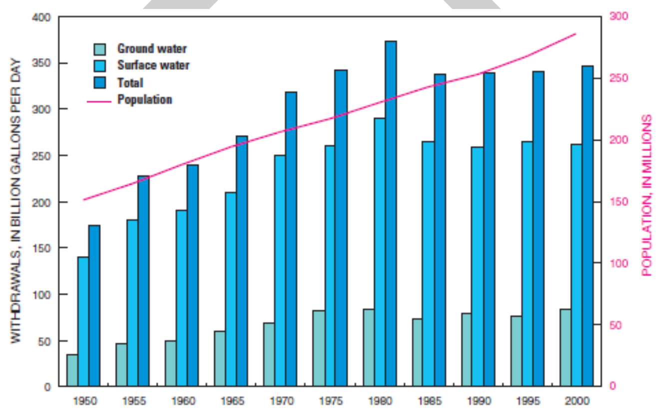
C. Total National, State, and Metro Withdrawals

1. National

Total U.S. water use and population over time are shown in figure 4. In 2005, total offstream water use was 150 trillion gallons. About 127 trillion gallons of this was freshwater. Of the freshwater usage, about 77% (99 trillion gallons) was surface water, and about 23% (29 trillion gallons) was groundwater. In 1995, about 29% (37 trillion gallons) of total U.S. freshwater use (125 trillion gallons) was consumptive (Solley et al. 1998). In 2005, nationwide per capita freshwater use (all uses) is estimated to have been 1,360 gallons per day; nationwide domestic use per capita is estimated to have been 98 gallons per day (Kenny et al. 2009).

Figure 4. Trends in population and freshwater withdrawals by source, 1950–2000.

(Data from Hutson 2004.)

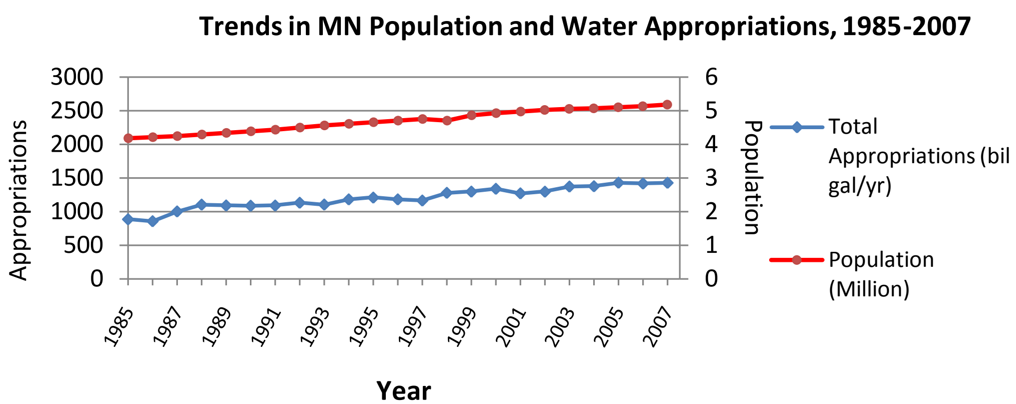


2. Minnesota

Trends in Minnesota's population and appropriated water use are shown in figure 5. From 2000 to 2007, annual DNR permitted water appropriations averaged 1.37 trillion gallons per year, with an average estimated state population of 5.06 million (Hunt 1999, 2001, 2003, 2005, 2007, 2009). USGS estimates for all offstream uses and population in Minnesota in 2000 and 2005 averaged 1.44 trillion gallons per year and 5.03 million residents (Kenny et al. 2009).

Figure 5. Minnesota population and total water appropriations, 1985–2007.

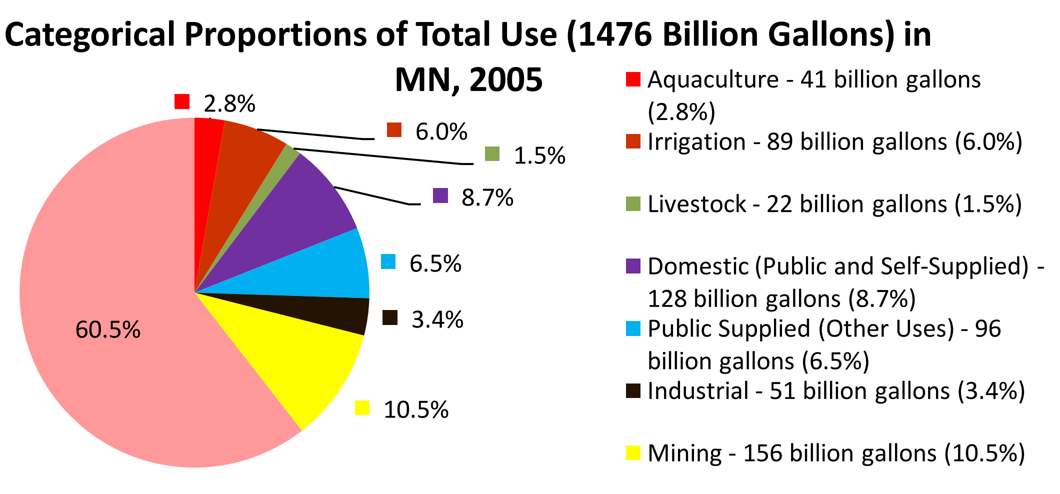
(Data from Hunt 1999, 2001, 2003, 2005, 2007, 2009.)



