Domestic Use
Technical Work Team Report

Minnesota Water Sustainability Framework
January 2011

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A. Key Findings

- Drinking water, stormwater, wastewater, and their impacts are interconnected, so they should be discussed and managed together.
- We need more information to assess relative costs and benefits of groundwater and surface water protection at the contaminant source versus treatment at the point of withdrawal.
- Domestic water conservation is hindered by the value placed on green lawns and gardens, economic factors, development and zoning practices, and decaying water infrastructure.
- Research is needed on issues related to potential stormwater and wastewater reuse.
- Increased infiltration due to stormwater BMPs may harm groundwater.
- The Safe Drinking Water Act and the Clean Water Act are insufficiently coordinated
- We need to manage domestic water use in the face of uncertain future conditions, including emerging contaminants, emerging technology, changing demographics and land use, climate change, economic uncertainty, and aging infrastructure.
- Behavior change is key to reducing human impact on water quantity and quality.
- Funding needs related to domestic water use is a challenge.
- Public perception of unlimited water resources impedes sustainable management.
- We have insufficient information to deal with situations in which water limits development.
- There is a need to balance costs and benefits of various degrees of water resource protection.
- Regulation of domestic water use by multiple agencies has benefits and challenges.
- Contaminants of emerging concern are an issue for drinking water and wastewater treatment.
- Climate change has implications for water quantity and quality and treatment infrastructure.
- Water treatment both uses and creates energy sources.
- Multiple funding sources are available for protecting water systems from terrorism.
- Private and rural drinking water systems need continued attention to ensure safe supplies.
- We need to shift from problem-based wastewater management to a comprehensive sustainability plan.
- A number of legislative and regulatory expectations surrounding wastewater management.
- With most wastewater treatment facilities approaching the end of their useful life, the cost of maintaining wastewater infrastructure is a looming issue.
- Wastewater management is inadequate in many unsewered areas.
- Sustainable wastewater management will require vision and priorities.
- Wastewater-related challenges and opportunities include energy costs and production opportunities, nutrient management costs and opportunities, contaminants of emerging concern, and water reuse.

- Flexible stormwater regulation would improve our ability to meet water resource objectives.
- The TMDL system has room for improvement.
- Enforcement of stormwater regulation compliance could be improved.
- Adoption of BMPs related to agricultural stormwater runoff could be improved.
- Education, incentives, and regulations are key to conserving, protecting, and restoring Minnesota's water resources.

B. Introduction

The domestic use technical work team was charged to develop a white paper on domestic water use in Minnesota for the Minnesota Water Sustainability Framework synthesis team to use in making policy recommendations. Domestic water use as defined here includes three separate but interrelated issues: drinking water, stormwater, and wastewater. This white paper discusses the following items: what we know about domestic water use, gaps in what we know, and issues to be addressed in the framework.

The team consisted of 35 members in three subteams (drinking water, wastewater, and stormwater). Team members came from academia, consulting groups, state agencies, watershed management organizations, municipalities, nongovernmental organizations, and private citizens (Appendix A). While most were from the Twin Cities metropolitan area, members also came from Duluth, Moorhead, Bemidji, and Mankato. The team met five times. The general process was to brainstorm issues, prioritize them, and then draft and refine narratives for each of the priority issues. A typical meeting consisted of a large group review of goals and progress, subteam breakouts to discuss the issues and narratives, a reconvening of the large group to share results and discuss cross-cutting issues. In addition, a considerable amount of time was spent outside the meetings, drafting and reviewing the narratives.

A good starting point for the discussion of domestic water use is a modified hydrologic cycle that specifically considers drinking water, wastewater, and stormwater and their interactions with each other and with surface and groundwater resources (Figure 1). Drinking water comes from surface water, groundwater, or both, and eventually is discharged to surface water (large municipal systems) or shallow groundwater (septic systems) as treated wastewater. Stormwater runoff is often routed to surface waters, but may be infiltrated to groundwater aquifers by some stormwater best management practices (BMPs) such as rain gardens, pervious pavements, and vegetated swales.

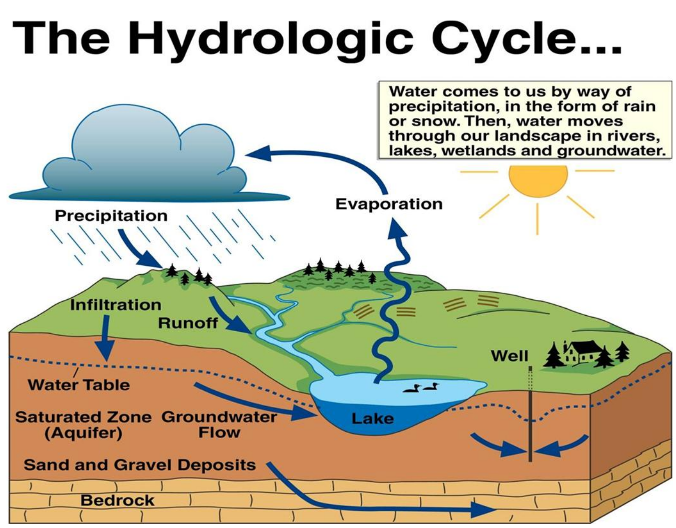

Figure 1.
Wastewater, stormwater, and drinking water all connect to each other and to other parts of the hydrologic cycle. (DNR, n.d.)

Because groundwater and surface water are interconnected, stormwater runoff, wastewater discharges, and drinking water production, which influence the quantity and quality of surface and groundwater resources, are also interconnected.

Human activities, including stormwater and wastewater management, may harm or benefit surface water quality and quantity. For example, wastewater discharge helps sustain surface water quantity. Contaminants discharged into surface waters via wastewater, however, may degrade water quality. Similarly, stormwater infiltration benefits surface water because it can reduce peak flows and flooding and can reduce contaminant loading in comparison to direct discharge via a sewer system. However, groundwater quality may be adversely impacted if the stormwater is polluted and the contaminants are not removed by the BMP or soil before the infiltrated water reaches an aquifer.

Vulnerability of groundwater to impacts from land surface activities varies considerably across Minnesota (Figure 2). Some areas, such as the karst region of southeastern Minnesota, the central sands region, and fractured bedrock areas in the northeast, have aquifers that are particularly susceptible to contamination from surface activities (Porcher 1989).

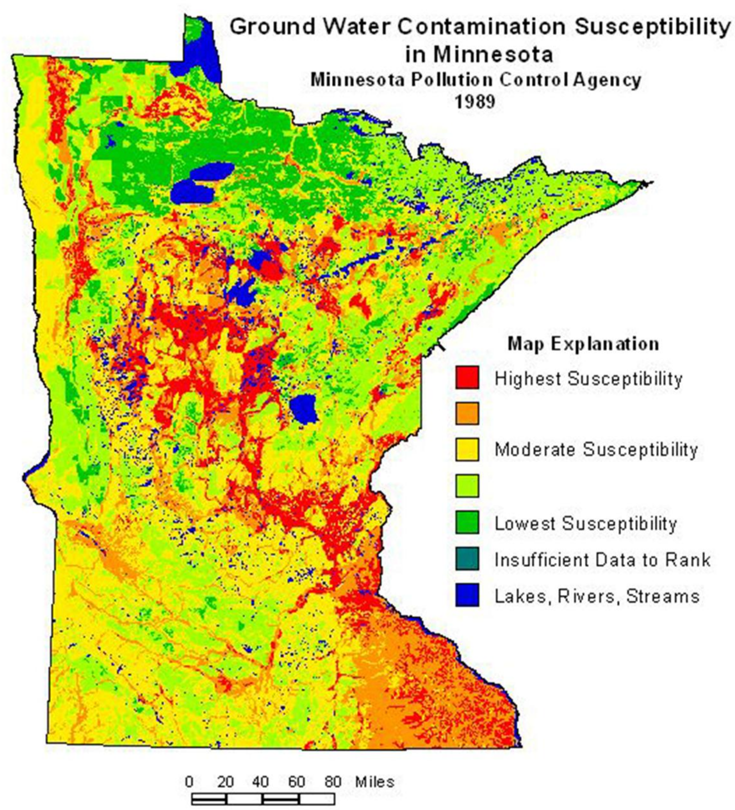

Figure 2.
Susceptibility of Minnesota groundwater to contamination (Porcher 1989)

Just as water resources are interconnected, their management involves a number of interconnected factors that influence both quantity and quality. It is important to consider local and regional relationships between ground and surface water when evaluating land- and water-use practices that may influence these water resources. The dynamic interplay between surface water and groundwater may be influenced by human activity such as pumping from high-capacity wells or large-scale infiltration of stormwater. *Whenever our activities influence the interaction between surface water and groundwater, there can be drinking water supply and environmental/ecological impacts* (Minnesota DNR 2000).

