Metropolitan Council

Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR 05-07d MCES Project No. 070186

Prepared for **Legislative Commission on Minnesota Resources**

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List of Abbreviations

$/1000 gallons	dollars per thousand gallons
bgy	billion gallons per year
CBOD	carbonaceous biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
COD	chemical oxygen demand
DBPs	disinfection byproducts
DIP	ductile iron pipe
ECOC	emerging contaminants of concern
ED	electrodialysis
EDCs	endocrine disrupting compounds
fps	feet per second
gpy	gallons per year
I&I	infiltration and inflow
LCMR	Legislative Commission on Minnesota Resources
MCES	Metropolitan Council Environmental Services
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MEC	Mankato Energy Center
Met Council	Metropolitan Council
mgd	million gallons per day
mgy	million gallons per year
MPCA	Minnesota Pollution Control Agency
MTBE	methyl tertiary-butyl ether
NDMA	N-nitrosodimethylamine
NH3	Ammonia
NPDES	National Pollutant Discharge Elimination System
PhACs	pharmaceutically active chemicals
psi	pounds per square inch
PVC	polyvinyl chloride pipe
RO	reverse osmosis
SMSC	Shakopee Mdewakanton Sioux Community
TDS	Total Dissolved Solids
Title 22	California Water Recycling Criteria, Title 22 California Code of Regulations
TMDL	total maximum daily load
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
UV	ultraviolet radiation
WWTP	wastewater treatment plant

Executive Summary

Vision

Conserving Minnesota's water resources is important to the state's long-term development. The potential to use treated municipal wastewater as a water supply for industrial use is of interest as a way to conserve water resources while supporting economic development.

> ***Guiding Goal:*** *Conserve Minnesota's water resources*
>
> ***Benefits:***
>
> - Reduce ground water depletion by providing an alternative supply for nonpotable water uses
> - Provide a reliable and potentially lower cost water source for industries

With interest in recycling treated municipal wastewater growing, the Metropolitan Council (Met Council) undertook this study titled, "Recycling Treated Municipal Wastewater for Industrial Water Use." Funding for this project was recommended by the Legislative Commission on Minnesota Resources (LCMR) from the Minnesota Environment and Natural Resources Trust Fund. The Met Council and other agencies provided in-kind contributions of staff time and production services.

The study's objectives were: (1) Determine the feasibility of recycling treated municipal wastewater for industrial water use in Minnesota, and (2) Identify implementation issues associated with this recycling.

Findings and Next Steps

Recycling treated municipal wastewater can conserve water resources and support industries and economic development. In coming to this conclusion, the study first evaluated the feasibility of wastewater recycling as an industrial water source and then identified implementation issues. Findings are summarized in Figure ES.1 and described below.

Figure ES.1. Key Findings

Objective 1
Feasibility for Industrial Water Use

Objective 2
Implementation Issues

Demand & Supply Analysis

- Supply is adequate for demand statewide: Supply=425 mgd* Demand=445 mgd** total, with 60 mgd for ground water
- Matching industries and wastewater treatment plants geographically can be an issue
- Most immediate benefit to water resources: industrial use of ground water to reserve aquifer for potable uses

Water Quality and Treatment Requirements

- Industrial water quality requirements can be met by adding new treatment processes or upgrading existing ones at municipal wastewater treatment plants
- Removal of hardness and high salt levels likely required for significant uses
- Technology is available to protect public health and meet all industry requirements

Costs

- Recycled wastewater can be competitive with traditional supplies in some cases
- Removal of hardness and high salt levels significantly adds to the cost
- Cost efficiency improves as wastewater usage increases, which favors systems delivering over 1 mgd

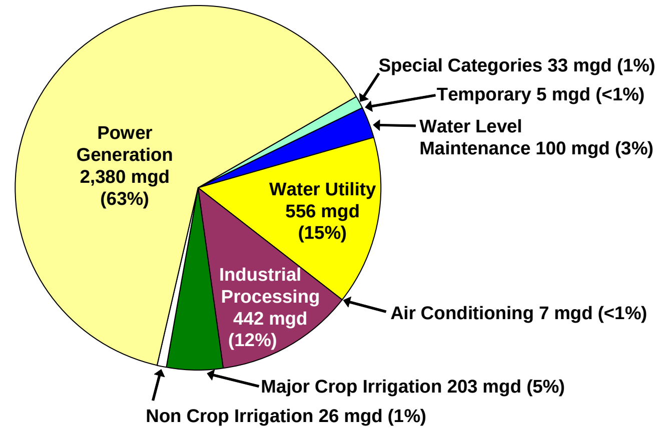
Implementation Issues

- Environmental Stewardship:
  - requires a positive image
  - industry view = "the right thing to do"
- Regulations: unknowns could deter some projects
- Incentives and Risk:
  - financial incentives to compete with low cost of traditional water source
  - liability issues to resolve
- Data and Research: studies to further gather technical information

*mgd: million gallons per day
**Excludes surface water use by power facilities; based only on permitted water users

Figure ES.2 shows that non-power industries in Minnesota use 442 million gallons per day (mgd) of water from their own permitted supplies. The quantity of treated municipal wastewater available statewide, estimated at 425 mgd, could fill a portion of this industry water demand. However, industries and wastewater plants are not always close to each other. Over half of the treated municipal wastewater, 255 mgd, is generated in the Twin Cities metro area while industrial water demand in the metro area is estimated at 75 mgd.

Figure ES.2. Water Use in Minnesota, 2004

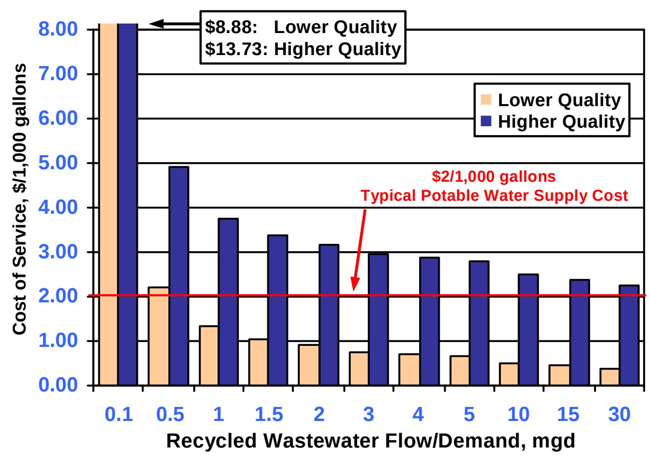


Source: DNR Water Appropriations Permit Program, 2004

Wastewater treatment technologies are available to meet the highest levels of water quality required by industries and protect public health. Treatment technologies are becoming more competitive. For some industry needs, only minimal changes to a wastewater plant's disinfection process would be required. In other cases, significant additional treatment would be needed. Typically, removal of hardness and high salt levels would be required.

For some industry water uses, the cost of treated municipal wastewater can be competitive with other water supplies. Recycled wastewater systems are cost competitive at capacities of 1 mgd or greater, as shown in Figure ES.3. Systems of this size would likely serve one large or several smaller industries or multiple recycled wastewater users, industrial and non-industrial.

Figure ES.3. Comparison of Treatment System Costs for 5-Mile Transmission



Stakeholders, including regulatory, industry, and broader-based representatives, identified implementation issues and deemed them addressable. Stakeholders considered wastewater recycling the "right thing to do" and advised more public education to move recycling from unknown to accepted and positive. The current case-by-case regulatory approach matches the current demand for permitting recycling projects but unknowns associated with this approach may deter some projects. Addressing industry concerns regarding liability and providing economic incentives beyond the market value of water versus treated wastewater would support new recycling projects.

Next steps could include demonstration projects with unilateral, partnered, or other approaches. A wastewater utility may unilaterally make treated wastewater available at a quality useable by various industries. In a "partnered" project, a partnered group with representatives from industry, water, wastewater, community, and regulatory sectors would walk hand-in-hand through the planning, design, and construction phases of a project.

Recycled treated municipal wastewater is an emerging water supply for Minnesota industries. Economic development, water supply limitations, and environmental regulations will increasingly drive the need to find alternative water supplies. Recycling treated municipal wastewater for industrial water use is feasible and, in some situations, cost competitive with other water supplies. Implementation issues are addressable. Recycling treated municipal wastewater can conserve water resources and support industries and economic development.

Section 1: Introduction

1.1 Project Vision

Conserving Minnesota's ground water and surface water resources is important to all the state's inhabitants and to the state's long-term development. The economic vitality of Minnesota requires the business sector to grow with the population of the state. While water supply availability is not currently considered a limitation for industrial development in many Minnesota communities, there are numerous areas in the state that have a limited supply of high quality water. Even within the Minneapolis/St. Paul metropolitan area (Twin Cities metro area), development is now extending to regions with less productive aquifers and future growth will increase competition for a limited water supply. Industries requiring abundant or high quality water may find it difficult to locate in some areas unless other water supply options are made known and available to them.

One potential supply in water-short areas is effluent from municipal wastewater treatment plants (WWTPs), also known as recycled wastewater or reclaimed water. Municipalities may benefit by offering recycled wastewater as an alternative water source to industries and by forging partnerships with industries to promote conservation of a limited potable water supply and improved protection of the state's water resources.

With interest in wastewater recycling growing in the state and water protection a consistent concern for Minnesotans, the Legislative Commission on Minnesota Resources (LCMR) provided Metropolitan Council (Met Council) a grant for the project documented in this report, titled, *Recycling Treated Municipal Wastewater for Industrial Water Use*. Funding for this project, conducted from July 2005 through June 2007, was recommended by the LCMR from the Minnesota Environment and Natural Resources Trust Fund. The Met Council provided additional funding for the project through in-kind contributions of staff time. In addition, other state agencies such as the Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MDNR) and the Minnesota Department of Health (MDH) participated via stakeholder meetings and technical review and input. It is estimated that 20% of project funding was from these in-kind contributions of staff time and 80% from the Minnesota Environment and Natural Resources Trust Fund.

Guiding Goal: *Conserve Minnesota's water resources*

Benefits:

- Reduce ground water depletion by providing an alternative supply for nonpotable water uses
- Provide a reliable and potentially lower cost water source for industries

The guiding goal for this project is to promote the conservation of Minnesota's ground water and surface water resources by recycling treated municipal wastewater for industrial use. The project is applicable to communities throughout Minnesota. Benefits include: (1) Less ground water aquifer depletion due to one-time use and discharge to surface waters; (2) Lower demand on finite water resources to support business and growth; and (3) Reliable and potentially lower cost water sources for industries.

Two basic objectives were established for the project: (1) Determine the feasibility of using treated municipal wastewater as an industrial water supply and (2) Identify implementation issues associated with recycling municipal wastewater in Minnesota for industrial use.

The project activities were directed at four areas of inquiry, as listed in Table 1.1. The ***demand and supply analysis*** asks the questions: Is there a match in the quantity of wastewater generated to the water supply demand of industries in the state? What is the proximity of existing WWTPs to industries? The ***water quality and treatment requirements*** task evaluates the quality of treated wastewater and quality requirements for various industrial uses. Potential treatment processes are identified for those applications where the supply quality does not meet the industry's needs. The evaluation of ***costs*** addresses the economic feasibility of wastewater recycling. These three project tasks address the first project objective – to determine the feasibility of wastewater recycling for industrial water use.

Table 1.1. Project Areas

Demand & Supply Analysis
Compare industrial water demands with the available treated municipal wastewater supply.
Water Quality & Treatment Requirements
Compare industry water quality requirements to treated municipal wastewater quality and identify treatment processes for recycled wastewater use by industry.
Costs
Estimate treatment and transmission costs.
Implementation Issues
Identify implementation issues.

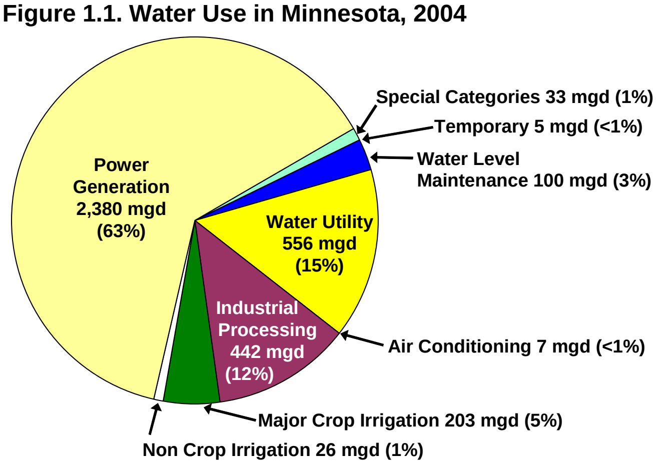
The ***implementation issues*** inquiry asks: What needs to be considered to implement wastewater recycling and what are the obstacles? The various considerations include technical, regulatory, legal, and institutional elements. The findings of the first three project tasks and input from various stakeholder meetings were used to address the second objective to identify implementation issues.

The remainder of this section provides background information on water use and wastewater recycling activities, with a focus on Minnesota. Sections 2-4 summarize the results of the four project areas of inquiry and Section 5 provides the project summary and recommended next steps. Volume II contains technical memoranda and related information that support the results shown in this report volume and provides additional details and references.

1.2 Water Use in Minnesota

How much water do Minnesotans use and what is it used for? Permitted water use in Minnesota ranged from 3.4 to 3.7 billion gallons per day (gpd) during 2000-2004. Water permits in Minnesota are required for all water users that withdraw more than 1 million gallons per year (mgy) and/or 100,000 gpd of ground or surface water. Permitted water use does not account for most domestic private well or surface withdrawals. The majority of the water use information reported in this document is based on the records maintained by the MDNR Appropriation Permits program. Water use data should be assumed to be based on the permit records of the MDNR unless referenced otherwise.

Figure 1.1. Water Use in Minnesota, 2004



Source: DNR Water Appropriations Permit Program, 2004

The MDNR tracks water use by nine industrial categories, shown in Figure 1.1 and listed in Table 1.2 on the following page. Over 60% of the water used in Minnesota is for power generation facilities, primarily for once-through cooling, supplied mostly by surface waters. The next largest use of water, about 15% of the total, is the water utility category (a potable-quality water supply), distributed by municipalities for domestic, commercial and industrial uses.

Table 1.2. Water Use in Minnesota, 2004

Category	Annual Average Water Use, mgd		
	Ground Water	Surface Water	Total
Air Conditioning	6	1	7
Industrial Processing	56	385	442
Major Crop Irrigation	175	28	203
Non-Crop Irrigation	20	6	26
Power Generation	4	2,375	2,380
Special Categories	19	15	33
Temporary	4	1	5
Water Level Maintenance	5	95	100
Water Utilities	355	201	556
Total	**644**	**3,106**	**3,750**

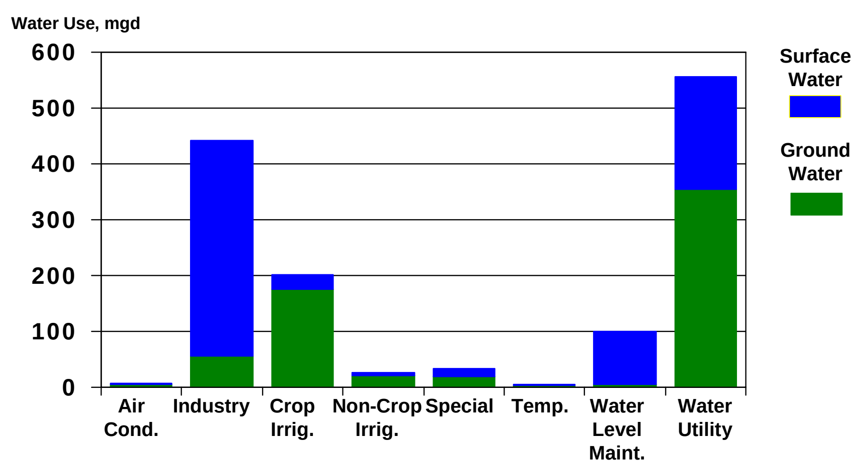
Source: MDNR, 2004

Nearly two-thirds of the potable-quality water supply in Minnesota is from ground water, as depicted in Figure 1.2. Water withdrawn by industries (those not served by water utilities) for various processing needs accounts for about 12% of the total water used in Minnesota.

In terms of 2004 daily average demands, nearly 2,500 million gallons per day (mgd) of water was used by the state's power generation industry and over 500 mgd served as a potable-quality supply for a variety of uses. Over 400 mgd was withdrawn directly by industries for use in their businesses.

Water use was analyzed with a focus on sources most vulnerable to water supply limitations. Because little water is consumed in once-through cooling processes, replacing surface water sources with recycled wastewater does little to conserve water. To benefit the state's water resources, recycled wastewater typically should replace a water supply that is used and not returned to its source of origin. This applies to all uses of ground water, even for once-through cooling water uses because the water is typically discharged to a surface water and not back to the original aquifer. It also pertains to surface water sources where water is consumed, as through evaporation in cooling towers or in the production operations of an industry. For industries with little water consumption, such as those that use water primarily for washing operations, the benefits of replacing a surface water source with recycled wastewater will be case-specific. Surface water sources could have quantity limitations that would require use of an alternative supply, particularly if the discharge of the water is not in proximity to the withdrawal or to a different watershed. To focus on water uses with the greatest benefit to Minnesota's water resources, this study evaluated industrial water demand without power generation facilities and in more detail for ground water uses.

Figure 1.2. Water Use in Minnesota Without Power Generation, 2004



Source: MDNR, 2004

The analysis of annual water use indicates that the various types of industrial water use represent a major component of the state's overall water use. Recycled wastewater could potentially be used by power generation facilities using ground water or recirculating cooling water systems (which consume water) and a variety of industries represented by the industrial processing category in the MDNR water use database. Some industries also use municipal potable supplies. The potable water supply used by industries was not assessed in detail for this study. It varies considerably from community to community, but on a regional or state-basis is estimated to be 10-20% of the potable water demand.

The total "industrial water use", defined by the combined water use of the power generation and industrial processing categories, is nearly 3 billion gpd, which is roughly 75% of the total major water use in the state. Ground water supplies are used to meet approximately 60 mgd or 22,000 million gpy. If we assume that Minnesota's water utilities have an industrial customer demand of 10% of their total supply, then an additional 40 mgd of ground water is used by industries. Under this assumption, the total industrial water demand for ground water is approximately 100 mgd. This equates to the typical, potable supply use of 1 million people, given the standard residential use engineering estimate of 100 gallons/person-day.

1.3 Wastewater Recycling Background

In Minnesota, WWTP effluent is typically discharged to a receiving stream or a land application system. However, wastewater effluent can also be beneficially used for a variety of purposes. There are various terms used to describe the beneficial use of WWTP effluent: wastewater recycling, wastewater reuse, water reuse, water recycling, or water reclamation are often used interchangeably.

While this project evaluates the beneficial reuse of wastewater effluent for industrial purposes, non-industrial uses are briefly described to indicate the full range of wastewater recycling practices. From the perspective of the municipality, investment in capital to provide recycled wastewater will typically involve a review of all options; multiple users are commonly required for wastewater recycling to be a cost-effective practice for the municipal utility. Wastewater recycling in the U.S. is typically categorized under the following major categories:

- Industrial
- Urban
- Agricultural
- Environmental and recreational
- Ground water recharge
- Augmentation of potable supplies

Industrial

Industrial reuse applications in the U.S. have steadily increased over the past decade, with an increasing diversity of industrial uses. The largest use of recycled wastewater in the U.S. has been for cooling water. The large water demands of power facilities for cooling water and other needs makes them an ideal facility for reuse. Recycled wastewater is also used as process water for a variety of applications at petroleum refineries, chemical plants, metal working, pulp and paper mills, and other production facilities. Another larger use of water by industries is for washing or wetting requirements for industries such as laundries, sand and gravel washing operations, or dust suppression.

Urban

Recycled wastewater is used for a variety of purposes in the urban setting. One common use, that is one of the few wastewater recycling applications in Minnesota, is for golf course irrigation. Other typical irrigation reuse applications include: public lands such as parks, athletic fields, highway medians and shoulders, landscaped areas for commercial properties, and landscaping for residential areas. Other examples of "urban" reuse applications include vehicle washing facilities, fire protection, toilet and urinal flushing in commercial buildings, decorative water features such as fountains and reflecting pools, street sweeping, and dust control and soil compaction for construction projects.

Agricultural

In many states, agricultural irrigation is a significant percent of the total water demand and is estimated to represent 40% of the total water demand nationwide [Solley et al, 1998]. Recycled wastewater has been used to irrigate a variety of agricultural applications including: pasture; orchards and vineyards; harvested feed, fiber and seed; food crops; processed food crops; and nursery and sod. Florida uses 19% of its recycled wastewater supply for agricultural irrigation [Florida Department of Environmental Protection, 2002] and California uses approximately 48% [California State Water Resources Control Board, 2002].

Environmental and Recreational

Recycled wastewater has been used for environmental improvements and recreational uses.

Environmental reuse includes wetland enhancement and restoration, creation of wetlands for wildlife habitat, and stream augmentation. Wetland reuse projects often include dual goals: to enhance downstream surface water quality and create additional wildlife habitat. Recreational applications for recycled wastewater include water impoundments restricted to boating and fishing, smaller landscape impoundments, and golf course ponds.

Ground Water Recharge

Ground water recharge using recycled wastewater has been used to reduce saltwater intrusion in coastal aquifers, augment potable or nonpotable aquifers, provide storage and/or further treatment of recycled wastewater for later use, and prevent ground subsidence. In areas with extensive agricultural irrigation, ground water recharge practices rely on the aquifers for storage, removing the need for storage facilities to meet seasonal demands.

Augmentation of Potable Supplies

Potable water supplies can be supplemented with treated wastewater by surface water augmentation, ground water recharge, and direct potable reuse. The first two applications are indirect potable reuse, which has been defined as the augmentation of a community's raw water supply with treated wastewater followed by an environmental buffer [Crook, 2001]. In this case, the treated wastewater is mixed with surface and/or ground water and receives additional treatment prior to entering the potable water distribution system. Direct potable reuse is defined as the introduction of treated wastewater directly into a water distribution system without intervening storage (pipe-to-pipe) [Crook, 2001]. There are no direct potable reuse applications in the U.S.

1.4 Wastewater Recycling in Minnesota

Setting and Drivers

Minnesota is known for its abundance of water, as the "Land of 10,000 Lakes." A safe, cost-effective, and adequate water supply has been easily attained for many Minnesota industries and communities, but there are some regions where water quality is impaired or declining or where water supply is limited. Section 2 provides additional information about these areas. Minnesota's environmental stewardship ethic has promoted the need to conserve water resources and programs have been implemented across the state. Conservation has gone hand-in-hand with improved water protection programs and more stringent regulations for surface water dischargers. In the future, residential and industrial growth in some areas of Minnesota could potentially be curtailed because of a limited water supply, even with more stringent conservation practices. Alternative supplies will be sought – and treated wastewater effluent is one potential supply.

Water quality considerations may also drive more wastewater recycling in Minnesota. As growing communities generate additional wastewater, there will be a need to provide higher and higher levels of wastewater treatment to maintain or decrease the discharge loads to the state's waterways. Finding other uses for the treated wastewater, through partnerships with industry, will decrease wastewater discharges.

The development of Minnesota's Total Maximum Daily Load (TMDL) program will affect the discharge allocations for many communities. For example, the Lake Pepin TMDL will affect nearly two-thirds of the state. With a potential reduction requirement of one-half the phosphorus and solids loads to Lake Pepin, and nonpoint source reduction practices still untested, it is likely that point source reductions will be part of the solution. Wastewater recycling may be a cost-effective solution for some communities, particularly when tertiary treatment processes are required to meet receiving stream discharge limits. If these communities are also experiencing water supply limitations, the benefits of a wastewater recycling option could be even more pronounced.

Wastewater Recycling Applications in Minnesota

Using recycled wastewater for irrigation has historically been practiced in Minnesota because surface discharges are not possible in some areas and land application is used. Many of Minnesota's rural pond systems spray irrigate agricultural fields during the summer months when the ponds discharge. More recent reuse applications involve cooling water for power generation, golf course irrigation in urban and resort areas, and as toilet flush water for an institutional building. Table 1.3 provides a list of facilities that are using treated, municipal wastewater effluent in Minnesota for uses other than agricultural irrigation. The urban irrigation and toilet flush water systems used wastewater recycling because this was the optimum practice for their wastewater discharge.

Table 1.3. Wastewater Recycling Facilities in Minnesota

Facility	Type of Reuse	Flow, mgd
Hennepin County Public Works	Toilet flush water	0.0056
Lake Allie	Golf course irrigation	0.0056
Turtle Run South	Golf course irrigation	0.0168
Izaty's Golf and Yacht Club	Golf course and alfalfa field irrigation	0.086
City of Nisswa	Golf course irrigation and other uses	0.038
City of Montgomery	Golf course irrigation and other uses	0.038
Shakopee Mdewakanton Sioux Community	Wetland enhancement	0.96
City of Mankato	Industrial – cooling water for power plant	6.2

The Shakopee Mdewakanton Sioux Community (SMSC)'s 0.96 mgd WWTP is permitted to discharge to one of two wetlands with downstream ponded areas that provide water for their golf course irrigation system. State agencies are working with the SMSC to explore aquifer recharge to be used primarily in the winter when irrigation is not needed.

The one industrial recycled wastewater application in Minnesota was developed because of water supply limitations. The Mankato Energy Center (MEC) uses 6.2 mgd of treated wastewater from the Mankato WWTP for its cooling water. Mankato expanded their WWTP, shown in Figure 1.3, to provide the water quality required for the cooling towers. The MEC cooling water discharge is returned to the plant as a permitted industrial user and commingled with treated effluent prior to dechlorination. The MEC uses an evaporative cooling process with an average loss of 75%. The MEC produces 365 megawatts with an ultimate capacity of 630 megawatts.

Figure 1.3. Mankato Water Reclamation Facility

1.5 Summary

Interest in wastewater recycling is growing in Minnesota. Implementation of several projects over the past few years demonstrates that some non-drinking water supply needs in Minnesota can be met by municipally treated wastewater. These applications were driven by either a limitation in the water supply quantity available or the receiving stream discharge options of an area. Limitations on water supply and wastewater discharges are expected to increase with future growth across the state. Recycled wastewater is an alternative water supply to potable water sources and, if the water use is consumptive, can reduce discharges to receiving waters. Of particular interest to this study are the wastewater recycling opportunities available for the industrial sector of Minnesota – looking to meet the needs of industry while also conserving Minnesota's water resources.

Minnesota's industries, represented by all power generation and industrial processing facilities, are the largest water users in the state – using about 75% of the 1,370 billion gallons of water withdrawn in 2004, or an equivalent 3,750 mgd. Over 60% of this supply is surface water used by power generation facilities for once-through cooling and is nearly all returned to the same surface water source in proximity to the withdrawal. Because little water is consumed in once-through cooling processes, replacing surface water sources with recycled wastewater does little to conserve water or reduce discharge loadings to state waterways. When power generation facilities using surface water are excluded, the industrial demand for water in 2004 was 445 mgd. Of this amount, 60 mgd was supplied by ground water. Coupling this 60 mgd with a conservative estimate of the amount of industrial water supply provided by a water utility, it is estimated that the total industrial water demand for ground water in the state in 2004 was 100 mgd.

1.6 References

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Section 2: Recycled Wastewater Demand and Supply

This section answers the question: Is there a sufficient treated wastewater supply in Minnesota to meet the industrial water demand? Historical water use in the state for major industrial users is reviewed in context with the location and production capacity of municipal WWTPs. Data are summarized on a state and watershed basis. General characteristics of area water supplies are summarized to identify areas with a higher need for alternative water sources. The Twin Cities metro area is also examined focusing on industries located within a specified radius of each WWTP. Customer inventories were developed for each watershed in Minnesota and for the areas tributary to each WWTP in the Twin Cities metro area. This section presents the customer inventory for the Lower Mississippi River watershed and the Empire WWTP as examples and summarizes demand and supply by watershed. Appendix II-1 provides the complete customer inventories for the other nine Minnesota watersheds and eight Twin Cities metro area WWTPs.

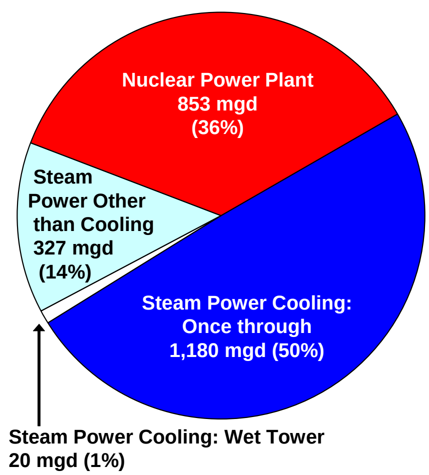
2.1 Statewide Inventory

Industrial Water Demand

As discussed in Section 1, this study used the MDNR water appropriations permit database (MDNR, 2004) to quantify Minnesota's industrial water demand. The MDNR categories of power generation and industrial processing are used to define the industrial demand. Subcategories further delineate the uses of industrial water supplies.

The largest use of water in Minnesota is for once-through cooling at steam power generation plants. As shown in Figure 2.1, these facilities use about half of the water used by the power generation industry. The next largest use of water for power generation is for nuclear plant cooling water, followed by other steam power non-cooling water uses. Almost all of the water used for power generation is supplied by surface waters, as indicated in Table 2.1.

Figure 2.1. Power Generation Facilities Total Water Use, 2004



Source: MDNR, 2004

Table 2.1. Power Generation Facilities Water Use in Minnesota, 2004

Category	Water Use, mgd		
	Ground Water	Surface Water	Total
Hydropower	0	<1	<1
Steam power cooling – once through	<1	1179	1180
Steam power cooling – wet tower	1	19	20
Steam power other than cooling	1	326	327
Nuclear power plant	<1	852	853
Power generation - miscellaneous	<1	<1	1
Total	**4**	**2,376**	**2,380**

Source: MDNR, 2004

For the non-power related industries under the industrial processing category, the mining and pulp and paper industries are the largest water users, as listed in Table 2.2 and shown in Figure 2.2. These industries use mainly surface water supplies. The mining industry consumes very little water. Most of the withdrawals are for dewatering and the water is stored in mining pits. The pulp and paper industry has mixed uses of water, with some facilities consuming a significant portion of their incoming water supply. Facilities within this industry continue to decrease their water requirements with process upgrades. The total pulp and paper facility use decreased nearly 20 mgd from 2000 to 2004.

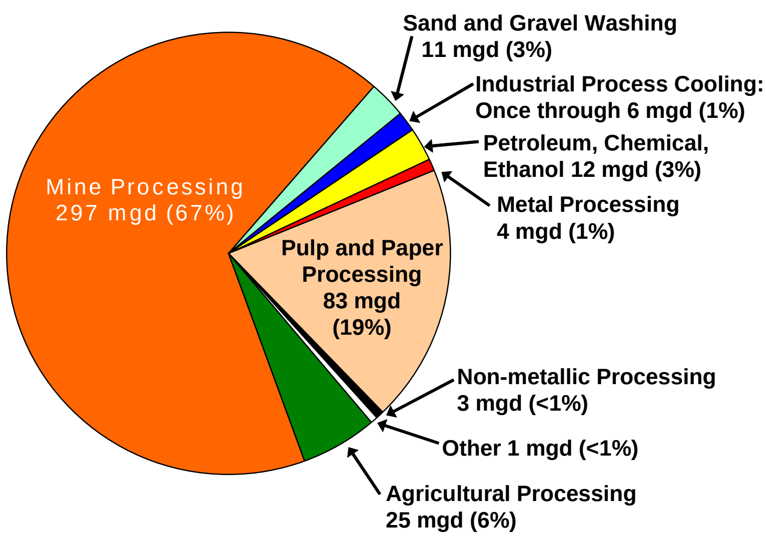
Table 2.2. Industrial Processing Water Use in Minnesota, 2004

	Water Use, mgd		
Category	**Ground Water**	**Surface Water**	**Total**
Agricultural processing (food & livestock)	25	<1	**25**
Pulp and paper processing	2	81	**83**
Mine processing (not sand & gravel washing)	<1	296	**297**
Sand and gravel washing	4	7	**11**
Industrial process cooling once-through	6	<1	**6**
Petroleum & chemical processing, ethanol	11	<1	**12**
Metal processing	4	0	**4**
Non-metallic processing (rubber, plastic, glass)	3	0	**3**
Other (miscellaneous)	1	0	**1**
Total	**56**	**385**	**442**

Source: MDNR, 2004

Following the mining and pulp and paper industry water use, the next largest water use category is agricultural processing, which relies primarily on higher quality ground water supplies. The agricultural processing category includes livestock management and all food and beverage production facilities, from raw products to packaged products. Water is used as cooling water, process water, or for facility and equipment washdown. It does not include water used for crop irrigation.