In Minnesota in 2005, total use per capita was an estimated 788 gallons per day; domestic per capita use was an estimated 68 gallons per day. In 2005, surface water accounted for about 79% (1,161 billion gallons) of total withdrawals (1,476 billion gallons), while groundwater accounted for 21% (315 billion gallons). If the "once-through cooling" subcategory (562 billion gallons)of thermoelectric use, a largely (97%–98%) nonconsumptive use primarily drawn from surface water (Solley et al. 1998), is removed, surface water and groundwater withdrawal are 66% (270 billion gallons) and 34% (314 billion gallons) of total use, respectively.

Figure 6. Minnesota water use by use category, 2005.

(Data from Kenny et al. 2009.)



In 2005, the USGS estimated that 1.11 million Minnesotans (22%) used self-supplied groundwater wells for their residential supply, with an estimated use of 28 billion gallons (22% of total domestic use). The remaining 4.02 million people (78% of MN population) received domestic water from public supply (approximately 100 billion gallons, or 78% of total domestic use), 69% of which came from groundwater and 31% of which came from surface water (Kenny et al. 2009). In 1995, Minnesota's consumptive use was estimated to be 12% (152 billion gallons) of total use (1,238 billion gallons, Solley et al. 1998). Minnesota's 2005 total (surface and groundwater) withdrawals are shown by use category in figure 6; 2005's groundwater and surface water withdrawals by use category are shown in figures 8 and 9, respectively. Figure 7 and table 2 express Minnesota's total use by use category over time (1985–2005).

Figure 7. Minnesota water use by use category, 1985–2005.

(Data from Hutson 2004; Kenny et al. 2009; Solley et al. 1988, 1993, 1998.)