This interconnectedness raises complex management questions, such as whether generators of contaminants or downstream users of water should bear the costs and responsibilities for removing water contaminants associated with human activities. For example, discharges of stormwater or wastewater upstream or up gradient of a drinking water system intake can affect the extent of treatment needed to provide safe drinking water. In addition, the use of chemicals and other treatments to meet Safe Drinking Water Act (SDWA) regulations may lead to violations of the Clean Water Act (CWA). For example, phosphorus added to drinking water to reduce corrosion in distribution systems may result in higher levels of phosphorus in wastewater, creating a challenge for the wastewater treatment plant or the potential for eutrophication if the phosphorus is not removed. *We need more information to assess the relative costs and benefits of groundwater and surface water protection at the contaminant source versus treatment at the point of withdrawal.*

In summary, drinking water, stormwater, and wastewater and their potential impacts on water resources are strongly interconnected. Thus, they should be discussed and managed together.

Issues relevant to domestic use of water in Minnesota are shown in Figure 3 and discussed below. No attempt was made to rank issues, and the order in which they appear is arbitrary.

Figure 3. Domestic water use issues

Cross-cutting Issues
Conservation and Reuse
Water Quality
Managing for Uncertainty
Behavior Change
Funding Needs

Drinking Water Issues
Water Availability and Water Resource Management
Development/Economic Issues
Regulatory Issues
Contaminants of emerging concern
Climate Change Impacts on Water Supplies
Energy Demand and Byproducts of Water Treatment
Water System Security/Terrorism
Private and Rural Drinking Water Supplies

Wastewater Issues
Paradigm Shift to Sustainability
Public, Legislative and Regulatory Expectations
Infrastructure Challenges

Stormwater Issues
Stormwater Regulatory Issues
Best Management Practices
Vision and Priorities
Agricultural Stormwater Runoff

C. Cross-cutting Issues

1. Conservation and Reuse

Water conservation is normally associated with arid areas. As Minnesotaĉs population grows, conservation will become an important component of water sustainability. Conservation is hindered by the perceived abundance of water in Minnesota. Conservation also is hindered by the value citizens place on green lawns and gardens, economic factors, development and zoning practices, and decaying water infrastructure (discussed below). Complementary to conservation is water reuse. The more we reuse stormwater and wastewater, the less water needs to be withdrawn from aquifers and surface water and treated to drinking water standards.

a. Conservation. The value Minnesotans put on lush, green bluegrass lawns has a tremendous impact on domestic water use. On an average to peak day, Minnesota communities use roughly 2.6 times more water during summer than winter (Minnesota DNR 2007). In the Twin Cities metro area, outdoor water use, mostly of lawn watering, accounts for 20% ï 30% of total annual public water supply use

(Metropolitan Council n.d.). Use of potable water for lawn watering means that high-value water is being used for a relatively low-priority purpose. To meet increased summertime demand, many communities must add wells and associated infrastructure. And water use conflicts between private well owners and public water suppliers sometimes arise from this summer peak demand.

Many Minnesota communities have or are adopting topsoil and planting requirements for new development. Use of grass species other than Kentucky bluegrass can result in up to 50% water savings (University of Missouri Extension 2010). Adding topsoil, particularly on sandy soils, can significantly reduce lawn watering requirements. U.S. Environmental Protection Agency (EPA) estimates that increasing soil organic matter 1% increases water absorption capacity 16,000 gallons per acre (Minnesota DNR 2007). *Incentive programs could help encourage yard and garden site preparation and species selection practices that facilitate water conservation*.

Water utilities sell water for profit. Reduced consumption lowers profits, an obstacle to conservation. Additionally, the cost of water in Minnesota is so low that it has only a minimal impact on many citizens and businesses. *Water pricing policies in Minnesota offer a possible route to improving water conservation.* A recent study in Florida found that use of an increasing block rate structure and increasing rates by 40% resulted in a 17% decrease in water use (Southwest Florida Water Management District n.d.). Finally, current water infrastructure only allows us to use high-quality drinking water for all uses, whether that be drinking, washing cars, or watering lawns. The cost of installing a nonpotable water supply is a significant barrier to change. *Nevertheless, a thorough investigation of (waste)water reuse is needed to see which options are practically and economically feasible in Minnesota.*

Standard suburban lot development zoning (requiring large minimum lot sizes) results in large lawns that drive increased summertime water use. *Conservation developments with smaller lots and common green spaces lend themselves to conservation practices such as stormwater reuse for watering. Policies can help promote such practices.*

Finally, infrastructure in many older communities is failing, causing drinking water or raw sewage to leak into the ground. *Such aging infrastructure issues need to be addressed.*

b. **Reuse.** *Stormwater reuse* refers to the capture of stormwater runoff from impervious surfaces, such as a roof, in a pond, rain barrel, or other storage facility and subsequent use, typically for irrigation. Many pollutants are removed by sedimentation in the storage facility, filtration through the soil, and uptake by soil microbes. Stormwater reuse typically requires installation of pumps and pipes and is potentially expensive. Systems must be inspected and maintained to ensure reliable function. In a cold climate the system must be shut down for winter. And stormwater runoff can contain pollutants. There is some concern about spreading pathogens through spray irrigation or contaminant buildup in the soil (particularly if used on playgrounds or ballfields) due to the reuse.

Wastewater reuse refers to rerouting treated wastewater for beneficial use, typically irrigation of commercial properties (e.g., golf courses). Concerns include exposure to pathogens, soil contamination, and eutrophication of surface waters. Of particular concern is the potential for clogging resulting from the presence of particles and nutrients that lead to growth of bacteria and biofouling. Logistics are also an issue (e.g., needing to pump and pipe water to irrigation sites).

We lack sufficient research on stormwater and wastewater reuse in Minnesota, particularly facility design, infrastructure costs and maintenance, public health risks of pathogens and soil contamination, and environmental risks from release of nutrients.

2. Water Quality

Surface waters are protected by the CWA and amendments. The CWA sought to ensure that all U.S. waters were fishable and swimmable by 1983. It largely succeeded at limiting inputs of major contaminants such as suspended solids and oxygen-demanding substances to waterways via municipal wastewater discharges and at limiting discharge of hazardous contaminants in industrial wastewater. Still, challenges remain. One is nonpoint-source pollution (urban/suburban stormwater and agricultural runoff). Another is the presence of trace organic pollutants, such as pharmaceutical compounds. CWA regulations largely ignore the water quality needs of drinking water suppliers, although they have helped water utilities by enhancing some water quality measures.

ñSource water protectionò refers to programs or practices intended to limit contaminants entering public drinking water supplies. The SDWA requires source protection to address both surface waters and groundwater (MDH n.d.). The 1986 amendments to the SDWA require states to have wellhead protection programs (MDH n.d.) to protect public water supply wells. The 1996 amendments to the SDWA require states to produce source water assessments for all public water systems (MDH n.d.). They also encourage surface water suppliers to develop source water protection plans. The plans are voluntary; Minneapolis, St. Cloud, and St. Paul are among the cities for which plans have been developed.

a. **Groundwater.** Groundwater contamination arises from a wide variety of sources, including improper waste disposal, chemical spills, leaking landfills, septic systems, and agricultural activities. There is some concern that infiltration BMPs such as rain gardens may facilitate transport of pollutants to shallow aquifers. Pollutants of concern for groundwater include pathogens, nitrate, and organic pollutants (e.g., pesticides, perfluorochemicals, and solvents). Groundwater contaminants may be transported to surface waters where they may adversely impact ecosystem services.

