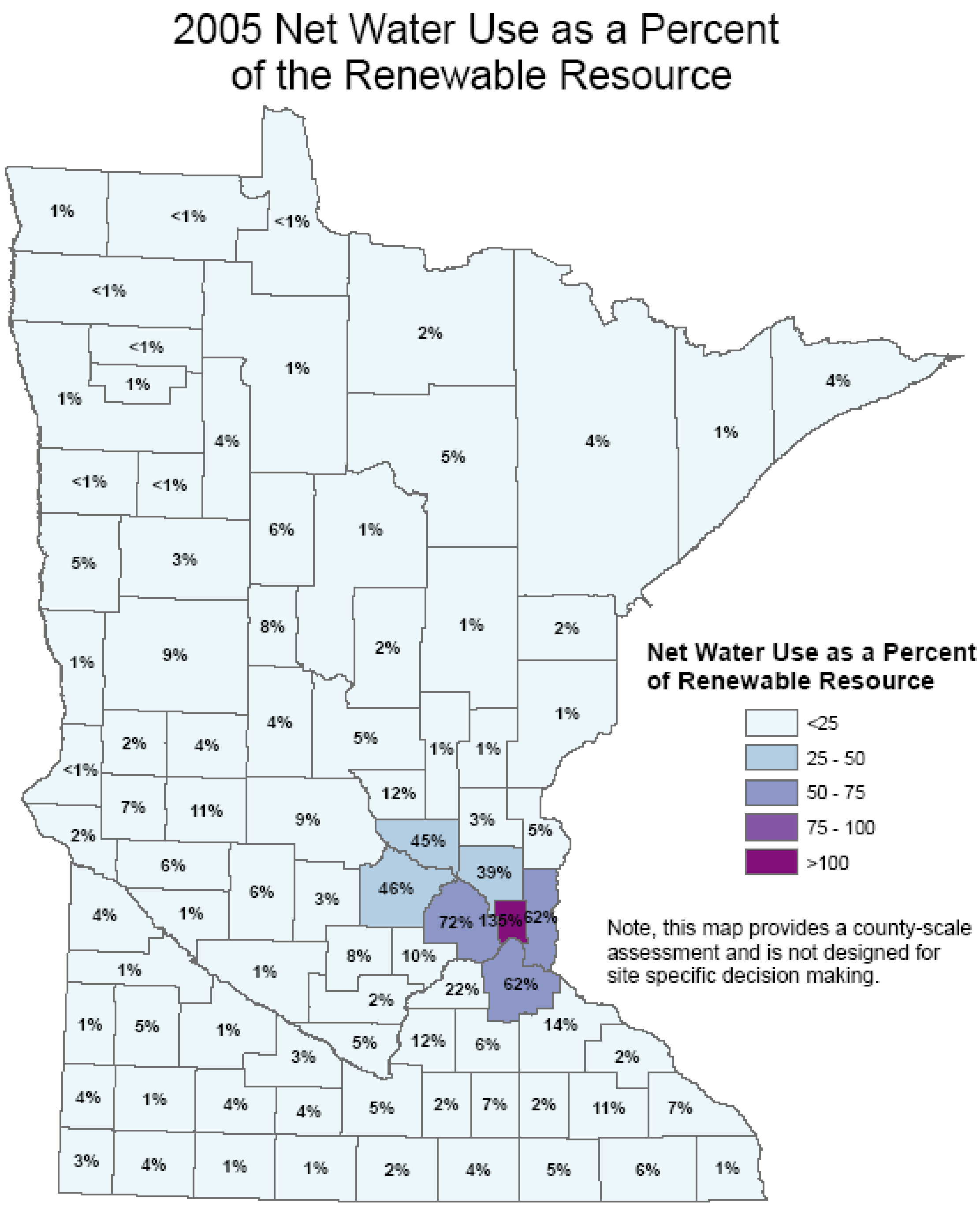
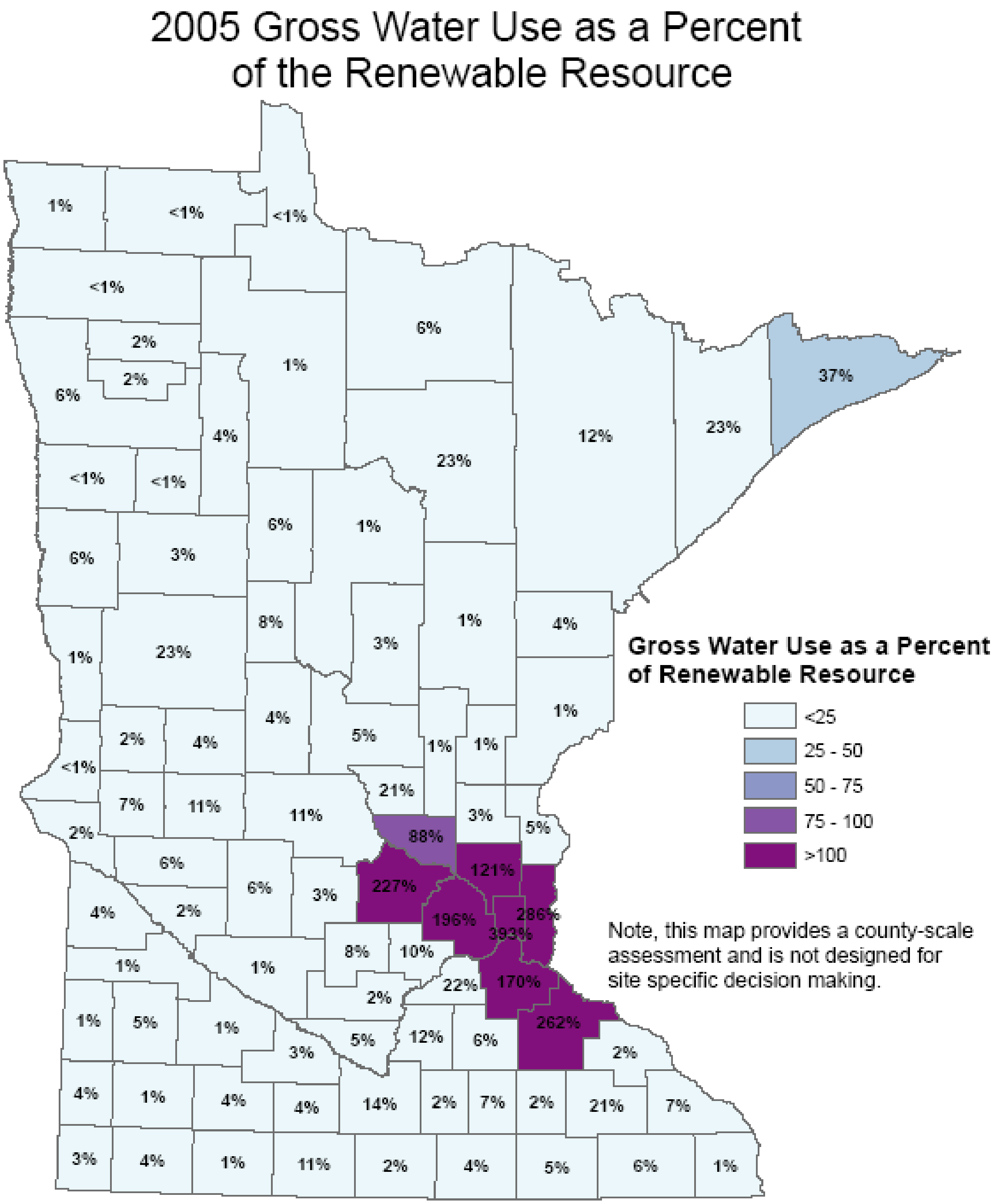