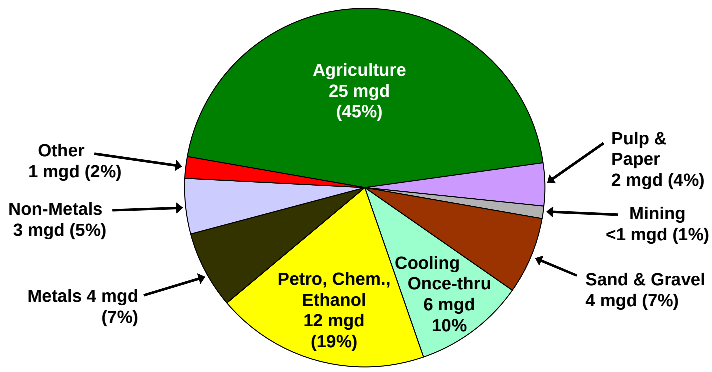
Figure 2.2. Industrial Processing Total Water Use, 2004



Source: MDNR, 2004

The annual average industrial demand for ground water supplies was nearly 60 mgd in 2004 and varied less than 1 mgd in the preceding four years. As depicted in Figure 2.3 on the following page, the agricultural processing industry sector uses about 25 mgd, or one-half the ground water supplied to Minnesota's industries (other than for power generation). The petrochemical, chemical, and ethanol industries combine to use nearly 20%, or 12 mgd, of the total industrial processing category ground water use. The next largest water use is for once-through cooling systems, followed by metal-related industries such as foundries, machine and tool shops, and facilities for electronic and computer production, electroplating, and other metal product fabrications. Sand and gravel operations located away from major rivers rely on ground water sources, accounting for about 7% of the industrial ground water supply use. The non-metal industries category includes production of building materials, glass products, leather products, plastics and other non-metal products. The metal, non-metal and miscellaneous industries rely solely on ground water sources. These industries are also the most likely to use a potable water supply provided by a water utility, given their size and quantity of water used, typical proximity to a town center, and water quality requirements. As discussed previously, the industrial demand supplied by water utilities is not included in the detailed demand analysis and will be generally addressed in the summary of this section.

Figure 2.3. Industrial Processing Ground Water Use, 2004



Source: MDNR, 2004

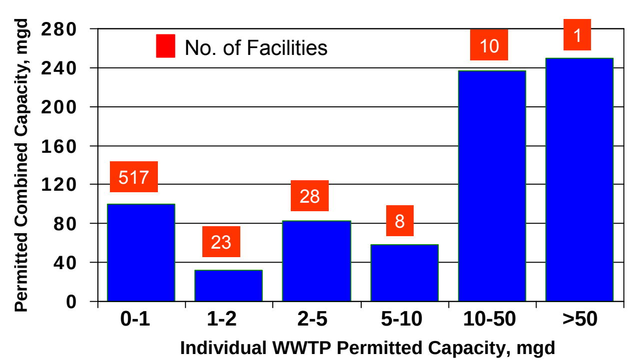
The future industrial water demand in Minnesota will be influenced by the continued improvements by industries to conserve water and the market growth for those industries. The historic water use record has varying trends by industry sector. For some industries, such as mining, where the market volatility creates a wide swing in production, water demand has major changes from year to year. There has been a consistent decrease in water use by the pulp and paper, petroleum/chemical/ethanol, metals, and non-metals industry sectors in the past five years. While varying production for these industries has obviously affected annual water demand, this trend suggests that water conservation is a factor and needs to be considered in future demand projections. The MDNR's policy and permit rate structure that enlists financial disincentives for water use in once-through cooling systems will also decrease water use as facilities move toward use of recirculating cooling systems.

The industry sector on a fast-pace growth in Minnesota is the ethanol industry. The majority of the water demand for these facilities is met with ground water. New facilities and facilities looking to expand are facing water supply limitations that need to be resolved before construction. State agencies have formed an ethanol team to provide an integrated approach to handle the permitting needs for the ethanol industry. Section 2.5 provides an industry-focus analysis for ethanol production.

Treated Wastewater Supply

The state of Minnesota has nearly 600 municipal WWTPs permitted for discharge to surface waters. While the majority of permitted WWTPs have capacities less than 1 mgd, the majority of the wastewater treatment capacity resides in the 11 WWTPs whose capacities exceed 10 mgd. As indicated in Figure 2.4, there are 517 WWTPs with capacities less than 1 mgd (the first column) that account for 100 mgd of the WWTP capacity in Minnesota. The 11 facilities with capacities in the 10-50 mgd range and greater than 50 mgd combine for a total capacity of 500 mgd.

Figure 2.4. Capacity and Number of Municipal WWTPs in Minnesota

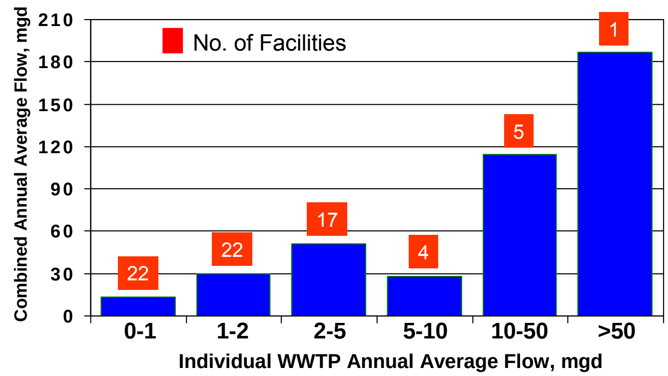


Source: MPCA, 2005

The annual average treated wastewater flow for Minnesota municipal WWTPs in 2005 was estimated to be 500 mgd. This estimate is based on a reported total flow of 425 mgd for larger WWTPs and estimated flow of 75 mgd for smaller

WWTPs. Larger WWTPs are defined in this study as WWTPs with permitted capacities greater than or equal to 1 mgd and smaller WWTPs have permitted capacities less than 1 mgd. The permitted capacity is the capacity defined in the National Pollutant Discharge Elimination (NPDES) Permit, and typically is the design average wet weather flow. The largest six WWTPs in the state treat over 60% of the state's wastewater, as represented by the plant flow ranges of 10-50 mgd and greater than 50 mgd in Figure 2.5. Many smaller WWTPs, with permitted capacities less than 1 mgd (not included in Figure 2.5), discharge intermittently and use of annual average data can be misleading. An estimated range of annual average flows for smaller WWTPs is assumed in this study to be 75% of the permitted capacity. Given a combined design capacity of 100 mgd for the 517 WWTPs with permitted capacities less than 1 mgd, approximately 75 mgd of treated wastewater supply could be available from smaller facilities. Table 2.3 summarizes the capacity and historic state treated wastewater supply, based on the MPCA Discharge Monitoring Report database (MPCA, 2005).

Figure 2.5. 2005 Annual Average Flows for WWTPs with Permitted Capacities >1 mgd in Minnesota



Source: MPCA, 2005

Table 2.3. Minnesota's Available Recycled Wastewater Supply

	All WWTPs	WWTPs with Permitted Capacities >1 mgd	WWTPs with Permitted Capacities <1 mgd
Permitted Design Capacity, mgd	763	663	100
2005 Annual Average Flow, mgd	500[1]	425	75[2]

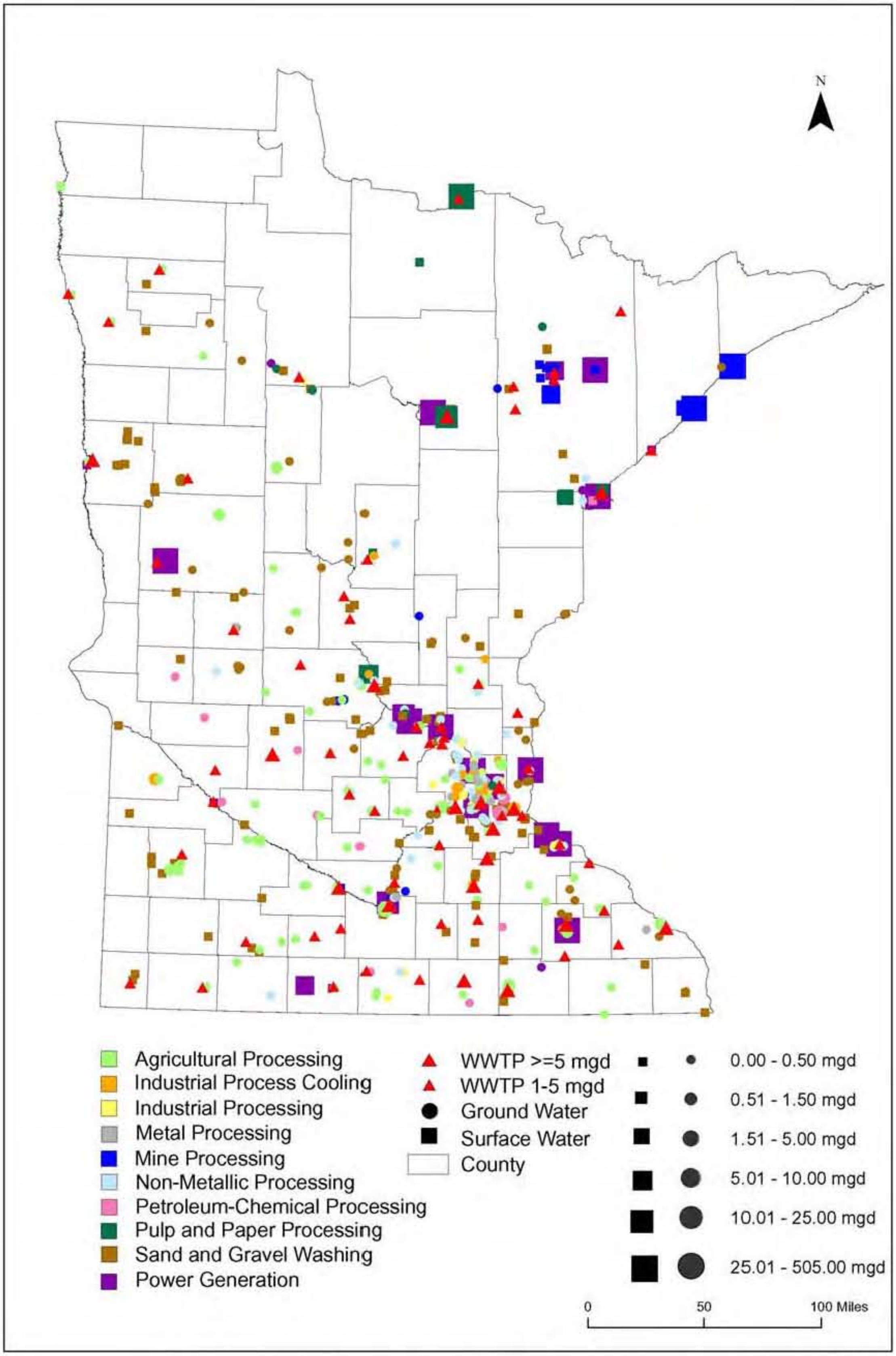
[1]Based on a flow of 425 mgd for WWTPs with permitted capacities >1 mgd and an estimate for flow from smaller WWTPs
[2]WWTP flow for plants with permitted capacities <1 mgd is an estimate assumed as 75% of the permitted capacity and is reported as a continuous daily discharge averaged over the year (many smaller facilities have intermittent discharges and higher daily flows during periods of discharge). A more conservative estimate of 50% would put the total flow in the range of 475-500 mgd.
Source: MPCA, 2005

Proximity of Industries Relative to WWTPs

While summaries of industrial water use and treated wastewater supply throughout the state are necessary to address the viability of using a recycled supply, these industries must be located near a WWTP for recycled wastewater to be an economically viable supply. A statewide map, shown in Figure 2.6, identifies industries, the relative volume of water they use, and the proximity of these industries to larger WWTPs. A more detailed review is provided on an individual watershed, WWTP, and industry-specific basis in the following subsections. Figure 2.6 presents all the permitted MDNR industrial water users for the state by category. The power generation industry subcategories were all grouped under the general heading of power generation, represented by the purple color. The relative volume of water used by these industries is depicted by the size of the symbol. Circles represent ground water-using industries and squares are surface water users.

Larger WWTPs (over 1 mgd design capacity) are identified by the triangles on Figure 2.6, with the relative size shown for each facilty's design capacity. While it is feasible for smaller plants (with design capacities less than 1 mgd) to supply industry's recycled wastewater, this study focused on opportunities associated with larger WWTPs. Larger treatment facilities are more likely to have the staff and municipal infrastructure to support treatment upgrades and the administrative role that is required for a wastewater recycling program. Site specific planning and analysis should consider smaller WWTPs if there appears to be a close correlation between a specific WWTP effluent supply and major industrial water demands in that area.

Figure 2.6. State Demand and Supply Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd); MPCA, 2005

2.2 Regional Inventory

Watershed Analysis Overview

Regional demand and supply were analyzed on a watershed basis to provide a more detailed account of industrial demand and proximity to a treated wastewater supply. Figure 2.7 identifies the ten major watersheds in Minnesota. This section of the report focuses on the Lower Mississippi River watershed as an example of the analysis provided for each watershed documented in Volume II-Appendix 1.

Indices on the availability of ground water supplies and the susceptibility of these supplies to contamination were also applied regionally to determine areas for which wastewater recycling may help protect ground water resources. Water supply availability is reviewed on a regional level using the MDNR's classification of Minnesota into six ground water areas (MDNR, 2005). The areas are categorized by the general availability of ground water in the bedrock and two overlying sediment layers classified as surficial sands and buried sands, shown in Figure 2.8. Appendix II-1 (Appendix D) contains the classification system and supporting documentation. Additional information on quantity and quality of ground water is summarized from the MPCA's regional ground water profiles (MPCA, 1995). The statewide assessment of susceptibility to ground water contamination (MPCA, 1989), as shown in Figure 2.9, is also used to identify ground water supply issues. These assessments by MDNR and MPCA provide higher level indicators of ground water quantity and quality concerns that can be applied uniformly across the state.

Industrial Water Use – Lower Mississippi River Watershed

The Lower Mississippi River watershed has a diverse base of industries, as summarized in Table 2.4 and Figures 2.10 and 2.11. The largest water use is related to power generation facilities (nuclear power plant, steam power cooling and miscellaneous power generation uses). Over 570 mgd of water was used for power generation in 2004, of which all but 1 mgd was obtained from surface water supplies. The Prairie Island Nuclear Plant used over 500 mgd in 2004 and another 70 mgd was used for once-through cooling at the Xcel facility near Red Wing and the Rochester Public Utilities plant. There are several agricultural processing facilities in this watershed with a combined water use of 2.9 mgd in 2004. Flint Hills Resources withdrew 6.5 mgd from its set of wells for processing of petrochemical products.

Table 2.4. Industrial Water Use in the Lower Mississippi River Watershed

	2004 Water Use, mgd		
Industry Category	**Ground Water**	**Surface Water**	**Total**
Agricultural Processing	3	0	**3**
Industrial Process Cooling - Once Through	<1	<1	**<1**
Metal Processing	<1	0	**<1**
Non-Metallic Processing	1	0	**1**
Nuclear Power Plant	<0.1	506	**506**
Petroleum - Chemical Processing, ethanol	7	0	**7**
Power Generation	<1	0	**<1**
Sand & Gravel Washing	<1	2	**2**
Steam Power Cooling - Once Through	0	71	**71**
Steam Power Cooling - Wet Tower	<1	0	**<1**
Total	**13**	**579**	**592**

Figure 2.7. Minnesota Watersheds

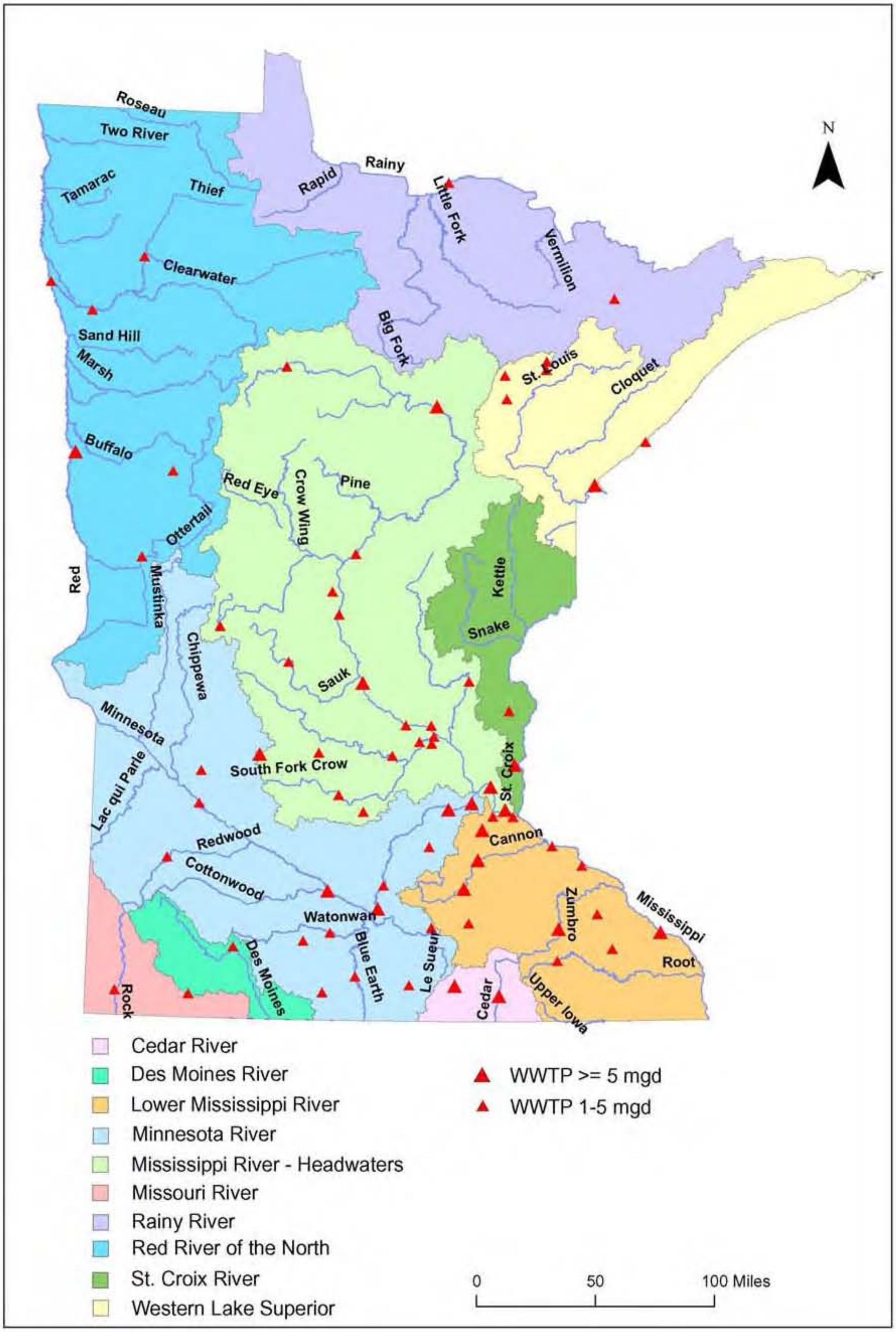
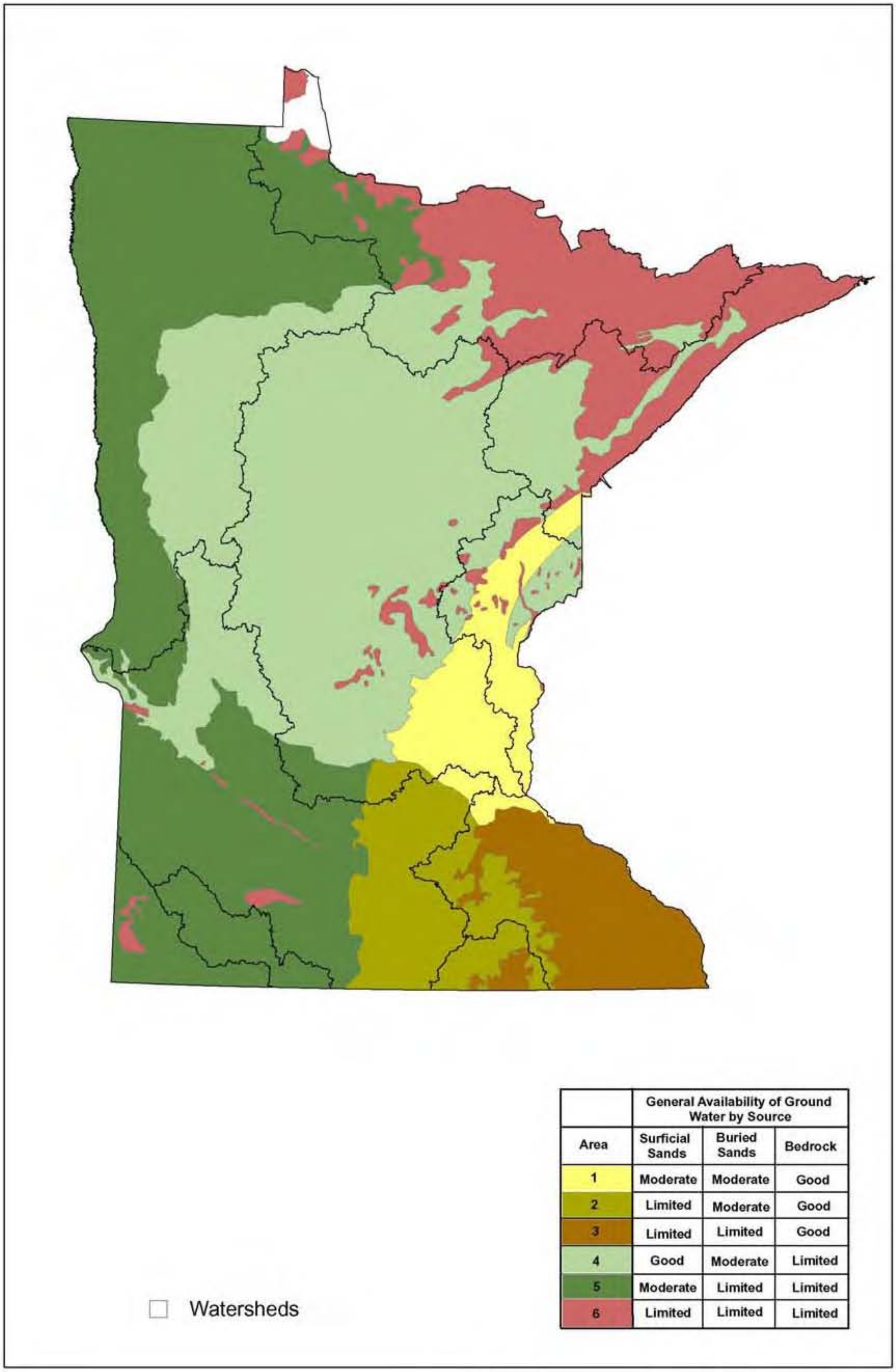
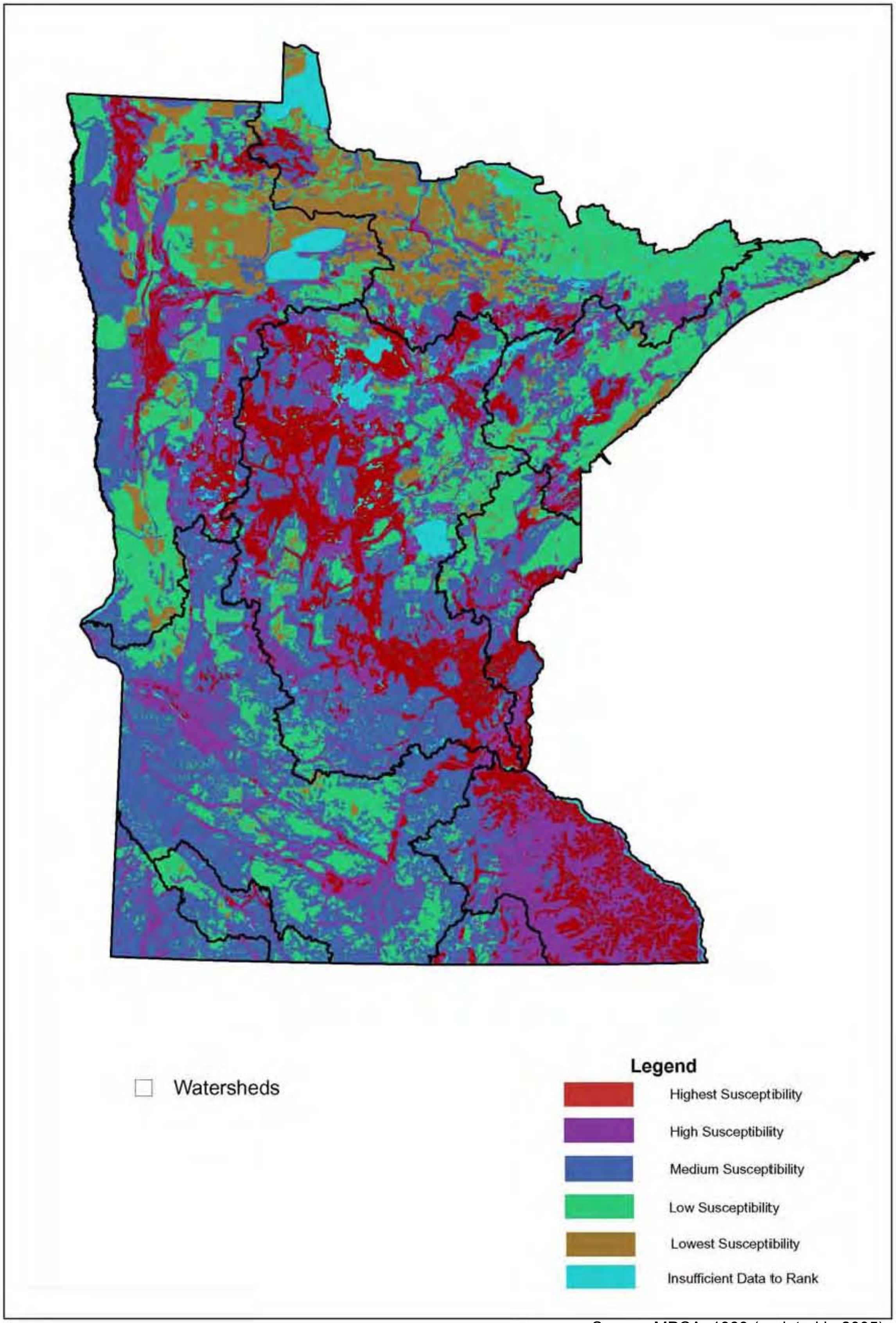


Figure 2.8. Ground Water Availability in Minnesota



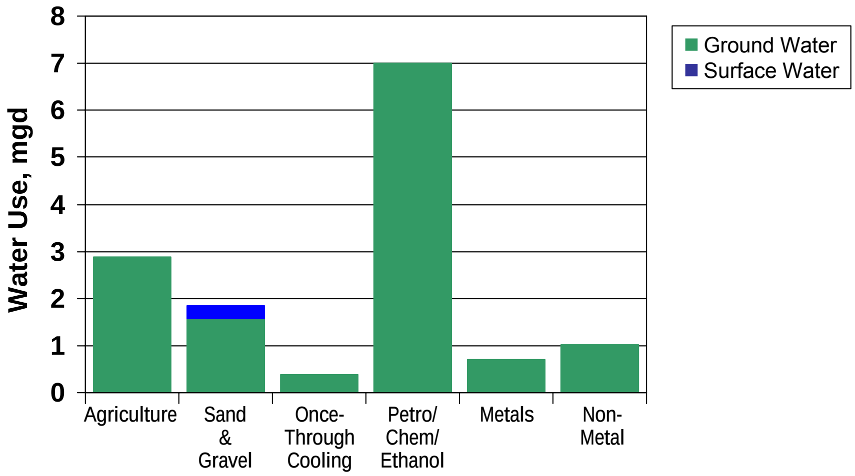
Source: Groundwater Provinces Data, Minnesota DNR, 2005

Figure 2.9. Ground Water Contamination Susceptibility in Minnesota



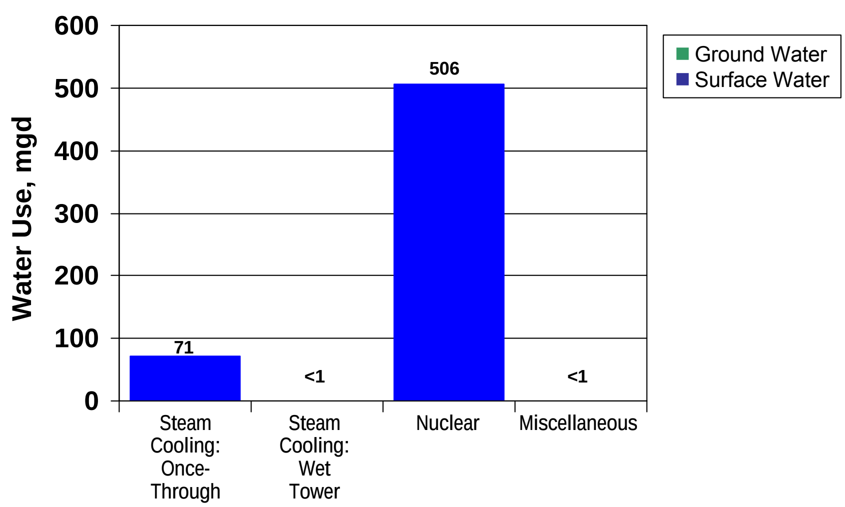
Source: MPCA, 1989 (updated in 2005)

Figure 2.10. Industrial Processing Water Use in the Lower Mississippi River Watershed, 2004



Source: MDNR, 2004

Figure 2.11. Power Generation Water Use in the Lower Mississippi River Watershed, 2004



Source: MDNR, 2004

Treated Wastewater Supply – Lower Mississippi River Watershed

There are 12 municipal WWTPs in the Lower Mississippi River watershed with design capacities greater than 1 mgd. Table 2.5 summarizes the design capacity and historic flows for the plants. There are three facilities within 70% of the design capacity: Owatonna, Plainview-Elgin, and Rochester. Rochester is nearing completion of construction for an expansion to 24 mgd. In 2005, approximately 40 mgd of treated wastewater was discharged into the Lower Mississippi River watershed from these 12 facilities. Smaller WWTPs account for 16% of the combined capacity of WWTPs discharging to surface waters in the Lower Mississippi River watershed. This would equate to an annual average flow of 15 mgd if these rural communities grew to use the full capacity of their WWTPs.