The Minnesota Groundwater Protection Act granted the Minnesota Department of Health (MDH) authority for wellhead protection in 1989. Wellhead protection (WHP) plans are developed and implemented to manage potential contaminant sources within public water supply well capture zones. Capture zones, called wellhead protection areas (WHPA), are designated for each public well. Zones are based on average water demands for public water supply wells using a minimum 10 years travel time (Minnesota Rules, Chapter 4720.5100-4720.5590). Wellhead protection plans are usually implemented and adopted through or by the local zoning authority or unit of government. The WHPA may or may not be within the zoning authority of the public water supply. Wellhead protection plans rely on voluntary cooperation between the zoning authority with jurisdiction and the local water supplier. *One significant concern is that economic development opportunities can persuade the zoning authorities to abandon or amend established WHP plans.*

Demand for groundwater increases during long-term drought, so groundwater capture zones expand during extended drought due to the increased pumping and may extend beyond WHP boundaries. *Current WHP plans are limited in their ability to protect groundwater resources during a drought. Furthermore, excessive pumping of groundwater could impair the quantity and quality of nearby surface waters.* Ensuring sustainable drinking water supplies under all conditions, including long-term drought, requires WHP plans that account for such extremes. Adequate protection of groundwater will require region-wide planning with input from citizens and local, state and federal units of government (Minnesota DNR 2010).

b. Surface water. Surface water can be hard to protect. Watersheds upstream of drinking water intakes can be under multiple units of government, and *it can be difficult to obtain cooperation of all of them to achieve surface water quality goals.* Pollutant sources are diverse and include municipal and industrial wastewater, stormwater, agricultural runoff, and atmospheric deposition. Pollutants include solids, pathogens, organic chemicals, nutrients, and heavy metals.

Drinking water suppliers must provide water that meets federal and state regulations. Drinking water utilities face a number of source water protection issues. *One is the lack of coordination between the SDWA and the CWA.* Contaminants that are not allowed in drinking water may be discharged into surface waters that serve as drinking water supplies. A related issue concerns controlled intermittent discharges of waste into surface waters that supply drinking water. Such discharges could expose consumers to contaminants, including hazardous chemicals and pathogens, and affect taste and odor. *Drinking water* *suppliers are not always notified when such intermittent wastewater discharges will occur so they can adjust their treatment systems, if necessary.*

The federal Municipal Separate Storm Sewer (MS4) program is designed to reduce surface water pollution from storm sewers. MS4s that discharge into designated ñspecial watersò and ñimpaired watersò require additional runoff controls and BMPs (MPCA n.d.). *However, data are insufficient to demonstrate the long-term efficacy of BMPs, especially in cold climates such as Minnesota, and funding for BMP testing and implementation is insufficient.*

c. Summary. Some work team participants expressed concern over what appears to be insufficient coordination among regulatory agencies and a lack of a holistic perspective. Regulations that limit stormwater and wastewater pollutant discharge do not adequately consider potential impacts on ecosystem services, recreation, and drinking water suppliers. A holistic ñno adverse impactò condition is not fully considered across state regulatory agencies or across interstate or international boundaries.

3. Managing for Uncertainty

Water management occurs in the context of uncertain future conditions. Issues include contaminants of emerging concern, emerging technologies and innovative management, changing demographics and land use, climate change, economic uncertainty, variable regulatory direction and support from elected officials, and aging infrastructure.

a. Contaminants of emerging concern. Recent advances in analytical techniques allow detection of contaminants not previously observed. Contaminants of emerging concern now known to be in water include estrogens and estrogen mimics, pharmaceuticals, personal care products, and perfluorinated compounds. Concerns include 1) for some contaminants, low concentrations can have profound effects (Kidd et al. 2007); 2) realization that such compounds are present in water could lead the public to distrust municipal drinking water supplies (Associated Press n.d.); and 3) the prevalence of antibiotics in water could lead to increasingly resistant strains of pathogens (LaPara n.d.). Key issues include identification and evaluation of sources, determination and communication of public health and ecosystem risks, determination of the most critical contaminants, and determination of best strategies for prevention or removal.

b. Emerging technology and innovative management. Approaches and technologies for addressing water issues have evolved rapidly in recent years. Some utilities are turning to advanced treatment options, including activated carbon, ozonation, ultraviolet (UV) light, and reverse osmosis. Low-impact design (LID, e.g., infiltration, bioretention, reuse) is being developed for stormwater management. Innovative management approaches such as pollutant trading, reuse of stormwater, and polluter pays could also impact stormwater management.

Wastewater management is shifting toward delivering resources to the environment and for human activities. Such new approaches and technologies can improve sustainability of water resources. However, they are expensive, are not viable in some situations, and could have unintended adverse effects, including increased energy demand and CO_2 emissions (Oliver et al. 2007), residuals disposal, cost, and movement of pollution downstream or into groundwater.

c. **Changing demographics and land use.** Development is shifting from exurban growth to infill development and redevelopment (sometimes on brownfield sites) in urban areas. This brings a different set of water issues. Greater population densities in the urban core will result in increased water use and wastewater generation in a smaller area. Infill development can lead to increased impervious surfaces and stormwater runoff in limited space. Brownfield development creates risk for mobilizing soil contaminants into groundwater and surface waters.

d. **Climate change.** Climate change has implications for water management, including:

(1) ***Water quantity.*** Decreases in snowmelt and spring streamflow and increasing summer water use due to higher temperatures are likely to exacerbate water shortages. Droughts will likely increase in frequency and duration. Increased intensity of summer rainfalls could render past stormwater designs inadequate. Interruptions to water supplies may occur.
(2) ***Water quality*.** Intense rainfalls and runoff will carry more contaminants to receiving waters (Patz et al. 2008). Inflow and infiltration may increase. More frequent freeze/thaw cycles trigger the use of more de-icing chemicals for public safety.
(3) ***Infrastructure.*** Flooding and tornadoes can threaten water supply infrastructure.

e. **Economic uncertainty.** Costs of infrastructure and treatment are becoming more difficult to predict. Construction costs vary widely based on global competition for raw materials. Operation and maintenance of facilities to meet higher levels of treatment are difficult to budget. The cost of energy and of chemicals used in treatment processes continues to fluctuate. Such uncertainties make it difficult for water managers to accurately budget capital improvement and operations.

f. **Aging infrastructure.** Aging wastewater treatment infrastructure is a concern, especially for communities with pipes and tunnels dating to the 1860s or that that find it difficult to use user fees to replace aging infrastructure and also meet treatment and regulatory requirements. Compounding the issue is the uncertainty of the risk: What is the likelihood of failure? What would be the impact to the environment and to public health and safety? Many large sanitary and storm sewer systems do not have redundancy built into them. If a piece of the system fails, where would the water be rerouted during repairs? Moving forward with ñgreen infrastructureò initiatives alone is not enough. Underfunding proper care and maintenance of infrastructure systems already in place has incalculable public and ecological health implications.

To address these emerging and uncertain future conditions, policymakers, regulators, and water managers will need to be flexible, adaptable, and creative. Specific issues include:

(1) Some existing regulations may obstruct new approaches (e.g., pollutant trading, gray/recycled water reuse, artificial aquifer recharge) and get in the way of better solutions.
(2) We do not have standards in place to regulate and manage changing conditions such as more intense rainfalls and contaminants of emerging concern.
(3) We need to continue to identify and assess sources of contaminants of emerging concern.
(4) We donôt know which contaminants of emerging concern are of greatest concern, or the best strategies and technologies for preventing or removing these contaminants.
(5) The science of stormwater management is still catching up with regulatory goals and philosophy. For example, LID approaches are being required in new regulations, yet acceptable design standards and methods and expected pollutant removal efficiencies have not yet been developed, and risks of groundwater contamination due to increased infiltration of polluted stormwater have not been quantified.
(6) Monitoring is needed not only to assess water quality but also to assess and evaluate emerging technologies.
(7) We donôt know the economic benefits and costs of emerging technologies.
(8) We need to know more about deficiencies in sanitary and storm sewer tunnel systems.
(9) Asset management training and technical assistance could help utility managers prioritize improvements.
(10) Adequate loan and grant funding of maintenance, repair, and replacement of aging or failing infrastructure is important.

4. Behavior Change

Lack of public understanding of water sources and water and wastewater treatment is an impediment to water management and conservation. Not everyone knows where tap water comes from and where and how it is treated. Not everyone recognizes that all water contains naturally occurring minerals, anthropogenic contaminants, and bacteria, so issues of contamination are really issues of acceptable risk. The public is often unaware of or unwilling to acknowledge their effect on that risk (e.g., by flushing prescription drugs). And the perception that water is infinitely available in Minnesota hinders conservation and leads to wasting drinking water for tasks such as lawn watering. *Behavior change is key to reducing human impact on water quantity and quality.*

To facilitate behavior change, a *three-tiered approach* typically is used. The first tier is *education*. The second tier involves *incentives* to promote desired behavior. Finally, when knowledge and incentives are not enough, *regulations and enforcement* can facilitate the desired behavior change. *Education, incentives, and regulations are key to conserving, protecting, and restoring Minnesota's water resources.* A number of formal and informal approaches exist, but *the scope is not sufficient. For behavior change to happen, education needs to take place at all levels, from individual citizens to large corporations and organizations. Education is important not only for individuals and households but for technical professionals, businesses, institutions, organizations, and governments as well.* The second tier for facilitating behavior change, incentives, could be offered to encourage water conservation or reuse. The third tier, regulation and enforcement, may include penalties for non-compliance.