Figure 3



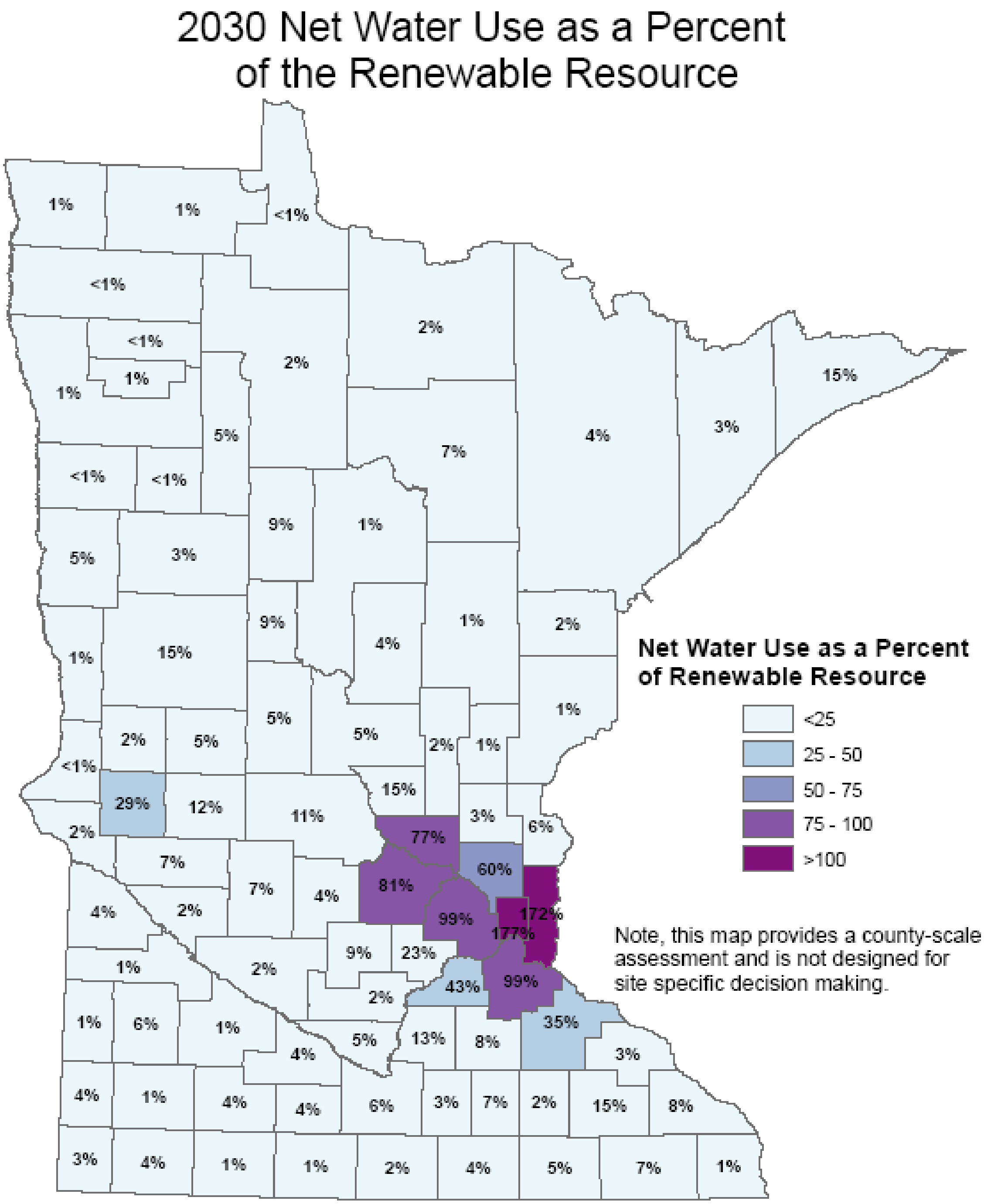
Results are reported as a percentage of renewable resource used.