Table 2.5. Larger WWTPs in the Lower Mississippi River Watershed

Facility Name	Permitted Capacity, mgd	2005 Annual Average Flow, mgd	Flow as % of Design Capacity
Faribault WWTP	7.0	3.7	53%
Lake City WWTP	1.5	0.6	37%
Met Council - Empire WWTP*	24.0	8.5	35%
Met Council - Rosemount WWTP*	1.3	0.9	70%
Northfield WWTP	5.2	2.1	40%
Owatonna WWTP	5.0	3.5	71%
Plainview-Elgin Sanitary District WWTP	1.4	1.1	74%
Red Wing WWTP	4.0	2.1	51%
Rochester Water Reclamation Plant	19.1	13.5	71%
Stewartville WWTP	1.1	0.5	48%
Whitewater River Regional WWTP	1.1	0.7	63%
Winona WWTP	6.5	4.0	61%
Total	**77**	**41**	**53%**

*The Rosemount WWTP is located in the Lower Mississippi River Watershed, but discharges into the Mississippi River-Headwaters watershed. In late 2007 the Empire WWTP will move its discharge near the Rosemount WWTP discharge and the Rosemount WWTP will be phased out. The Empire WWTP and Rosemount WWTP design capacities are used, instead of permitted capacities.

Source: MPCA, 2005

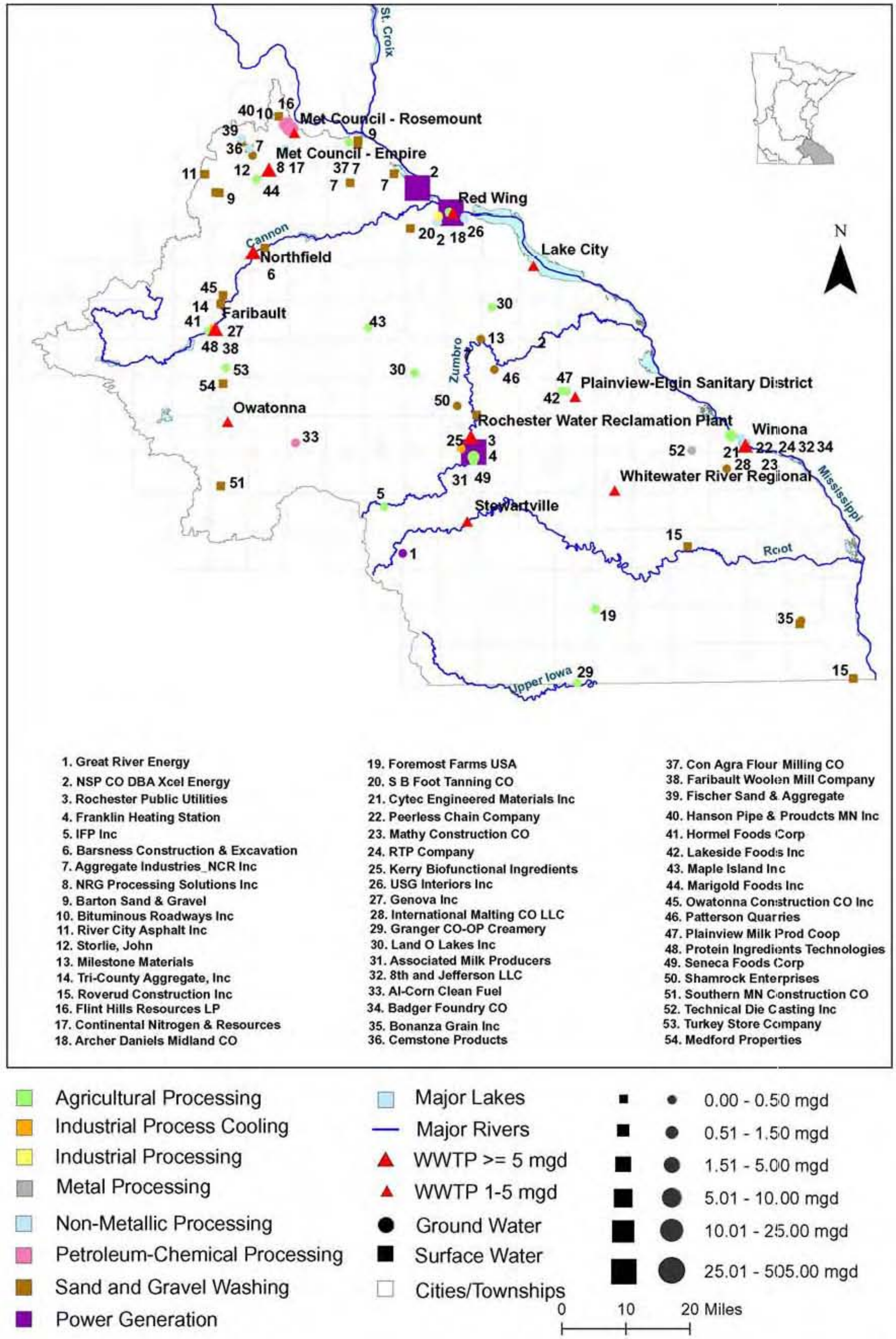
Proximity of Industries Relative to WWTPs – Lower Mississippi River Watershed

A total of 56 industries are permitted to withdraw ground and/or surface water in the Lower Mississippi River watershed and 25 of these are located within 4 miles of a larger municipal WWTP. Figure 2.12 presents the location of the industries and WWTPs in the Lower Mississippi River watershed. Table 2.6 summarizes the industries within a 4-mile radius of a WWTP. Appendix II-1 (Appendix C) provides the full industry list.

Winona has the largest number of industries in close proximity to its WWTP. Water is used for metal processing by Badger Foundry Company and Peerless Chain Company, non-metallic processing by RTP Company, industrial process cooling by Cytec Engineered Materials, and agricultural processing by International Malting Company. Red Wing and Faribault are two other cities with multiple industries within the proximity of their WWTP.

There are several agricultural processing facilities within 4 miles of a WWTP. The larger agricultural processing water users are Associated Milk Producers (2.7 mgd) near the Rochester Water Reclamation Plant, International Malting Co. (1 mgd) in the Winona area, and Marigold Foods (0.3 mgd) near the Met Council's Empire WWTP.

Figure 2.12. Lower Mississippi River Watershed Demand & Supply Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Table 2.6. Industries in the Lower Mississippi River Watershed Within 4 Miles of a WWTP

Industry Name by Category	ID No. for Map	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP
Agricultural Processing					
ARCHER DANIELS MIDLAND CO	18	G	0.206	1.0	Red Wing
ASSOCIATED MILK PRODUCERS	31	G	0.696	2.7	Rochester
HORMEL FOODS CORP	41	G	0.272	1.0	Faribault
IFP INC	5	G	0.012	1.0	Faribault
INTERNATIONAL MALTING CO LLC	28	G	0.964	3.3	Winona
LAKESIDE FOODS INC	42	G	0.075	3.0	Plainview - Elgin
MARIGOLD FOODS INC	44	G	0.319	2.0	Met Council-Empire
PLAINVIEW MILK PROD COOP	47	G	0.191	3.0	Plainview - Elgin
PROTEIN INGREDIENT TECHNOLOGIES INC	48	G	0.052	2.0	Faribault
SENECA FOODS CORP	49	G	0.049	4.0	Rochester
Industrial Process Cooling – Once Through					
CYTEC ENGINEERED MATERIALS	21	G	0.077	3.3	Winona
FARIBAULT WOOLEN MILL COMPANY	38	S	0.006	1.0	Faribault
KERRY BIOFUNCTIONAL INGREDIENTS INC	25	G	0.298	2.5	Rochester
Metal Processing					
BADGER FOUNTRY CO	34	G	0.425	1.0	Winona
PEERLESS CHAIN COMPANY	22	G	0.266	1.0	Winona
Non-Metallic Processing					
8TH AND JEFFERSON LLC	8	G	0.001	1.0	Winona
GENOVA INC	27	G	0.139	1.0	Faribault
RTP COMPANY	24	G	0.436	2.5	Winona
S B FOOT TANNING CO	20	G	0.307	2.6	Red Wing
USG INTERIORS INC	26	G	0.035	2.3	Red Wing
Power Generation – Miscellaneous					
FRANKLIN HEATING STATION	4	G	0.503	4.0	Rochester
Sand and Gravel Washing					
BARNESS CONSTRUCTION & EXCAVATION	6	S	0.000	2.3	Northfield
CEMSTONE PRODUCTS	36	G	0.011	3.8	Met Council-Empire
Steam Power Cooling – Once Through					
NSP CO DBA XCEL ENERGY	2	S	44.763	1.0	Red Ring
ROCHESTER PUBLIC UTILITIES	3	S	26.622	3.0	Rochester
Steam Power Cooling – Wet Tower					
ROCHESTER PUBLIC UTILITIES	3	G	0.405	3.0	Rochester

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Flint Hills Resources is the largest non-power related industrial water user in this watershed. Approximately 6.5 mgd was pumped from its well field in 2004 for its total facility use. They are in the process of system modifications to reuse their process wastewater rather than add an additional well. Municipal WWTP effluent use at Flint Hills Resources was evaluated during the facility planning stages of the Met Council's Empire WWTP expansion; the outfall for this plant will be moved to discharge into the Upper Mississippi River watershed and will be within 2 miles of Flint Hills Resources. While the use of recycled wastewater from Empire by Flint Hills Resources was not pursued because of water quality issues, notably high chlorides in the Empire WWTP effluent, it is possible that potential future Flint Hills Resources expansions could consider this source. Also, the industrial areas along the outfall could benefit from this potential 24 mgd source of recycled wastewater.

Factors Influencing Potential for Industrial Use of Recycled Wastewater – Lower Mississippi River Watershed

The majority of the Lower Mississippi River watershed has a good water supply from bedrock that most communities rely on as their primary water source. Most of the watershed is in Ground Water Area 3 of the state, with eastern regions in Area 2 and the northern reaches in Area 1 (refer to Figure 2.8). All three areas have a reliable and productive bedrock aquifer.

Area 3 has extensive near-surface karst areas that result in its aquifers being vulnerable to contamination. There is wide-spread nitrate contamination in near-surface aquifers as well as occurrences of pesticides and other contaminants. The susceptibility to contamination index places this watershed in the medium to highest range (refer to Figure 2.9). Area 2 on the western edge of the watershed has a more productive buried sand aquifer, but still limited surficial sand aquifers. The northern watershed, in Area 1, has a reliable supply for all three general aquifer levels.

Portions of the Lower Mississippi River watershed will be affected by the TMDL for Lake Pepin. The planning process for this TMDL has established preliminary targets of phosphorus and solids loading reductions of one-half into Lake Pepin. While nonpoint sources are significant contributions to this load, it is likely that loading reductions for most point sources will be considered.

2.3 Twin Cities Metro Area Inventory

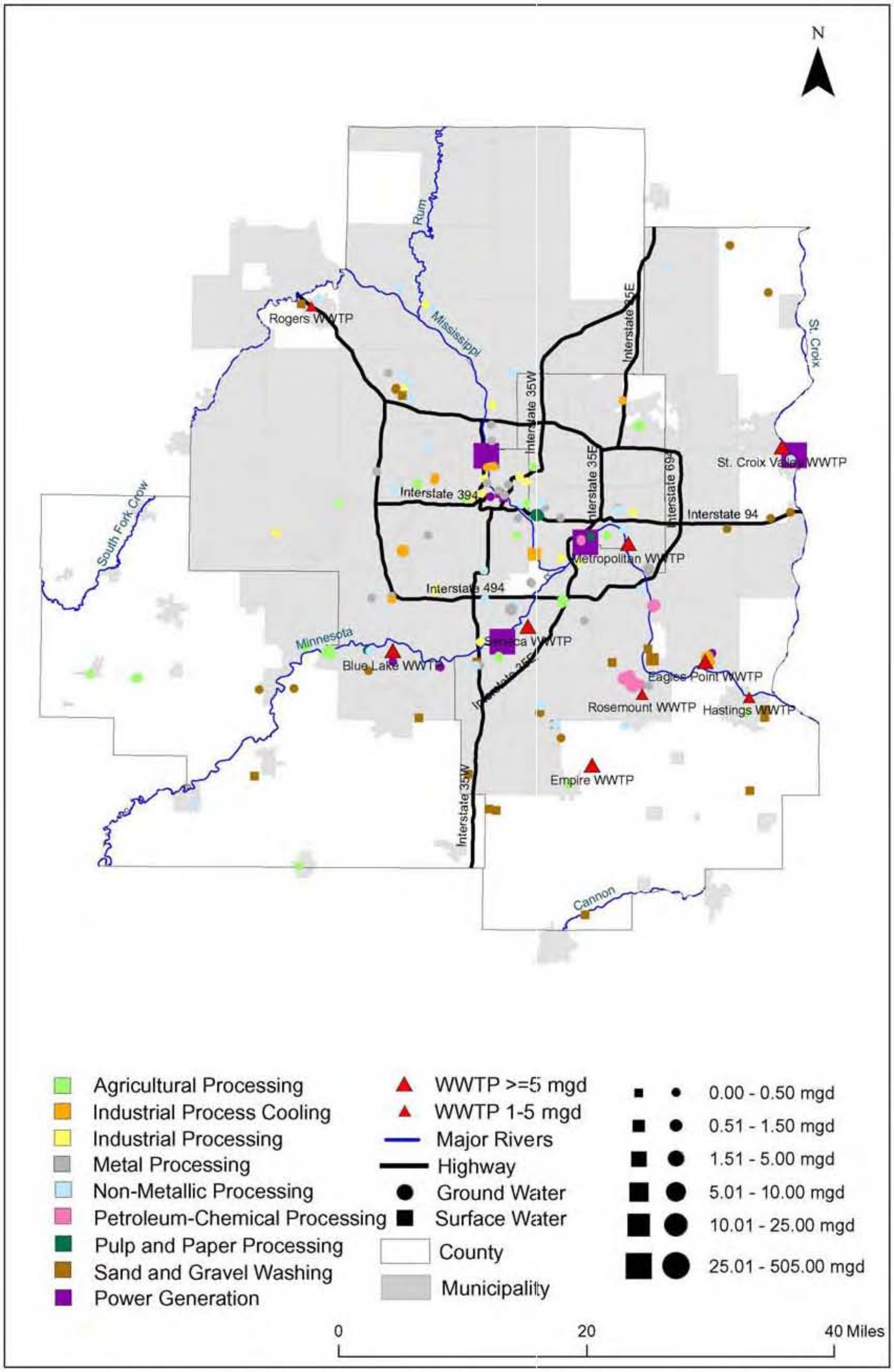
The industrial inventory for the Twin Cities metro area indicates a diversity of industries and a prevalence of potential recycled wastewater customers along the river corridors. The industry inventory in the Twin Cities metro area was based on the same MDNR database as for the state and watershed analysis plus those industries discharging to the Met Council's sewer system for treatment at one of eight WWTPs. Figure 2.13 presents the industries with water permits (MDNR appropriation permits) and Figure 2.14 locates a larger set of industries in the Twin Cities metro area, based on Met Council's Industrial Dischargers permit program (Met Council, 2005).

The Met Council database provides for a more detailed categorization of the industries, as shown in the legend of Figure 2.14. These industry categories are documented with subcategories in Appendix II-1 (Appendix E). Figure 2.14 also identifies if the industry obtains its water from a municipal (potable) source or another source, which typically would be through a MDNR appropriations permit. The other source could be ground water (well), surface water or a combination of both. The municipal designation was rolled up to include any industry that uses a municipal supply.

The Met Council (specifically, the Environmental Services division or MCES) Industrial Dischargers Permit database includes any discharger to the Met Council's sewer system. It does not include all industries in the area, because some have their own treatment systems and discharge permits. Some dischargers use little water, such as landfill leachate systems, and mainly collect and treat water for discharge. These industries were excluded from the evaluation.

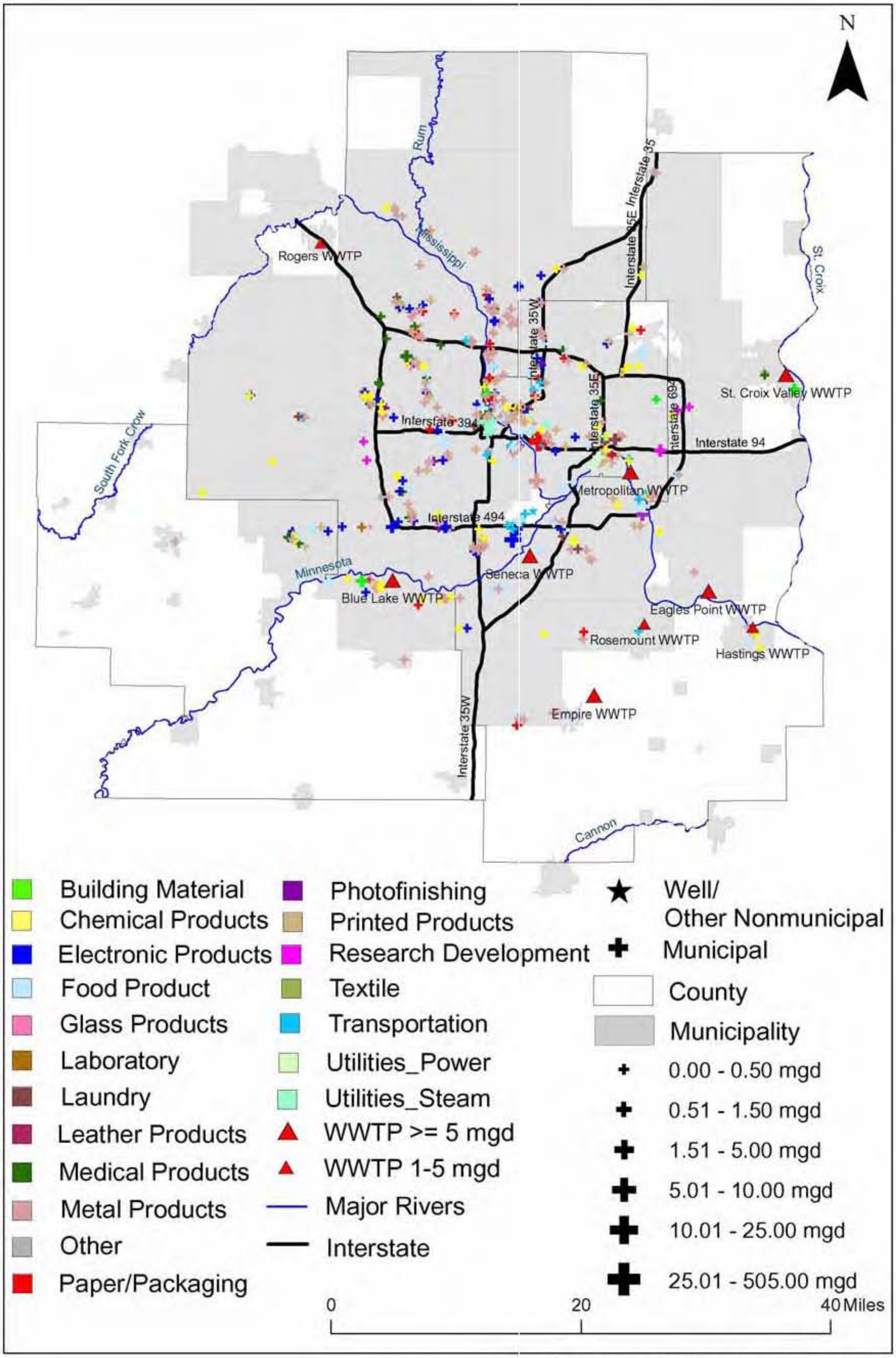
The industries in the Twin Cities metro area discharging to the sewer system, as shown in Figure 2.15, had a combined water demand of 65 mgd in 2005. The largest water users were food industries, at 15 mgd, followed by the metal products industries at 10 mgd. Water used in the electronic products and paper/packaging industries and for power/steam/air conditioning and health care facilities, all had category totals over 5 mgd.

Figure 2.13. Twin Cities Metro Area Demand & Supply Inventory – DNR Water Appropriations Permits



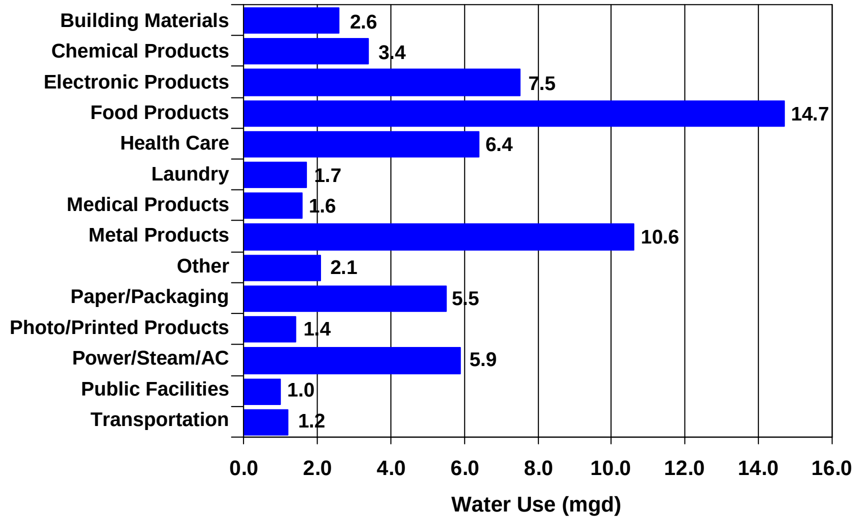
Source: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Figure 2.14. Twin Cities Area Demand & Supply Inventory – MCES Industrial Dischargers



Source: MCES Industrial Dischargers Permit Program, 2005

Figure 2.15. Metro Area Industrial Water Demand, 2005



Source: Met Council, 2005

The total Twin Cities metro area industrial demand is estimated to be 75 mgd. This estimate is based on an analysis of both databases to determine a reasonable estimate of the industrial demand supplied by water utilities. Industries that supply their own water through MDNR appropriations permits used approximately 30 mgd in 2004. The Twin Cities metro area water utilities used 350 mgd in 2004. Assuming that 13% of potable water supply customers are industries, another 45 mgd of industrial demand is supplied by water utilities.

2.4 WWTP Focus – Empire and Rosemount WWTP Inventories

This study inventoried the industries in proximity to major WWTPs in the seven-county Twin Cities metro area. This section provides the inventory for the Met Council's Empire & Rosemount WWTPs, located in the Lower Mississippi River watershed. Appendix II-1 provides the inventories for the other WWTPs.

The Empire WWTP was recently expanded from 9 mgd to 24 mgd and the 1.3 mgd Rosemount WWTP will be phased out with wastewater from its service area treated at the Empire WWTP. The Empire WWTP, which currently discharges to the Vermillion River, will have a new discharge to the Mississippi River in the vicinity of the one currently used by the Rosemount WWTP. Figure 2.16 identifies the industries near each plant and Table 2.7 lists those within a 5-mile radius of each plant. The outfall for the Empire WWTP to the Mississippi River is also shown on Figure 2.16. The list of industries is restricted to the radius around each plant, but could be broadened to include industries along the outfall.

As described previously in the Lower Mississippi River Watershed Inventory section, Flint Hills Resources is the high water demand industry using ground water in the area, withdrawing over 6 mgd in 2004. The industry with the next largest water use is Aggregate Industries, with a demand of 1.1 mgd, supplied by surface water at a facility near the Mississippi River. Another Aggregate Industries facility is located closer to the Empire WWTP and uses a ground water supply of 0.4 mgd. The industry with the largest water demand near the Empire WWTP is Marigold Foods, which uses 0.32 mgd of ground water supplied by its own well field. Another food product industry, Kemps, has a demand of 0.25 mgd. The other industries in the area have a combined demand of 0.32 mgd.

Figure 2.16. Industries in Proximity to Empire & Rosemount WWTPs

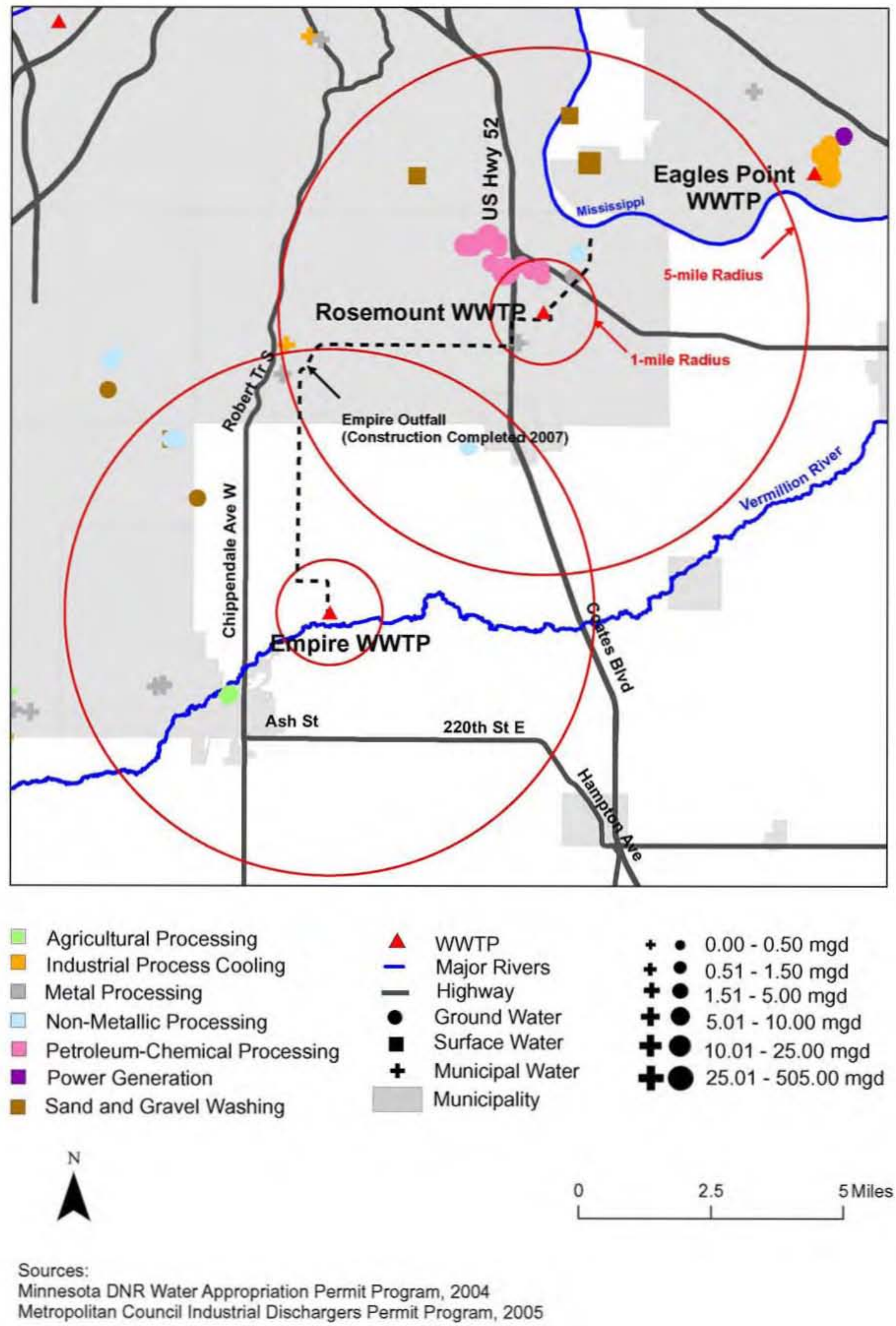


Table 2.7. Industries Within a 5-Mile Radius of Empire and Rosemount WWTPs

Industry Name	MDNR Permit	Water Source*	Annual Average Water Use, mgd	Industry Category (MDNR Appropriations Permit Database)
Aggregate Industries-NCR Inc	x	G & S	1.462	Sand & Gravel Washing; Non-Metallic Processing
Bituminous Roadways Inc	x	S	0.004	Sand & Gravel Washing
Cannon Equipment		M	0.010	Metal Processing
Cemstone Products	x	G	0.107	Sand & Gravel Washing
Continental Nitrogen & Resources	x	G	0.085	Petroleum or Chemical Processing, Ethanol
CF Industries Inc	x	G	0.010	Non-Metallic Processing
Flint Hills Resources LP	x	G	6.531	Petroleum or Chemical Processing, Ethanol
Greif Bros Corp		M	0.038	Industrial Processing
J I T Powder Coating		M	0.014	Metal Processing
Kemps LLC		M&G	0.256	Agricultural Processing
Marigold Foods Inc	x	G	0.319	Agricultural Processing
NRG Processing Solutions LLC	x	G	0	Non-Metallic Processing
Performance Industrial Coating		M	0.009	Metal Processing
Spectro Alloys Corp	x	G	0.006	Metal Processing
Valmont/Lexington		M	0.004	Metal Processing
Wayne Transports Inc		M&G	0.030	Metal Processing

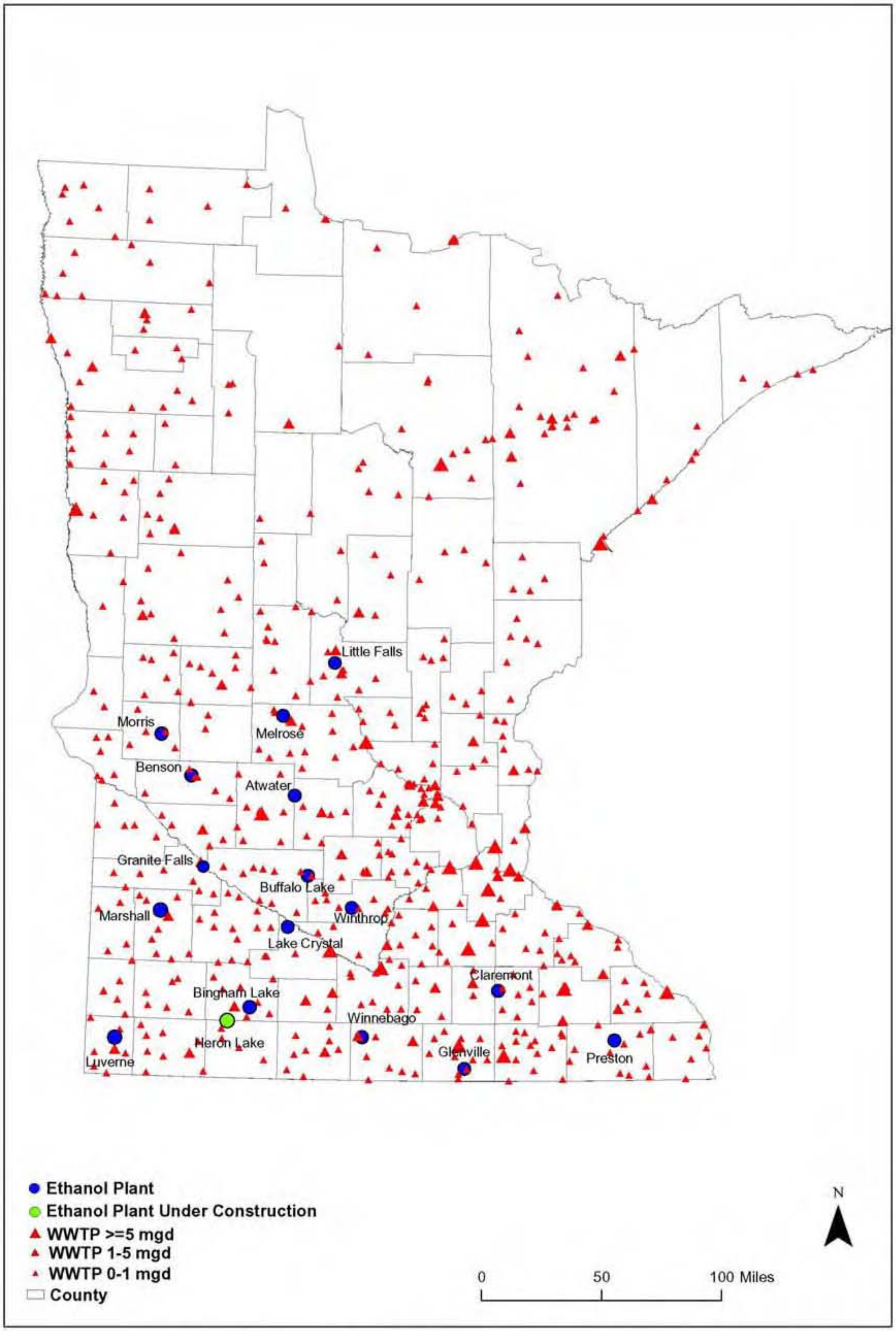
* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: S: Surface Water.