5. Funding Needs

Driven by federal mandates, we are moving toward increasingly stringent and costly regulatory controls. Funding water-related needs can be a challenge. Issues and needs include:

a. There is no comprehensive reporting on the full extent of funding for water-related efforts.
b. There is no comprehensive reporting on the full extent of public investment in water-related infrastructure and improvements.
c. There is no comprehensive report on state agency staff allocations for water-related efforts.
d. There is little understanding of the investment of local staff time to water-related efforts.
e. There is no comprehensive strategic plan with short and long-range goals, action steps, and key milestones for water-related efforts. Priorities and projects frequently address only project or program goals.
f. Water-related research priorities and decisions have typically been set and made with limited knowledge and participation of significant stakeholders.
g. There is no forum for coordinated strategic planning that addresses all these decisions in a comprehensive manner.
h. There is no comprehensive process that lists all these decisions, and addresses the relationships and linkages among these decisions.
i. We need to identify and list all the water-related funding decisions.
j. We need to develop short- and long-term strategic goals.
k. We need to identify and list all funding sources.
l. We need to develop and describe a structure for making funding decisions that includes the public, key stakeholders, state agencies, and the Legislature.

m. We need to establish comprehensive reporting processes, structures, and protocols that address all water-related efforts (coordinated across all projects, programs, and agencies) and make funding decisions transparent and accountable.

D. Drinking Water Issues

1. Water Availability and Water Resource Management

Minnesota appears to have abundant water supplies. Thus, it is not surprising that the public generally believes we have unlimited water resources and balks at attempts to impose limitations. *This misperception, arising from a lack of knowledge regarding water resources, presents a significant impediment to conservation and sustainable water resource management.* In reality, some regions are deficient in water, and with growth and development, water supply conflicts have become more frequent in recent years (Leuthe et al. 2010). The Metropolitan Council has concluded that the rapidly growing Twin Cities metropolitan area sits in the midst of abundant, though limited, groundwater and surface water supplies (Metropolitan Council 2010). *However, water supply conflicts have developed and adverse ecological impacts have already been measured in numerous parts of the state. Unfortunately, Minnesotans typically do not see the connection between their actions and water availability and degradation.*

Minnesota Statutes, section 103G.261, lays out a priority system for water use. While domestic water supply is top priority, all public water suppliers also supply much lower priority users, such as commercial and industrial users, with the same system. That means at least part of the municipal supply drops down in the priority scale to the level of those users, below power production and agricultural irrigation. *Thus, there is a need to revisit this ranking system.*

We have historically managed water on a permit-by-permit basis, thinking that if we could manage each well or withdrawal site, the whole system would be fine. Weøve learned this doesnøt work because of the complexities of hydrogeological systems and the interconnectedness of water resources. *We need a more comprehensive monitoring system with more frequent (near real-time) and spatially dense water level and flow measurements and accurate and calibrated groundwater flow models in order to develop a holistic water resource management plan to ensure the sustainability of water resources.*

Insufficient information on surface waters and aquifers limits our ability to accurately assess water availability and the impacts of our actions (EQB 2008). Every water appropriation or storm/wastewater discharge impacts ecological services in some way. The issue is how much of an impact is acceptable to society. *Research is needed to characterize the tipping points for ecological systems so we can avoid driving a system to that point.*

2. Development/Economic Issues

Availability of water has rarely been a limiting factor to growth over most of Minnesota.

With the continuing increase in population and a steady increase in groundwater withdrawals for irrigation and certain industries in rural areas, however, insufficient water supplies may limit development and growth in some areas. Options to be considered when water is the limiting factor for development include: (1) importing water, (2) applying conservation practices to reduce demand, (3) reusing water, and (4) collecting stormwater for irrigation. *We have insufficient information concerning the feasibility and safety of these various options in Minnesota.* For example, collected stormwater cannot be used for spray irrigation in Minnesota without treatment because of concerns over human exposure to pathogens or other contaminants, even though health risks of doing so have not been thoroughly investigated. When these options fail for technical or cost reasons, water availability should limit development. *Water resources should not be stressed beyond sustainable levels simply for the sake of development.*

There is also a need to carefully consider the appropriate balance between the costs and benefits of protecting water resources. For example, achieving zero contamination or no impact on an ecosystem might cost much more than allowing even a very low level of contamination or impact. If the costs of protecting water resources are too high, new development could be inhibited and the local economy may suffer. These trade-offs must be carefully considered when making water management decisions. Key questions are, ñWhat level of impact is sustainable and acceptable to the public?ò and ñHow can technical information and public opinions and values inform policies and regulatory tools that ensure the sustainability of water resources without significantly disrupting the economic well-being of local communities and the state?ò

3. Regulatory Issues

Several agencies have unique roles and perspectives in water supply oversight and planning in the state. MDH ensures compliance with the SDWA and State Well Code (Minnesota Rules, chapters 4720 and 4725). Public water suppliers are responsible for providing a reliable water supply at the tap that meets SDWA requirements through treatment and/or source water protection (MDH 2009). Other entities involved in various aspects of water quality and quantity management include the Minnesota Pollution Control Agency (MPCA), Minnesota Department of Agriculture, Minnesota Board of Water and Soil Resources (BWSR), watershed districts, counties, and soil and water conservation districts. The Department of Natural Resources (DNR) manages water resources to ensure an adequate supply to meet long-range seasonal requirements (Minnesota Statutes, sections 103G.265, 103G.271, and 103G.291). In the Twin Cities metro area, the Metropolitan Council is responsible for planning for long-term water supply needs and reviewing local water supply plans (Minnesota Statutes, sections 473.1565 and 473.859).

Multiple agency involvement in water supply management allows agencies to be more responsive to specific issues. *It also creates a lack of continuity in assessing and addressing water quantity and quality needs.* For instance, one player might promote infiltration of stormwater runoff that could harm groundwater that is the water source for a public water system. Another example is development of separate water supplies in adjacent communities where a more efficient approach would be a single common water system. *A comprehensive approach would consider the impacts of current and future land use, projected water demands, stormwater management, and groundwater quantity and quality, and facilitate interjurisdictional cooperation.*

Another issue is that conflicts may arise when attempting to meet both SDWA and CWA requirements. For example, addition of orthophosphate to meet the lead and copper rule increases phosphorus loading to the wastewater treatment plant. And when water is treated to remove radium from potable water supplies, treatment residuals containing the radium typically are discharged to local surface waters. Finally, infiltration of stormwater to meet CWA requirements may contamination groundwater and create problems for meeting the SDWA requirements.

4. Contaminants of Emerging Concern

Recent analytical advances have allowed detection of previously unobserved organic contaminants in water, including estrogens and mimics, pharmaceuticals, personal care products, and perfluorochemicals. Concerns about these include 1) many are designed to elicit a biological response, and in some cases low concentrations can have profound effects (e.g., Kidd 2007), and 2) there is concern that the realization that such compounds are present in water supplies may lead the public to distrust municipal drinking water supplies (Associated Press n.d.). Both drinking water and wastewater treatment facilities face issues regarding contaminants of emerging concern. The following summarizes these issues from a drinking water perspective.

a. **Source identification.** Treated municipal wastewater (Kolpin et al. 2002), industrial wastes and wastewaters (Lundgren and Novak 2009, MPCA n.d.), landfills (Barnes et al. 2004), confined animal feeding operations (Campagnolo et al. 2002), stormwater, and runoff from fields irrigated with treated wastewater/fertilized with sludge are potential sources of contaminants of emerging concern (Topp et al. 2008, Pedersen et al. 2005). Other sources, such as septic tanks, are not well characterized (Conn et al. 2006). The relative importance of these sources in terms of the total loads and impacts on drinking water sources is not known. Although MDH has received Clean Water Fund money to develop human health exposure limits, there is a need to expand research on the public health implications of such chemicals in drinking water.

b. **Critical contaminants.** It is unclear which of the hundreds contaminants of emerging concern are of greatest concern. Risk may be driven by a few potent compounds, or it may be easier to treat the entire class together. Effects on humans is an active area of research.

c. **Removal and perception.** While drinking water treatment removes organic contaminants, there is evidence that some compounds persist through treatment (Associate Press n.d., Snyder and Benotti 2010, Rosario-Ortiz et al. 2010). One question is whether their presence poses a real or even perceived risk. Another is whether it is better to upgrade treatment drinking water treatment or reduce discharge by enhanced wastewater treatment (Hollender et al. 2009) or regulation (Minnesota House of Representatives 2010).