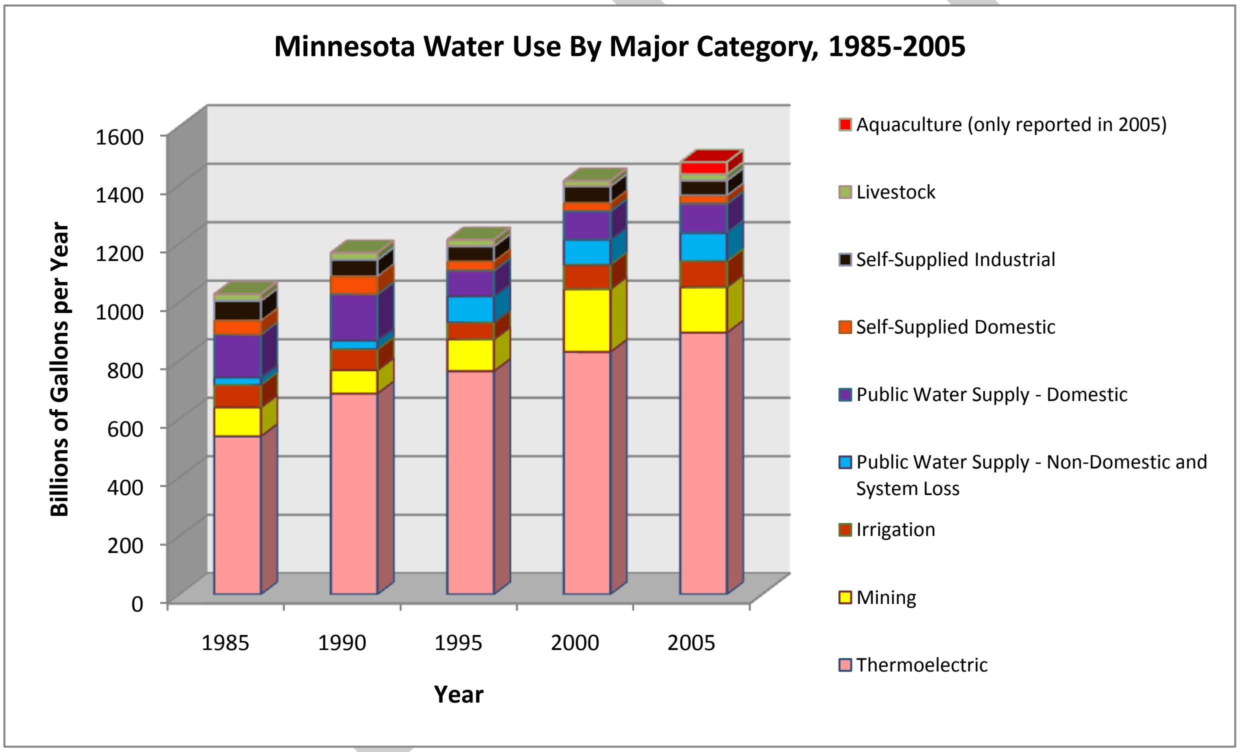


Table 2. Minnesota water use by use category, 1985–2005

Year / Use Category	1985	% of 1985	1990	% of 1990	1995	% of 1995	2000	% of 2000	2005	% of 2005
Public Water Supply (Domestic)	147	14.2	158	13.2	87	7.0	96	6.8	100	6.8
Public Water Supply (All Other Uses and System Loss)	26	2.5	30	2.4	90	7.3	86	6.1	96	6.5
Domestic (Self-Supplied)	48	4.6	61	5.1	32	2.6	30	2.1	28	1.9
Industrial (Self-Supplied)	67	6.5	56	4.7	51	4.1	56	4.0	51	3.5
Irrigation	76	7.4	71	5.9	57	4.6	83	5.9	89	6.0
Livestock	23	2.2	24	2.0	23	1.9	19	.3	22	1.5
Aquaculture									41	2.8
Mining	99	9.6	80	6.7	109	8.8	215	15.2	156	10.6
Commercial (Self-Supplied)	26	2.5	71	5.9						
Thermoelectric	541	52.3	687	57.5	763	61.6	829	58.7	895	60.6
Total Annual Use (billions of gallons)	1034	101.8	1194	103.4	1238	97.9	1413	99.1	1476	100.2

Data from Hutson 2004; Kenny et al. 2009; Solley 1988, 1993, 1998. Numbers may not add to 100% due to rounding.

Figure 8. Minnesota groundwater withdrawals by use category.

(Data from Kenny et al. 2009.)

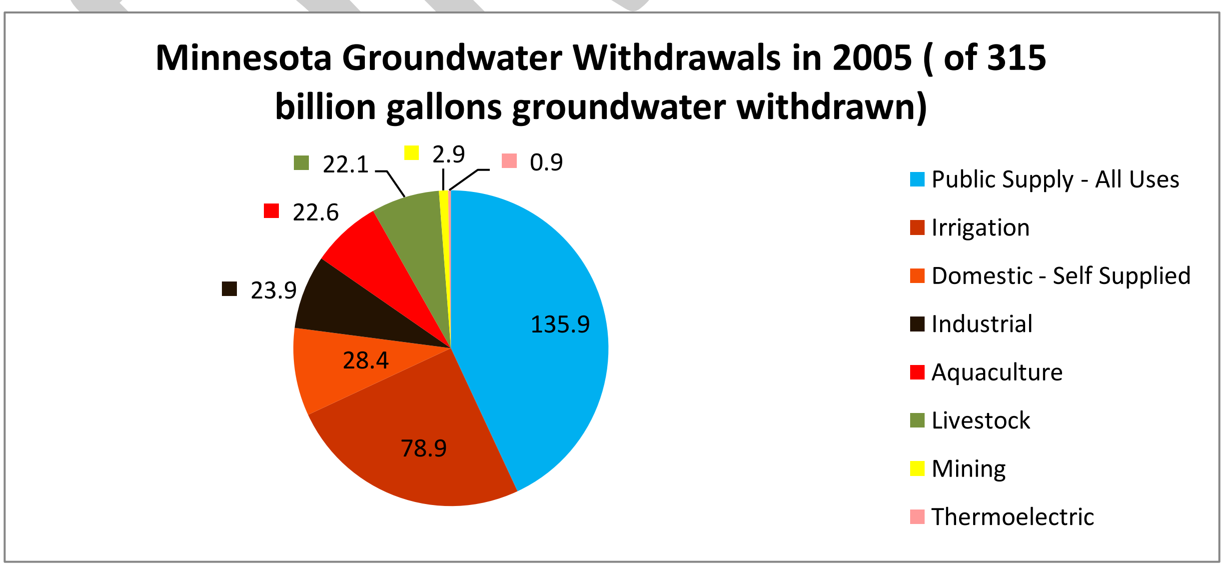
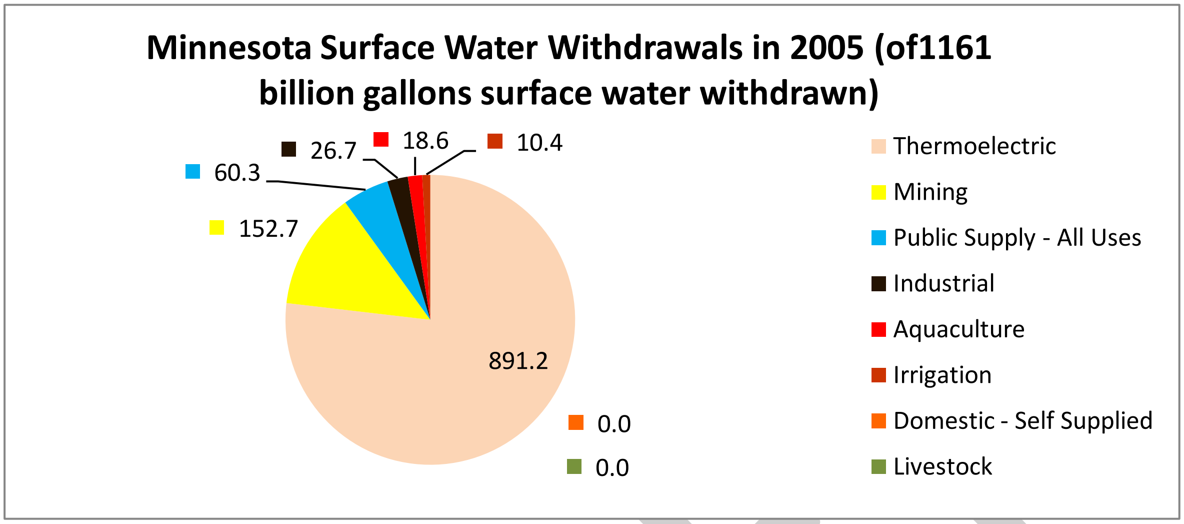


Figure 9. Minnesota surface water withdrawals by use category.