2.5 Industry Focus – Ethanol Plant Inventory

The expansion of the ethanol industry in Minnesota has stimulated the exploration of wastewater recycling for this industry. Ethanol production is a fairly water intensive process, requiring on average 3-6 gallons of water to produce 1 gallon of ethanol (gallons water/gallon ethanol). In Minnesota, the lowest water use rate in 2005 was 3.6 gallons water/gallon ethanol at the Chippewa Valley Ethanol Company (Institute for Agriculture and Trade Policy, 2006) and rates were greater than 7 gallons water/gallon ethanol for some facilities pre-2002. While improved practices have reduced water use in ethanol production, it still requires a significant allocation of water resources. In addition, most ethanol facilities are located in areas with limited water supplies. To properly address the water appropriations permitting and other permitting requirements for the ethanol industry, state agencies have formed teams to work specifically on the environmental issues of this industry sector. One action developed from these teams is to investigate the use of recycled wastewater as a water supply for ethanol facilities. State agencies are exploring funding options for specific application to wastewater recycling projects with ethanol facilities during the summer 2007 budget process.

Facilities within the state have the capacity to produce over 550 million gallons of ethanol a year from sixteen locations across the middle and south part of the state (MDA, 2006). Assuming a higher end water use rate of 5 gallons water/gallon ethanol, the estimated water demand for the state's ethanol production capacity is about 7.5 mgd. An inventory of ethanol facilities in conjunction with WWTPs in the state is shown in Figure 2.17. The facilities and water demands for facilities with their own permitted supply are listed in Table 2.8.

Figure 2.17. Ethanol Plants in Minnesota



Source: MN Department of Agriculture, April 2006 (www.mda.state.mn.us/ethanol) & St Paul Pioneer Press, April 2007

Table 2.8. Ethanol Plant Capacity and Water Use

City (plant name)	Ethanol Capacity mgy	Corn Production Required million bushels/yr	Start-up Year	2004 Water Use (MDNR Permit Only) mgd[1]
Marshall (ADM)	40	14.8[2]	1988	
Morris (DENCO)	24	9	1991	0.368
Winnebago (Corn Plus)	47	17.4	1994	0.272
Winthrop (Heartland)	37	13.7	1995	0.278
Benson (CVEC)	45	16.7	1996	0.401
Claremont (Al-Corn)	34	12.6	1996	0.387
Bingham Lake (Ethanol2000)	31	11.5	1997	--
Buffalo Lake (MN Energy)	19	7	1997	0.239
Melrose (Dairy Proteins)	3	Cheese whey	1986	--
Preston (Pro-Corn)	42	15.6	1998	--
Luverne (Corn-er Stone)	21	7.8	1998	--
Little Falls (CMEC)	22	8.1	1999	--
Albert Lea (Exol/Agra Resources)	41	15.2	1999	0.563
Lake Crystal	50	18	2005	--
Granite Falls Energy	50	18	2005	--
Atwater (Bushmills Ethanol)	45	16.6	2005	--
TOTAL	**551**	**200**		

Sources: MDA, 2006 (www.mda.state.mn.us/Ethanol) and MDNR Water Appropriations Permit Program, 2004.
[1] Water use data only available for those with MDNR permits in 2004.
[2] Refer to source: portion of plant processing used for ethanol.

Table 2.9. Select Ethanol Plants in Relation to Recycled Wastewater Supply

Ethanol Plant[1]	Closest WWTP[2]	Distance to the WWTP (miles)	WWTP Permitted Capacity (mgd)	WWTP 2005 Flow (mgd)	2004 Water Use (mgd)	Assumed Cooling Water Demand (mgd)[3]
Diversified Energy Co LLC	Morris	1.7	0.964	0.60	0.37	0.22
Chippewa Valley Ethanol Co	Benson	1.7	0.985	0.43	0.40	0.24
Minnesota Energy	Hector	3.4	0.66	0.21	0.24	0.14
Heartland Corn Products	Gaylord	3.2	0.55	0.36	0.28	0.17
Al-Corn Clean Fuel	Blooming Prairie	8	0.899	0.51	0.39	0.23
Corn Plus	Winnebago	2	1.7	0.59	0.27	0.16
Agra Resources Corp	Albert Lea	10	18.38	4.23	0.56	0.34

[1] Ethanol plants with MDNR water appropriations permits in 2004; 2004 water use is the reported use to the MDNR Water Appropriations Permit program – it is possible that some facilities used other sources of water and total water use is more than listed in this table.
[2] Selection criteria: closest WWTP with sufficient flow (based on 2005 flow data) for water use at the ethanol plants.
[3] Assumed 60% of total water use is for cooling water requirements.

The proximity of several ethanol plants to a WWTP was investigated. As shown in Table 2.9 there are several ethanol plants a reasonable distance from a WWTP that may have an adequate supply to meet at least the cooling water demands for the facility, estimated at 60% of the total facility water use. Additional information is needed on the diurnal variation of the WWTP flow and water quality to determine if these WWTPs could feasibly provide the water supply for these ethanol plants.

2.6 Summary

Demand vs. Supply

The statewide and Twin Cities metro area demand and supply analysis, summarized in Table 2.10, determined that the recycled wastewater supply can fulfill 95% of the industrial water demand and that there is ample recycled wastewater in the Twin Cities metro area to provide industries a water supply. However, as the spatial analysis showed, the proximity of a WWTP to an industry is not always optimum.

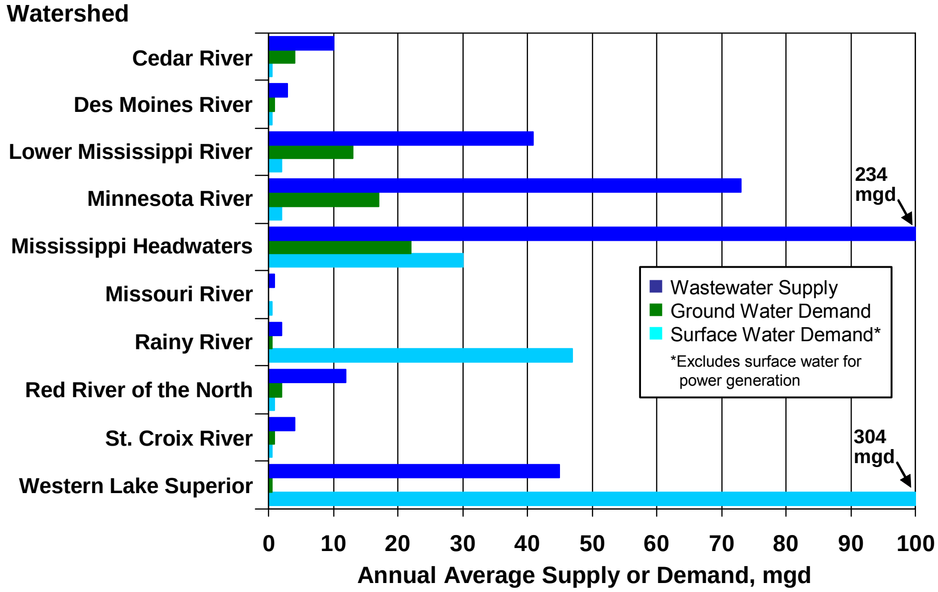
Table 2.10. Annual Average Demand and Supply Summary

	Industry Water Demand* (mgd)	Recycled Wastewater Supply (mgd)
State	445	425
Twin Cities Metro Area	75	255

*Excludes surface water supplies for power facilities
Source: MDNR, 2004; MPCA, 2005

The average flow for larger WWTPs totaled 425 mgd (2005) and industrial demand totaled 2,760 mgd (2004). If the power plants using surface water supplies are not considered a customer for recycled wastewater, then the industrial demand is 445 mgd. Of this demand, the majority is for the mining and pulp and paper industries in northern Minnesota. Demand for ground water supplies in 2004 was 60 mgd. Table 2.11 summarizes the demand and supply by watershed for ground and surface water supplies and includes totals with and without the power generation industry sector. Figure 2.18 excludes the larger surface water demands of the power facilities and provides a more appropriate scale to compare recycled wastewater supply to industrial water demands that could be met with this alternative water supply.

Figure 2.18. Comparison of Treated Wastewater Supply to Industrial Demands by Watershed



The comparison of historic ground water use by industries and WWTP effluent discharge flows indicates that each watershed currently processes enough wastewater to supply the industrial ground water demand, but the industries are not always in proximity to WWTPs. The larger surface water demands of the existing power generation, mining, and pulp and paper industries cannot be met by the state's recycled wastewater supply. New power facilities that will likely use recirculating cooling systems and partial needs of other high water demand industries could be supplied by recycled wastewater. The proximity of some of these facilities to WWTPs will make recycled wastewater a more favorable water supply option.

Table 2.11. Industrial Water Demand and Recycled Wastewater Supply Summary by Watershed

	DEMAND				SUPPLY			ATTRIBUTES		
Watershed	Ground Water	Surface Water	Total	Total Without Power Facilities*	Larger WWTP Capacity (WWTPs > 1 mgd)	Smaller WWTP Design Capacity (WWTPs < 1 mgd)	Larger WWTP Discharge Flow, 2005	No. of Industry Categories with Water Permits	Ground Water Availability	Ground Water Contamination Susceptibility
	2004 Industrial Water Use, mgd				mgd	mgd	mgd	No.	✓=Favors Recycling	
Cedar River	4.1	0.1	4.1	4.1	26.9	2.6	9.7	4	No Factor	No Factor
Des Moines River	0.6	0.1	0.7	0.7	5.8	3.1	3.1	2	✓	No Factor
Lower Mississippi River	13.3	578.8	592.1	14.9	77.3	15.8	41.0	10	No Factor	✓
Minnesota River	17.3	327.7	345.0	19.0	123.5	22.4	73.4	10	No Factor	Potential Factor
Mississippi River-Headwaters	21.5	939.6	961.1	51.3	337.4	31.5	233.6	15	No Factor	No Factor
Missouri River	0	0.1	0.1	0.1	1.5	2.0	0.7	1	✓	No Factor
Rainy River	<0.1	46.9	46.9	46.92	3.8	3.3	2.0	3	✓	No Factor
Red River of the North	2.2	55.2	57.4	3.0	19.8	7.9	11.7	3	✓	No Factor
St. Croix River	0.9	325.7	326.6	1.3	5.8	5.2	3.9	3	No Factor	No Factor
Western Lake Superior	0.2	486.4	486.5	304.2	60.9	6.9	44.9	7	✓	No Factor
TOTAL	**60**	**2,760**	**2,820**	**445**	**663**	**100**	**425**			

*Excludes surface water uses for power generation facilities.

Factors Influencing Potential for Industrial Use of Recycled Wastewater

The availability of higher quality ground water, typically sought first for municipal and industrial purposes, is a key factor in planning for growth in most of Minnesota. The summary of watershed inventories presented in Table 2.11 includes the assessment of indicators favoring recycled wastewater applications. This high level assessment indicates several areas of the state with limited ground water supplies. These areas are in the Des Moines River and Missouri River watersheds, in the southwest part of the state, northwestern Minnesota in parts of the Red River of the North watershed, and in the Rainy River and Western Lake Superior watersheds, in north central and northeastern Minnesota. The water requirements for ethanol facilities in the southwest part of the state have prompted agencies and industries to work together to meet immediate water demands while protecting the aquifer supplies for long-term use.

There are also community-specific water supply limitations in quality and quantity. Ground water contamination is found throughout the state and certain aquifer characteristics make some aquifers a less reliable supply, as in the karst area of the Lower Mississippi River watershed. In general, the water quality of an area and susceptibility to contamination must be assessed on a site specific basis. Community-level planning has usually been used to assess water supply needs in Minnesota. Planning has moved to the watershed level as observed in the state's water-limited areas of the Des Moines River, Missouri River, and Red River watersheds. Water supply planning, including identification of future water supply limitations, has encompassed a regional scale in the 7-county Twin Cities metro area, as directed under Minnesota Statutes, Section 473.1565.

As the state moves forward with TMDL development and new WWTPs or existing ones are expanded, evaluations of wastewater recycling facilities to reduce pollutant discharges are expected to become more prevalent. However, municipalities will not be able to recycle without partners – industries and other wastewater recycle customers need to commit to meeting their water demands with this alternative supply. As observed in the expansion of the ethanol industry and the construction of the Mankato Energy Center – a limited water supply was the key factor that led to consideration of a recycled wastewater supply. While other drivers may lead to wastewater recycling partnerships between municipalities and industries, the most significant driver in the near-term is expected to be water supply limitations, principally ground water supplies limited by quantity or quality issues.

2.7 References

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Section 3: Recycled Wastewater System Components and Costs

This section presents the third area of inquiry into the feasibility of Minnesota's industries using recycled wastewater by addressing the question: Is wastewater recycling an economical practice? The answer begins with identification of the system components which include treatment facilities for a range of treatment requirements and potential facilities to meet those requirements. After establishing a basis for the system components, a system of cost curves was developed for varying system sizes and transmission distances. Costs are presented by industry category as cost of service, on a dollar per gallon basis, to compare a recycled wastewater supply to traditional supplies. Appendix II-3 provides background information and more detail on the treatment requirements, treatment technologies, and cost assumptions used in the analysis.

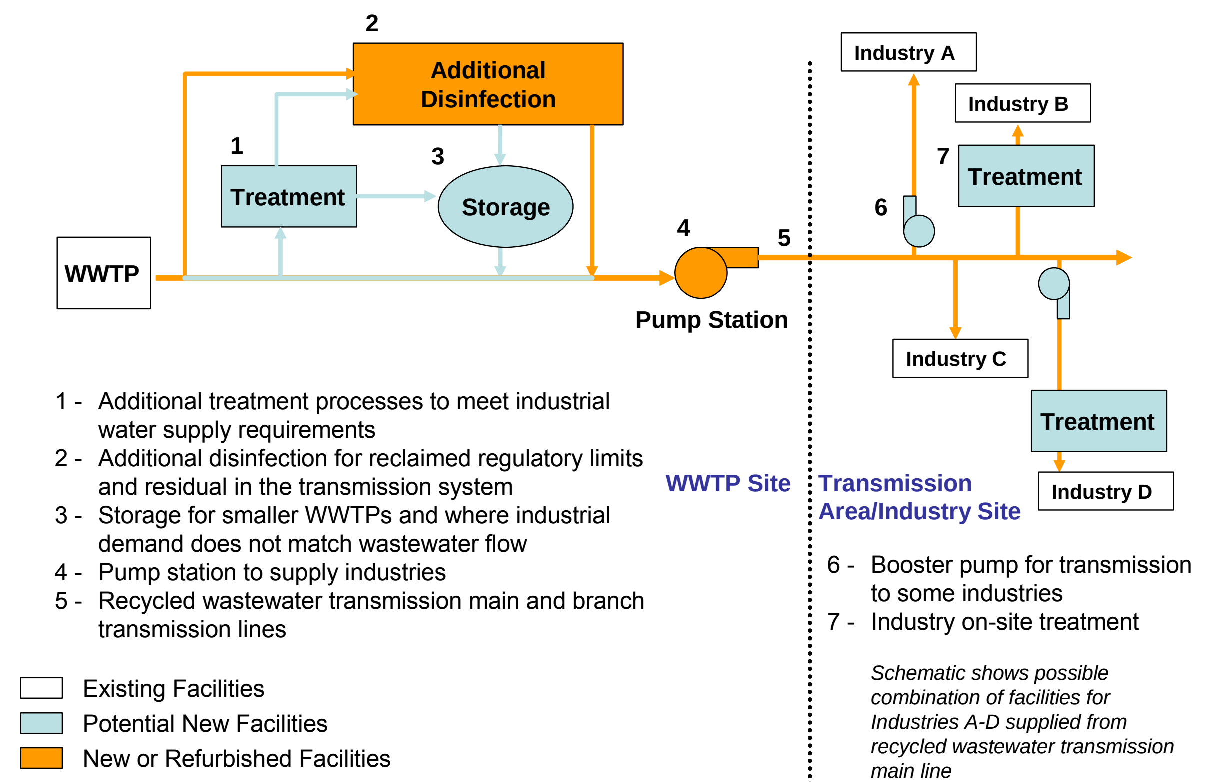
3.1 Recycled Wastewater System Overview

Recycled wastewater systems can be configured in many ways. Commonly used components are shown in Figure 3.1 and are described below. This study assumed certain components, identified as (1) through (7) and attributes for those components to develop costs. These assumptions are also described below.

- Treatment of WWTP Effluent (1)
  - Additional processes to those currently used by an existing WWTP, if needed.
  - New WWTP processes to replace existing processes during a plant upgrade, such as membrane filtration to replace clarification.
- Additional Disinfection (2)
  - A residual disinfectant is often used in the transmission system to minimize bacterial growth. Liquid chlorine (sodium hypochlorite) is assumed for this study.
  - Additional disinfection is required for year-round disinfection and more stringent pathogen limits. The existing facilities may be able to achieve this, but it is assumed new equipment is required.
- Storage (3)
  - In some instances, storage will be required to balance the diurnal or other WWTP flow variations, with the requirements of a specific industrial demand for different peak hour, weekly or other dominant demand patterns.
  - Storage will likely be required for WWTPs that reclaim over 50 percent of their flow. Smaller facilities, with less equalization capacity, are more likely to need storage.
  - The cost curves developed assume no storage requirements. Appendix II-3 provides storage system cost information.
- Pump Station (4)
  - A pump station located onsite at the WWTP.
  - For cost development purposes, this study assumes delivery of supply to industry at a pressure of 40 pounds per square inch (psi) and the same elevation as the WWTP.
- Recycled Wastewater Transmission System (5)
  - Transmission main and branch transmission lines supplying water to industries.
  - Variable flows and distances. This study evaluated flows of 0 to 30 mgd and distances of 1 to 10 miles.
- Booster Pumps (6)
  - Some industries may require booster pumps depending on their location and delivery pressure requirements.
  - Industries A-D shown on the schematic represent potential configurations for pumping and treatment facilities not located on the WWTP site (either at the industry or in the transmission system).

- Industrial Site Treatment (7)
  - Some industries already treat their existing water supply. These same processes or modifications may be required with a recycled supply.
  - Some industries may require new treatment processes with a recycled supply. It may be a cost-effective option to locate the treatment system at the industry site.

Figure 3.1. Recycled Wastewater System Conceptual Model



Many industries have their own wastewater treatment systems. Some industries treat their wastewater and recycle the water for traditional water supply uses. For many industrial facilities, treatment of their own WWTP effluent for reuse is the cost-effective alternative, given adequate space, facilities and staff to operate the treatment systems. The technologies presented in this memorandum can also be applied to wastewater recycling within an industrial facility, recognizing that industrial wastewater effluent characteristics are industry-specific and different from domestic wastewater effluent.

3.2 Water Quality Requirements

The suitability of a treated wastewater supply for industrial water use will depend on the effluent quality from the specific WWTP and the requirements of a particular industry. Some industrial water uses will require no additional treatment of wastewater effluent, except for modifications to disinfection facilities. Modifications to disinfection facilities and/or practices are usually needed to meet more stringent requirements for destruction of pathogenic organisms in a recycled wastewater supply than is typically required for discharge to surface waters. Other industrial water uses will require additional treatment beyond the conventional and advanced secondary treatment system processes used at most Minnesota WWTPs. This subsection identifies the regulatory and industry-specific constituents of concern to consider in assessing the suitability and selection of treatment processes to provide a recycled wastewater supply to an industry.

Water Quality Overview

There are two water quality drivers that affect the treatment requirements for a specific recycled wastewater supply:

- **Regulatory requirements**: typically for the protection of public health and the environment, with a focus on microbiological parameters.
- **User-specific requirements**: specific water supply uses, which in the case of industries is a very specific set of water quality criteria for a given facility.

Recycled wastewater for industrial use in Minnesota is currently required to meet regulatory limits based on the California Water Recycling Criteria, Title 22 California Code of Regulations (Title 22). The complete list of criteria is included in Appendix A. The criteria specific to industrial applications (excluding any irrigation uses) are listed in Table 3.1. The MPCA handles permitting recycled wastewater as part of the NPDES permit process. The MPCA establishes recycled wastewater water quality criteria on a case-by-case basis and bases its assessment on the Title 22 criteria. Therefore, the Title 22 criteria will serve as the basis for selection of treatment technologies to meet regulatory requirements in this study.

Table 3.1. California Water Recycling Criteria (Industrial Uses)

Type of Use	Total Coliform Limits	Treatment Required
Cooling water where no mist created Process water with no worker contact Boiler feed Mixing concrete	≤ 23/100 ml[1] ≤ 240/100 ml (max in any 30-day period)	Secondary Disinfection
Cooling water where mist created[2] Process water where worker contact likely	≤ 2.2/100 ml[1] ≤ 23/100 ml (max in any 30-day period)	Secondary Coagulation[3] Filtration Disinfection

Source: Adapted from State of California [2000].
[1] Based on running 7-day median; daily sampling is required.
[2] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.
[3] Not required under certain conditions.

The total coliform limits and treatment process requirements imposed by the Title 22 regulations are the only regulatory criteria that must be met for all Minnesota industrial recycled wastewater uses. The other water quality criteria that will drive the treatment process selection will vary with the specific use of the water. These use-specific criteria do not need to meet a regulatory permit limit, but would likely be listed as concentration requirements in an agreement between a municipality and industry for supply of recycled wastewater. Generalized water quality limits for various industrial uses are provided in Table 3.2 and several constituents are discussed below.

Figure 3.2. Generalized Water Quality Criteria for Select Industrial Uses

	Cooling Water	Boiler Feed Water			Pulp & Paper					Textiles		
Constituent (in mg/l)	(Makeup for Recirculating Systems)*	Low Pressure (<150 psig)	Medium Pressure 150-700 psig)	High Pressure (>700 psig)	Mechanical Piping	Chemical, Unbleached	Pulp & Paper, Bleached	Chemical	Petrochem & Coal	Sizing Suspension	Scouring, Bleach & Dye	Cement
Alkalinity (as $CaCO_3$)	20-350	350	100	40	--	--	--	125	--	--	--	400
Aluminum (Al)	0.1	5	0.1	0.01	--	--	--	--	--	--	--	--
Calcium (Ca)	50	--	0.4	0.01	--	20	20	70	75	--	--	--
Chemical Oxygen Demand (COD)	45	5	5	1	--	--	--	--	--	--	--	--
Chloride (Cl)	100-500	--	--	--	1,000	200	200	500	300	--	--	250
Color (units	--				30	30	10	20	25	5	5	--
Copper (Cu)	--	0.5	0.05	0.05	--	--	--	--	0.05	0.01	--	--
Dissolved Oxygen (DO)	--	2.5	0.007	0.007	--	--	--	--	--	--	--	--
Iron (Fe)	0.5	1	0.3	0.05	0.3	1	0.1	0.1	1	0.3	0.1	2.5
Hardness as $CaCO_3$)	130-650	350	1	0.07	--	100	100	250	350	25	25	--
Bicarbonate (HCO_3)	25-200	170	120	48	--	--	--	130	450	--	--	--
Magnesium (Mg)	--	--	0.25	0.01	--	12	12	20	30	--	--	--
Manganese (Mn)	0.5	0.3	0.1	0.01	0.1	0.5	0.05	0.1	--	0.05	0.01	0.5
Ammonia (NH_3)	24	0.1	0.1	0.1	--	--	--	--	40	--	--	--
Nitrate (NO_3)	--	--	--	--	--	--	--	5	10	--	--	--
Phosphorus (Total: TP)	1	--	--	--	--	--	--	--	--	--	--	--
pH (units)	--	--	--	--	6 – 10	6 – 10	6 – 10	5.5-9.0	6 – 9	--	--	6.5 – 8.5
Silicondioxide (SiO_2)	50	30	10	0.7	--	50	50	50	60	--	--	35
Sulfate (SO_4)	200	--	--	--	--	--	--	100	600	--	--	250
Total Dissolved Solids (TDS)	500	700	500	200	--	--	--	1,000	1,000	100	100	600
Total Suspended Solids (TSS)	100	10	5	0.5	--	10	10	5	10	5	5	500
Zinc (Zn)	--	--	0.01	0.01	--	--	--	--	--	--	--	--

*Maximum of value range refers to concentration in final cooing stream discharge.
Source: Adapted from Water Pollution Control Federation, 1989; Goldstein et al, 1970; Metcalf & Eddy, 2007

Industrial Water Quality Concerns

Industrial uses of recycled wastewater include cooling, process water, stack scrubbing, boiler feed, washing, transport of material, and as an ingredient in a product. Cooling is the predominant recycled wastewater application, accounting for more than 90 percent of the total volume of recycled wastewater in the U.S. used for industrial purposes. As shown in the demand analysis of Section 2, cooling water is also the predominant industrial water use in Minnesota. Cooling and boiler feed water are water uses applicable to multiple industry categories. The constituents of concern for these water uses and some process water uses are listed in Table 3.2 and are discussed in more detail below.

Cooling Water

The constituents of concern for cooling water uses include: pathogenic microorganisms, inorganic matter that leads to scale formation, dissolved solids that can cause corrosion, and organic matter and nutrients that promote biological growth and the formation of slimes. These problems are caused by constituents in ground or surface waters and potable water, as well as recycled wastewater, but the concentrations of some constituents in recycled wastewater may be higher. These constituents need to be controlled in the supply to the cooling systems and may also have to be removed from the blowdown prior to discharge, depending on the cycles of concentration and discharge option (surface water, land application, or sewer system) and the corresponding limits.

Pathogenic microorganisms in water supplied to cooling towers must be eliminated prior to use so there is no hazard to workers and to the public in the vicinity of cooling towers from aerosols and windblown spray. Biocides are added to all cooling waters onsite to prevent slimes and otherwise inhibit microbiological activity, which has the secondary effect of eliminating or greatly diminishing the potential health hazard associated with aerosols or windblown spray. Biocide addition is required for recycled wastewater and traditional water supplies. Aerosols produced in the workplace or from cooling towers also may present hazards from the inhalation of VOCs. This same hazard exists with traditional water supplies that could have VOCs present. There has been no indication that VOCs have created health problems at any existing recycled wastewater site. Closed-loop cooling systems using recycled wastewater present minimal health concerns unless there is inadvertent or intentional misuse of the water.

All cooling water systems should be operated and maintained to reduce the *Legionella* threat, regardless of the origin of the source water. There have been no reported cases to show that recycled wastewater is more likely to contain *Legionella pneumophila* bacteria than waters of non-sewage origin.

Cooling water should not lead to the formation of scale, i.e. hard deposits in the cooling system. Such deposits reduce the efficiency of the heat exchange. The principal causes of scaling are calcium (as carbonate, sulfate, and phosphate) and magnesium (as carbonate and phosphate) deposits. Scale control through chemical addition or other treatment processes is common for facilities using potable, supplies or their own permitted ground or surface supply with naturally hard water. The higher concentrations of these inorganic constituents in recycled wastewater may require more extensive treatment than with an existing supply.

High levels of dissolved solids, ammonia, and heavy metals in cooling water can cause serious corrosion problems. Corrosion potential is higher in recycled wastewater where total dissolved solids (TDS) concentrations are between 100-400 mg/L more than in traditional water supplies [Puckorius and Hess, 1991; Tchobanoglous et al., 2003]. Of particular concern in Minnesota are high chloride levels. Many of Minnesota's recycled wastewater supplies may have high chloride levels as a result of softening system salt brine disposal from homes and commercial and industrial businesses. This was evident in the sampling of Twin Cities metro area WWTPs that identified higher levels of chlorides in communities served by potable ground water supplies without centralized softening treatment. Chloride concentration in WWTP effluent has also been linked to the influence of infiltration and inflow (I&I) and chlorides imparted from road salt used for winter deicing.

Ammonia can induce corrosion in copper-based alloys. Ammonia is present at high concentrations in the treated wastewater effluent of plants without advanced secondary treatment processes. Dissolved gases and certain metals with high oxidation states also promote corrosion. For example, heavy metals, particularly copper, can plate out on mild steel, causing severe pitting. Corrosion also may occur when acidic conditions develop in the cooling water.

The moist environment in a cooling tower is conducive to biological growth. Microorganisms can significantly reduce the heat transfer efficiency, reduce water flow, and in some cases generate corrosive by-products [California State Water Resources Control Board, 1980]. Recycled wastewater used in cooling systems may require treatment to control the nutrients, ammonia and phosphorus, and/or organic matter which promote the growth of slime-forming organisms. Organic matter is measured by surrogate parameters such as carbonaceous biochemical oxygen demand (CBOD) or total organic carbon (TOC).

Sulfide-producing bacteria and sulfate-reducing bacteria are the most common corrosion-causing organisms in cooling systems using recycled wastewater. These anaerobic sulfide producers occur beneath deposits and cause pitting corrosion that is most severe on mild and stainless steels. Serious corrosion is caused by thiobaccillus bacteria, an acid-producer that converts sulfides to sulfuric acid. Similarly, nitrifying bacteria can convert ammonia to nitric acid, thus causing pH depression, which increases corrosion on most metals.

Boiler Feed Water

Boiler feed water has very stringent water quality requirements that typically requires a treatment system even with potable water supplies. Boiler feed water must be treated to remove hardness. Calcium and magnesium salts are the principal contributors to scale formation and deposits in boilers. Excessive alkalinity contributes to foaming and results in deposits in heater, reheater, and turbine units. Bicarbonate alkalinity, under the influence of boiler heat, may lead to the release of carbon dioxide, which is a source of corrosion in steam-using equipment. Silica and aluminum form a hard scale on heat-exchanger surfaces, while high concentrations of potassium and sodium can cause excessive foaming in the boiler.

Process Water

The suitability of recycled wastewater for use in industrial processes depends on the particular use and is highly variable. For example, the electronics industry requires a very high water quality for washing circuit boards and other electronic components. On the other hand, the tanning industry can use relatively low-quality water. Requirements for textiles, pulp and paper, and metal fabricating are intermediate. The constituents of concern for the pulp and paper industry are discussed in more detail to provide an example of the variety of water quality parameters that must be considered for any process water use.

Use of recycled wastewater in the paper and pulp industry is a function of the grade of paper produced. The higher the quality of the paper, the more sensitive it is to water quality. Impurities found in water, particularly certain metal ions and color bodies, can cause the paper to change color with age. Biological growth can cause clogging of equipment and odors and can affect the texture and uniformity of the paper. Corrosion and scaling of equipment may result from the presence of silica, aluminum, and hardness. Discoloration of paper may occur due to iron, manganese, or micro-organisms. Suspended solids may decrease the brightness of the paper.

Emerging Contaminants of Concern

Several emerging contaminants of concern (ECOC) are under evaluation for recycled wastewater applications that could affect potable water supplies, such as aquifer recharge. They are likely not an issue for industrial applications with recycled wastewater because water uses are all non-potable, but are mentioned because it is a concern for potable water treatment and recycled wastewater practices in general and could affect future regulations and the direction for best management practices that would impact the entire recycled wastewater industry. The ECOCs gaining attention in recycled wastewater practices with direct or indirect aquifer recharge include:

- pharmaceutically active chemicals (PhACs)
- endocrine disrupting compounds (EDCs)
- disinfection by products (DBPs) such as N-nitrosodimethylamine (NDMA)
- a host of ground water supply contaminants such as 1,4-dioxane and methyl tertiary-butyl ether (MTBE)
- new and reemerging pathogenic microorganisms such as *Legionella pneumophilia*, *Cryptosporidium, and Giardia*

Several ECOCs occur in trace amounts and are of concern to humans for toxicity to the chemicals with repeated exposure through consumption of the source water. There are also reemerging microorganisms, thought to be essentially eliminated, linked to disease outbreaks. ECOCs, such as endocrine disruptors, are also being evaluated for their environmental impact on aquatic communities. Endocrine disruptors and several of the ECOCs are of domestic, commercial or industrial origins and can concentrate in a wastewater system. These compounds are not removed with typical WWTP processes and are discharged with the effluent. The evaluation of the risks associated with these compounds, whether discharged to surface water, applied to the land with an irrigation recycled wastewater practice, or to aquifers with recharge practices is just beginning. With improved laboratory analytical equipment that provides measurement at much smaller concentrations, and increased monitoring for these compounds, the technical base of information is growing – ECOCs are expected to be a topic for consideration of all future water supplies, including recycled wastewater.