d. **Pathogens.** U.S. public water supplies are largely free of disease-causing microorganisms. Nevertheless, waterborne disease may occurð for example, because organisms are resistant to disinfection via chlorine, or because they break through filters. In addition, a growing number of individuals are immunocompromised (NRC 2004), so the frequency of harm from waterborne disease is likely to increase. Pathogens such as viruses occur not only in surface water, but also in private (Borchardt et al. 2003) and public wells (Borchardt et al 2004). *Research is needed to determine the occurrence of pathogens in surface water and groundwater and the risk they pose. Groundwater is of particular concern because it typically receives little to no treatment.*

5. Climate Change Impacts on Water Supplies

Climate change is causing rising surface temperature, melting ice and snow, rising sea levels and increasing climate variability. These global phenomena are highly likely to cause wide fluctuations in regional and local climate. Extreme events such as floods, droughts, and tornadoes can impact water supplies and water treatment facilities. *As extreme weather events become more frequent, water systems need resiliency and capacity to handle them in order to ensure a safe and reliable supply of drinking water.*

a. **Water quantity.** Changes in precipitation, decreases in snowmelt and spring streamflow, increasing water demand, and increasing average temperatures are likely to exacerbate water shortages (Patz et al. 2008), particularly in areas already facing shortages, such as metro-west, west, central-west, and southwest Minnesota. During extreme drought, surface water suppliers may turn to groundwater, creating conflict with other groundwater users and adding stress to drinking water aquifers. Groundwater suppliers may look for new sources or be forced to activate seasonal and/or emergency wells that need additional treatment to meet standards.

b. **Water quality.** Change in streamflow and lake levels can affect water quality in many ways. Intense precipitation and runoff carry high levels of contaminants to water bodies. Extreme flows typically increase erosion, resulting in turbidity and pulses of pollutants that increase costs to produce safe drinking water (California Department of Water Resources n.d.). Flood flows may contaminate drinking water wells, interrupting water supplies and making it more difficult to produce safe drinking water. Drought and decreased river flows and lake or reservoir water levels affect water quality by promoting growth of microorganisms. This could result in greater concentrations of undesirable byproducts such as taste-and-odor compounds and toxins.

c. **Water treatment infrastructure.** Climate change could create a need for infrastructure upgrades to water treatment systems. Threats of flooding, severe storms, high-speed winds, and tornadoes mean that infrastructure may need to be made structurally more robust or relocated. Additional treatments will likely be required to handle possible water quality changes. Advanced treatment technologies such as ozone, UV light irradiation, activated carbon adsorption, or membrane filtration may be needed. These are not only relatively expensive but in some cases also energy intensive. *Thus, funds likely will be needed for water utility infrastructure improvement and possibly increased power generation capacity.*

d. **Planning for climate change.** Minnesotaõs water utilities have insufficient plans to handle the effects of a changing climate (Wallis et al. 2008**).** Also, not enough are members of MnWARN, a mutual aid program providing emergency assistance to water, wastewater, and stormwater utilities damaged by a disaster (www.mnwarn.org). Finally, not all water utility personnel are adequately training in the federal water sector incident command system.

6. Energy Demand and Byproducts of Water Treatment

To deal with emerging water quality issues, new regulations, and degradation of source water, some utilities are turning to activated carbon, ozonation, UV light, reverse osmosis, and other advanced treatment options. Such treatment options are expensive and have other potential adverse effects. *It is not clear whether the economic and ecological costs of these systems outweigh the benefits.* The following are a summary of the key issues on this topic.

a. **Energy demand.** Generation of ozone, use of UV light or membranes, and disposal/regeneration of activated carbon all require energy. Treating wastewater with advanced technologies may be economically and environmentally undesirable due to the increased energy consumption and the associated economic costs and CO_2 emissions (Jones et al. 2007).

b. **Residuals disposal.** Brines from membrane or ion exchange treatments are disposed of in sanitary sewers. Activated carbon is disposed of in landfills or regenerated (using energy). Thus, these advanced treatments move the pollution and (further) treatment costs ñdown the pipeline.ò

c. **Affordability.** For small communities, treatments needed to meet new regulatory guidelines (e.g., arsenic) may consume a significant portion of treatment budgets.

d. **Alternatives.** Enhanced treatment is just one means to deal with water quality problems. Another option is to find a new source of water.

Citizens should be aware of the economic costs and carbon footprint of improved treatments and the potential hazards of treatment byproducts. As water resources are stretched, utilities may need to think about using water supplies of marginal *quality and consider potential costs (both economic and ecological) of advanced treatment.*

7. Water System Security/Terrorism

Should Legacy Amendment dollars be spent on water/wastewater system security and anti-terror measures? In answering this question, other sources of funding deserve consideration. Congress provides funding to help states protect drinking water from terrorism. Nationally integrated and federally funded security groups provide utility operators information on security threats. Additional grants are available through The Homeland Security Grant Program (9/11 Act of 2007, Public Law 110-53). Examples are the State Homeland Security Program and the Urban Area Security Initiative. And public water systems bill customers for the water they use, so through budgeting and planning, they should be able to pay for security and anti-terror measures.

8. Private and Rural Drinking Water Supplies

a. Private supplies. *Approximately 23 percent of Minnesotans rely on privately owned and operated wells as their source of drinking water.* Private well owners are responsible for monitoring the quality of their water supply. This differs greatly from municipal or public water system users, where routine monitoring and management of the source of water and distribution system is required under the federal SDWA and state public water supply protection programs. Well water quality depends on the construction and depth of the well, how the well and land around it are managed, local geologic conditions, and potential contaminant sources in the area.

Private wells are often constructed in shallow unconfined aquifers, many of which are highly vulnerable to contamination. These aquifers may contain contaminants from multiple sources. *The number of private wells in Minnesota that are contaminated beyond safe levels is not known because these wells are rarely if ever tested after installation. Research is needed to determine the extent of contamination of private wells and the main causes, and to develop cost-effective approaches to prevent and/or treat the contamination.*

MDH regulates well construction via the state well code, designed to minimize drinking water contamination due to poor construction or placement. Well drillers must be licensed, construct wells according to code, and have the new well water tested for contaminants such as nitrate, fecal coliform bacteria, and arsenic. Still, many private wells are in use that were constructed prior to the well code or are subject to contamination due to poor management or changes in land use. Wells that do not meet code are more likely to have poor water quality than wells that do.

A variety of outreach and educational programs provide private well owners with information about their drinking water quality. The county water management plan program allows local staff and citizens to identify groundwater and drinking water protection as a priority, and allows agency staff and citizens to address land use issues impacting drinking water. MDA helps sponsor nitrate testing clinics. Over the last 17 years, more than 52,000 private well owners have had their water tested for contaminants. MDH also supports counties that wish to establish water quality monitoring networks and informs property owners about well construction and management. County staff provides information to help private well owners protect their wells. *We don't know the extent to which available information reaches private well owners. Research is needed to optimize and expand outreach and education for maximum impact.*

As the state becomes more urbanized, the challenge is not to lose sight of the fact that many Minnesotans will continue to obtain their drinking water from private wells. There is a need for ongoing coordination among state agencies and support for groundwater protection in rural areas. There is also a need for state and local agencies to continue to work together and support groundwater- and drinking water–related monitoring, protection, and education.

b. **Rural water systems.** Some rural areas lack shallow groundwater resources of sufficient quantity and quality to allow use of private wells. This has led to establishment of six rural water systems in northwestern and southwestern Minnesota. Five of the six systems obtain water from shallow unconfined aquifers vulnerable to contamination. Protection of these aquifers requires coordination among the rural water system, public agencies, and farmers. *There is a need to continue to protect vulnerable aquifers, including those used by rural water systems, especially where drinking water resources are limited. Educational programs and incentives may need to be expanded to encourage farmers to minimize the risk of contaminating these aquifers.*

E. Wastewater Issues

Achieving sustainable water quality and quantity over the next 25 years will require 1) adequate funding to address aging wastewater collection and treatment facilities to ensure that we donąt lose the gains we have made; 2) funding and education to help improve on-site and small community wastewater systems; and 3) a paradigm shift from point-source management to managing on an aquifer and watershed basis, including promotion of adaptive water quality improvement measures based on watershed needs over a one-size-fits-all approach.

1. Paradigm Shift to Sustainability

We need to shift from the current environmental legislative model to develop a comprehensive statewide water sustainability plan. Early federal legislation was typically generated by crises, leading to public outcry that addressed a specific issue and form of pollution. This mindset makes it difficult, if not impossible, to create a sustainable framework to protect, conserve, and enhance the quality and quantity of the stateąs groundwater and surface water without causing a severe impact on other limited resources whose sustainability is just as important. Sustainability requires a proactive, global perspective even at the local level.