(Data from Kenny et al. 2009.)



a. **Current Use vs. Estimated Supply.** The Environmental Quality Board (EQB) estimated water supply availability in Minnesota by using four different methods to generate five renewable resource estimates for each of Minnesota's counties. Each county's median estimate was then compared with its estimated net (consumptive) usage (VanBuren 2007). The EQB found that 14 of 87 Minnesota counties reported net (consumptive) water usage that was more than 10% of their estimated available renewable water in 2005 (figure 10). When looking at permitted volume (not volume actually used) versus estimates of available renewable water, 29 of 87 counties had more than 10% of their available water allocated for consumptive use (figure 11).

b. **Projected Use.** The EQB projected that most Minnesota counties would be able to meet their water supply needs from their own renewable resources through 2030. Eighteen counties are projected to be using more than 10% of their renewable resource in 2030 (figure 12). However, if nonconsumptive portions of use are included in the estimates ("gross water use" in figure 13), 22 counties would be projected to be using more than 10%, and 16 counties to be using more than 20%, of their estimated renewable resource (see figure 13). The report acknowledges that water availability within aquifers and ecosystem water needs are not well understood. The EQB report calls for research to define and characterize groundwater resources; to assess how much of the resource is renewable; to develop supply quantification methods; to characterize groundwater–surface water interactions; to describe and quantify ecosystem needs; and to understand the impacts of climate change as well as drainage and other land uses on rates of recharge and water demand, in order to effectively and sustainably manage Minnesota's water resources (VanBuren 2007).

Figure 10. Net 2005 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)

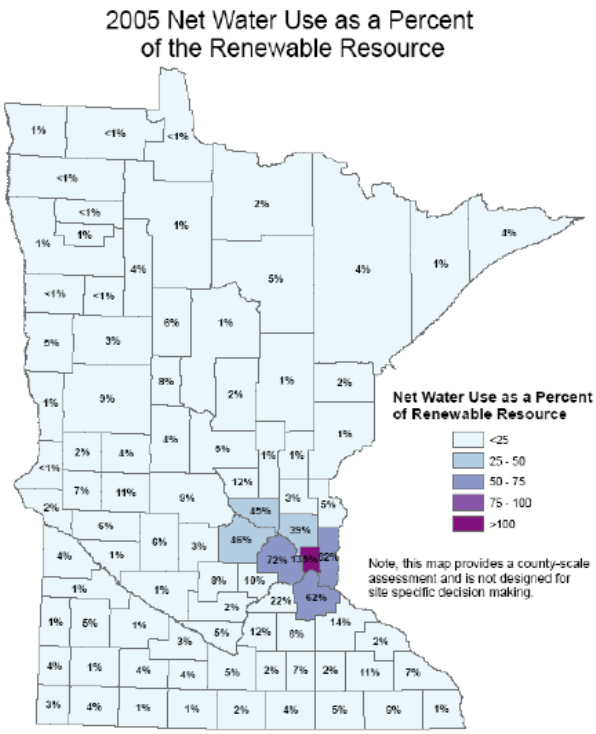


Figure 11. Net 2005 water allocations as a percentage of renewable resource.

(Map from VanBuren 2007.)

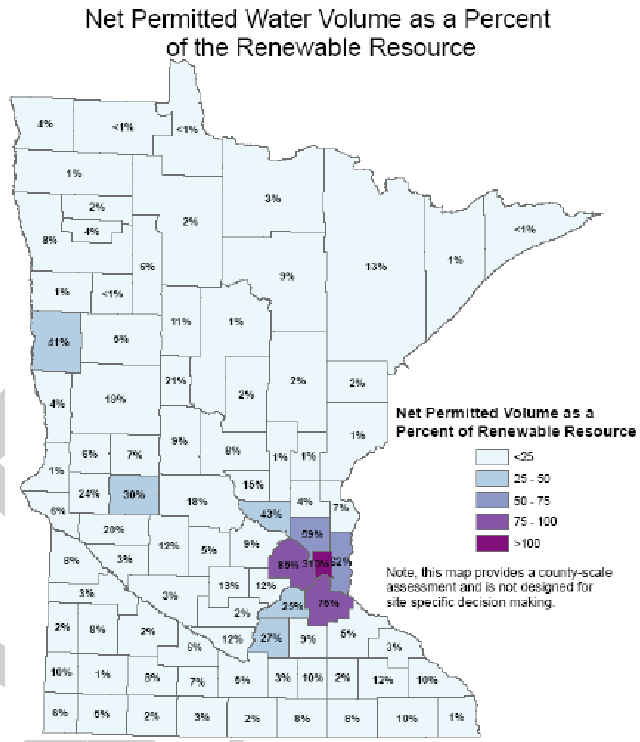


Figure 12. Projected net 2030 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)