3.3 Recycled Wastewater Quality and Treatment Technologies

Overview

The treatment requirements and technologies selected for specific industrial reuse applications are based on a variety of factors summarized in Table 3.3. With all these variables, the treatment process and transmission system selected is a site and case-specific one. For the purposes of planning and assessing the feasibility of recycled wastewater systems, some general assumptions were made to define classes of treated wastewater to meet various industrial uses. A technology-based approach is used to establish the treatment system and costs for each class of recycled wastewater.

Table 3.3. Treatment Requirements and Technology Selection Factors

Treatment Requirement Factors:	Technology Selection Factors:
■ recycled wastewater regulations ■ the intended use of the water by the industry ■ the WWTP effluent quality, which is characterized by the specific: — quality of the source water used by a community — industrial, commercial, and domestic discharges to the WWTP — treatment processes used at the WWTP	■ the WWTP's existing process train ■ the quantity of wastewater recycled at a given location (there are more cost-effective technologies for smaller or larger treatment systems) ■ whether treatment is incorporated at the WWTP, at the industry, or at a satellite facility ■ if storage is required because additional treatment may be required

The regulatory requirements impose two basic treatment process modifications or additions for all Minnesota WWTPs providing recycled wastewater:

- Disinfection – higher levels of disinfection, year-round disinfection (currently required only from April – October in Minnesota), and for transmission system residual
- Filtration and possibly coagulation processes (or membrane processes), for industrial water uses where worker contact is likely

Recycled Wastewater Quality

Municipal wastewater treatment processes generally include pretreatment, primary and secondary treatment processes. The secondary treatment processes perform the dissolved organic removal and final solids removal step in what is typically referred to as a secondary treatment system. In some WWTPs, the secondary process also removes ammonia, through the process of nitrification. Complete nitrogen removal, which includes removal of the nitrates produced through nitrification, is less common at Minnesota WWTPs, but several facilities are equipped for it. Phosphorus removal is also performed at many facilities in Minnesota. For this study, the term advanced secondary treatment, is used to define a secondary wastewater treatment plant that removes ammonia and phosphorus.

The historic water quality record of WWTP effluent is extensive for constituents of concern to the receiving waters. These constituents include carbonaceous or total biochemical oxygen demand (CBOD, TBOD, or BOD), total suspended solids (TSS), ammonia (NH3), total phosphorus (TP), and fecal coliform. Many WWTPs also have a historic record of heavy metals and priority pollutant compounds collected on a less frequent basis. These parameters are also important in characterizing the effluent quality and applicability for industrial use. However, there are many other constituents of concern for industrial applications, as discussed previously, and the majority of these are not commonly characterized in municipal WWTP effluent. Sampling performed for this project, reported in Appendix II-2, and literature values provide a general basis for establishing wastewater effluent quality assumptions for these parameters.

Historic records of Minnesota's municipal WWTP effluent quality (MPCA, 2005) were evaluated for this project and are summarized in Appendix II-4. The results from the 2005 analysis indicate that larger facilities (greater than 1 mgd in capacity) produce a high quality effluent with organic, solids, and microbiological concentrations at levels acceptable for many industrial uses. Over 90% of the larger WWTPs produced effluent with annual average CBOD and TSS concentrations less than 10 mg/L. Most smaller WWTPs also produced high quality effluent, with over 250 facilities reporting TSS concentrations under 10 mg/L and over 400 facilities reporting CBOD concentrations less than 10 mg/L. Phosphorus was shown to meet a 1 mg/L limit at over 40% of the larger WWTPs, or approximately 30 facilities.

Sampling conducted for this study characterized water quality constituents not routinely analyzed by WWTPs, many of which are listed in Table 3.2. The results of the monitoring of four of the Met Council WWTPs, review of Minnesota surface and water supply data, and literature values were used to define a standard quality of recycled wastewater to assess use of this water by industries. Recognizing that water quality varies over the state, a broad assumption was made that Minnesota's waters tend to be harder than other regions of the country, and higher in dissolved solids in many regions of the state. The constituents associated with hardness and dissolved solids are generally not removed by advanced secondary treatment processes.

The identification of treatment technologies and estimation of system costs required that a standard WWTP effluent water quality be identified. This study uses an advanced secondary treatment WWTP to define a "base" WWTP effluent quality or a "base" supply. The reason for this selection is based on the future expectations for WWTP process requirements and the water quality requirements for Minnesota's larger industrial water uses.

As more restrictions are being placed on loadings to our waterways, the removal of the nutrients, nitrogen and phosphorus, will be implemented at more WWTPs and limits could be lowered for those already removing nutrients. New facilities and major expansions permitted in the state are anticipated to have nutrient limits that would dictate the use of an advanced secondary treatment process train. In addition, because one of the largest and most likely industrial uses of recycled wastewater is for cooling water, which requires minimal levels of phosphorus and ammonia, use of an advanced secondary treatment system effluent is an optimum starting point. This assumption does not exclude consideration of other types of wastewater treatment facilities for water reclamation, such as fixed film systems (trickling filters and rotating biological contactors), stabilization ponds, chemical/physical package systems, or natural systems (wetland treatment). However, it is likely that these facilities would require additional treatment processes to meet the water quality requirements of a specific industry and the regulatory requirements.

Recycled Wastewater Classifications

Five types of recycled wastewater, listed in Table 3.4, are used to categorize the recycled wastewater options available for specific industrial water supply requirements. The classification is based on a train of treatment technologies to meet a set of water quality goals. All classifications provide a safe supply from a public health perspective – the different water quality goals relate to the specific requirements for the industrial water use. All classifications assume an initial WWTP effluent quality typical of a secondary activated sludge system with ammonia and phosphorus removal, defined as the “base” supply. Additional treatment processes following secondary treatment are required to produce the other four classes of recycled wastewater. The term ‘tertiary’ is used to define these classifications because the treatment process generally follows the secondary treatment process at a WWTP.

Table 3.4. Recycled Wastewater Classifications

Classification	Characteristics
Base Advanced Secondary	■ For non-contact industrial uses with low concern for hardness and dissolved solids ■ Base WWTP process train – a secondary treatment system with ammonia and phosphorus removal
Tertiary 1 Conventional	■ For industrial uses with human contact potential and/or industries that require partial hardness or phosphorus removal ■ Requires a coagulation/flocculation/sedimentation process with filtration; chemical used depends on target constituent ■ Removes hardness (with lime) and some dissolved salts; provides some soluble organic removal and color removal
Tertiary 2 Membrane Filtration	■ For industrial uses with human contact potential and/or industries that can use hard/high salt water ■ Provides soluble organic removal and color removal ■ Provides pathogen removal and reduces disinfection requirements
Tertiary 3 Membrane Softening	■ For industries requiring low dissolved salts ■ Requires Tertiary 2 water followed by softening with reverse osmosis (RO) or electrodialysis (ED) depending on the target constituents
Tertiary 4 Advanced Processes	■ For industries requiring low dissolved salts and removal of trace constituents ■ Requires Tertiary 3 water with RO and either ion exchange, carbon adsorption or advanced oxidation processes, depending on the target constituent.

Table 3.5 identifies the typical water quality constituent concentrations for the five classes of recycled wastewater.

Table 3.5. Water Quality for Recycled Wastewater Classifications[1]

Constituent	Recycled Wastewater Concentration[2]				
	Base Advanced Secondary	Tertiary 1 Conven-tional	Tertiary 2 Membrane Filtration	Tertiary 3 Membrane Softening	Tertiary 4 Advanced Processes
BOD, mg/L	5-10	≤5	<1-5	≤1	≤1
TSS, mg/L	5-10	≤3	≤2	≤1	≤1
Total Phosphorus, mg/L	≤1	≤0.4	≤1	≤0.5	≤0.5
Ammonia, mg/L	≤3	≤2	≤3	≤0.1	≤0.1
Nitrate, mg/L	10-30	10-30	10-30	≤1	≤1
Total Coliform[3], No./100 ml	< 23	<2.2	<2.2	Approx. 0	Approx. 0
TOC, mg/L	8-20	1-5	0.5-5	0.1-1	Approx. 0
Turbidity, NTU	3	0.3-2	≤1	0.01-1	0.01-1
TDS, mg/L	750/1500	<500/800	750/1500	≤5-40	≤5-30
Hardness, mg/L as CaCO3	250/400	100/200	250/400	<30	<20
Trace Constituents	Variable	Variable	Variable	Variable	Approx. 0

Source: Multiple sources including Metcalf & Eddy, 2007; HDR Engineering, Inc, 2001; Minnesota Discharge Monitoring Reports, 2004; and vendor literature.

[1] Classifications are described in Table 3.4 of this document.

[2] Average or maximum effluent concentration of constituent. When two concentrations are given, these represent the average concentration for two different supplies: Source A (Average), Source B (Hard, High Salt).

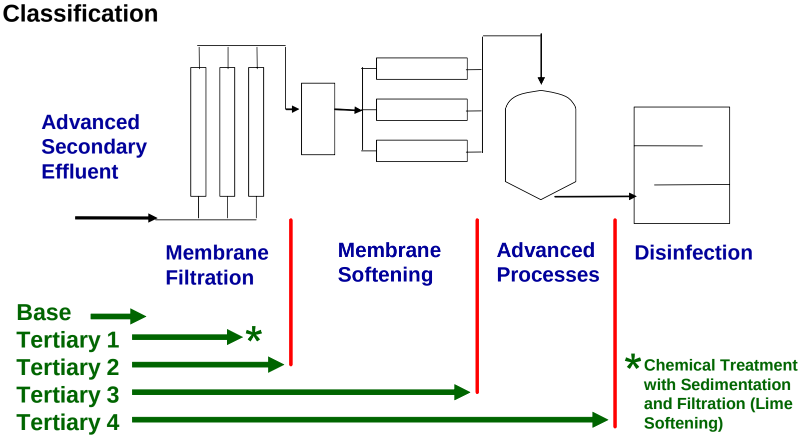
[3] Median concentration for seven day period, where the number does not exceed 240/100 ml for advanced secondary treatment and 23/100 ml for tertiary treatment in more than one sample in any 30 day period.

New facilities or major expansions could incorporate membrane bioreactors, which are not considered in this classification system. Use of membrane bioreactors at municipal WWTPs is an emerging technology that would be applicable to wastewater recycling situations. For comparison purposes, the effluent quality of membrane bioreactors would be similar to Tertiary 2-Membrane Filtration.

Treatment Technologies

The five classes of water generally incorporate higher degrees of treatment moving from the Base to the Tertiary 4 supply, as depicted in Figure 3.2. The base supply has organic, solids, and nutrient concentrations at levels suitable for a variety of industrial uses. From the regulatory perspective, the only additional treatment needed to meet the regulatory wastewater recycling requirements is additional disinfection to achieve the prescribed total coliform limits. The base supply can be used for any non-contact (meaning no contact with humans) water use by an industry, such as closed-loop cooling systems. The ability to use the base supply for non-contact uses will depend on the specific water use. The dissolved solids and residual solids may dictate further treatment requirements based on the type of water use.

Figure 3.2. Treatment Technologies by Recycled Wastewater Classification



The tertiary supplies are required for water uses where human contact is likely. Tertiary 1 treatment processes would be applicable to WWTPs that need to remove phosphorus or hardness and do not need to remove a significant amount of dissolved salts. The process train consists of conventional chemical addition, coagulation, flocculation and sedimentation processes, followed by filtration.

The Tertiary 2 supply is based on the use of membrane microfiltration. This technology meets the regulatory filtration requirements and provides higher pathogen removals than the Base or Tertiary 1 supplies. However, it does not remove hardness as Tertiary 1 treatment does. Similar to Tertiary 1 treatment, Tertiary 2 treatment does not remove dissolved salts. Membrane softening, the key Tertiary 3 treatment process, is required to reduce the dissolved solids, which includes chlorides. For this study, reverse osmosis was selected as the membrane softening process for the cost analysis. In addition to removing hardness, reverse osmosis also removes nearly all pathogens, organic and inorganic compounds. Nanofiltration and electrodialysis are two other potential technologies that could be used to meet hardness goals, but provide for lower removals and, in the case of electrodialysis, no additional pathogen removal.

For waters that require very low levels of constituents, advanced processes such as granular activated carbon, ion exchange, ultraviolet radiation (UV), and UV in combination with oxidants can be used. These are processes that could be used to treat emerging contaminants of concern that are present at very low levels. The Tertiary 4 treatment processes are ones that would likely be used by an onsite industry with its existing water supply. For example, a Tertiary 4 treatment process with ion exchange is a typical technology used to treat boiler feed water. In this case, the level of treatment provided by a Tertiary 4 process would exceed that provided by a traditional water supply. In some instances, there could be constituents needing removal that are related to discharges into the sewer system, such as heavy metals from industry or pharmaceutical-compounds. Tertiary 4 treatment processes could be located at either the WWTP or industry site depending on the specific attributes of the recycled wastewater application.

An industry sector assessment of treatment needs, presented in Table 3.6, shows the range of options that an industry would need to evaluate. The variability in WWTP effluent quality and industry water quality requirements dictates a site-specific evaluation to determine the treatment alternatives. Table 3.6 also lists the dominant water uses within an industry category and Table 3.7 provides the subcategories for major industry categories that have a wide range of industry types.

Table 3.6. Water Quality and Treatment Requirements by Industry Category

Industry Category	Type of Water Use	Recycled Wastewater Quality Classification Required				
		Base Advanced Secondary	Tertiary 1 Conven-tional	Tertiary 2 Membrane Filtration	Tertiary 3 Membrane Softening	Tertiary 4 Advanced Processes
Agricultural	Cooling, Boiler Feed		x		x	x
Pulp & Paper	Cooling, Process, Boiler Feed		x	x	x	x
Mining	Process, Boiler Feed	x	x		x	x
Sand & Gravel Washing	Process	x				
Industrial Cooling-Once-Through	Cooling	x	x		x	
Petroleum, Chemical & Ethanol	Cooling, Process, Boiler Feed		x		x	x
Metals	Process, Cooling, Boiler Feed		x		x	x
Non-Metals	Process, Cooling, Boiler Feed	x	x	x	x	x
Other	Process	x	x	x	x	x
Power Cooling-Once Through/Other	Cooling, Boiler Feed	x	x	x	x	
Power Cooling-Recirculating	Cooling, Boiler Feed		x	x	x	x

Table 3.7. Select Industry Subcategories

Agricultural	**Pulp and Paper**
Food Production	Mills
Beverage Production	Paper and Packaging
Non-Metals	Printed Products
Building Materials	**Metals**
Glass Products	Foundries
Leather Products	Metal Product Fabrication
Plastics	Machine and Tool Shops
Rubber Products	Electronic and Computer Products
Miscellaneous Non-Metal Products	Electroplating
Other	
Other Industries (not defined above)	

3.4 Storage and Transmission

Overview

An integral part of the planning, operation, and maintenance of recycled wastewater systems is the transmission of the recycled wastewater to the customer. Transmission costs, both capital and O&M, are a significant cost component of recycled wastewater projects. Transmission systems typically include on-site storage, pump station(s), piping, off-site storage, diversion structures to off-site storage ponds, service connections, and metering. Wastewater recycling regulations and guidelines generally include standards for the design, installation, operation, and maintenance of the transmission systems. In addition, there are very specific guidelines and requirements for any cross-connections to other systems, use of backflow preventions devices and other plumbing features.

Storage

The conceptual recycled wastewater system, presented previously in Figure 3.1, provides for storage facilities on the WWTP site to meet a range of storage volumes. The base recycled wastewater system assumes that no storage is required, which is valid for a larger WWTP serving smaller industrial demands. The cost curves developed for this study do not include storage requirements, but cost information was developed to asses the impact of storage on system costs and is detailed in Section 5.5 of Appendix II-3.

For purposes of this study, it is assumed that where storage is needed, it is for diurnal, daily, or weekly industrial demand patterns that the WWTP cannot meet with their continuous supply. Storage requirements for industrial applications can vary widely. Some industries may have adequate storage to meet peak hour requirements, but most would not have storage to handle significant volumes. Storage would likely be needed with smaller WWTPs where the diurnal flows could drop below the required demand of an industry or group of industries. Weekly demand patterns of industry could also change and should be accounted for when establishing storage requirements.

This study does not consider any seasonal storage requirements for a reclaimed supply. Seasonal storage would be required for WWTPs that incorporate reuse practices to reduce their discharges to waterways and supply seasonal customers. These facilities would need to store and/or dampen peak flows to meet NPDES limits during periods when the seasonal recycled wastewater customers do not use water. Seasonal storage may also be required to meet a seasonal water demand, where peak demands cannot be consistently matched by the WWTP flow. The majority of Minnesota's industries have year-round water demands. Some exceptions include: agricultural processing industries, which may depend on seasonal crops; industries that use recycled wastewater for landscape irrigation; and some cooling water applications. Seasonal storage facilities are common in recycled wastewater systems for irrigation practices.

Recycled wastewater storage can also provide system reliability with a short-term supply if there is a process disruption as well as additional contact time for chlorine disinfection.

Pumping

This study assumes a pump station is located on the WWTP site and is owned by the municipality. The pump station is assumed to include standby and reliability features consistent with state water supply requirements. The pump station is sized for peak flow and a residual pressure at the end of the pipe line of 40 psi, assuming delivery at the same elevation as the WWTP.

Transmission Pipelines

The majority of recycled wastewater transmission piping is polyvinyl chloride pipe (PVC) or ductile iron pipe (DIP) meeting specific industry standards. For this study, the transmission system is assumed to be all force main with the following characteristics: pipe with a diameter of 24 inches or less is PVC, DR 18, Class 150 and greater than 24 inch diameter pipe is DIP, Class 51 with push-on joints. Pipelines are sized to carry the peak hour demand of a given industry at a target velocity of 5 to 7 feet per second (fps). Details assumed for the cost analysis are provided in Appendix II-3.

3.5 Costs

Basis and Assumptions

Costs were developed as a cost of service in dollars per 1000 gallons ($/1000 gallons), assuming a 20-year debt service. Cost curves are used to provide the cost of service to supply a range of demands from 0.1 to 30 mgd for a 10-mile range from the WWTP. The financial assumptions and detailed basis of cost are presented in Appendix II-3.

Costs were estimated for the Base and Tertiary 1 through Tertiary 4 water treatment processes described previously. The base level quality is defined as a hard water that meets regulatory standards for non-contact industrial water uses. The "base recycled wastewater system" includes treatment processes and the transmission system for delivery from the WWTP to the industry. "Alternative recycled wastewater systems" differ from the base system in the treatment processes used to produce a prescribed set of water quality goals, presented previously in Table 3.5. The recycled wastewater system costs are based on a wastewater quality typical of a WWTP with secondary treatment and ammonia and phosphorus removal.

Base Recycled Wastewater System Costs

The cost curves developed for the base system indicate that, for some industries, a recycled wastewater supply system can be cost competitive with potable water supplies in Minnesota. This assumes that an advanced secondary wastewater treatment plant effluent water quality is suitable for that industry, or that the industry already has a treatment system in place for its existing supply that can be used or upgraded for a recycled supply. As shown in Figure 3.3 and tabulated in Appendix II-3 (Appendix C), a reclaimed water system designed for an annual average flow of less than 0.5 mgd is not expected to be competitive with most potable water supplies. As the system capacity increases above 1 mgd, a 10-mile system shows a comparable potable water supply cost of $2/1000 gallons. For flows greater than 5 mgd, as shown in Figure 3.4, costs drop to less than $0.60/1000 gallons, even at a distance of 10 miles for 30 mgd. Potable water supplies in the Minneapolis/St. Paul area range from $1-$3/1000 gallons and fluctuate around that cost in other areas of Minnesota. Some rural water systems have costs over $5.00/1000 gallon.

Figure 3.3 Recycled Wastewater System Cost of Service for 0-5 mgd Capacity Base System

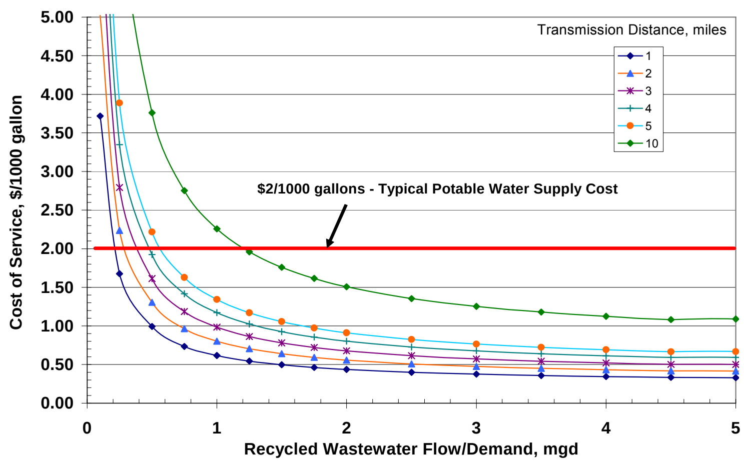
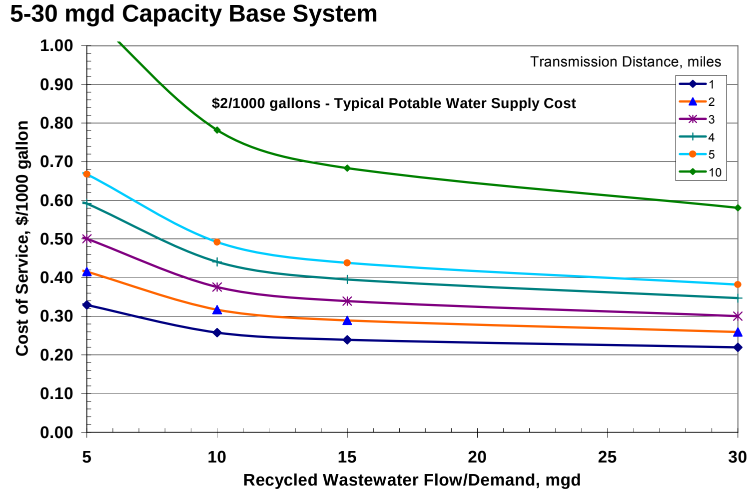


Figure 3.4. Recycled Wastewater System Cost of Service for 5-30 mgd Capacity Base System

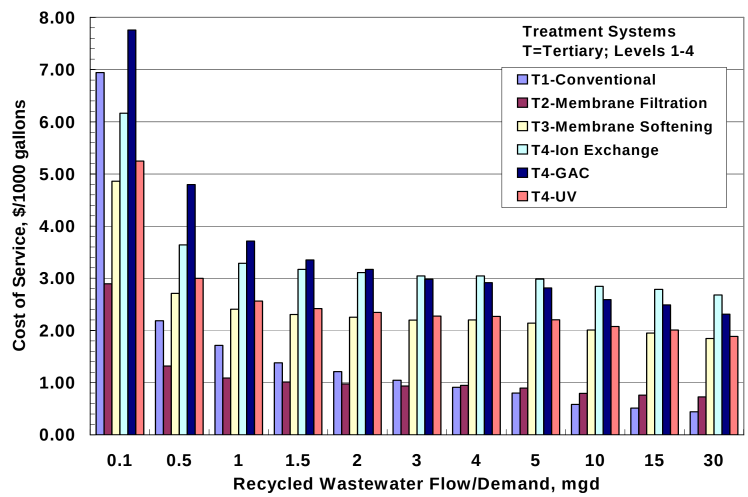


The base system provides a water quality that could possibly be suitable for a once-through cooling process or sand and gravel washing. It would also be sufficient for irrigation of restricted areas on industrial site grounds. To meet the anticipated water requirements for much of Minnesota's industrial water demand, additional treatment at the WWTP or the industry site will be required. For example, some cooling water applications will require a softening process to reduce hardness and dissolved salts.

Alternative Recycled Wastewater Treatment Costs

The cost to treat WWTP effluent water beyond the base level processes is estimated to be $1.25 - $5.00/1000 gallons for a 0.5 mgd supply, $1 - $4.00/1000 gallons for a 1 mgd supply, and in the range of $0.50 - $3.00/1000 gallons for a 30 mgd supply. Table 3.8 and Figure 3.5 summarize the costs for flows from 0.1 to 30 mgd for each of the tertiary reclaimed water classifications. These costs are for treatment in addition to the base system treatment, transmission, and other system costs.

Figure 3.5. Treatment Costs for Tertiary 1 through Tertiary 4 Processes



In comparing conventional treatment to membrane systems to soften the water and remove dissolved solids, the membrane process is more expensive except when treating smaller supplies. However, additional credit in microbial removal with membranes could offset disinfection costs. Blended supplies and treatment streams could also be considered to optimize treatment costs and meet multiple water supply needs. The lower costs of conventional treatment for larger supplies may be underestimated because it is assumed that a WWTP has adequate land for the treatment facilities and uses a less costly solids disposal practice, such as land application of lime sludge. This may not be an option for some municipalities or industries.

Table 3.8. Treatment Costs for Tertiary 1 through Tertiary 4 Systems*

	Cost of Service for Treatment, $/1000 gallons					
	Tertiary 1	Tertiary 2	Tertiary 3	Tertiary 4		
Flow/ Demand, mgd	Conven-tional	Membrane Filtration	Membrane Softening	Ion Exchange	GAC	UV
0.1	6.90	2.90	4.85	6.15	7.75	5.25
0.5	2.20	1.30	2.70	3.65	4.80	3.00
1	1.70	1.10	2.40	3.30	3.70	2.55
1.5	1.40	1.00	2.30	3.15	3.35	2.40
2	1.20	0.95	2.25	3.10	3.15	2.35
3	1.05	0.95	2.20	3.05	3.00	2.25
4	0.90	0.95	2.20	3.05	2.90	2.25
5	0.80	0.90	2.15	3.00	2.80	2.20
10	0.60	0.80	2.00	2.85	2.60	2.10
15	0.50	0.75	1.95	2.80	2.50	2.00
30	0.45	0.70	1.85	2.70	2.30	1.90

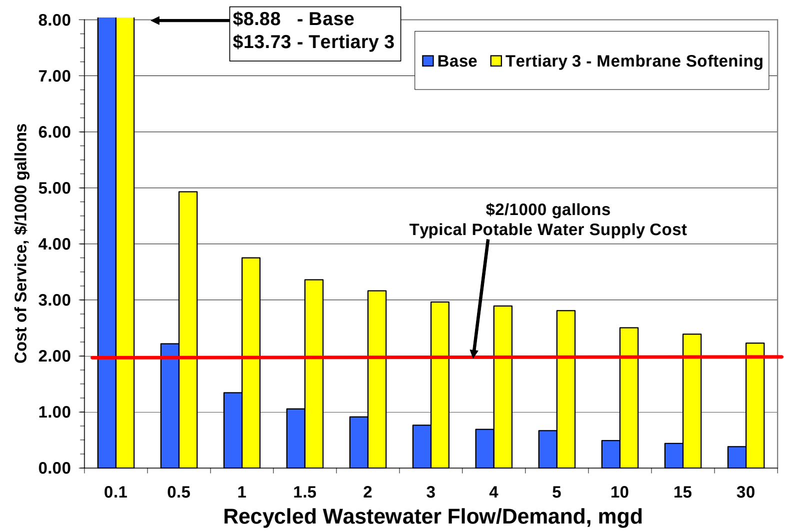
*In addition to recycled wastewater base system costs

The cost analysis indicates that there are economically viable applications to provide treated wastewater effluent as a water supply to industries. The technology is available and as competition increases in the membrane market, more economical solutions can be anticipated to meet the specific water quality needs for a spectrum of industries in Minnesota. Treatment costs were estimated to range from $0.50/1000 gallons for larger supplies (30 mgd) with water quality suitable for cooling water to over $7.00/1000 gallons for smaller supplies (0.1 mgd) treated to meet stringent industrial water requirements.

Total System Costs

To provide a comparison of total system costs to treatment costs, a 5-mile transmission system was evaluated as shown in Figure 3.6. The cost to deliver a base supply, inclusive of transmission costs, disinfection system costs (assumed as part of the base system) and administrative/laboratory costs ranged from $0.40/1000 gallons for 30 mgd to $8.88/1000 gallons for a 0.1 mgd supply. For membrane softening, the costs range from $2.20/1000 gallons to $13.73/1000 gallons. Both transmission and treatment system costs on a per gallon basis become more economical as the system capacity exceeds 1 mgd.

Figure 3.6. Comparison of Base and Membrane Softening System Costs for 5-Mile Transmission



The evaluation of a 1 mgd recycled wastewater supply transmitted 5 miles was estimated to have a cost of service ranging from $1.35/1000 gallons to $3.75/1000 gallons, depending on the water quality delivered. As summarized in Table 3.9, industrial water uses that are non-contact and have little concern with higher salts and hard water (base supply) are very competitive, at $1.35/1000 gallons, with potable water supplies assumed at a typical cost of $2.00/1000 gallons. For industries that may have similar water quality requirements to the base supply, but may have human contact with the supply water, the cost is $2.45/1000 gallons. Cooling water and process water requirements for many industries will likely require softened water and removal of dissolved solids, as provided by Tertiary 3 treatment processes, which is estimated to cost $3.75/1000 gallons. The treatment requirements for Tertiary 3 processes place these system costs above typical potable supply costs, but it is not out of the range of some rural system water utility costs. While system costs for ground water supplies would likely be less than this, for areas with water shortages or watershed discharge limitations, recycled wastewater could be a cost-effective water supply.

Table 3.9. Estimated Costs for a 1 mgd Recycled Wastewater System*

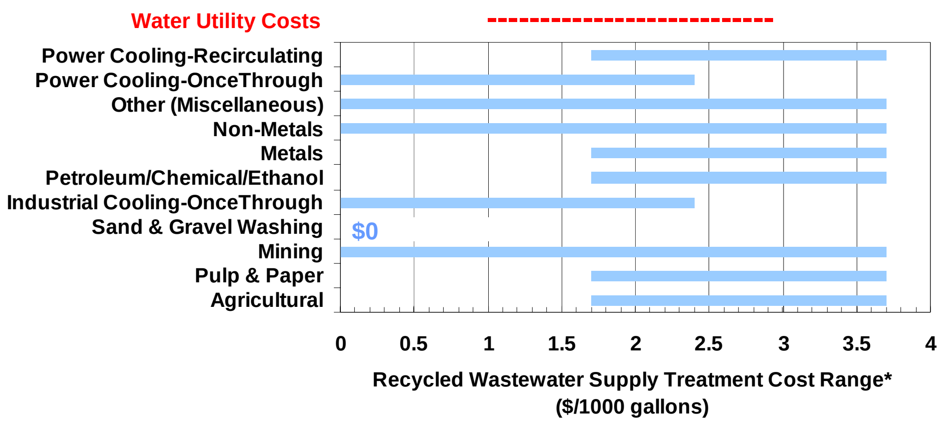
Water Quality Classification	Characteristics	System Cost of Service, $/1000 gallons
Base	Non-contact uses No concern for hardness or high dissolved solids	1.35
Tertiary 2 – Membrane Filtration	Potential contact uses No concern for hardness or high dissolved solids	2.45
Tertiary 3 – Membrane Softening	Potential contact uses Require soft water with lower dissolved solids	3.75

*Based on a 5-mile transmission system

Cost by Standard Industry Categories

The potential costs for a recycled wastewater supply are shown in Figure 3.7 and listed in Table 3.10 for the general industry categories. Costs listed in Table 3.10 are for both the treatment and total system costs of a 5-mile transmission system, while Figure 3.7 displays only the treatment costs. As expected, the range of costs is high given the diversity of industries in these general industry categories and the variable water quality of WWTP effluent. However, the values indicate that, for a 1 mgd supply transmitted 5 miles, the cost of service for lower levels of treatment can compete with potable water supplies. Most industries with a water demand of 1 mgd or less are more likely to use a potable source, depending on their water quality requirements. For these industries, reclaimed water could provide an alternative to a potable source, assuming multiple industries are supplied from one WWTP for a combined demand of 1 mgd or higher.