Figure 4



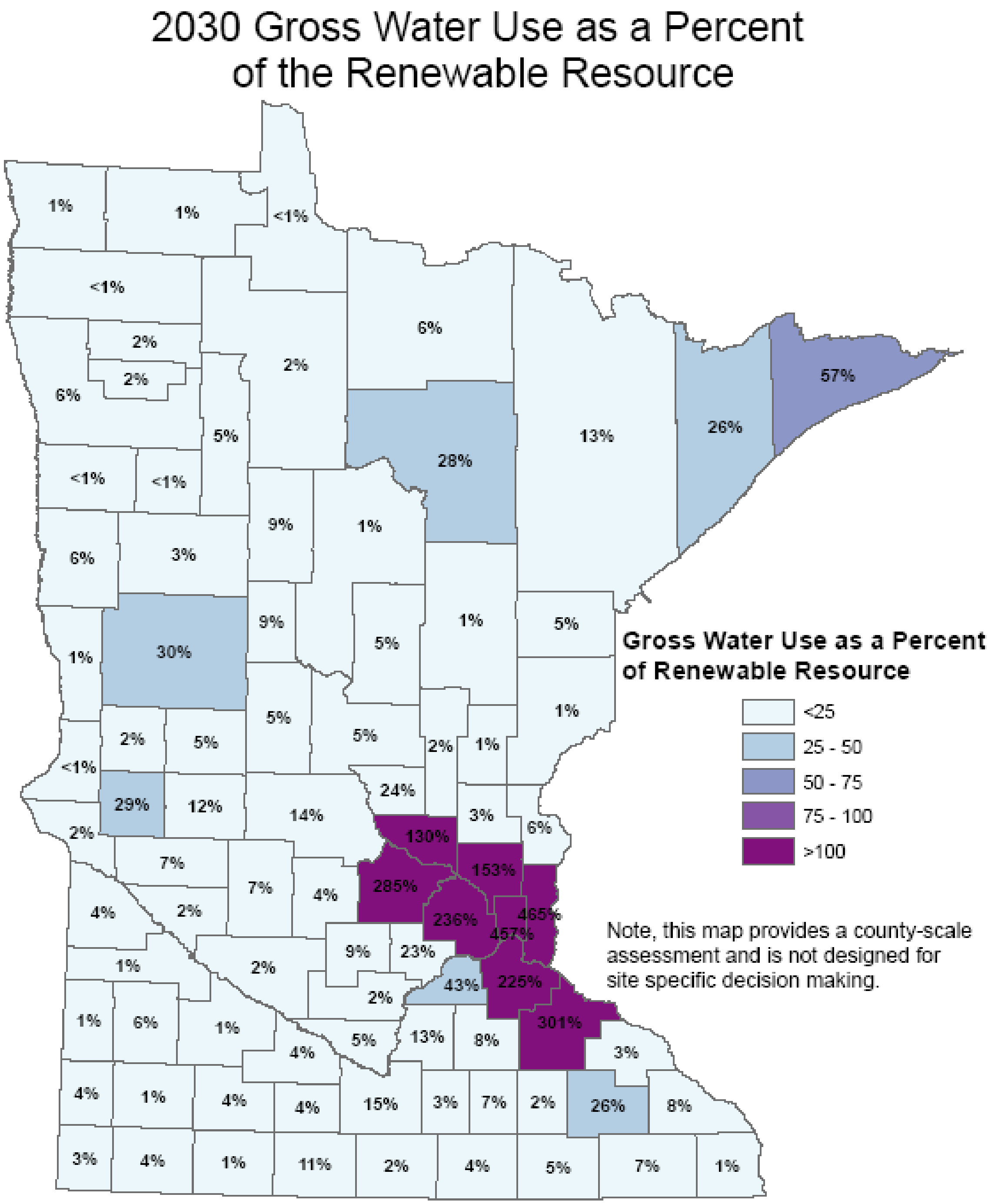
Results are reported as a percentage of renewable resource used.