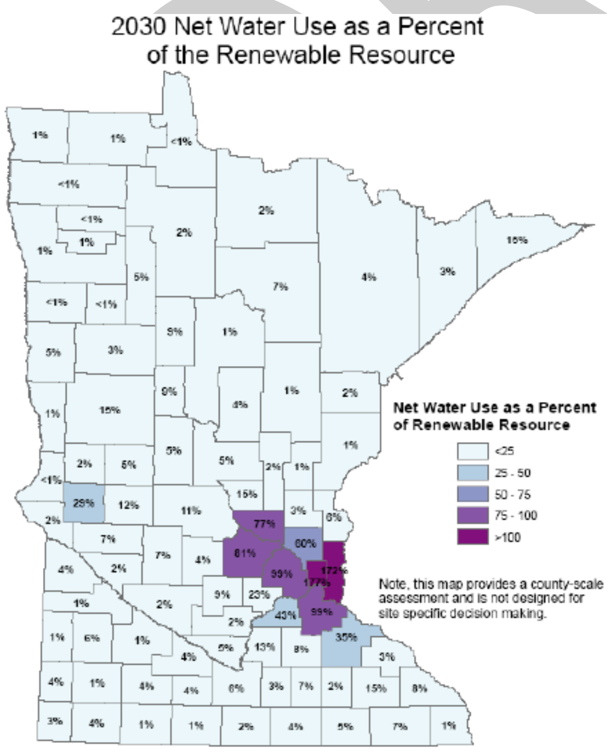
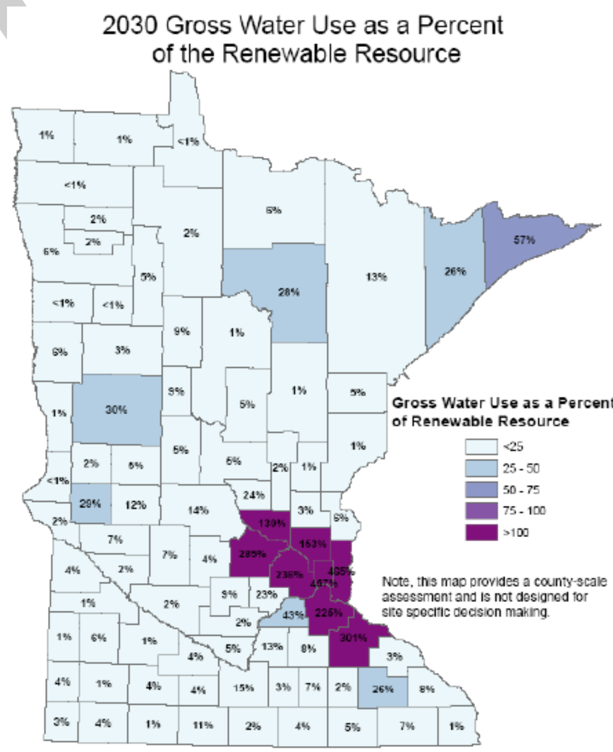


Figure 13. Projected gross 2030 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)



3. Twin Cities Metropolitan Area

a. Recent. Twin Cities metropolitan area counties use a higher proportion of their assessed renewable resources than the rest of Minnesota (VanBuren 2007), as might be expected given the higher population density. Groundwater sources provide approximately two-thirds of the water consumed in the Twin Cities metro area, and serve about 1.6 million people through municipal water systems. An additional 290,000 people are estimated to be using self-supplied wells in the metro area. Approximately 880,000 people in the Twin Cities metro region rely, at least in part, on surface water as their drinking water source (Metropolitan Council 2007a, 2004).

Metro area water use in 2004 can be seen in figure 14. Metro counties' portions of annual total withdrawals (2000–2007) are shown in figure 15. Figures 16 and 17 show metro surface and groundwater use over time with and without thermoelectric use, respectively. The Twin Cities metro area used approximately 163 billion gallons of water in 2004(Metropolitan Council 2007a). Of this total, 46.3 billion gallons (9%) were self-supplied for nondomestic purposes. Another 116 billion gallons (22%) were delivered through municipal public supply. Of this municipal supply, 81.2 billion gallons (70%) were delivered for residential use by approximately 2.5 million people. These estimates do not include use for power generation. Power generation, although deemed nonconsumptive, accounted for approximately 345 billion gallons in the metro area for 2004, more than double all other reported uses combined (Hunt 2005, figure 14). As noted earlier, the movement toward the use of recirculation cooling in place of once-through cooling may call into question the presumption that power-generating use is nonconsumptive (Kenny et al. 2009, U.S. Environmental Protection Agency 2009). When including thermoelectric usage in state and metro use estimates, metro usage (508 billion gallons) accounts for approximately 37% of Minnesota's total 2004 usage (1,379 billion gallons); not including thermoelectric, metro usage (163 billion gallons) accounts for 32% of Minnesota's 2004 usage (506 billion gallons; Hunt 2005, Metropolitan Council 2007a, Metropolitan Council 2007b).