Figure 3.7. Range of Treatment Costs for a 1 mgd Supply by Industry Category



*Costs in addition to recycled wastewater base system costs

Storage Costs

While most WWTPs have a consistent diurnal pattern that varies during the weekdays and weekend, recycled wastewater demand will vary with the customer or set of customers. For this study, storage costs were estimated based on the assumption that 50% of the water volume produced per day could be stored. Additional storage that may be required by individual customers and located at the customer's sites was not considered in this analysis.

Storage was assumed to be provided in an underground concrete tank, for which the unit cost of construction is estimated to be $1.70/gallon of the storage. The capital cost of storage was estimated to be $850,000 per mgd of the annual average recycled wastewater demand. When included in the cost of service, storage is estimated to add approximately 20 cents to the total system cost to produce 1000 gallons. Storage costs equate to about 13% of the cost of service for a 1 mgd supply with a 5-mile transmission system. For a 1 mgd recycled wastewater system supplying a "base" quality water, storage was estimated to increase costs from $1.35/1000 gallons to $1.55/1000 gallons.

Table 3.10. Costs to Supply Recycled Wastewater to Minnesota Industries

		Cost of Service, $1000 gallons[1] of Recycled Wastewater Quality Classification[2]					Range of Costs, $/1000 gallons	
		Base	Tertiary-1	Tertiary-2	Tertiary-3	Tertiary-4		
Industry Category	Type of Water Use	Advanced Secondary	Conven-tional	Membrane Filtration	Membrane Softening	Advanced Processes	Treatment Above Base System	Total System
Agricultural	Cooling, Boiler Feed	–	$1.70/$3.05	–	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Pulp & Paper	Process, Boiler Feed	–	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Mining	Process, Boiler Feed	$0/$1.35	$1.70/$3.05	–	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Sand & Gravel Washing	Process	$0/$1.35	–	–	–	–	$0	$1.35
Industrial Cooling-Once-Through	Cooling Water	$0/$1.35	$1.70/$3.05	–	$2.40/$3.75	–	$0-$2.40	$1.35-$3.75
Petroleum, Chemical & Ethanol	Cooling, Process, Boiler Feed	–	$1.70/$3.05	–	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Metals	Process, Cooling, Boiler Feed	–	$1.70/$3.05	–	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Non-Metals	Process	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Other (Miscellaneous)	Process	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Power Cooling-Once-Through/Other	Cooling, Boiler Feed	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Power Cooling-Recirculating	Cooling, Boiler Feed	–	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00

[1]Represent the costs to provide 1 mgd of recycled wastewater a distance of 5 miles. First value is the treatment cost and the second value is the total system cost in $/1000 gallons. (e.g. For Metals industries: the treatment costs are estimated to range from $1.70-$3.70/1000 gallons and the total system costs are estimated to range from $3.05-$5.00/1000 gallons).

[2]Refer to Table 3.6 for relationship of recycled wastewater classification to industry categories.

Costs and Planning Considerations

The generalized costs for recycled wastewater systems developed in this study confines costs to discreet projects for a set of basic assumptions. As municipalities and industries evaluate recycling opportunities, an integrated approach to handling water infrastructure needs for the community can be used to evaluate the impacts on other system costs. Some considerations are provided below.

An accurate comparison of costs for the higher quality water must include the industry's onsite treatment cost and cannot be compared solely to the incoming water supply cost. Most industries requiring Tertiary 4 reclaimed water have their own onsite treatment systems to provide this water quality. In many cases, the industry provides this additional treatment to potable supplies. Some industries also have treatment processes to provide water of similar quality to Tertiary 1-3 recycled wastewater. With water conservation practices promoting cooling systems with higher levels of recirculation there will be the need to use a higher quality of incoming water so that the concentrations of the recycle do not cause corrosion or scaling problems.

Specific facility planning activities should evaluate the relationship of recycled wastewater system with potable water system infrastructure. For some communities, recycled wastewater systems provide an alternative to potable water supply system capital expenditures. Increased domestic demand can be met without expansion of the potable water distribution system if a portion of the industrial sector uses recycled wastewater and the total demand for the potable water system is kept constant. A complete analysis of a recycled wastewater system needs to integrate the entire water resources planning of communities and regions.

This cost analysis was based on treating WWTP effluent from an advanced secondary treatment process. Wastewater recycling practices can also be integrated into the design and construction of new WWTPs. It may be more cost-effective to implement appropriate treatment technologies into the main WWTP process train and construct new pipelines and facilities, rather than retrofit existing ones. Also, with new WWTP construction, a recycled wastewater pipeline can be integrated into the potable and collection system infrastructure, resulting in total system cost reductions. New WWTP site selection can also include comprehensive planning to integrate industrial parks in close proximity to wastewater facilities.

3.6 Summary

The economic viability of wastewater recycling in Minnesota will depend on the specific match of WWTP effluent quality to an industry's water quality requirements, the system capacity, transmission distance, and the availability of traditional water supplies in the area. The major conclusions from this study's assessment of recycled wastewater quality and system costs include the following:

- Recycled wastewater can be competitive with traditional water supplies in some cases.
- Removal of hardness and high salt levels significantly adds to the cost.
- Cost efficiency improves as recycled wastewater usage increases and favors systems delivering more than 1 mgd.
- Emerging contaminants of concern will likely be a future issue for wastewater recycling applications as it will for all water supplies.
- Historic records of important constituents of concern for industrial water uses are not usually available for WWTP effluent and are needed to fully evaluate alternative water supplies.
- This study provided a high-level assessment that estimated a range of costs for low to high quality water supplies. WWTP-specific water quality and specific industrial treatment requirements must be thoroughly assessed in the evaluation of recycled wastewater system costs.

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Section 4: Implementation Considerations

Minnesota's industrial water demand can be supplied in many areas by recycled municipal wastewater. Treatment technologies are available to meet the highest levels of water quality required by industries and protect public health. In some cases, recycled wastewater is a cost-competitive supply to traditional water sources. A remaining area to consider is what issues need to be addressed to implement recycled wastewater projects in Minnesota.

4.1 Overview

In addition to technical issues, there are regulatory, legal, and institutional issues such as funding and fees, agency jurisdictions, ordinances, and public involvement that must be addressed to successfully implement wastewater recycling programs. Implementation issues associated with the development of wastewater recycling programs in other states and specific research on the topic has provided a base of knowledge for Minnesota to draw upon. However, because each state has its own regulatory program for recycled wastewater, as well as other environmental permitting practices and government structures, a complete list of issues will contain some that are state-specific. To begin to address the many facets of implementing wastewater recycled projects in Minnesota, a series of stakeholder meetings were held.

4.2 Stakeholder Input

Stakeholder Representation

Three stakeholder forums were held:

- Regulatory
- Industrial
- Broader-Base

Two regulatory meetings held early in the project included representatives of the MPCA, MDNR, MDH, Dakota County, and Met Council staff from water supply and wastewater services. These meetings were used to gain input on the state agency setting for wastewater recycling, how these practices are handled now, and any plans for the future.

Two meetings were held with industrial representatives. A total of 11 industries participated in the workshops with 15 representatives attending. A range of industry sectors and business sizes were represented. Table 4.1 lists the industries attending the two workshops.

Table 4.1. Industry Workshop Attendees

March 8, 2007	March 15, 2007
Great River Energy	ADC Telecommunications Inc
Kraemer Mining & Materials, Inc	CertainTeed Corporation
Marathon Ashland Petroleum LLC	Fagen Engineering LLC
Rock-Tenn Company	Flint Hills Resources LP
Twin City Tanning Co/SB Foot Tanning Co	Gopher Resources Corporation
	Xcel Energy

The main question addressed was: What issues/concerns does your industry have with using a recycled wastewater supply? Followup discussions focused on project elements for demonstration projects and any issues the industry might have if looking to site a new facility. The discussion of issues was segmented into technical issues and institutional issues. In some cases, issues overlapped these general categories.

The third forum brought together a full spectrum of stakeholders: the same regulatory agencies, two industries from the previous meetings (CertainTeed Corporation and Marathon Petroleum), a cross-sector group (Minnesota Environmental Initiative), wastewater utilities (Mankato and Met Council), and water utilities (represented by the Water Utility Council of Minnesota). This group reviewed the outcomes of the previous stakeholder meetings and discussed next steps to promote wastewater recycling on a broader scale in Minnesota.

Figure 4.1. Implementation Issue Focus Areas

Outcomes

The implementation issues identified in the stakeholder meetings generally fit into one of the four focus areas listed in Figure 4.1.

Key points for each focus area are presented below.

Environmental Need & Stewardship	
Minnesota's commitment to natural resources protection can serve as a catalyst for recycling treated municipal wastewater practices.	**Need** ■ Water supply shortages and watershed water quality issues occur in Minnesota and have been the driver for recycling treated municipal wastewater applications in areas where thresholds were reached with few options. The state needs to be prepared for an increase in water issues that can be solved with recycling treated municipal wastewater applications. ■ A vision for wastewater and water supply systems in Minnesota beyond the typical 20-year planning cycle is needed – looking to Minnesota's long-term economic vitality and quality of life. **Stewardship** ■ Water conservation awareness in Minnesota is increasing and many industries are adopting water protection measures. Industries recognize that recycling treated municipal wastewater can be of benefit to their business and the community. Recycling treated municipal wastewater practices can build on this awareness. ■ A positive image for recycling treated municipal wastewater needs to be established: it protects Minnesota's water resources and it is a safe supply. Customers and suppliers will be less likely to engage in recycling treated municipal wastewater projects if there will be resistance from the community. Wastewater recycling needs to move from an unknown to a positive image.

Regulations	
The regulatory requirements and permitting process should encourage industries and municipalities to pursue recycling treated municipal wastewater.	■ Current regulations: MN handles recycling treated municipal wastewater applications on a case-by-case basis using the California Water Recycling Criteria. This approach matches the demand. ■ Municipalities and industries identified several permit-related issues that without resolution early in the planning process would deter them from recycling treated municipal wastewater. ■ Existing regulatory requirements for wastewater facility planning to include wastewater recycling alternatives needs to be enforced and linked to water supply studies. ■ There currently is not a demand for recycled wastewater that requires investment in water regulation development. However, without resolution of some issues, it may inhibit the planning for recycling treated municipal wastewater practices that should be occurring for long-term sustainability of Minnesota's water resources.

Economic Incentives and Risk Assessment	
Economic incentives and assessment/ resolution of risks will attract industries to use recycled wastewater and municipalities to incorporate recycling in their WWTP practices.	▪ Establishing partnerships to foster recycling of treated municipal wastewater will provide examples to evaluate reuse practices in Minnesota and the information to develop potential, future regulatory infrastructure, address concerns with risk and legal language for user agreements, and other institutional elements. There are unresolved industrial concerns with risk and liability. ▪ To gain acceptance and to recognize the benefits of recycling treated municipal wastewater, particularly when economics are perceived to be in favor of current practices, economic incentives will attract suppliers and customers – and can jumpstart a broader recycling wastewater practice in Minnesota. ▪ The cost of water currently does not factor in the benefits of conservation and recycled wastewater competes against a low cost supply in many areas.

Data Collection and Research	
Information on-hand related to treatment requirements for recycled wastewater would expedite the planning process for recycling treated municipal wastewater projects.	▪ Information related to the treatment and distribution of recycled wastewater for Minnesota-specific applications is lacking, specifically for cold weather and hard, high salt concentration waters. ▪ Site-specific water quality and customer-specific uses require water sampling and analysis. Many of the parameters of interest in planning treatment of a water supply are not analyzed by WWTPs discharging to receiving streams. If water quality data were readily available, wastewater recycling may be evaluated more in the planning stages for new or expansions/improvements or existing industries and WWTPs.

"Demonstration" Projects

One of the questions addressed at the industrial and broad-base stakeholder meetings was what type of demonstration projects would address the issues and concerns that were identified. The overall goal of the project(s) would be to provide industries and municipalities information to better assess the costs and implementation hurdles – resulting in better informed suppliers and users of recycled wastewater with an understanding of the issues before they take on a project. Project results are also a useful part of a public information program, showing that the recycling practice is meeting all the regulations and health indices.

Project elements and features considered important include:

Project with Established Partners. Identify regulatory, industry, municipal wastewater utility, water utility, and other partners to form a working group that is involved with the project(s). This group would walk "hand-in-hand" through the project and provide review and assessment of the project upon completion.

Complete Project Process. Project partners would be involved in the complete project process: the initial conceptual plan, facility plan, design, and construction.

Regulatory Process. As part of the complete project process, the regulatory steps for wastewater recycling can be explored and documented. A separate subgroup could be formed to evaluate specific regulatory elements and development of guides or fact sheets for permittees.

Public Information. A public information program integrated at the initial project stages is critical to the success of a wastewater recycling project. This includes educating the personnel at the facility, the local community, and those along the transmission route. This could be part of a complete project process, a special project with more of a focus on public education methods, or a state-wide campaign to enhance the 'image' for wastewater recycling in Minnesota.

Specific Technologies. Some projects can have a more technical focus to improve cost information and a better understanding of the operation and maintenance issues for certain wastewater recycling practices.

The demonstration projects could also be performed by one entity or other approaches, rather than a partnered group. For example, a municipality may unilaterally make treated wastewater available at a quality useable by various industries. In the case of specific treatment technology evaluations, a full-partnered process may not be required.

4.3 Summary

Stakeholders were encouraged by the interest expressed in the topic of wastewater recycling. The general outlook carried from the workshops is that the institutional issues are addressable and need to be solved or in the evaluation process before significant consideration is given to a recycled wastewater project. While there are certainly some technical issues that must be resolved and better understood, the meeting participants were confident that technical solutions could be found. It would be a matter of cost and related benefits that would dictate the feasibility - if the institutional issues are first addressed.

Section 5: Summary and Potential Next Steps

5.1 Summary

This study directed its inquiry into four project areas to address the project objectives.

Project Objectives

- Determine the feasibility of recycling treated municipal wastewater for industrial water use in Minnesota.
- Identify implementation issues associated with recycling municipal wastewater for industrial water use in Minnesota.

Demand and Supply Analysis

- There is adequate treated wastewater supply to meet industrial water demand in some regions of the state. The Twin Cities metro area has more supply than demand and some larger industries in smaller communities cannot fulfill their demand with the available treated wastewater supply.
- The largest industrial water users are power plants with once-through cooling systems. River water provides over 2,000 mgd of water for once-through cooling, while ground water provides 4 mgd for power generation uses and 6 mgd for other industrial facility once-through cooling water systems. Replacing river water with recycled wastewater does little to preserve water supplies because the once-through cooling process consumes little water and over 98% is returned back to the river. There is also no added benefit to the receiving stream from reduced pollutant loadings, because the recycled wastewater is discharged back to the watershed. In addition, these facilities typically require more water than can be supplied by WWTPs.
- Statewide in 2004/2005, municipal WWTPs produced 425 mgd on average, and the non-power industrial water demand, excluding power plant surface water demand, was an estimated 445 mgd. Industrial demand for ground water was 60 mgd.
- The largest industry use of ground water is for the industry sectors of food, petroleum, chemical, and ethanol processing, along with once-through cooling systems for a range of industries. These industry/use categories use over 40 mgd of water and it is estimated that at least half of this total, or 20 mgd, is for cooling water use.

Project Areas

Demand & Supply Analysis

Compare industrial water demands with the available treated municipal wastewater supply.

Water Quality & Treatment Requirements

Compare industry water quality requirements to treated municipal wastewater quality and identify treatment processes for recycled wastewater use by industry.

Costs

Estimate treatment and transmission costs.

Implementation Issues

Identify implementation issues.

Water Quality & Treatment Requirements

- Wastewater recycling treatment technologies are available to protect public health and meet all industry water quality requirements.
- Industrial water quality requirements can be met by adding new treatment processes or upgrading existing ones at municipal WWTPs.
- The constituents of concern with the broadest implications for Minnesota industrial water uses are hardness and dissolved salts. Minnesota waters tend to be hard and high in dissolved salts and concentrations increase in the wastewater through domestic, commercial and industrial practices. Advanced secondary wastewater treatment processes do not remove hardness and dissolved salts; tertiary treatment processes will be required if these constituents are to be removed.
- The data routinely monitored by WWTPs do not provide all the water quality data for a complete assessment of WWTP effluent as an industrial water supply without new monitoring being performed.

- The continued advances in wastewater and water treatment technology, including reductions in cost, will benefit the wastewater recycling market.

Costs and System Features

- Wastewater recycling is competitive with traditional water supplies in some situations.
- Removal of hardness and high salt levels significantly adds to the cost of a recycled wastewater system.
- Cost efficiency improves as wastewater usages increases, favoring systems delivering more than 1 mgd.
- The two recycling configurations likely to emerge within the framework of existing WWTPs and industries in Minnesota are for either one large industrial demand to be met with a dedicated pipeline or for a cluster of industries to be served from a transmission main. In both configurations, a program of mixed use that also provides for other uses such as irrigation along the transmission main would provide additional benefits and cost sharing.
- As water resources become limited because of drought or aquifer depletion with excessive withdrawals, or because supplies become contaminated, the cost difference with traditional supplies will narrow.

Implementation Issues

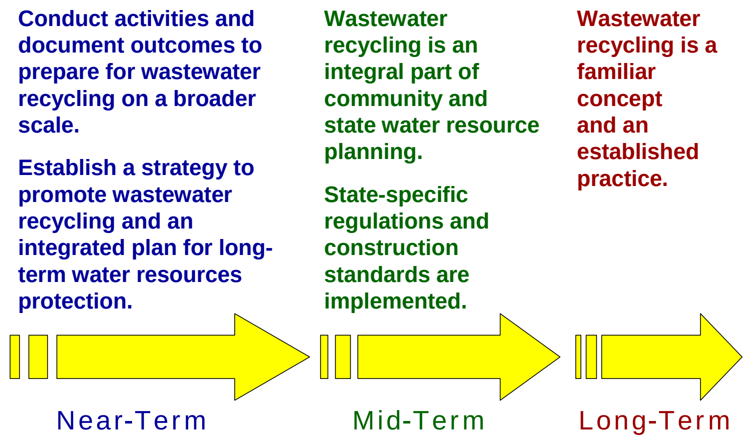
- Stakeholder workshops successfully defined key issues for Minnesota to consider as the state looks to wastewater recycling as part of its water conservation program. The stakeholders deemed the issues addressable.
- Environmental Stewardship
  - Wastewater recycling is seen as the "right thing to do" and industries are responsive to learning more and considering this new water supply.
  - The wastewater recycling public image needs to move from unknown to positive. Industries are hesitant to embark in recycling without the public's perception that this is a positive action.
- Regulations
  - The case-by-case regulatory approach matches the current permit demand and it is difficult to justify investment at this time in a new approach to regulating this practice.
  - However, the case-by-case approach may deter some recycling projects because there are too many uncertainties. There are also many unknowns related to the TMDL process or how recycling will affect NPDES permitted constituents and conditions.
- Incentives & Risk
  - Without economic incentives it will be difficult for recycled wastewater to compete with the cost of the traditional water sources until it is a proven water supply in Minnesota.
  - There are unresolved industry concerns with risk and liability that need to be addressed before many industries will consider a recycled wastewater supply.
- Data Collection & Research
  - Additional municipal WWTP effluent data with specific constituents of concern to industries are needed to more completely assess wastewater recycling for specific applications and accurately compare system costs to traditional supplies.
  - Colder weather and site-specific water quality concerns need to be explored by testing treatment technologies. This will also assist in a better assessment of treatment costs.

Long-Term Vision

The Land of 10,000 Lakes is experiencing regional and localized water supply limitations that will drive the search for alternative supplies. As water demand continues to grow, recycled wastewater can be an emerging water supply to counter those limitations in Minnesota. Growth in the development of the ethanol industry is a prime example of the limitations new industries might face and the benefits of promoting wastewater recycling as an alternative water supply.

While the state does have experience with wastewater recycling, it is still an unknown concept to most Minnesotans. The implementation issues identified in this study indicate the range of items to address as wastewater recycling becomes more common in Minnesota. A review of wastewater recycling program development in other states identified three phases to consider in planning a program, as shown in Figure 5.1. Minnesota will start in the Near-Term phase if it is to pursue and promote development of wastewater recycling throughout the state.

Figure 5.1. Steps in Implementation of Broad-Scale Wastewater Recycling Programs



5.2 Potential Next Steps

Potential next steps to carry on the development of wastewater recycling in Minnesota include engaging in demonstration projects to address the various issues that were brought forth by stakeholders. These projects can take a variety of forms, but the one that was considered to be of the most value to industries is a project with an established group that walks "hand-in-hand" through the planning, design, and construction phases of a project. This would include all regulatory agencies, community groups, water utilities, and the wastewater utility and industry involved in the project. The purpose is to identify and resolve implementation issues associated with successfully launching recycled wastewater projects whose underlying goal is the protection of Minnesota's water resources.

Exhibit A: California Water Recycling Criteria

Type of Use	Total Coliform Limits[a]	Treatment Required
Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers	■ None required	■ Oxidation
Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	■ ≤23/100 ml[a] ■ ≤240/100 ml in more than ■ one sample in any 30-day	■ Oxidation ■ Disinfection
Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries	■ ≤2.2/100 ml[a] ■ ≤23/100 ml in more than one ■ sample in any 30-day period	■ Oxidation ■ Disinfection
Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	■ ≤2.2/100 ml[a] ■ ≤23/100 ml in more than one ■ sample in any 30-day period ■ 240/100 ml (maximum)	■ Oxidation ■ Coagulation[h] ■ Filtration[i] ■ Disinfection
Nonrestricted recreational impoundments	■ ≤2.2/100 ml[a] ■ ≤23/100 ml in more than one ■ sample in any 30-day period ■ 240/100 ml (maximum)	■ Oxidation ■ Coagulation ■ Clarification[j] ■ Filtration[i] ■ Disinfection
Groundwater recharge by spreading	■ Case-by-case evaluation	■ Case-by-case evaluation

[a] Based on running 7-day median; daily sampling is required.
[b] No contact between reclaimed water and edible portion of crop.
[c] Food crops that undergo commercial pathogen-destroying prior to human consumption.
[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.
[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.
[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.
[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.
[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.
[i] The turbidity after filtration through filter media cannot exceed an average of 2 nephelometric turbidity units (NTU) within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.
[j] Not required if reclaimed water is monitored for enteric viruses, *Giardia*, and *Cryptosporidium*.

Source: Adapted from State of California. 2000. *Water Recycling Criteria*. Title 22, Division 4, Chapter 3, California Code of Regulations. California Department of Health Services, Drinking Water Program, Sacramento, California.

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Metropolitan Council
Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR05-07d

MCES Project Number 070186

VOLUME II

Craddock Consulting Engineers
In Association with
CDM and James Crook

Metropolitan Council

Recycling Treated Wastewater for Industrial Water Use Project

LCMR05-07d

MCES Project Number 070186

TECHNICAL MEMORANDUM 1

Recycling Treated Wastewater for Industrial Water Use in Minnesota:

Implementation Issues and Customer Inventory

June 29, 2006

Craddock Consulting Engineers

In Association with

CDM and James Crook

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Recycling Treated Wastewater for Industrial Water Use in Minnesota:

Implementation Issues and Customer Inventory

June 29, 2006

Prepared for:

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Contents

Appendices

Section 1
Introduction

1.1 Project Vision

Conserving Minnesota's ground water and surface water resources is important to all sectors in the state and is key to the state's long-term economic development. The economic vitality of Minnesota requires the business sector to grow with the population of the state. While water supply availability is not presently considered a limitation for industrial development in many Minnesota communities, there are numerous areas in the state that have a limited supply of high quality water. Even within the metro area of the Twin Cities, development is now extending to areas with less productive aquifers and future growth will increase competition for a limited water supply. Industries requiring abundant or high quality water could be restricted from locating in some areas unless other water supply options are made known and available to them.

One potential supply in these water-short areas is effluent from municipal wastewater treatment plants (WWTPs), also known as reclaimed water. Municipalities may benefit by offering "water reuse" as an alternative water source to industries and by forging partnerships with industries to promote conservation of a limited potable water supply and improved protection of the state's water resources.

In July 2005, the Metropolitan Council (Met Council) was awarded a $300,000 grant from the Legislative Commission on Minnesota Resources for this project titled, "Recycling Treated Municipal Wastewater for Industrial Water Use." The timeframe for the project is July 1, 2005 to June 30, 2007. Funding for this project was recommended by the Legislative Commission on Minnesota Resources from the Minnesota Environment and Natural Resources Trust Fund. The Met Council is providing additional funding for the project through in-kind contributions of staff time. In addition, other state agencies such as the Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MDNR) and the Minnesota Department of Health (MDH) are participating via stakeholder meetings and technical review and input. It is estimated that 20% of project funding is from these in-kind contributions of staff time and 80% from the Minnesota Environment and Natural Resources Trust Fund.

The guiding goal for this project is to promote the conservation of Minnesota's ground water and surface water resources by recycling treated municipal wastewater for industrial use. The project is applicable to communities throughout Minnesota. Benefits include: (1) Less ground water aquifer depletion due to one-time use and discharge from surface waters; (2) Lower demand on finite water resources to support business and growth; and (3) Reliable and potentially lower cost water sources for industry in the long-term.

This project will provide a statewide and Minneapolis/St. Paul metro area inventory of industries and assess their potential as wastewater reuse customers. It will also outline an implementation plan that addresses the technical, regulatory, institutional, and financial elements of an industrial water reuse strategy.

The project is comprised of two main tasks:

- Task 1: Industrial Water Use (Demand Assessment) to be completed by June 30, 2006
- Task 2: Municipal Wastewater Treatment (Supply Assessment) to be completed by June 30, 2007

The main purpose of this project is to identify whether and how water reuse can reduce the potential for water supply to be a limiting factor to future industrial development in Minnesota. Because the state of Minnesota currently has few water reuse applications, the implementation plan in Task 2 will highlight reuse practices in other states and the various factors that must be considered for Minnesota to have a viable water reuse program.

This technical memorandum documents the work completed under Task 1. The main products of Task 1 include:

- an inventory of major industrial water use and users (i.e., potential candidates for industrial reuse)
- identification of regulatory, technical, and institutional elements that are usually considered in establishing a water reuse program/project

In Task 2, the industrial reuse customer inventory will be evaluated to rank candidate industrial customers for reuse projects. Costs associated with conveyance and additional treatment facilities will be estimated for candidate industrial customers. Costs and non-monetary factors will be evaluated in an implementation analysis and presented to stakeholders. With stakeholder input, an implementation plan will be developed that identifies steps the State and/or Met Council could initiate to promote industrial water reuse projects.

1.2 Water Use in Minnesota

How much water do Minnesotans use and what is it used for? Major water use in Minnesota ranged from 3.4 to 3.7 billion gallons per day (gpd) during 2000-2004. This represents all permitted water users that withdraw more than 1 million gallons per year (mgy) and/or 100,000 gpd of ground or surface water, and therefore, does not account for most domestic private well or surface withdrawals. The majority of the water use information reported in this document is based on the records maintained by the MDNR Appropriation Permits program. While the water use information presented in this document does not include all uses since it excludes private, low volume users, it is based on a well-maintained data record that provides an accurate accounting of the users that are monitored.

The MDNR tracks water use by nine industrial categories, listed in Figure 1.1 and Table 1.1. Over 60% of the water used in Minnesota is for power generation facilities, mainly for once-through cooling, supplied mostly by surface waters (as indicated in Table 1.1 and Figure 1.2). The next largest use of water, about 15% of the total, is as a potable-quality water supply (waterworks), distributed by municipalities for domestic, commercial and industrial uses. Nearly two-thirds of the potable-quality water in Minnesota is supplied by ground water. Water withdrawn by industries (those not served by waterworks) for various processing needs accounts for about 12% of the total water used in Minnesota.

In terms of 2004 daily average demands, nearly 2,500 mgd of water was used by the state's power generation industry and over 500 mgd served as a potable-quality supply for a variety of uses. Over 400 mgd was withdrawn by industries for direct use in their business. Year 2004 water records were used for this study for analysis of industrial water demands on a state-wide basis because it was representative of the previous four years of record, as documented in Appendix A, and was the last year of reported data available.

Clearly, the various types of industrial water use represent a major demand on the state's water resources. For purposes of this project, the MDNR categories of power generation and industrial processing represent demands that in theory could use reclaimed water. Some industries also use municipal potable supplies, but there are insufficient data on a state basis to identify this portion of the industrial sector. Recognizing these limitations, the total "industrial water use" (power generation and industrial processing) in Minnesota is nearly 3 billion gpd, which is roughly 75% of the total major water use in the state.

Table 1.1. Water Use in Minnesota, 2004

	Water Use, mgd		
Category	**Ground Water**	**Surface Water**	**Total**
Air Conditioning	6.0	0.9	6.8
Industrial Processing	56.3	385.4	441.7
Major Crop Irrigation	174.9	27.6	202.5
Non-Crop Irrigation	20.3	5.5	25.8
Power Generation	3.6	2,375.1	2,378.8
Special Categories	18.9	14.5	33.3
Temporary	4.2	0.7	4.9
Water Level Maintenance	4.8	95.4	100.2
Waterworks	354.6	201.3	555.9
Total	643.6	3,106.3	3,749.8

Source: MNDR, 2004

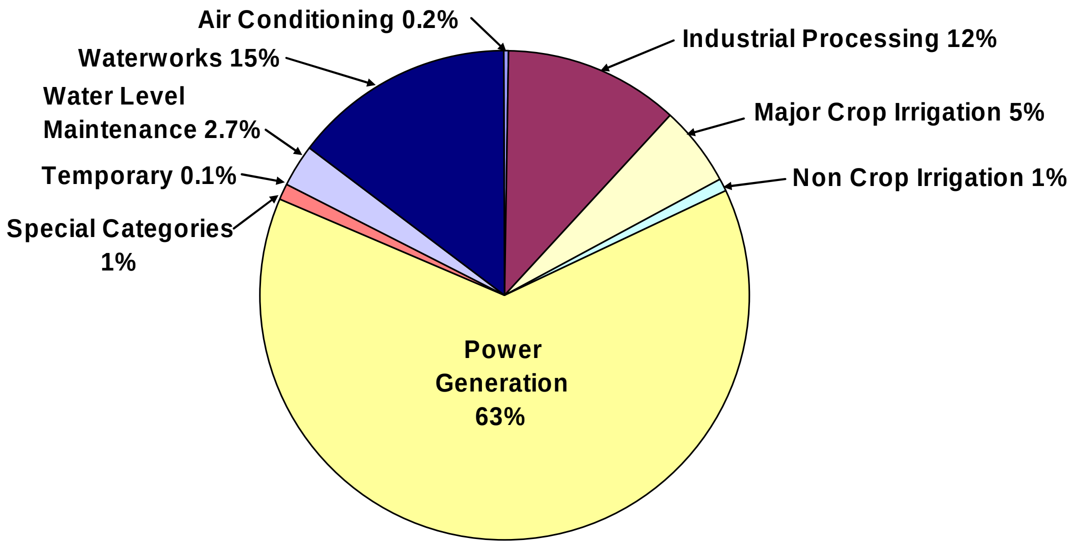

Figure 1.1. Water Use in Minnesota, 2004
Source: MDNR, 2004

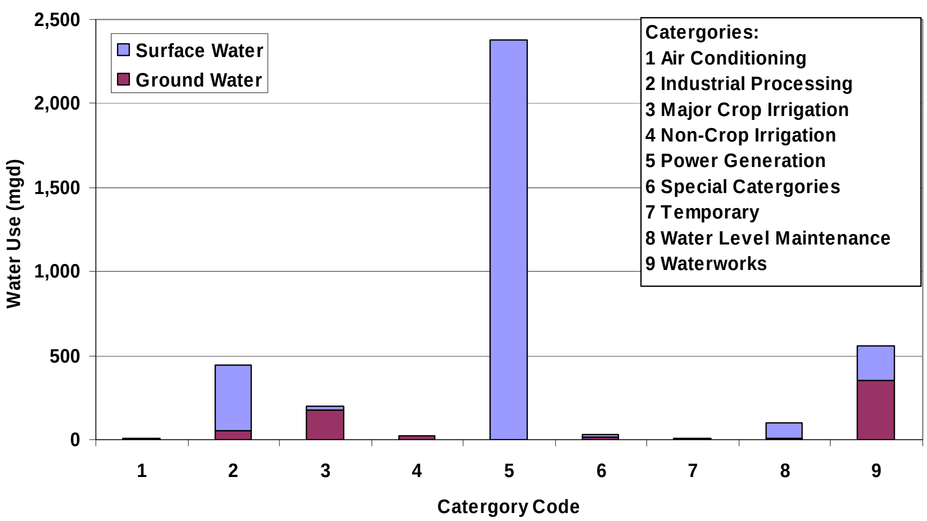

Figure 1.2. Water Use in Minnesota by Source, 2004
Source: MNDR, 2004

1.3 Wastewater Reuse Background

In Minnesota, WWTP effluent is typically discharged to a receiving stream or a land application system. However, wastewater effluent can also be beneficially used for a variety of purposes. There are various terms used to describe the beneficial use of WWTP effluent: water reuse, wastewater reuse, water recycling, or water reclamation are often used interchangeably.