Figure 5



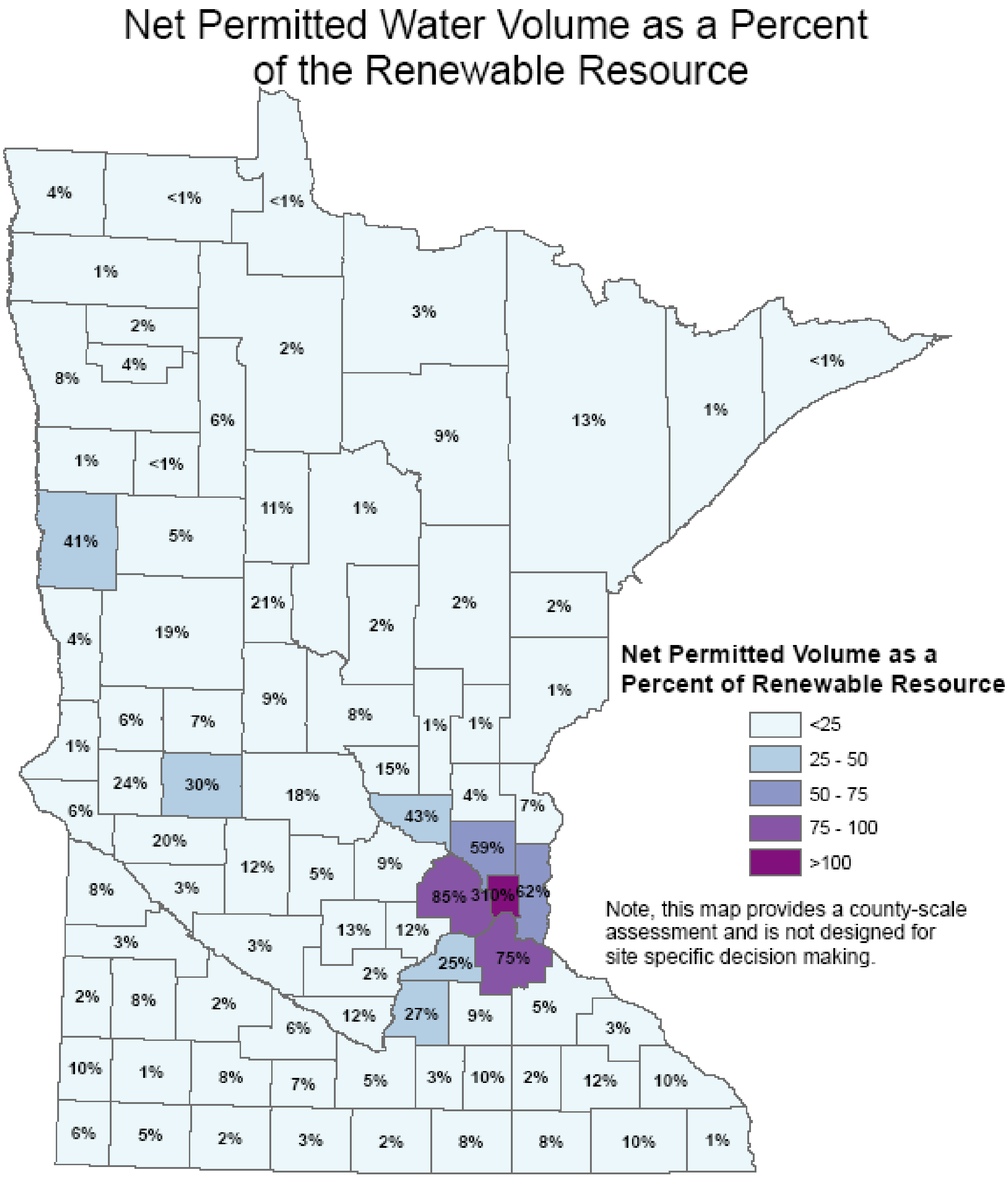
Results are reported as a percentage of renewable resource used.