Figure 14. Water use in the Twin Cities metropolitan area, 2004.

(Data from Metropolitan Council 2007a, 2007b.)

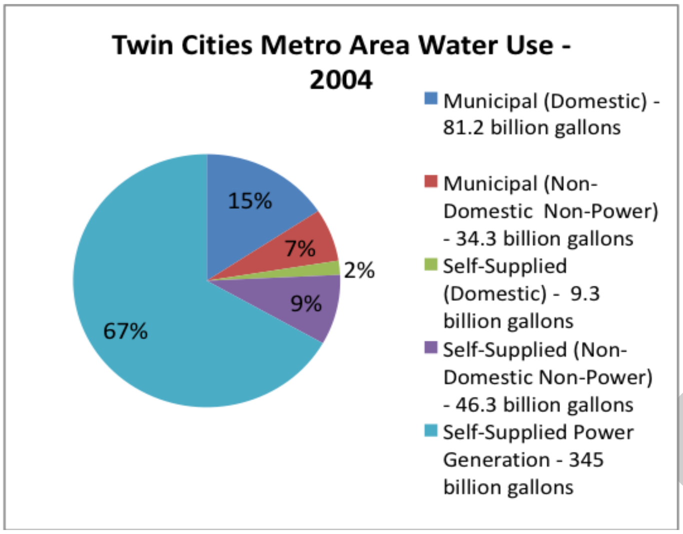


Figure 15. Annual metro water use by county.

(Data from Hunt, 1999, 2001, 2003, 2005, 2007, 2009.)

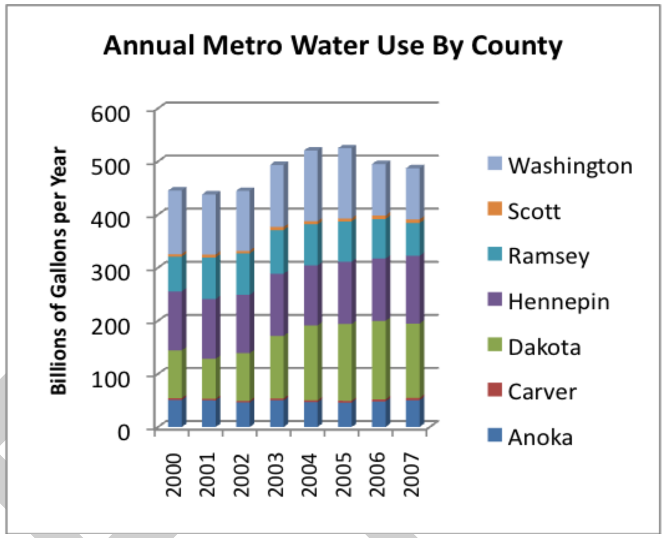


Figure 16. Metro area source withdrawals, 2001–2007.

(Data from Hunt 2003, 2005, 2007, 2009.)

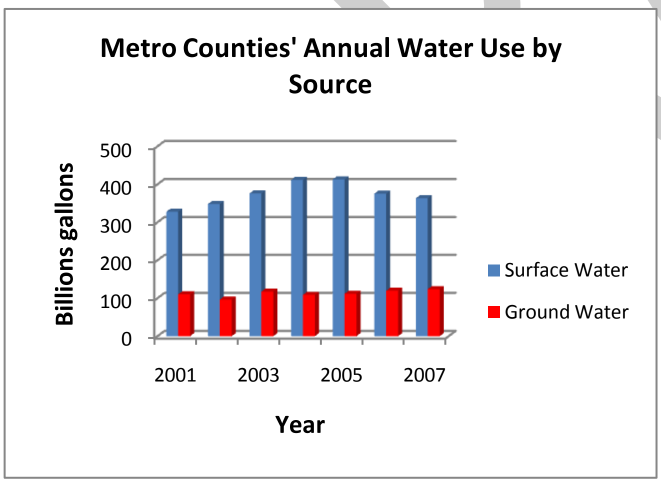
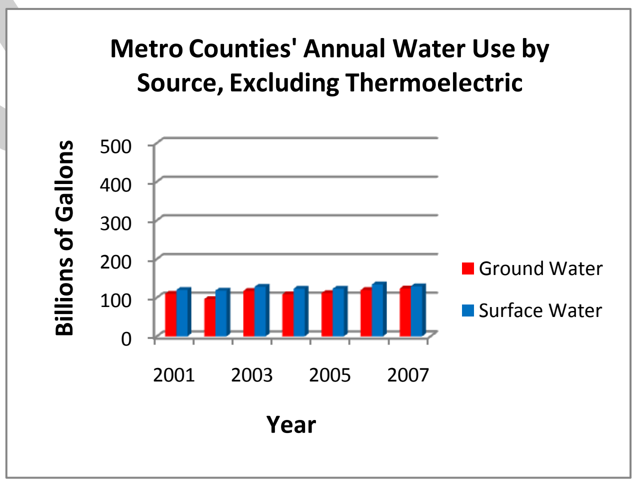


Figure 17. Metro area source withdrawals excluding thermoelectric 2001–2007.