Stakeholders must refrain from evaluating water quality problems from a narrow single perspective. Problems cross boundaries and can interact with land or air issues. However, each stakeholder competes for equally valuable resources (e.g. energy, funding) that must also be sustainable. The list of contaminants of emerging concern is growing daily, and the single-contaminant approach to legislation is unsustainable. Water quality problems can be solved one step at a time as long as all steps move toward the ultimate goal of water sustainability. Preserving this natural resource is paramount to overall protection of our ecosystems.

Agriculture has had a large impact on Minnesotaŝ physical environment: Less than 200,000 acres of the original 18 million acres of prairie remain; less than 2% of the original 2,000 square miles of Big Woods remain; and less than 10% of the stateŝ prairie wetlands remain. It is unreasonable to assume that these lands can be restored to their original use or that end-of-pipe point source solutions can solve the problems caused by such widespread land use changes.

2. Public, Legislative, and Regulatory Expectations

Minnesotansô support for clean water is evidenced by the passage of the Clean Water Land and Legacy Amendment. Federal and state programs update water quality standards based on new information. They are not required to consider whether new limits will have a measurable effect in the receiving waters during normal flow when the effects are masked by nonpoint sources of the same pollutants. This situation occurs because discharge limits are based on drought conditions. Regulators are also not required to look at the financial impact on wastewater dischargers of maintaining their current infrastructure or their ability to afford or finance upgrades associated with new standards.

Legislative directives do not always consider environmental benefits or financial costs when driven by ancillary political issues. At times the Legislature can create unnecessary mandates best left to the regulatory agencies. These mandates make it more difficult for communities to maintain current infrastructure, comply with state and federal rules/regulations, and provide affordable wastewater treatment rates to residents. Many communities cannot afford to do what is necessary to maintain infrastructure, let alone meet new legislative requirements. Wastewater effluent is a valuable resource; financial incentives established by legislation could be used to promote reuse.

Specific public, legislative, and regulatory expectations include:

a. **Wastewater quality and ecosystem health.** The regulatory expectation is to treat wastewater for an extreme condition (e.g., the seven-day minimum flow over a 10-year running average). Wastewater treatment is generally excellent, so further improvements in water quality in receiving water typically cannot be achieved by improved wastewater treatment.

b. **Water reuse.** This is an emerging issue for the state. Current regulations are based on California regulations, which potentially make them suboptimal for Minnesota. Questions that need to be resolved include: What are the incentives and drivers for water reuse? How do we justify water reuse given public aversion to the practice?

c. **Value.** The value of wastewater as a resource (i.e., as water for reuse or as a source of nutrients and/or energy) is generally not realized. There seems to be a disparity in the perceived value of wastewater between small and large communities.

d. **Development/demand.** In some cases, municipal development is limited by wastewater infrastructure.

e. **Cost of infrastructure.** The cost/funding of wastewater treatment is limited to that which meets minimum standards.

f. **Quality of infrastructure.** Wastewater treatment facilities must be designed by licensed professional engineers and operated by licensed operators to assure that infrastructure operates effectively and that the life of the asset is optimized.

g. **Trading.** The regulatory framework does not allow dischargers to trade discharge credits with others that can provide the same reductions at a cheaper price.

h. **Human health.** The expectation of wastewater treatment is that it not contribute to people getting sick when recreational activity is reasonable. This goal is largely satisfied. Other, indirect consequences of human health are generally not considered.

3. Infrastructure Challenges

a. **Sewered areas.** In the years following passage of the CWA, wastewater collection and treatment improved dramatically. Many impaired waterways became suitable for recreation and fishing within two to five years of elimination of direct municipal and industrial discharge. Public support to construct and improve municipal treatment plants in the 1970s and ’80s was strong in large part due to concern over contamination and federal funding that kept local costs low. Federal investment in wastewater infrastructure has declined over the past 20 years, while state investment has increased. Changes in subsidies mean municipalities now must be more responsible for capital costs to keep their infrastructure operational and meet regulatory requirements. For most municipalities this has meant a steady increase in rates. This upward pressure on rates is expected to continue as documented in the latest EPA wastewater infrastructure needs survey (WINS).

The 2009 WINS was used to collect information on current and future wastewater and collection system needs in Minnesota. This survey identified 1,200 wastewater projects with a total estimated cost of $4.3 billion. This is a substantial increase from the $2.5 billion reported in the 2003 WINS survey. The table below compares the distribution of requests for both surveys.

Table 1. Infrastructure need

Infrastructure Need	2009 WINS (millions)	2003 WINS (millions)	Difference (millions)
Sewer System Rehabilitation	$1,890	$315	$1,575
New Collection	$187	$486	($299)
New Interceptors	$475	$206	$269
Combined Sewer Overflow	$17	$5	$12
Inflow and Infiltration	$216	$206	$10
Unsewered Area Projects	$188	$277	($89)
Advanced Treatment	$192	$272	($80)
Secondary Treatment	$1,167	$773	$394
Total	$4,332	$2,540	$1,791

Capital needs for greater Minnesota and the Twin Cities metro area and associated communities are 44% and 56%, respectively. A key difference between the 2003 and 2009 surveys is the large increase in projected capital needs associated with sewer system rehabilitation. Sewer systems over 50 years old are generally considered beyond their reasonable life. Minneapolis and St. Paul have the largest percentage of collection pipes above 50 years of age (72%), in contrast with greater Minnesota, where approximately one-third of the collection system is over 50 years old, and the Twin Cities metropolitan area suburbs, with only 10% of sewers over 50.

Major structural components of wastewater treatment facilities have an estimated useful life of 40 years. Most treatment facilities were built in the early to late 1970s and are rapidly approaching the end of their useful life. Investments in clarifiers, pumps, secondary treatment capacity, and structural improvements make up the majority of capital requests.

It should be noted that these estimates are conservative and do not include capital expenditures associated with treating emerging pollutants of concern (e.g., EDCs, mercury). Spending on additional regulatory requirements would significantly increase these estimates.

Reduced availability of state and federal grants means some projects have become unaffordable to municipalities. With the exception of the Twin Cities metro area, which has had significant population growth, most of the state struggles with the affordability of wastewater infrastructure. This is particularly serious for smaller communities. The U.S. Department of Agriculture Rural Development has identified 1.5 percent of median household income (MHI) as the affordability benchmark for wastewater treatment. The table below details the percent of proposed projects that exceed 1.5 MHI.

Table 2. Population

Population	% above 1.5 MHI
Less than 600	79%
601ï 1,500	38%
1,501ï 3,000	37%
3,000ï 6,000	24%

With the estimated capital needs in the 2009 WIN report, there is risk that the cost of maintaining current wastewater treatment facilities will be prohibitively high for much of the state.

b. Unsewered areas. There are approximately half a million subsurface sewage treatment systems in ñunseweredò areas in Minnesota (i.e., systems serving small communities, unincorporated areas, and individual residences in rural areas). Sustainable wastewater management in these areas faces several major challenges. Individual septic tanks are effective only on large properties with favorable soil and groundwater conditions. Small community systems face financial challenges and other barriers with respect to management, technical support, decision making, and leadership. Whatôs more, community systems above a certain size require advanced treatment to remove nitrogen, which cannot be done in conventional septic tanks.

A 2006 MPCA survey found 1,025 small communities in Minnesota with inadequate wastewater management. The combined population of the communities was 108,970, and total discharge was 2.3 billion gallons per year. Problems included straight pipes without treatment, aging equipment and structures, and untreated sewage discharged at the surface due to improper community drainfield or mound system sizing, overloading, age, or poor soils. The number of failing or inadequate systems reported each year is most likely lower than the actual number because many counties lack the resources or initiatives to identify the extent of the problem.

Of special concern are lake homes with failing or noncompliant systems that cannot be replaced due to small lot size, unfavorable soil or groundwater conditions, or shoreline setbacks. Owners must either install holding tanks or wait for costly regional solutions to become available.

Another challenge in unsewered areas is the number of very small unsewered rural communities. These communities are often less than 30 households with poor soil conditions, small lots, and very low market values. Often the cost of building adequate wastewater facilities can exceed $25,000 to $35,000 per household. These projects require very large public subsidies and can raise the question of whether a voluntary buy-out program would be more effective.

c. Related challenges. Municipal wastewater collection systems and treatment plants have historically been perceived as wastewater delivery and end-of-pipe treatment with the objective to prevent eutrophication and minimize health hazard in surface water. There are several factors that are changing the focus of wastewater collection and treatment, and many challenges and opportunities to realizing this focus.