While this project is to evaluate the beneficial reuse of wastewater effluent for industrial purposes, non-industrial uses are briefly described to indicate the potential competition for use of reclaimed water as is commonly practiced around the globe. From the perspective of the municipality, investment in capital to provide reclaimed water will typically involve a review of all options; multiple users are commonly required for water reclamation to be a cost-effective practice for the municipal utility.

Many U.S. communities use WWTP effluent for a variety of nonpotable purposes, typically categorized under the following major types:

- Industrial
- Urban
- Agricultural
- Environmental and recreational
- Ground water recharge
- Augmentation of potable supplies

Industrial

Industrial reuse applications in the U.S. have steadily increased over the past decade, with an increasing diversity of industrial uses. The largest use of reclaimed water in the U.S. has been for cooling water. Because recirculating evaporative cooling water systems consume water (versus the once-through cooling water system that has no evaporation), they are the most common industrial system using reclaimed water. The large water demands of power facilities for cooling water and other needs makes them an ideal facility for reuse. Reclaimed water is also used as process water for a variety of applications at petroleum refineries, chemical plants, metal working, pulp and paper mills, and other production facilities. Other industries with a potential to use reclaimed water are industries using water for washing or wetting requirements, such as laundries and sand and gravel washing operations.

Urban

Reclaimed water is used for a variety of purposes in the urban setting. One common use, that is one of the few applications in Minnesota, is for golf course irrigation. Other typical irrigation reuse applications include: public lands such as parks, athletic fields, highway medians and shoulders, landscaped areas for commercial properties, and landscaping for residential areas. Other examples of "urban" reuse applications include vehicle washing facilities, laundry facilities, fire protection, toilet and urinal flushing in commercial buildings, decorative water features such as fountains and reflecting pools, street sweeping, and dust control and soil compaction for construction projects.

Agricultural

In many states, agricultural irrigation is a significant percent of the total demand for freshwater and is estimated to represent 40% of the total water demand nationwide [Soley et al, 1998]. Reclaimed water has been used to irrigate a variety of agricultural applications including: pasture; orchards and vineyards; harvested feed, fiber and seed; food crops; processed food crops; and nursery and sod. Florida uses 19% of its reclaimed water supply for agricultural irrigation [Florida Department of Environmental Protection, 2002] and California uses approximately 48% [California State Water Resources Control Board, 2002].

Environmental and Recreational

Reclaimed water has been used for environmental improvements and recreational uses. Environmental reuse includes wetland enhancement and restoration, creation of wetlands for wildlife habitat, and stream augmentation. Wetland reuse projects often include dual goals: to enhance downstream surface water quality and create additional wildlife habitat. Recreational applications for reclaimed water include water impoundments restricted to boating and fishing or for full body contact activities such as swimming, smaller landscape impoundments, and golf course ponds. Lubbock, Texas uses 4 mgd of reclaimed water for recreational lakes (fishing and boating) in the Yellowhouse Canyon Lakes Park (Water Pollution Control Federation, 1989].

Ground Water Recharge

Ground water recharge using reclaimed water has been used to reduce saltwater intrusion in coastal aquifers, augment potable or nonpotable aquifers, provide storage and/or further treatment of reclaimed water for later use, and prevent ground subsidence. In areas with extensive agricultural irrigation, ground water recharge practices rely on the aquifers for storage, removing the need for storage facilities to meet seasonal demands.

Augmentation of Potable Supplies

Potable water supplies can be supplemented with treated wastewater by surface water augmentation, ground water recharge, and direct potable reuse. The first two applications are indirect potable reuse, which has been defined as the augmentation of a community's raw water supply with treated wastewater followed by an environmental buffer [Crook, 2001]. In this case, the treated wastewater is mixed with surface and/or ground water and receives additional treatment prior to entering the potable water distribution system. Direct potable reuse is defined as the introduction of treated wastewater directly into a water distribution system without intervening storage (pipe-to-pipe) [Crook, 2001]. There are no direct potable reuse applications in the U.S..

1.4 Wastewater Reuse in Minnesota

Minnesota is known for its abundance of water, as the "Land of 10,000 Lakes." A safe, cost-effective, and adequate water supply has been easily attained for many Minnesota industries and communities, but there are some regions with an abundance of poor quality water or a limited supply of high quality water. Section 3 highlights these areas in the watershed inventories. Over the past two decades, Minnesota's environmental stewardship has promoted the need to conserve water resources and programs have been implemented across the state. Conservation has gone hand-in-hand with improved water protection programs and more stringent regulations for surface water dischargers. As we look to the future, residential and industrial growth in some areas of Minnesota could potentially be curtailed because of a limited water supply, even with more stringent conservation practices. Alternative supplies will be sought – and treated wastewater effluent is one potential supply for a specific area, industry, or group of industries.

Water quality considerations may also drive an increased role for reuse in Minnesota. As growing communities generate additional wastewater, there will be a need to provide higher and higher levels of wastewater treatment to maintain or decrease the discharge loads to the state's waterways. Finding other uses for the treated wastewater, through partnerships with industry, will decrease wastewater discharges.

The urgency for the water quality consideration is driven by the development of the Total Maximum Daily Load (TMDL) program in Minnesota which will affect the discharge allocations for many communities. For example, the Lake Pepin TMDL will affect nearly two-thirds of the state. With a potential reduction requirement of one-half the phosphorus and solids loads to Lake Pepin, and nonpoint source reduction practices still untested, it is likely that point source reductions will be part of the solution. Wastewater reuse may be a cost-effective solution for some communities, particularly when tertiary treatment processes are required to meet receiving stream discharge limits. If these communities are also experiencing water supply limitations, the benefits of a wastewater reuse option could be even more pronounced.

1.5 Document Contents

This technical memorandum presents background information on the project and water reuse in general, implementation considerations, and an inventory of the industrial water demand and supply of treated wastewater.

Section 1: Presents the project vision, drivers for water reuse in Minnesota, general water use in Minnesota in context with water used by industries, and an overview of reuse practices and specific wastewater reuse issues for Minnesota.

Section 2: Provides an overview of considerations for the industry and municipal supplier that affect the implementation of a water reuse project. Regulatory, technical and institutional issues are identified to educate the stakeholders on the diversity of issues that must be addressed for successful implementation and operation of wastewater reuse facilities.

Section 3: Reviews the historical water use in the state for major industrial users in context with municipal WWTPs' location and production capacity. A more in-depth review of industry water demand and municipal WWTP supply is provided for each individual watershed. General information on the existing water sources in the watersheds and areas that may be prone to water supply problems is also provided. The Minneapolis/St. Paul metro area is examined on a WWTP basis, where industries located within a one- and five-mile radius of each existing metro-area WWTP are identified. The section concludes with a summary of industrial water use demand in context with the supply of reclaimed water.

1.6 References

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Section 2
Implementation Considerations

The decision to implement an industrial water reuse program depends heavily on site-specific and area-specific conditions. For a wastewater treatment provider to partner with one or more industries in developing an industrial reuse program usually requires one or more economic and/or non-economic drivers. Several key drivers for industrial reuse are discussed in Section 2.1.

Even with the proper incentives, implementation of an industrial reuse program is contingent on successfully addressing a number of implementation challenges, such as:

- development and application of reuse regulations
- technical considerations such as industrial water quality requirements, wastewater treatment needs to achieve the users' water quality requirements, and fee structures
- institutional considerations such as local ordinances, public perception, and legal agreements

Each of these subjects is discussed in this section. Section 2 concludes with example case studies of industrial reuse projects throughout the U.S.

2.1 Drivers for Reuse

Industry considers use of reclaimed water 'reuse' if there is a reason (driver) to seek an alternative to use of municipal potable supplies or direct use of ground or surface water. Usually, the driver is the lack of sufficient water of the appropriate quality. In some cases, financial incentives associated with the use of reclaimed water (e.g., rates lower than potable water) make it economically attractive.

Use of reclaimed water is not uncommon in those states that have state-wide or large regional water supply issues. In Minnesota, some areas have had similar supply limitations. In the case of the southwestern portion of the state, a reliable supply was found outside Minnesota's border. One power plant has found reclaimed water a better option than treating the poor quality water from the Minnesota River. As population growth continues to put pressure on metro area and larger community aquifers, some areas in Minnesota will have water supply limitations and use of reclaimed water will be a viable option.

Drivers for reclaimed water use for industrial purposes on a national level include the following:

- Need for water – lack of adequate local supply of appropriate quality or quantity

- Conservation – conserves natural waters for potable supplies
- Reliable supply – reclaimed water is nearly always available, not affected by droughts
- Pollution abatement – alternative to discharge to environmentally sensitive waters
- Economically attractive supply – may be less costly than treatment needed for discharge or alternative sources of supply
- Regulatory or statutory mandates – regulatory or statutory requirement to use or consider reclaimed water for certain water demands under certain conditions

In Minnesota, a key driver for industrial reuse of treated wastewater will be the lack of an adequate local water supply of appropriate quality or quantity. If sufficient supply is available, but of a poorer quality than reclaimed water, the treatment costs might favor reuse. Similarly, if an appropriate quality water is available, but at a significant distance and requires conveyance and annual pumping costs, then reuse may be more cost-effective. While Minnesotans are embracing conservation measures and water supply plans emphasize reliability in supply, conservation and reliability most likely will be added benefits, not the main driver to spur industrial water reuse. Municipalities in Minnesota, particularly in developing areas, may seek to foster relationships with reuse customers because of increased pressures to reduce the discharge of pollutants to the state's waterways. Minnesota's industries, particularly if located or planned for location in proximity to a WWTP, could be sought as partners in the continued conservation and protection of Minnesota's water resources.

2.2 Regulatory Requirements

Current Water Reuse Practice in Minnesota

Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* [State of California, 2000a], as summarized in Table 2.1, to evaluate water reuse projects on a case-by-case basis.

In Minnesota, water reuse requirements are included in NPDES permits administered by the Minnesota Pollution Control Agency. A change in the location of a wastewater treatment facility's discharge (as would be required for a reuse application) or any modifications to a facility to provide treatment and conveyance for a reuse application requires an NPDES permit modification.

There are several rural Minnesota facilities that discharge their effluent for agricultural irrigation purposes, typically because there is not a receiving stream with available load capacity. Small systems are also being installed for golf course irrigation. The largest water reuse application in Minnesota will be implemented in 2006 as the City of Mankato provides treated wastewater effluent to the Mankato Energy Center. Over 6 mgd of water will be provided for cooling and process water needs. Section 2.5 provides additional information on the Mankato industrial reuse project and other reuse applications in Minnesota.

Table 2.1. 2000 California Water Recycling Criteria

Type of Use	Total Coliform Limits[a]	Treatment Required
Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers	▪ None required	▪ Oxidation
Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	▪ ≤23/100 ml[a] ▪ ≤240/100 ml in more than one sample in any 30-day	▪ Oxidation ▪ Disinfection
Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period	▪ Oxidation ▪ Disinfection
Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation[h] ▪ Filtration[i] ▪ Disinfection
Nonrestricted recreational impoundments	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation ▪ Clarification[j] ▪ Filtration[i] ▪ Disinfection
Groundwater recharge by spreading	▪ Case-by-case evaluation	▪ Case-by-case evaluation

[a] Based on running 7-day median; daily sampling is required.
[b] No contact between reclaimed water and edible portion of crop.
[c] Food crops that undergo commercial pathogen-destroying prior to human consumption.
[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.
[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.
[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.
[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.
[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.
[i] The turbidity after filtration through filter media cannot exceed an average of 2 nephelometric turbidity units (NTU) within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.
[j] Not required if reclaimed water is monitored for enteric viruses, *Giardia*, and *Cryptosporidium*.

Source: Adapted from State of California [2000a].

Comparison to Other State Regulatory Practices

There are no federal regulations governing water reclamation and reuse in the United States; regulations are developed and implemented at the state government level. The lack of federal regulations has resulted in differing standards among states that have developed water reuse regulations. In the 1990s, several states adopted or revised their respective regulations, and it was common practice to base reuse criteria on those of states that had comprehensive regulations, guidelines, and background information to support them. The *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 1992], which were published in 1992 (revised in 2004), were also used as a resource by states that had limited or no regulations or guidelines. Since then, there has been increased interest in water reuse in several states that previously did not have water reuse regulations.

At present, no states have regulations that cover all potential uses of reclaimed water, but several states have extensive regulations that prescribe requirements for a wide range of end uses of the reclaimed water. Other states have regulations or guidelines that focus on land treatment of wastewater effluent, emphasizing additional treatment or effluent disposal rather than beneficial reuse, even though the effluent may be used for irrigation of agricultural sites or public access lands.

Status of Water Reuse Regulations and Guidelines

The status and summary of water reuse regulations and guidelines in the United States as of 2004 have been documented in the EPA *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 2004] and are provided in Table 2.2. The absence of state regulations and guidelines for specific reuse applications does not necessarily prohibit those applications; many states evaluate specific types of water reuse on a case-by-case basis. Based on the data in Table 2.2, 25 states have adopted regulations regarding the use of reclaimed water, 16 states have guidelines or design standards, and 9 states have no regulations or guidelines. These data are somewhat misleading, as they include regulations and guidelines directed at land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse.

The number of states with regulations or guidelines for each type of reuse is summarized in Table 2.3. As indicated in Table 2.3, agricultural and landscape irrigation represent the reclaimed water uses most commonly regulated, and many states have implemented regulations that apply only to those types of use. As noted above, these data include state regulations that pertain to land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse.

The standards in states having the most reuse experience tend to be more stringent than those in states with fewer reuse projects. States that have water reuse regulations or guidelines typically set standards for reclaimed water quality and specify minimum treatment requirements, although a few states, such as Texas and New Mexico, do not prescribe treatment processes and rely solely on water quality limits.

Table 2.2. Summary of State Reuse Regulations and Guidelines for Nonpotable Reuse Applications

State	Regulations	Guidelines	No Regulations or Guidelines	Unrestricted Nonpotable Urban Uses	Restricted Nonpotable Urban Uses	Agricultural Irrigation of Food Crops	Agricultural Irrigation of Non-Food Crops	Unrestricted Recreational Impoundments	Restricted Recreational Impoundments	Environmental Uses	Industrial Uses
Alabama		●			●		●				
Alaska	●						●				
Arizona	●			●	●	●	●		●		
Arkansas		●		●	●	●	●				
California	●			●	●	●	●	●	●		●
Colorado	●			●	●						●
Connecticut			●								
Delaware	●			●	●		●				
Florida	●			●	●	●	●			●	●
Georgia		●		●	●		●				
Hawaii		●		●	●	●	●		●		●
Idaho	●			●	●	●	●				
Illinois	●			●	●		●				
Indiana	●			●	●	●	●				
Iowa	●				●		●				
Kansas		●		●	●	●	●				
Kentucky			●								
Louisiana			●								
Maine			●								
Maryland		●			●		●				
Massachusetts		●		●	●		●				
Michigan	●					●	●				
Minnesota			●								
Mississippi			●								
Missouri	●				●		●				
Montana		●		●	●	●	●				
Nebraska	●				●		●				
Nevada	●			●	●	●	●	●	●		
New Hampshire			●								
New Jersey		●		●	●	●	●				●
New Mexico		●		●	●	●	●				
New York		●					●				
North Carolina	●			●	●						●
North Dakota		●		●	●		●				
Ohio		●		●	●		●				
Oklahoma	●				●	●	●				
Oregon	●			●	●	●	●	●	●		●
Pennsylvania		●					●				
Rhode Island			●								
South Carolina	●			●	●		●				
South Dakota		●		●	●		●			●	
Tennessee	●			●	●		●				
Texas	●			●	●	●	●	●	●		●
Utah	●			●	●	●	●	●	●		●
Vermont	●						●				
Virginia			●								
Washington		●		●	●	●	●	●	●	●	●
West Virginia	●					●	●				
Wisconsin	●						●				
Wyoming	●			●	●	●	●				

Source: Adapted from U.S. Environmental Protection Agency [2004].

Table 2.3. Number of States with Reuse Regulations or Guidelines for Different Types of Use

Type of Use	Number of States with Regulations or Guidelines	Description
Unrestricted urban water reuse Irrigation Toilet flushing Fire protection Construction Landscape impoundment Street cleaning	28 28 10 9 9 11 6	Irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences. Toilet flushing, air conditioning, fire protection, construction, cleansing, ornamental fountains, and aesthetic impoundments.
Restricted urban water reuse	34	Irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.
Agricultural irrigation of food crops	21	Irrigation of food crops which are intended for human consumption. Food crop is to be processed. Food crop is consumed uncooked.
Agricultural irrigation of nonfood crops	40	Irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
Unrestricted recreational water reuse	7	An impoundment of water in which no limitations are imposed on body-contact water recreation activities.
Restricted recreational water reuse	9	An impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
Environmental water reuse	3	Reclaimed water used to create manmade wetlands, enhance natural wetlands, and to sustain stream flows.
Industrial water reuse	9	Reclaimed water used in industrial facilities primarily for cooling system makeup water, boiler-feed water, process water, and general washdown and cleansing.
Groundwater Recharge	5	Used via infiltration basins, percolation ponds or injection wells, reclaimed water is used to recharge groundwater aquifers.
Indirect Potable Reuse	5	The intentional discharge of highly treated reclaimed water into surface waters or groundwater that will be used as a source of potable water supply.

Adapted from U.S. Environmental Protection Agency [2004].

Regulatory Requirements for Nonpotable Uses of Reclaimed Water

In the past, most state water reuse regulations were developed in response to a need to regulate a growing number of water reuse projects in the particular state. Recently, some states that currently have few reuse projects have taken a proactive approach and have adopted criteria, which tend to encourage implementation of projects. Arizona, California, Florida, and Texas, which have had comprehensive criteria for a number of years, have revised their water reuse regulations within the last ten years to reflect additional reclaimed water uses, advances in wastewater treatment technology, and increased knowledge in the areas of microbiology and public health protection.

State water reuse regulations typically include one or more of the following elements:

- Treatment Process Requirements
- Biochemical Oxygen Demand (BOD)/Total Suspended Solids (TSS), and Turbidity Requirements
- Coliform Bacteria Limits
- Limits and Monitoring for Pathogenic Organisms
- Disinfection Requirements
- Treatment Reliability
- Storage Requirements
- Cross Connection Control
- Irrigation-Specific Requirements

Appendix B defines these regulatory requirements and provides state-specific examples. State regulations for indirect potable reuse are also summarized in Appendix B.

The variations and inconsistencies among state regulations are illustrated in Table 2.4, which includes examples of several states' reclaimed water standards for uses ranging from fodder crop irrigation to toilet and urinal flushing in buildings.

Table 2.4. Examples of State Water Reuse Criteria for Selected Nonpotable Applications

State	Fodder Crop Irrigation[1]		Processed Food Crop Irrigation[2]		Food Crop Irrigation[3]		Restricted Recreational Impoundments[4]	
	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required
Arizona	▪ 1,000 fecal coli/100 ml	▪ Secondary	Not covered	Not covered	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection
California	Not specified	▪ Oxidation	Not specified	▪ Oxidation	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[5] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml	▪ Oxidation ▪ Disinfection
Colorado	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered
Florida	▪ 200 fecal coli/100 ml ▪ 20 mg/L CBOD[6] ▪ 20 mg/l TSS[7]	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	Use prohibited	Use prohibited	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection
New Mexico (Policy)	▪ 1,000 fecal coli/100 ml ▪ 75 mg/L TSS ▪ 30 mg/L BOD	Not specified	Not covered	Not covered	Use Prohibited	Use Prohibited	▪ 100 fecal coli/100 ml ▪ 30 mg/L BOD ▪ 30 mg/L TSS	Not specified
Utah	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection
Texas	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	Use prohibited	Use prohibited	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified
Washington	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml	▪ Oxidation ▪ Disinfection

1 In some states more restrictive requirements apply where milking animals are allowed to graze on pasture irrigated with reclaimed water.
2 Physical or chemical processing sufficient to destroy pathogenic microorganisms. Less restrictive requirements may apply where there is no direct contact between reclaimed water and the edible portion of the crop.
3 Food crops eaten raw where there is direct contact between reclaimed water and the edible portion of the crop.
4 Recreation is limited to fishing, boating, and other nonbody contact activities.
5 Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.
6 CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD
7 TSS – total suspended solids

Table 2.4. Examples of State Water Reuse Criteria for Selected Nonpotable Applications (cont'd)

State	Restricted Access Irrigation[1]		Unrestricted Access Irrigation[2]		Toilet Flushing[3]		Industrial Cooling Water[4]	
	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required
Arizona	▪ 200 fecal coli/100 ml	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Filtration ▪ Disinfection	Not covered	Not covered
California	▪ 23 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Coagulation[4] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[4] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[4] ▪ Filtration ▪ Disinfection
Colorado	▪ 126 *E.coli*/100 ml ▪ 30 mg/L TSS	▪ Secondary ▪ Disinfection	▪ 126 *E.coli*/100 ml ▪ 3 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	Not covered	Not covered	▪ 126 *E.coli*/100 ml ▪ 30 mg/L TSS	▪ Secondary ▪ Disinfection
Florida	▪ 200 fecal coli/100 ml ▪ 20 mg/L CBOD[6] ▪ 20 mg/l TSS[7]	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection
New Mexico (Policy)	▪ 200 fecal coli/100 ml ▪ 30 mg/L BOD ▪ 30 mg/L TSS	Not specified	If within 100 ft of dwelling: ▪ 5 fecal coli/100 ml ▪ 10 mg/L BOD ▪ 3 NTU	Not specified	▪ 100 fecal coli/100 ml ▪ 30 mg/L BOD ▪ 30 mg/L TSS	Not specified	Not covered	Not covered
Utah	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/TSS	▪ Secondary ▪ Disinfection
Texas	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified
Washington	▪ 23 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection

1 Classification varies by state; generally includes irrigation of cemeteries, freeway medians, restricted access golf courses, and similar restricted access areas.
2 Includes irrigation of parks, playgrounds, schoolyards, residential lawns, and similar unrestricted access areas.
3 Not allowed in single-family residential dwelling units.
4 Cooling towers where a mist is created that may reach populated areas.
5 Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.
6 CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD
7 TSS – total suspended solids

Common Uses. Water reuse regulations focus on public health implications of using the water, and water quality criteria not related to health protection usually are not included in water reuse regulations. Most states with extensive water reuse experience have comparable, conservatively-based water quality criteria or guidelines. Arguments for less restrictive standards are most often predicated upon a lack of documented health hazards rather than upon any certainty that hazards are small or nonexistent. In the absence of definitive epidemiological data and a unified interpretation of scientific and technical data on pathogen exposures, selection of water quality limits will continue to be somewhat subjective and inconsistent among the states. Regulatory requirements for some nonpotable uses of reclaimed water not included in Table 2.4 are summarized below and detailed in Appendix B.

Wetlands. In most cases, the primary intent in applying reclaimed water to wetlands is to provide additional treatment of effluent prior to discharge or reuse, although wetlands are sometimes created solely for environmental enhancement. In such cases, secondary treatment is usually acceptable as influent to the wetland system. Very few states have regulations that specifically address the use of reclaimed water for creation of artificial wetlands or the restoration or enhancement of natural wetlands. Where there are no regulations, regulatory agencies prescribe requirements on a case-by-case basis. In addition to state requirements, natural wetlands, which are considered waters of the United States, are protected under EPA's NPDES Permit and Water Quality Standards programs. Constructed wetlands built and operated for the purpose of wastewater treatment generally are not considered waters of the United States.

Industrial Uses Other than Cooling. Due to the myriad of industrial processes that use water, regulatory agencies generally prescribe water reuse requirements for industrial applications other than cooling on an individual case basis. In many cases, the specific industrial reuse customer will have additional criteria (or more stringent criteria) than those imposed by the regulatory agency.

Reclaimed water from conventional wastewater treatment processes is of adequate quality for many industrial applications that can tolerate water of less than potable quality. Industrial uses of reclaimed water include cooling, process water, stack scrubbing, boiler feed, wash water, transport of material, and as an ingredient in a nonfood-related product. Regulatory considerations for reuse of water in industrial applications include generation of aerosols, safety of manufactured products, and associated food and beverage production.

For example, Florida regulations address the use of reclaimed water for food processing at industrial facilities. Florida's reuse rule specifically prohibits the use of reclaimed water in the manufacture or processing of food or beverage for human consumption where the reclaimed water will be incorporated into or come in contact with the food or beverage product. Similarly, Washington standards do not allow the use of reclaimed water for food preparation and prohibit its use in food or drink for humans.

While many industrial uses require water of higher chemical quality than that typically present in reclaimed water (e.g., computer chip manufacturing requires reverse osmosis treatment to produce ultra-pure wash water), water reuse regulations are intended to provide health protection and only include requirements to attain that end.

Miscellaneous Nonpotable Uses. While all states that have water reuse regulations or guidelines include criteria for crop and/or landscape irrigation, some include requirements for less common uses of reclaimed water, such as flushing sanitary sewers, street cleaning, dust control, soil compaction, making concrete, snowmaking, decorative fountains, commercial laundries, commercial car washes, equipment washing, and fire protection systems. For these and similar uses, the various state standards impose wastewater treatment process requirements, reclaimed water quality limits, and design and operational requirements reflective of the degree of human exposure to the water that are in concert with other more common uses of reclaimed water.

For example, secondary treatment with a minimal level of disinfection is acceptable for uses where there is little or no expected human contact with the water, such as flushing sanitary sewers or making concrete. Conversely, uses such as snowmaking and vehicle washing are likely to result in contact with the reclaimed water, and tertiary treatment with a high level of disinfection is usually required.

Regulatory Mandates

States such as California and Florida have regulations that mandate water reuse under certain conditions. The Florida Water Policy [Florida Department of Environmental Protection, 1995] establishes a mandatory reuse program that is actively enforced. The policy requires that the state's water management districts identify water resource caution areas that have water supply problems that have become critical or are anticipated to become critical within the next 20 years. State legislation requires preparation of water reuse feasibility studies for treatment facilities located within the water resource caution areas, and a "reasonable" amount of reclaimed water use from municipal wastewater treatment facilities is required within the designated water resource caution areas unless reuse is not economically, environmentally, or technically feasible. Water reuse also may be required outside of designated water resource caution areas if reclaimed water is readily available, reuse is economically, environmentally, and technologically feasible, and rules governing the imposition of requirements for reuse have been adopted in those areas by the water management district having jurisdiction.

In California, laws and regulations exist that mandate water reuse under certain conditions. Section 13550 of the California Water Code states that the use of potable domestic water for nonpotable uses, including, but not limited to, cemeteries, golf courses, highway landscaped areas, and industrial and irrigation uses, is a waste or an unreasonable use of the water if reclaimed water is available which meets certain conditions [California State Water Resources Control Board, 2000]. The conditions are: the source of reclaimed water is of adequate quality for these uses and is available for these uses; reclaimed water may be furnished for these uses at a reasonable cost to the user; after concurrence with the State Department of Health Services, the use of reclaimed water from the proposed source will not be detrimental to public health; and use of reclaimed water for these uses will not adversely affect downstream water rights, will not degrade water quality, and is determined not to be injurious to plant life, fish and wildlife.

The Water Code mandates that no person or public agency shall use water from any source or quality suitable for potable domestic use for nonpotable uses if suitable reclaimed water is available and meets the conditions stated above. Other sections of the code allow for mandating reclaimed water use for irrigation of residential landscaping, industrial cooling applications, and toilet and urinal flushing in nonresidential buildings. Some local jurisdictions in the state have taken action to require the use of reclaimed water in certain situations.

U.S. EPA Guidelines for Water Reuse

In recognition of the increasing role of water reuse as an integral component of the nation's water resources management – and to facilitate the orderly planning, design, and implementation of water reuse projects – the U.S. Environmental Protection Agency (EPA), in conjunction with the U.S. Agency for International Development, published *Guidelines for Water Reuse* in 1992 [U.S. Environmental Protection Agency, 1992]. The U.S. EPA took the position that national water reuse standards were not necessary and comprehensive guidelines, coupled with flexible state regulations, would foster increased consideration and implementation of water reuse projects.

The guidelines were updated in 2004 [U.S. Environmental Protection Agency, 2004] to include technological advances, research data, and other information generated in the last decade. The guidelines address various aspects of water reuse and include recommended treatment processes, reclaimed water quality limits, monitoring frequencies, setback distances, and other controls for various water reuse applications. The suggested guidelines for wastewater treatment and reclaimed water quality are presented in Appendix B.

It is explicitly stated in the *Guidelines for Water Reuse* that the recommended treatment unit processes and water quality limits presented in the guidelines "are not intended to be used as definitive water reclamation and reuse criteria. They are intended to provide reasonable guidance for water reuse opportunities, particularly in states that have not developed their own criteria or guidelines." [U.S. Environmental Protection Agency, 2004].

Water Reuse Criteria for Industrial Uses

Water reuse criteria are principally directed at health and environmental protection and do not typically include water quality requirements that are unrelated to health and environmental protection. Examples of reclaimed water quality requirements for industrial applications for California and Florida are provided in Tables 2.5 and 2.6, respectively.

Table 2.5. California Water Recycling Criteria (Industrial Uses)

Type of Use	Total Coliform Limits	Treatment Required
▪ Cooling water where no mist created ▪ Process water where no worker contact ▪ Boiler feed ▪ Mixing concrete	▪ ≤ 23/100 ml	▪ Secondary ▪ Disinfection
▪ Cooling water where mist created[1] ▪ Process water where worker contact likely	▪ ≤ 2.2/100 ml	▪ Secondary ▪ Coagulation[2] ▪ Filtration ▪ Disinfection

[1] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.
[2] Not required under certain conditions.
Source: Adapted from State of California [2000a].