(Data from Hunt 2003, 2005, 2007, 2009.)

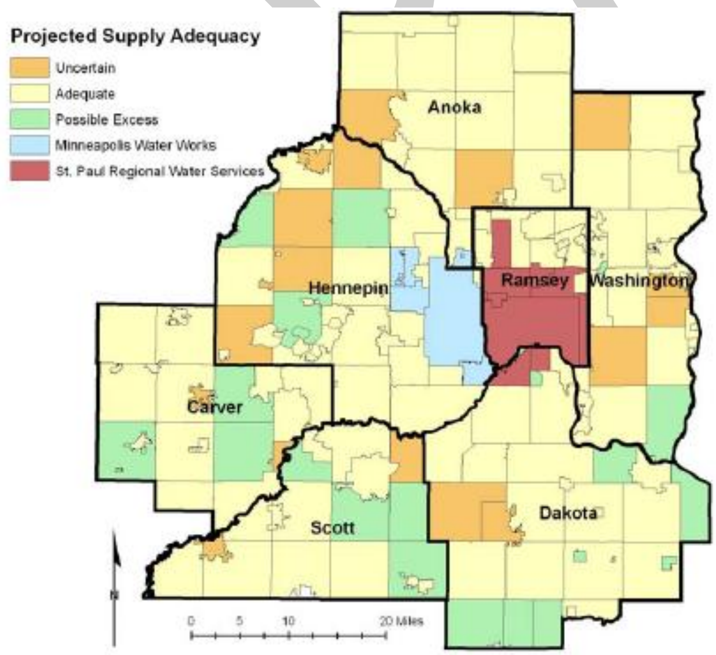


b. Projected. Compared to 2004, the Twin Cities metro area population is expected to increase about 33% by 2030, and about 60% by 2050 (Metropolitan Council 2007a, 2007b). The Metropolitan Council projected that related *municipal* water demands would increase about 27% by 2030, and about 52% by 2050. Projected municipal water use increases at a slightly lower rate than population growth based on the assumption that use of water-efficient appliances and general water conservation will increase in the future. *Total* water demand is projected to increase about 16% between 2004 and 2030, and 35% from 2004 to 2050. This projection incorporates expected increases in efficiency in domestic, commercial, and industrial uses, as well as reductions in withdrawals associated with once-through cooling, quarry dewatering, and agricultural uses during this period (Metropolitan Council 2007a, 2007b).

Based on these projections and estimates of available renewable supply, the Metropolitan Council found that 143 of 161 communities in the metro area are likely to have adequate supplies to meet their needs through 2030, with 23 of these communities likely having excess supply (figure 18). This is acknowledged to be a preliminary evaluation; further research is suggested in order to increase understanding of sustainability issues such as aquifer recharge and contamination, groundwater–surface water interactions, surface water contamination, low-flow impacts on availability, and well interference. Once again, thermoelectric use is not included in these estimates (Metropolitan Council 2007a, 2007b).

Figure 18. Projected adequacy of local supplies in 2050

(source: Metropolitan Council 2007a.)



VanBuren (2007) projected that metro counties will use a higher proportion of their renewable resources than will other Minnesota counties in 2030. Estimates of net (nonconsumptive) use as a percent of renewable supply for each metro county were: Anoka, 60%; Carver, 23%; Dakota, 99%; Hennepin, 99%; Ramsey, 177%; Scott, 43%; Washington, 172% (figure 12). When looking at gross (consumptive and nonconsumptive) use, the average metro county was projected to be using 229% of its renewable resource in 2030 (figure 13).

D. Uncertainties

The nature of the data makes a number of uncertainties inherent to this analysis. Among them:

- As has been stated above, consumptive use estimates are no longer provided in the USGS reports. Return flows from various uses may have altered composition or temperature. There is noted uncertainty related to consumptive use estimations when made on a category and statewide scale (Hutson 2004). As such, recent consumptive use estimates at such scales are difficult to obtain.

- Consumption related to thermoelectric use is often omitted from quantifications due to its being deemed largely nonconsumptive. However, given that recirculation cooling consumes a much higher proportion of the withdrawn water than does once-through cooling, and that recirculation cooling is becoming more common for new facilities, the nonconsumptive presumption regarding thermoelectric use should be examined. Note that the Metropolitan Council did not include thermoelectric use in its estimates (Metropolitan Council 2007b).

- Estimates of self-supplied domestic withdrawals are based on estimates of per capita use and total population not obtaining water from a public supplier, which could be subject to some error. This estimate amounts to about 2% of total Minnesota use (Kenny et al. 2009), however, so uncertainty in this category does not create as much overall uncertainty as does thermoelectric uncertainty.

- Different estimation methods used by different organizations also add uncertainty, especially when comparing information from different sources. As stated previously, the DNR includes mining withdrawals in the category of industrial processing, whereas the USGS lists mining as a separate category. The DNR does not include self-supplied domestic withdrawals or other withdrawals that do not require a permit in its reports, whereas the USGS does.

- Water needs for ecological services may need greater consideration to define flows necessary for maintenance of biological communities and the physical characteristics of water bodies.