Figure 6



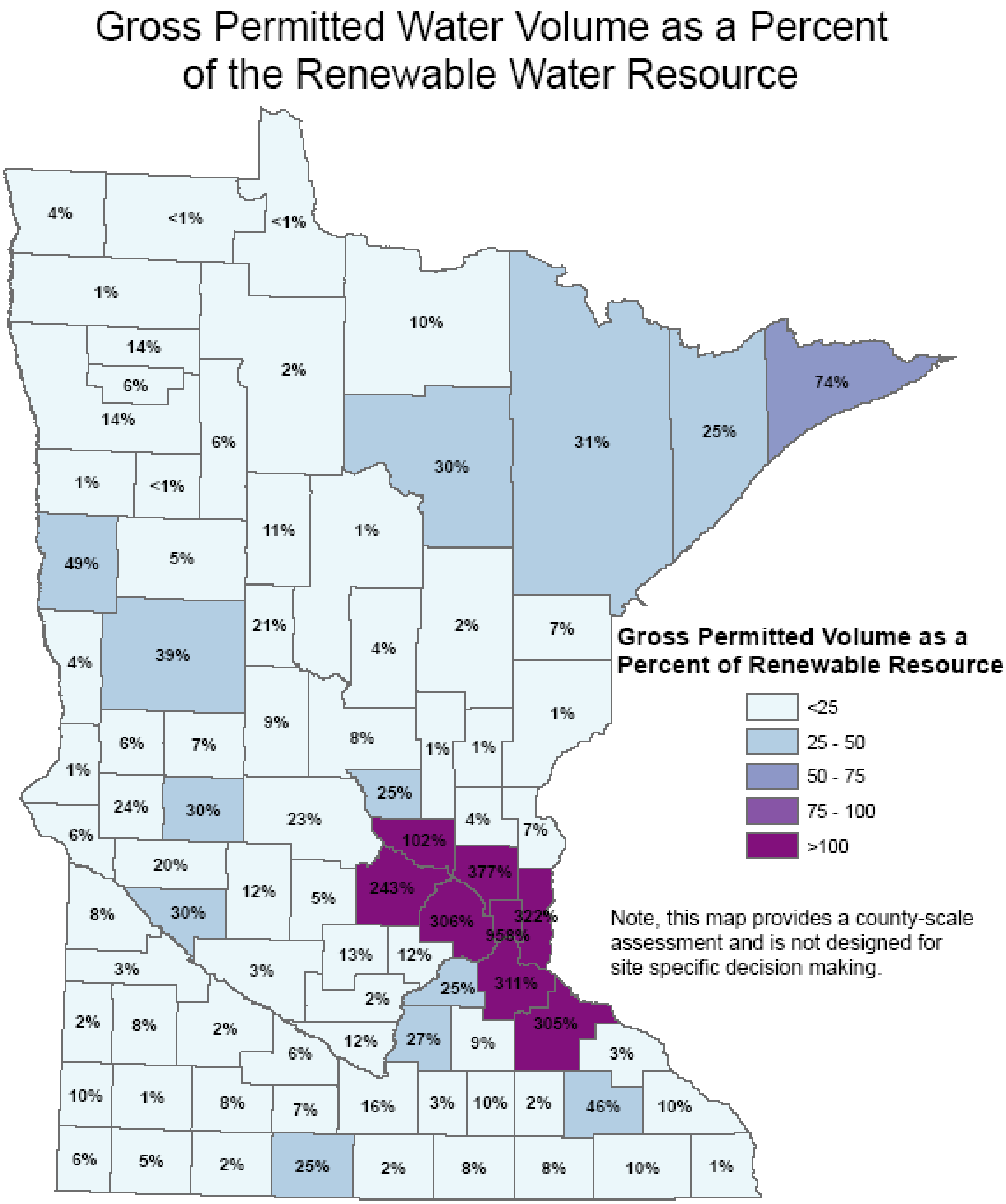
Results are reported as a percentage of renewable resource used.