(1) ***Energy.*** The national average for energy use for wastewater treatment is 1,200 kWh per million gallons (Keith Carns, Global Energy Partners). Increasing energy costs will be passed on to municipalities and their customers. Municipal wastewater and wastewater solids have energy value, presenting an opportunity for offsetting energy cost of wastewater treatment.

(2) ***Nutrients.*** Minnesota is establishing total maximum daily load (TMDL) limits for phosphorus and nitrogen discharges to receiving streams as a part of EPA regulations. In many cases, new limits will require costly upgrades to wastewater treatment plants. At the same time, the value of nitrogen and phosphorus for use in agriculture and industry is rising. The capture and recycling of nutrients presents an opportunity to potentially offset the cost of treatment improvements.

(3) ***Contaminants of emerging concern.*** The impact of hormonally active chemicals on surface water quality and aquatic habitat is a growing area of interest. Hormonally active contaminants are known to influence sex differentiation in fish. If it is determined that these compounds should be removed from wastewater, significant capital will be required. Traditional treatment facilities are not capable of addressing such pollutants of concern with existing technology.

(4) ***Water Reuse.*** Repair and replacement of aging infrastructure will provide a chance to incorporate wastewater scalping and water reuse to satisfy growing water demands.

Wastewater collection and treatment challenges are placing an increased focus on quantity and quality of effluents. According to the Neptune Project (http://www.eu-neptune.org/index_EN) for New Sustainable Concepts and Processes for Optimization and Upgrading Municipal Wastewater and Sludge Treatment, wastewater collection and treatment will be seen more and more as the interface between sanitation and environment. Wastewater treatment plants are delivering resources to the environment and for human activities (recharge of drinking water reservoirs, recycling of nutrients, efficient energy use). This focus shift has implications on the quality goals set for wastewater treatment plant products as follows:

Table 3. Wastewater focus

Existing Focus	New Focus
Water treatment	Water reuse
Nutrient removal	Nutrient recycling
Pathogens removal	Micropollutants and ecotoxicity removal
Energy optimization	Energy production
Sludge disposal	Reuse of sludge and its resources

4. Conclusions

Despite significant point-source discharge reductions, the rate of improvement to water quality has slowed significantly. Increasing amounts of resources are spent to continue curtailing end-of-pipe discharges, but a proportionate return on investment is not being seen in the quality of the stateʹs waters. In the 35 years since the CWA was passed, treatment facilities have significantly upgraded treatment processes and increased environmental protection capabilities. Publicly owned treatment works will continue to play a major role in water quality improvement as aging infrastructure is repaired or replaced and new practices achieve better performance. However there is a disconnect between state water sustainability goals and the historic focus on-end-of-pipe treatment as the primary method to address this challenge.

Achieving sustainable water quality and quantity over the next 25 years will require:

a. adequate funding to address aging wastewater collection and treatment facilities to ensure that we donʹt lose the gains we have made
b. funding and education to improve onsite and small community wastewater systems
c. a paradigm shift from point-source management to managing on an aquifer and watershed basis, including use of adaptive water-quality improvement measures based on individual aquifer and watershed needs

F. Stormwater Issues

1. Stormwater Regulatory Issues

a. Flexibility. Different entities (ultra-urban, urban, rural, linear, etc.) have different stormwater needs, tools, goals/directives, land configurations, and funding mechanisms. Some are regulated; others are not. Current stormwater rules and standards do not always recognize these differences and allow entities flexibility in the BMPs.

One example of inflexibility is requiring specific BMPs. This can create unintended consequences and limit the opportunity to use other technologies that may be equally as good or better. In the past, for example, Nationwide Urban Runoff Program (NURP) ponds had to be built to meet water quality regulations. We are now finding contaminants in the fine sediments of ponds, creating environmental and financial challenges in the removal and disposal of these sediments. Today most watershed management organizations are requiring stormwater infiltration to reduce the amount of water and pollutants running into surface waters. Not yet understood or addressed is the potential impact on groundwater.

Whatộs needed now is some solid research about new approaches and technologies for managing stormwater. This includes an evaluation of the effectiveness and economics of various emerging BMPs. Along with this research, we need a thorough and transparent public discussion of all the issues surrounding stormwater regulations, including the full range of affected stakeholders. We need flexibility in the implementation of regulations to allow for the best and most cost-effective means of achieving water resource objectives.

Finally, knowledge about BMP design, installation, operation, and maintenance needs to be conveyed to those responsible for BMP implementation and stormwater regulation. One way to accomplish this is through periodic updates to state-level guidance documents such as the Minnesota Stormwater Manual or the University of Minnesotaộs Stormwater Treatment: Assessment & Maintenance Manual and website.

Gaps and issues include:

(1) We need solid research on the costs and effectiveness of emerging BMPs to allow for better science behind stormwater management decisions.
(2) We need a thorough and transparent discussion of stormwater regulatory issues that includes all affected stakeholder groups.
(3) We need flexibility to address the local, watershed, state, and federal regulations and water impairments in a cost-effective manner that will improve water quality. We need to avoid overemphasizing the preferred solution of the day and allow for other technologies that would serve equally well or better.
(4) We need to ensure that efforts to protect and enhance surface water do not harm private and public drinking water supplies or create a risk to public health and safety.
(5) State-level guidance documents for BMPs need regular updating.

b. TMDLs and lake classifications. TMDLs are required for all impaired waters. Impairments are based on water bodiesô classification. This system presumes waters are classified correctly. However, many lakes have simply been lumped into a default classification of fishable/swimmable. This has set an unreasonably high standard for some. It has also resulted in an inflated number of impaired waters and resulting need for TMDLs. There is a need to revisit water body classifications to ensure that reasonable standards are set.

TMDLs are developed on a first-come, first-served basis. MPCAôs ñOne Watersò program will lump the TMDLs together, but will still not address prioritization. Needed is a watershed-based approach to prioritizing TMDL monitoring, funding, study, implementation, and assessment.

Under current rules, TMDLs only require actions from regulated entities within the TMDL area. In many cases, actions of regulated entities will not be sufficient to restore impaired waters. There is a need to get unregulated entities to also address the impairments identified in TMDLs.

Issues and gaps include:

(1) We need to revisit the current waterbody classifications because many waterbodies were given the default classification of fishable/swimmable, which may be inappropriate.
(2) We need to ensure that there is a consistent, prioritized, streamlined, common-sense process for selecting impaired waters for the development of TMDLs. We need a watershed-based process for prioritizing the preparation and funding of TMDLs.
(3) We need unregulated entities to address the impairments identified in TMDLs. We need to take a more proactive approach to working with farmers to improve runoff water quality. We need to make sure the future burden of TMDL monitoring is not placed solely on MS4s.
(4) We need to ensure that there is funding for enough staff, at all levels of government, to address new water programs and directives.

c. **Overlapping regulations.** In Minnesota, water resources are regulated at the local, regional, watershed, state, and federal level. Local ordinances and design guidelines govern stormwater management. The Metropolitan Council reviews municipal surface water management plans to ensure conformity with its planning framework. Watershed management organizations regulate stormwater practices. Numerous state and federal agencies regulate water resources through permits, antidegradation rules, TMDLs, and wetland regulations. All of these agencies and regulations have led to overlaps, redundancies, and conflicting rules. In numerous instances a single development has resided in three watersheds, resulting in different stormwater rules for different portions. In some cases, goals and priorities of different regulators conflict. For example, most stormwater regulators advocate infiltration for stormwater management, while groundwater and drinking water regulators are concerned about the potential for groundwater contamination from this practice.

Overlaps, redundancies, and conflicts have resulted in inefficiencies, delays, and high costs in responding to the various regulations; high staff costs of multiple agencies being involved in the regulatory process; and widely varying effectiveness in protecting water resources. There is a strong need for consistent, predictable, and well-reasoned water resource regulations backed by sound science. There is also a need for streamlined regulatory processes with fewer sets of differing rules and procedures and fewer regulatory entities involved.

Issues and gaps include:

(1) We need consistent and predictable water resource regulations backed by sound science.
(2) We need to align the stormwater regulatory structure in order to reduce overlap, inefficiencies, redundancies, and conflicts between and within local, regional, watershed, state, and federal stormwater regulations.
(3) We need a streamlined way to implement developments and public improvement projects.
(4) We need to consider combining and simplifying local watersheds and water resource regulatory functions within and across state agencies to increase efficiency, simplify processes, reduce overlap, and better use our resources.

d. Compliance and enforcement. For stormwater regulations in Minnesota, inspections of sites and facilities and enforcement of permit requirements need improvement to achieve better permit compliance. In general, the processes for inspection and enforcement need to be more effective, cost efficient, and consistent across types of developments, projects, and watersheds.