- Estimates of future human demand for water entail uncertainty related to potential increases in efficiency and changes in use habits.

- Water supply estimation has acknowledged uncertainties. Increased understanding and characterization of Minnesota's glacial aquifers, aquifer recharge, and groundwater–surface water interactions would improve confidence in water supply estimations.

- Impacts of long-term climate change and of normal variations in precipitation and temperature on water use and water supply add to the uncertainty in estimating how much water we will have and how much we will need.

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Appendix A. Glossary

Aquaculture water use - water use associated with raising organisms that live in water (e.g., finfish and shellfish) for food, restoration, conservation, or sport. Aquaculture production occurs under controlled feeding, sanitation, and harvesting procedures primarily in ponds, flow-through raceways, and (to a lesser extent) cages, net pens, and closed-recirculation tanks.

Commercial water use - water use by motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from publicly supplied sources, such as a county water department, and self-supplied sources, such as local wells. Some commercial use estimates include public supply deliveries to golf courses.

Consumptive use - (1) the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment (USGS); (2) water withdrawn that is not directly returned to its original source. Under the second definition, all groundwater withdrawals are consumptive unless the water is returned to the aquifer from which it was obtained. Surface-water withdrawals are considered consumptive if the water is not directly returned to the source so that it is available for immediate further use (DNR).

Domestic water use - water used for indoor household purposes(e.g., drinking, food preparation, bathing, washing clothes and dishes, flushing toilets) or outdoor household purposes (e.g., watering lawns and gardens). This term can refer solely to self-supplied domestic water, or it may include both publicly supplied and self-supplied water used for domestic purposes.

Hydroelectric power water use - classified as an instream use, refers to the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

Industrial water use - water use for fabrication, processing, washing, and cooling, in such industries as steel, chemical, paper, and petroleum refining. The DNR includes mining in this category, whereas the USGS distinguishes mining as a separate category.

Instream use - the use of freshwater in situ (for example, within a river or stream). This can include recreation, tourism, scientific and cultural uses, ecosystem maintenance, hydroelectricity and commercial activities, and dilution of waste. The volume of water required for most instream uses cannot be quantified, with the exception of hydroelectricity generation.

Irrigation water use - water application on land to assist in plant growth in agriculture and horticulture or to maintain plant growth in land used for recreation or other purposes, such as parks, golf courses, and cemeteries. Irrigation also includes water applied for pre-irrigation, frost protection, application of chemicals, weed control, field preparation, crop cooling, harvesting, dust suppression, or leaching salts from the root zone, and water lost in conveyance. Irrigation water use includes self-supplied withdrawals and deliveries from irrigation companies, irrigation districts, cooperatives, or governmental entities.

Livestock water use - water use for livestock watering, feedlots, dairy operations, fish farming, and other on-farm needs. Livestock water uses include cooling of facilities for animals and animal products such as milk, dairy sanitation and wash-down of facilities, animal waste disposal, and incidental water losses. All withdrawals are considered self-supplied. The livestock category excludes on-farm domestic use, lawn and garden watering, and irrigation.

Mining water use - water use for the extraction of minerals in the form of solids, such as coal, iron, sand, and gravel; liquids, such as crude petroleum; and gases, such as natural gas. The category includes quarrying, milling (crushing, screening, washing, and flotation of mined materials), reinjecting extracted water for secondary oil recovery, and other operations associated with mining. Dewatering is not reported as a mining withdrawal unless the water was used beneficially, such as dampening roads for dust control.

Offstream uses - uses in which water is removed from its source by pumping or diversion.

Other uses - includes water withdrawn for activities including air conditioning, construction dewatering, water level maintenance, and pollution confinement

Public supply - surface water and groundwater distributed by community suppliers for domestic, commercial, industrial, and public users. Depending on context, this term connotes either a source (e.g., publicly supplied domestic vs. self-supplied domestic) or a use (e.g. water appropriated for public suppliers vs. that appropriated for self-supplied industrial use).

Public-supply delivery - delivery of water from a public supplier to users for domestic, commercial, industrial, thermoelectric power, or public use.

Public-supply water -water withdrawn by public and private suppliers that furnish water to at least 25 people at least 60 days per year or have a minimum of 15 connections. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power, and public water use.

Public water use - use of water from a public supplier for purposes such as firefighting, street washing, flushing of water lines, and maintaining municipal parks and swimming pools. Generally, public water use is not billed by the public supplier.

Thermoelectric power water use - use of water in thermoelectric power generation. Power plants that burn coal and oil are examples of thermoelectric power facilities. Most water withdrawn by thermoelectric plants is used for condenser and reactor cooling. Thermoelectric cooling systems can be "once-through cooling" or "recirculation" systems. In **once-through cooling systems,** also known as open-loop systems, water is withdrawn from a source, circulated through heat exchangers, and then returned to a body of water at a higher temperature. The USGS has estimated that less than 3% of water used in these systems is consumed. In **recirculation (closed-loop cooling) systems,** water is withdrawn from a source, circulated through heat exchangers, cooled, and then recycled. Subsequent water withdrawals for a closed-loop system are used to replace water lost to evaporation, blow-down, drift, and leakage.