Figure 7



An additional assessment was done that compared the total permitted water volume to supply. Permitted values are generally greater than reported use values because they represent the maximum quantity permittees may use. Permitted volumes were totaled for each county and compared to supplies to provide another perspective in the supply – demand assessment. These estimates were not projected to 2030, however, since permitted amounts generally include a future component.

Figure 8


Gross Permitted Water Volume as a Percent
of the Renewable Water Resource
4%
<1%
<1%
1%
10%
14%
2%
6%
74%
14%
6%
31%
25%
30%
1%
<1%
11%
1%
49%
5%
21%
2%
7%
4%
39%
4%
9%
1%
6%
7%
8%
1%
1%
1%
25%
24%
30%
23%
4%
6%
7%
102%
20%
377%
243%
12%
5%
8%
30%
306%
322%
958%
3%
3%
13%
12%
25%
311%
2%
2%
8%
2%
305%
6%
12%
27%
9%
3%
10%
1%
8%
7%
16%
3%
10%
2%
46%
10%
6%
5%
2%
25%
2%
8%
8%
10%
1%
Gross Permitted Volume as a
Percent of Renewable Resource
<25
25 - 50
50 - 75
75 - 100
>100
Note, this map provides a county-scale
assessment and is not designed for
site specific decision making.

Glossary

Terms as used in the report

Consumptive use The portion of withdrawn water that is removed from the water source; in this report consumptive use includes all appropriated ground water and that portion of appropriated surface water removed and not returned to its original watercourse or water body

Combined use The use of both surface water and ground water in order to minimize the undesirable economic, social and environmental effects of using only a single source

Gross water use The total volume of water used in Minnesota, without consideration of non-consumptive use or imported waters; in this report, gross water use is displayed as percentage of the total renewable water resource estimated for a given county

Imported waters Surface waters that originate outside a county's boundary, but are available within the county (for example, the Mississippi River flowing into Wright County)

Instream flows Stream flows needed to protect and preserve instream resources and values, such as fish, wildlife and recreation

Net water use The volume of water used minus non-consumptive uses and allocations from imported waters; in this report, net water use is displayed as percentage of a county's renewable water resource

Non-consumptive water use The portion of surface water that is returned to its source water body or watercourse after use

Recharge The replenishment of a water source

Renewable water resource The quantity of water that can be removed from the system on a long-term basis without drawing down the resource

Safe yield For both water table and artesian conditions under Minnesota Rules 6115.0630, subparts 15 and 16, the annual amount of water that can be taken from a source or supply over a period of years without depleting that source beyond its ability to be replenished naturally in "wet years"

Sustainable development As defined in *Minnesota Statutes*, section 4A.07, development that maintains or enhances economic opportunity and community well-being while protecting and restoring the natural environment upon which people and economies depend

Sustainable supply The quantity of ground water and surface water available to meet human needs over the long term without harming ecosystems; in this report, recharge is used as a surrogate for sustainable supply by three of the supply methods

Sustainable water use The use of water to provide for the needs of society, now and in the future, without unacceptable social, economic or environmental consequences

Water availability or water supply Ground water and surface water obtainable for use

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