Shortcomings include:

(1) number of inspectors, frequency of inspections, and inspection coverage
(2) insufficient understanding, coordination, and protocols to allow and promote effective cooperation between state and local regulatory authorities
(3) inappropriate monetary penalties even when appropriate corrective actions are taken on time
(4) definition of a nuisance condition needs to be linked to a two-year event as EPA has done

The MPCA appears to be moving toward placing the additional burden on MS4 stormwater permittees of inspection and enforcement for the statewide industrial stormwater permit, construction site stormwater permit, and MS4 permit. An open and transparent discussion that includes all appropriate stakeholders (permitted parties and regulatory authorities at multiple governmental levels) is needed to address these shortcomings and needs. Discussion needs to take place with the permittees regarding local capacity and local training and funding needs.

New industrial permit and foreseeable new MS4 permit shortcomings include:

(5) The industrial permit has placed the burden of monitoring industrial facilities on MS4 permit holders, yet funding and training are not provided.
(6) The MS4 permit is headed in the direction of placing the construction inspection burden on MS4 cities. There is no state oversight to ensure consistency with nonmunicipal MS4s. There has been no discussion of funding for additional staff to take on this responsibility.

Issues and gaps include:

(7) We need consistent programs across the state.
(8) We need all entities to follow the same compliance and inspection program.
(9) We need a fair distribution of inspection frequency, compliance, and enforcement for each type of project (e.g., industrial, commercial, residential, streets, and utilities).
(10) We need to evaluate the effectiveness of state and local compliance, inspection, and enforcement strategies and protocols.
(11) We need to avoid overlaps and gaps.
(12) We need to build state and local capacity for inspections.
(13) We need to ensure that the existing system is not undermined and that enforcement (project shutdown and monetary fines) remains with DNR and MPCA.
(14) We need an open and transparent discussion between regulators and the permittees regarding local capacity and local training and funding needs.

2. Best Management Practices

BMPs help prevent pollution from entering waterways. In the past, stormwater ponds were the primary BMP used to control and treat runoff. In recent years, new BMPs have been developed to reduce the rate and volume of runoff and associated pollutants. The focus of many has been on reducing impervious surfaces, designing around natural features to treat the runoff created on site, treating stormwater through infiltration and plant uptake, and providing storage and reuse of stormwater. These practices, which fall under the umbrella of LID, include both structural and nonstructural approaches and can include infiltration and bioretention facilities (e.g., rain gardens), ordinances, public education, street sweeping, preserving stands of trees, maintaining ecological function, and land use planning. The scale can range from project-level to regional.

The methodology for using stormwater ponds to manage runoff was developed as part of NURP. There is a corresponding need to develop calculation methodologies for LID practices. Through funding provided during the 2009 legislative session, the MPCA is beginning an effort called minimal impact design standards that may help to address this need.

As stormwater management continues to evolve, we can expect improvements in how we treat and manage stormwater. Research is needed to form the basis of these practices and to develop effective, scientifically based design methodologies. The University of Minnesota and the St. Anthony Falls Laboratory are national leaders in research and development of new technologies (e.g., the use of iron filings in a sand filter system to take up soluble phosphorus). Such cutting-edge research is vital for advancing the science of stormwater management.

Many documents have been produced to guide stormwater management. Although knowledge about stormwater management has changed, these documents have not been updated regularly. Known shortcomings have not been addressed. New or revised practices have not been incorporated. Project designers and permittees have struggled with inadequate guidance. Inspections and enforcement have been hampered. Valuable new BMPs have not been incorporated into projects or regulations because they are not in the out-of-date guidance documents.

BMP-related issues and gaps include:

a. We need to develop calculation methodologies and design specifications for new BMPs.
b. We need to determine the operation and maintenance required for new BMPs.
c. We need a costs-benefit analysis to help determine the best approaches. This should include an analysis of life-cycle costs of BMPs, including operation, maintenance, and replacement.
d. We need to evaluate BMPs as they relate to the environment in which they will be located (ultra-urban, urban, rural, agricultural). Project testing and demonstration sites need to be constructed to demonstrate site-specific effectiveness and local impacts.
e. We need to monitor the effectiveness of BMPs, to determine if they are operating as designed and providing the expected water quality benefits.
f. We need to expand research on emerging technologies to address stormwater issues.
g. We need to develop and fund protocols and procedures to update and revise stormwater guidance documents so new knowledge is incorporated into current practices.

3. Vision and Priorities

There are not enough dollars to solve every water problem in Minnesota, let alone protect unimpaired waters. Over 2,800 waters are considered impaired, and more are being added. The cost to rectify even small problems can run into hundreds of thou-sands of dollars. The CWA neither sets priorities nor addresses flooding, aging infrastructure, or other stormwater issues. However, Legacy Amendment funds can be allocated based on state priorities.

Specific issues and gaps related to vision and priorities include:

a. Minnesota needs a clear vision of how it plans to address stormwater on a comprehensive and sustainable basis. A system of prioritization is essential.
b. To ensure a successful, sustainable outcome, priorities must be based on environmental *and* economic *and* social considerations. As examples, planning for clean water needs to be fully linked to planning for transportation, land use, growth, solid waste, and energy.
c. We need to gather information to address the criteria that are established.
d. We need adequate funding for projects to protect and restore water resources as well as for research and state and local agency programs that address stormwater issues on a daily basis.

4. Agricultural Stormwater Runoff

Runoff from agricultural land is a source of sediment and pollutants. Practice changes and technology continue to evolve to reduce water quality issues arising from agriculture. However, there is a lot we donĝt know and a need for better adoption of proven BMPs. Tools available to help do this include research, education, incentives, and regulation.

a. Research and education. New knowledge has influenced technology development and practices in agriculture production. However, availability of and competition for research funds for agricultural water quality issues is a problem. There is a strong need to continue agricultural runoff research and translate research results to cost-effective practices. This takes meaningful farmer involvement in development of practices and a good education program.

b. Incentives. Most producers want to do the right thing, but it is often cost-prohibitive to implement needed practices. Cost-share incentives are a key. There is a need to target incentives to the greatest need is and to where the practice can make the most difference.

c. Regulation. Regulation and enforcement are also key tools in promoting better water quality from agriculture runoff. The appropriate level needs to be determined; enforcement is not a one-size-fits all tool. If we feel the base of water quality data and knowledge of stormwater management is sufficient and we have exhausted incentive approaches, we should begin to discuss and decide whether current regulations regarding the control of runoff and pollutants from agricultural land are adequate or where additional regulations may be appropriate. This discussion must be broad-based and transparent. We must be careful not to implement regulations where there are limitations to the technology such that regulation may result in increased cost and lower production without any improvement in water quality. If our base of data and knowledge is not sufficient, we should identify and list gaps and develop a strategy to address them to support a decision about regulations in the future.

Specific issues and gaps related to vision and priorities include:

(1) We need continued agricultural runoff research to identify specific problems and look at specific practices to cost-effectively remediate them is insufficient.
(2) We need targeted incentive programs that garner the most bang for the buck to remediate agriculture runoff affecting water quality.
(3) We need to determine whether we have enough information to support a decision whether additional regulations are appropriate and needed to control farmland runoff and pollutants.
(4) If we do, we need a process for establishing the regulations.
(5) If we donqt, we need to identify gaps and develop a strategy to address them.

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Appendix A. Domestic Use Technical Work Team Members

Figure A-1. Domestic use team composition

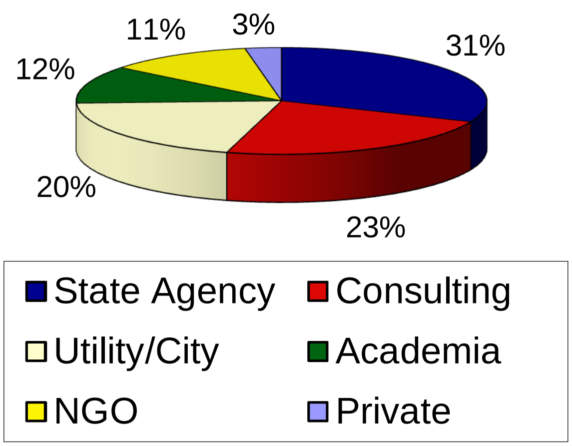

Figure A-2. Geographic distribution of domestic use team members