Table 2.6. Florida Reuse Rule (Industrial Uses)

Type of Use	Total Coliform Limits	Treatment Required
▪ Wash water[1] ▪ Process water[1]	▪ ≤ 200 fecal coli/100 ml ▪ ≤ 30 mg/L BOD ▪ ≤ 30 mg/L TSS	▪ Secondary ▪ Disinfection
▪ Once through cooling in closed system	▪ ≤ 30 mg/L BOD ▪ ≤ 30 mg/L TSS	▪ Secondary
▪ Once through cooling where mist created (alternative requirements acceptable if certain conditions met)	▪ No detectable fecal coli/100 ml ▪ ≤ 20 mg/L BOD ▪ ≤ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection [2]

[1] Manufacture or processing of food or beverage where the water will be incorporated into or come in contact with the product is prohibited.
[2] Reclaimed water must be sampled at least once every two years for *Giardia* and *Cryptosporidium*.
Source: Adapted from Florida Department of Environmental Protection [1999].

Implications of No Water Reuse Guidelines or Regulations

Minnesota has not developed water reuse criteria and currently considers each water reuse project on a case-by-case basis, using California's Water Recycling Criteria as a guideline for imposition of standards. Case-by-case determination of reclaimed water requirements can lead to inconsistencies in permit requirements across the state and may result in requirements that represent "moving targets," leaving proponents unsure (and perhaps unable) to determine the requirements that may be placed on them. A statewide set of comprehensive water reuse regulations would provide definitive information to assist industries and municipalities in the planning and implementation of projects. On the other hand, a case-by-case system can allow for greater flexibility in developing reuse projects.

2.3 Technical Considerations

The main technical issues that must be addressed with water reuse involve water quality and conveyance of water from the WWTP to the industry. The most cost-effective source would be one where the wastewater effluent water quality meets all the industrial water quality criteria and conveyance requirements are minor. In most cases, some additional treatment is required to meet the industrial process requirements or health-related criteria. This section will provide some general industry water quality requirements and issues with reclaimed water use. Treatment requirements and technologies are summarized for several industrial uses. Conveyance considerations are very site specific and are not discussed in this Technical Memorandum. However, an assessment of conveyance requirements will be conducted as part of Task 2 of this project.

Water Quality

Industrial Water Quality Concerns

Due to the myriad of industrial processes that use water and site-specific conditions, regulatory agencies generally prescribe water reuse requirements on an individual case basis, except for some common widespread uses such as cooling water. Reclaimed water from conventional wastewater treatment processes is of adequate quality for many industrial applications that can tolerate water of less than potable quality, and it has the important advantage of being a reliable supply. Industries are often located near populated areas that generate large volumes of wastewater. Industrial uses of reclaimed water include cooling, process water, stack scrubbing, boiler feed, washing, transport of material, and as an ingredient in a product. Cooling is the predominant reuse application, accounting for more than 90 percent of the total volume of reclaimed water used for industrial purposes.

Cooling Water. Pathogenic microorganisms in reclaimed water used in cooling towers present potential hazards to workers and to the public in the vicinity of cooling towers from aerosols and windblown spray. In practice, however, biocides are usually added to all cooling waters onsite to prevent slimes and otherwise inhibit microbiological activity, which has the secondary effect of eliminating or greatly diminishing the potential health hazard associated with aerosols or windblown spray. Aerosols produced in the workplace or from cooling towers also may present hazards from the inhalation of VOCs, and although little definitive research has been done in this area, there has been no indication that VOCs have created health problems at any existing water reuse site. Closed-loop cooling systems using reclaimed water present minimal health concerns unless there is inadvertent or intentional misuse of the water.

There is no indication that reclaimed water is more likely to contain *Legionella pneumophila* bacteria than waters of non-sewage origin. All cooling water systems should be operated and maintained to reduce the *Legionella* threat, regardless of the origin of the source water.

In general, the major problems related to power plants employing municipal effluents as makeup water are scale formation, corrosion, foaming, and biological fouling due to high residual organic substrate and nutrient concentrations in the wastewater. These problems are caused by contaminants in potable water as well as reclaimed water, but the concentrations of some contaminants in reclaimed water may be higher.

Cooling water should not lead to the formation of scale, i.e. hard deposits in the cooling system. Such deposits reduce the efficiency of the heat exchange. The principal causes of scaling are calcium (as carbonate, sulfate, and phosphate) and magnesium (as carbonate and phosphate) deposits. Scale control for reclaimed water is achieved through chemical means and sedimentation. Acidification or addition of scale inhibitors can control scaling. Acids (sulfuric, hydrochloric, and citric acids and acid gases such as carbon dioxide and sulfur dioxide) and other chemicals (chelants such as EDTA and polymeric inorganic phosphates) are often added for pH and alkalinity control to increase the water solubility of scale-forming constituents, such as calcium and magnesium. Lime softening removes carbonate hardness and soda ash removes noncarbonate hardness. Other methods used to control scaling are alum treatment and sodium ion exchange.

High levels of dissolved solids, ammonia, and heavy metals in reclaimed water can cause serious increased corrosion rates [Puckorius and Hess, 1991]. The concentrations of TDS in municipally treated reclaimed water can increase electrical conductivity and promote corrosion. Ammonia can induce corrosion in copper-based alloys. Dissolved gases and certain metals with high oxidation states also promote corrosion. For example, heavy metals, particularly copper, can plate out on mild steel, causing severe pitting. Corrosion also may occur when acidic conditions develop in the cooling water. Corrosion inhibitors such as chromates, polyphosphates, zinc, and polysilicates can be used to reduce the corrosion potential of the cooling water. These substances may have to be removed from the blowdown prior to discharge. An alternative to chemical addition is ion exchange or reverse osmosis.

Reclaimed water used in cooling systems should not supply nutrients or organic matter that promote the growth of slime-forming organisms. The moist environment in the cooling tower is conducive to biological growth. Microorganisms can significantly reduce the heat transfer efficiency, reduce water flow, and in some cases generate corrosive by-products [California State Water Resources Control Board, 1980].

Sulfide-producing bacteria and sulfate-reducing bacteria are the most common corrosion-causing organisms in cooling systems using reclaimed water. These anaerobic sulfide producers occur beneath deposits and cause pitting corrosion that is most severe on mild and stainless steels. Serious corrosion is caused by thiobaccillus bacteria, an acid-producer that converts sulfides to sulfuric acid. Similarly, nitrifying bacteria can convert ammonia to nitric acid, thus causing pH depression, which increases corrosion on most metals.

Removal of BOD and nutrients during treatment reduces the potential of the reclaimed water to sustain microorganisms. Chlorine is the most common biocide used to control biological growth because of its low cost, availability, and ease of operation. Chlorination is also used as a disinfectant to reduce potential pathogens in the reclaimed water. Frequent chlorination and shock treatment are generally adequate.

Non-oxidizing microbiocides are generally required in addition to chlorine because of the high nutrient content typically found in wastewater. Since most scale inhibitors and dispersants are anionic, either anionic or nonionic biocides are usually used. Low-foaming, nonionic surfactants enhance microbiological control by allowing the microbiocides to penetrate the biological slimes. Chemical coagulation and filtration during the phosphorus removal treatment phase significantly reduce the contaminants that can lead to fouling. Chemical dispersants are also used as required.

In many cases, power plants utilize disinfected secondary effluent for cooling water, although additional treatment often is needed for recirculating cooling systems. Additional treatment may include lime or alum treatment, filtration, ferric chloride precipitation, ion exchange, and reverse osmosis. In some cases, only additional chemical treatment is necessary, which may include many of the chemicals mentioned above and others, such as phosphonates or calcium phosphate for destabilization, polyacrylates for suspended solids dispersion, and anti-foaming agents for dispersion of foam caused by phosphates and some organic compounds.

Boiler Feed Water. The use of reclaimed water for boiler feed water often requires extensive additional treatment and is not a common use of reclaimed water. Quality requirements for boiler-feed makeup water are dependent upon the pressure at which the boiler is operated. Generally, the higher the pressure, the higher the quality of water required.

Reclaimed water must be treated to remove hardness. Calcium and magnesium salts are the principal contributors to scale formation and deposits in boilers. Excessive alkalinity contributes to foaming and results in deposits in heater, reheater, and turbine units. Bicarbonate alkalinity, under the influence of boiler heat, may lead to the release of carbon dioxide, which is a source of corrosion in steam-using equipment. Silica and aluminum form a hard scale on heat-exchanger surfaces, while high concentrations of potassium and sodium can cause excessive foaming in the boiler. Depending on the characteristics of the reclaimed water, lime treatment (including flocculation, sedimentation, and recarbonation) may be required, possibly followed by multi-media filtration, carbon adsorption, and nitrogen removal. High-purity boiler-feed water for high-pressure boilers might also require treatment by reverse osmosis or ion exchange [Meyer, 1991]. The considerable treatment and the relatively small amounts of makeup required make boiler-feed a poor candidate for reclaimed water.

Process Water. The suitability of reclaimed water for use in industrial processes depends on the particular use and is highly variable. For example, the electronics industry requires a very high water quality for washing circuit boards and other electronic components. On the other hand, the tanning industry can use relatively low-quality water. Requirements for textiles, pulp and paper, and metal fabricating are intermediate.

Use of reclaimed water in the paper and pulp industry is a function of the grade of paper produced. The higher the quality of the paper, the more sensitive it is to water quality. Impurities found in water, particularly certain metal ions and color bodies, can cause the paper to change color with age. Biological growth can cause clogging of equipment and odors and can affect the texture and uniformity of the paper. Corrosion and scaling of equipment may result from the presence of silica, aluminum, and hardness. Discoloration of paper may occur due to iron, manganese, or micro-organisms. Suspended solids may decrease the brightness of the paper.

Water used in textile manufacturing must be nonstaining; hence, it should be low in turbidity, color, iron, and manganese. Hardness causes curds to deposit on the textiles and causes problems in some of the processes that use soap. Nitrates and nitrites may cause problems in dyeing.

Recommended Industrial Water Quality

Each industrial use of reclaimed water has unique water quality requirements, and it is not possible to elaborate on the recommended requirements for the myriad of possible industrial applications in Minnesota. However, water quality guidelines are available for some common industrial uses of water, such as cooling water (Table 2.7) and boiler feed water (Table 2.8). Recommended water quality for several other industrial applications are listed in Table 2.9.

Tables 2.7-2.9 demonstrate that the water quality requirements vary considerably with the type of industry and specific processes. Requirements for specific Minnesota industries will be presented in the project final report as part of Task 2 work activities.

Table 2.7. Recommended Cooling Water Quality (Makeup for Recirculating Systems)

Parameter	Recommended Limit (mg/L)
Alkalinity	350
Aluminum	0.1
Ammonia	24
Bicarbonate	200
Calcium	50
Chloride	500
Hardness	650
Iron	0.5
Manganese	0.5
Phosphorous	1.0
Silica	50
Total Suspended Solids	100
Sulfate	200
Total Dissolved Solids	500

Source: Adapted from Water Pollution Control Foundation [1989] and Goldstein *et al.* [1979].

Table 2.8. Recommended Industrial Boiler Feed Water Quality

Parameter	Recommended Limit (mg/L)		
	Low Pressure (<150 psig)	Medium Pressure (150-700 psig)	High Pressure (>700 psig)
Alkalinity	350	100	40
Aluminum	5	0.1	0.01
Ammonia	0.1	0.1	0.1
Bicarbonate	170	120	48
Calcium	*	0.4	0.01
Chemical Oxygen Demand	5	5	1
Copper	0.5	0.05	0.05
Dissolved Oxygen	2.5	0.007	0.007
Hardness	350	1.0	0.07
Iron	1.0	0.3	0.05
Magnesium	*	0.25	0.01
Manganese	0.3	0.1	0.01
Silica	30	10	0.7
Suspended Solids	10	5	0.5
TDS	700	500	200
Zinc	*	0.01	0.01

Source: Adapted from various sources.

Table 2.9. Industrial Process Water Quality Requirements

	Pulp & Paper			Chemical	Petrochem & coal	Textiles		Cement
Parameter*	**Mechanical Pulping**	**Chemical, Unbleached**	**Pulp & Paper Bleached**			**Sizing Suspension**	**Scouring, Bleach & dye**	
Cu	--	--	--	--	0.05	0.01	--	--
Fe	0.3	1.0	0.1	0.1	1.0	0.3	0.1	2.5
Mn	0.1	0.5	0.05	0.1	--	0.05	0.01	0.5
Ca	--	20	20	68	75	--	--	--
Mg	--	12	12	19	30	--	--	--
Cl	1,000	200	200	500	300	--	--	250
HCO_3	--	--	--	128	--	--	--	--
NO_3	--	--	--	5	--	--	--	--
SO_4	--	--	--	100	--	--	--	250
SiO_2	--	50	50	50	--	--	--	35
Hardness	--	100	100	250	350	25	25	--
Alkalinity	--	--	--	125	--	--	--	400
TDS	--	--	--	1,000	1,000	100	100	600
TSS	--	10	10	5	10	5	5	500
Color	30	30	10	20	--	5	5	--
pH	6 – 10	6 – 10	6 – 10	6.2 – 8.3	6 – 9	--	--	6.5 – 8.5
CCE	--	--	--	--	--	--	--	1

*All values in mg/L except color and pH.

Source: Water Pollution Control Federation [1989].

Treatment Requirements and Technologies

The treatment requirements for industrial reuse applications will be based on the quality of the source water used by a community, industries discharging to the wastewater treatment facility, the wastewater treatment processes, and the intended use of the water by the industry. The type of technology selected will depend on whether treatment is incorporated into the wastewater treatment facility's process train, at the industry, or at a satellite facility along the distribution line that could benefit multiple customers. If storage is required for a constant flow, additional treatment may be required. With all these variables, the treatment process and conveyance system selected is certainly a site and case-specific one.

This subsection presents an overview of treatment processes used to provide reclaimed water to industries, as well as other customers. More specific treatment requirements will be identified for the Minnesota candidate industries selected under Task 2 work activities and will be presented in the project final report.

Wastewater Plant Effluent Quality

The constituent concentrations in wastewater plant effluent are different for every facility. However, given common permit limits, some constituent concentrations are universal to most facilities based on the general treatment trains as presented in Table 2.10. In Minnesota, all municipal wastewater treatment facilities have secondary treatment and many have nutrient removal processes, particularly for nitrogen. Many plant upgrades will likely include the requirement for phosphorus removal. There are few facilities in Minnesota that have filtration processes, but this practice may become increasingly common as receiving streams reach their maximum load capacity and additional pollutant removal is necessary.

Table 2.10. Typical Wastewater Treatment Plant Effluent Quality

	Constituent Concentration, mg/L		
Constituent	**Secondary Treatment**	**Secondary Treatment with Nutrient Removal***	**Tertiary Treatment with Filtration**
BOD	5-20	5-10	≤5
TSS	5-20	5-10	≤2
Fecal Coliform	< 200/100 ml	< 200/100 ml	< 2.2/100 ml
pH	6-9	6-9	6-9
Total Phosphorus	4-15	≤1	≤0.4
Ammonia	10-30	≤3	≤1

*Ammonia limit of 3 mg/L and total phosphorus limit of 1 mg/L

The most common water quality problems in cooling water systems are corrosion, scaling and biological growth. These are also potential issues for other industries, particularly as industries are conserving water within their system through internal recycling. These problems occur with contaminants in any water supply, not just reclaimed water. However, some contaminants may occur in higher concentrations in reclaimed water, and will vary highly with the water source, the industrial and domestic wastewater influent characteristics, and wastewater treatment processes. Table 2.11 demonstrates the variability in reclaimed water quality for constituents of concern for many industries.

Treatment Processes

Cooling and Process Water. The overview of industrial water quality concerns in the preceding subsection identified treatment practices for industrial water use for cooling water and boiler feed water. The treatment processes commonly used for industrial cooling water are shown in Figure 2.1. Nitrification is usually used to remove ammonia that causes stress in copper based alloy pipes. Ferric chloride or alum is used to precipitate phosphorus to levels less than 0.6 mg/L, to avoid precipitation and scale formation.

Table 2.11. Florida and California Reclaimed Water Quality – Industrial Constituents of Concern

Water Constituent (mg/L)	Orlando	Tampa	Los Angeles	San Francisco
Conductivity, umho/m	1200-1800	600-1500	2000-2700	800-1200
Calcium Hardness	180-200	100-120	260-450	50-180
Total Alkalinity	150-200	60-100	140-280	30-120
Chlorides	20-40	30-80	250-350	40-200
Phosphate	18-25	10-20	300-400	20-70
Ammonia	10-15	5-15	4-20	2-8
Total Suspended Solids	3-5	3-5	10-45	2-10

Source: U.S. EPA Guidelines for Water Reuse [2004]

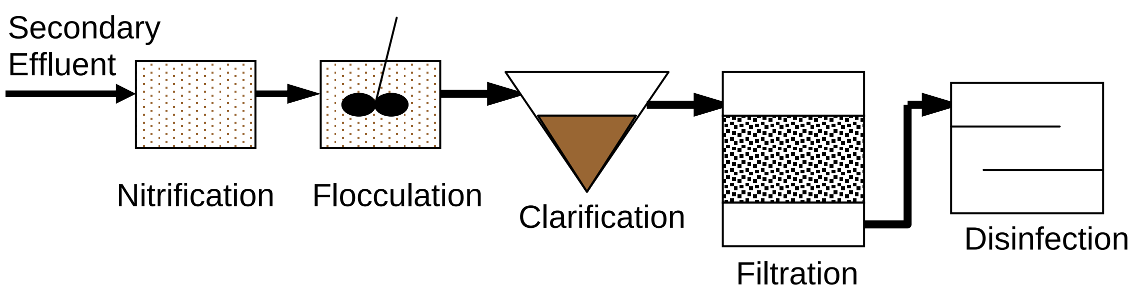

Figure 2.1. Typical Treatment Train of Reclaimed Water for Power Plant Cooling Water

Many Minnesota WWTP process trains include nitrification, clarification and disinfection. Additional processes needed to provide the quality required for cooling water include chemical addition/mixing (flocculation) and filtration.

Disinfection. Disinfection is required for all uses of reclaimed water to meet the pathogen standards and protect public health. While Minnesota's municipal wastewater treatment facilities have disinfection requirements, the level of treatment may not meet the lower pathogen requirements for some industrial uses. Chlorine disinfection is the most commonly used practice in Minnesota. Higher chlorine dosages and contact time may be required for reclaimed water uses. For plants under capacity this may be a minor modification; if the plant is running closer to capacity, then additional basin volume and/or chemical feed equipment may be needed to meet the required contact times.

UV disinfection is used at many wastewater treatment facilities and is becoming more common at Minnesota facilities. Its application is dependent on the wastewater effluent characteristics and site-specific economics. While there are several factors to evaluate to determine if UV is the optimum disinfection practice, better performance is typically achieved with lower suspended solids and smaller particle sizes. Hence, for plants with process trains with filters, UV may be the cost-effective technology to achieve the higher levels of disinfection required for most reuse applications. UV disinfection has been successfully used for reclamation water production to achieve fecal coliforms of less than 20/100 ml [Smith and Brown, 2002], a limit that provides the pathogen protection required for many reuse practices. In addition to meeting pathogen limits prior to leaving a facility, a disinfectant residual is typically maintained in the transmission lines to the reuse customer. Chlorine residuals of 0.5 mg/L or greater in the conveyance system are typically recommended to reduce odors, slime and bacterial growth.

Other Processes. The majority of reuse applications, particularly for industries, will require advanced wastewater treatment processes. The general processes that have been used for water reclamation include:

- Filtration
- UV Treatment of n-nitrosodimethylamine (NDMA)
- Nitrification
- Denitrification
- Phosphorus Removal
- Carbon Adsportion
- Membrane Processes

Filtration, nitrification, denitrification, and phosphorus removal are processes that are commonly used at municipal wastewater treatment facilities. In 20 years, Minnesota regulations will likely be in place that could require these or alternate new processes to meet discharge limits. Carbon adsorption and UV treatment of NDMA are processes used to address specific organic contaminant removal. NDMA is a potent carcinogen produced with use of chlorine or chloramines for disinfection. To address concerns with NDMA and other trace organics in reclaimed water, several utilities in California have installed UV/hydrogen peroxide treatment systems for treatment of reverse osmosis permeate [CDM, 2004].

Carbon adsorption, a process used by potable water supply systems for taste and odor control or removal of organic contaminants, can be used to reduce the biodegradable and refractory organic constituents in wastewater effluent. Carbon adsorption following a secondary treatment and filtration treatment train can produce an effluent with a BOD of 0.1-5 mg/L, a COD of 3-25 mg/L and a TOC of 1-6 mg/L. It can also be used to remove several metal ions, particularly cadmium, hexavalent chromium, silver, and selenium. Activated carbon has also been used to remove uncharged elements such as arsenic and antimony from an acidic stream. Endocrine disrupting compounds have also been successfully removed with activated carbon [Hunter and Long, 2002]. The use of activated carbon for reclaimed water would be a very industry specific requirement. Given that filtration is typically required prior to the carbon adsportion process, and that most municipal plants in Minnesota do not have filters, a different technology, notably membranes, might be selected to meet organic and metal removal goals, as well as serve other process needs.

Figure 2.2. Membrane System Used as a Tertiary Treatment Process.

Membrane processes are moving into the wastewater treatment arena. They have been used for water reclamation in much the same capacity as for potable water supply treatment. Figure 2.2 shows a typical membrane system for tertiary treatment. New technologies are providing the ability to use membranes in the secondary process train. This advancement provides flexibility and/or simplification of the process train to meet wastewater process performance goals and produce the higher quality effluent required for many reuse applications.

The type of membrane used is dependent on the various quality goals. As an extension from potable water industry applications, membranes are typically characterized by the pathogen requirements as shown in Figure 2.3. For industries, other constituents are targeted to select the proper membrane system. The West Basin Municipal Water District of Carson, California, produces several grades of reclaimed water. They use secondary effluent followed by microfiltration and reverse osmosis for low pressure boiler feed at refineries and add lime softening to the process train for water delivered to injection wells for indirect potable reuse. Double pass reverse osmosis is used for water delivered to refineries for high pressure boiler feed water (Miller).

Reliability in Treatment. The treatment technologies selected must also incorporate redundancy or other reliability features. In Minnesota, the MPCA has regulations and guidelines for redundancy in wastewater treatment systems. If reclaimed water is the primary source for the industry, then the reliability features will likely need to meet higher standards. If the industry is able to maintain a backup source, then this can be factored into the facility design. Reliability requirements are another element of a reuse project that will be subject to regulatory review, as well as the user agreements between the industry and municipal supplier of the reclaimed water.

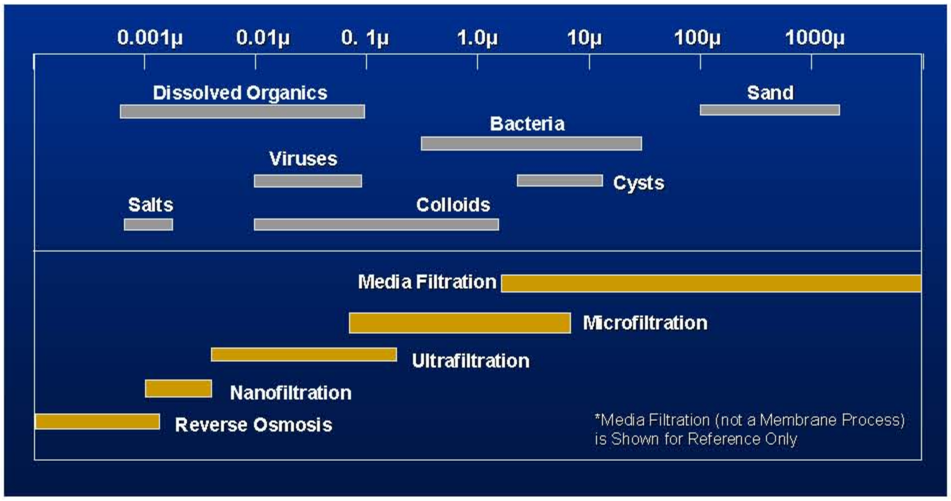

Figure 2.3. Constituent Rejection by Membranes

Industrial Water Costs for Existing Sources of Supply

Industries with specific water quality requirements typically seek a water source that minimizes the costs associated with supplying water for their various uses. The costs for supplying water include any treatment costs of the source water and conveyance costs, including pumping and infrastructure costs. Many industries are able to use a source supply with minimal treatment, while others, as described earlier in this section, have specific water quality requirements and require treatment processes to use the water.

For these industries to seek a treated wastewater effluent source for their water supply, it must be reasonably cost-competitive to what the industry currently uses or traditionally uses for their source supply. To provide a basis of comparison for water reuse costs developed under Task 2 of the project, the costs associated with the existing or traditional source supply were reviewed. This initial perspective provides the treatment costs for broad industry categories based upon the treatment technologies typically associated with the water quality requirements for that industry. This review focuses on industries more prevalent in Minnesota and only defines the treatment costs, specifically the equipment capital costs. O&M costs are highly variable with source water quality characteristics and industry finished water requirements. O&M costs will be reviewed in Task 2 of the project. Similarly, costs associated with pumping and conveyance facilities are not included in this preliminary review of treatment costs.

The water supply treatment costs for several industry categories are negligible. Power generation facilities using once-through cooling processes require large volumes of water, but of lower quality. In most instances in Minnesota, river water is used with little to no treatment. Sand and gravel washing operations also have low water quality requirements and require no additional treatment from the source supply.

Cooling water used for power generation or other industry process needs that uses a recirculating process has more restrictive water quality requirements. Some smaller facilities may use a municipal water supply and no other treatment if the water quality meets the constituent thresholds. Industries using larger volumes of water, will likely use a ground water supply if it is available. If it is not available, a surface water source would be used. Higher levels of treatment are required for a surface water source that is higher in solids, organics, and contains pathogens. Some ground water supplies high in total dissolved solids (TDS) and other constituents may also require additional treatment. If a standard chemical addition, coagulation, flocculation, sedimentation, filtration and disinfection process is used, the capital cost would be approximately $1.5 per gpd of treatment capacity for a facility treating 1 mgd or less based on cost curves escalated to June 2006 costs [James M. Montgomery, Consulting Engineers, 1985].

Microfiltration or ultrafiltration may be a more appropriate technology to provide cooling water for recirculating systems or for boiler feed water, which typically requires a higher quality water, or for other industry processes. The capital costs for micro and ultrafiltration decrease with the volume of water processed: costs on a per mgd basis are much higher for membrane plants less than 1 mgd, decrease rapidly from 1 to 10 mgd and then the cost per mgd is relatively flat after 10 mgd [AWWARF, 2005]. While these costs are based on larger, municipal system supplies, the lower volume costs are applicable. The total membrane system cost for a 1 mgd system is estimated to be $2.1 million for a 0.5 mgd system ($4.20/gpd) and $2.4 million for a 1 mgd system ($2.40/gpd) based on cost curves published in 2005 and escalated to June 2006 costs [AWWARF, 2005].

A majority of industries use municipal water for their industrial processing water supply. The costs of water supplies in the metro area range from $0.75 to $3.50 per 1,000 gallons of water, based on an analysis of municipal system pricing structures in 2002 [Metropolitan Council, 2004]. Ground water supplies typically have a lower pricing structure, between $1.50-$2.00 per 1,000 gallons, and surface supplies were in the $2.50-$3.00 per 1,000 gallon cost range.

Industries requiring additional removal of color or organic compounds, as in the pulp&paper or textile industry, may use granular activated carbon (GAC) treatment technology. The cost for GAC treatment equipment (following a standard treatment process as described for cooling water) ranges from $75,000 for a 0.1 mgd system ($0.75/gpd) to $500,000 for a 1 mgd system ($0.5/gpd), based on cost curves for smaller GAC systems with a 10 minute empty bed contact time [U.S. EPA, 2005]. This does not include GAC replacement costs.

The metal finishing and electronics industries require high quality water. In some instances and for some processing needs potable supplies are adequate. However, often reverse osmosis technology is used to obtain the water quality required for this industry. The costs for reverse osmosis system with a capacity in the 1 mgd range (assuming pretreatment with a microfiltration process) is between $1.80-$2.00 per gpd, based on cost curves scaled to June 2006 [AWWARF, 1996]. A demonstration study using reclaimed water at an electronics facility indicated that the costs to treat reclaimed water were comparable to those treating the municipal supply currently used. This study focused on the operating costs of a microfiltration followed by reverse osmosis process train. The costs to treat the reclaimed water were $3.78/1,000 gallons and for the potable supply were $4.50/1,000 gallons [Gagliardo, P. et al, 2002].

2.4 Institutional Considerations

There are several institutional issues that need to be addressed. Laws, policies, rules, and regulations that affect the planning and implementation of water reuse projects include – for example – water rights, conflicting laws and regulations, permitting, local planning ordinances, environmental assessment and impact, public involvement/education, legal agreements or contracts, agency jurisdictions, fee structures, etc. Task 2 of this project involves working with key state agencies (MPCA, MDH, and MDNR) to identify their specific roles as they relate to water reuse and develop recommendations regarding potential policies and regulations that are in concert with each other.

2.5 Examples of Reuse in Minnesota and Industrial Reuse

Minnesota Reuse Applications

The first uses of reclaimed water in Minnesota were for agricultural irrigation, mainly because the wastewater treatment facilities did not have an acceptable receiving stream. More recent reuse applications involve golf course irrigation in urban and resort areas, and as toilet flush water for an institutional building. In the majority of these cases the driver for reuse was to provide a discharge for the wastewater generated onsite. Table 2.12 provides a list of facilities that are using treated, municipal wastewater effluent in Minnesota. The one industrial application, use of cooling water for the Mankato Energy Center, is discussed below.

Table 2.12. Wastewater Reuse Facilities in Minnesota

Facility	Type of Reuse	Flow, mgd	Treatment Type
Hennepin County Public Works	Toilet Flush Water	0.0056	Activated sludge, activated carbon, membrane filtration (Zenon, Inc.)
Lake Allie	Golf course irrigation	0.0056	Activated sludge, activated carbon, membrane filtration (Zenon, Inc.)
Turtle Run South	Golf course irrigation	0.0168	Recirculating gravel filter
Izaty's Golf and Yacht Club	Golf course and alfalfa field irrigation	0.086	Recirculating gravel filter, sand filter
City of Nisswa	Golf course irrigation and other uses	0.038	Aerated stabilization ponds, dual media filter
City of Montgomery	Golf course irrigation	0.1	Aerated ponds, sand filter
City of Mankato	Industrial (cooling water for power plant)	6.2	Disinfected tertiary recycled water

Sources: Communications with MPCA and City of Mankato [April 2006]

Cooling Water

There are more than 20 steam electric generating plants in the U.S. that use municipal wastewater, primarily as cooling water. A variety of treatment processes are used and are dependent on the water characteristics, treatment facility location (at the WWTP or the power plant) and site specific requirements. Typically the process train consists of oxidation, coagulation, filtration, and disinfection. Some examples illustrate the different treatment processes and variety of power facility applications for reuse.

One of the first industrial reuse applications in Minnesota is the Mankato Energy Center (MEC), with construction completion scheduled by the end of 2006. Wastewater plant effluent from the Mankato WWTP (maximum 6.2 mgd) will be pumped to the MEC and MEC cooling water discharge will be returned to the plant as a permitted industrial user and commingled with treated effluent prior to dechlorination. The MEC uses an evaporative cooling process with an average loss of 75%. The MEC will initially produce 365 megawatts with an ultimate capacity of 630 megawatts.

New facilities constructed at the Mankato WWTP include: high-rate clarification for tertiary phosphorus removal with ferric chloride and polymer (Kruger Actiflo units), cloth media disk filtration, expanded chlorination using sodium hypochlorite, transfer pumping, and ancillary structures and equipment. Tertiary phosphorus removal is required to provide a supply with total phosphorus concentrations less than the permitted limit of 1 mg/L to the MEC. Chemicals containing phosphorus are added at the power plant to reduce scale formation. Because the MEC's discharge is returned to the WWTP with a concentration potentially greater than l mg/L, the plant WWTP effluent must be less than 1 mg/L, so the combined flow (MEC and WWTP discharge) consistently meet the NPDES permit phosphorus limit of 1 mg/L of total phosphorus. The process train was selected to meet the MPCA's limits, following the California Title 22 requirements. The NPDES permit was modified to account for the additional monitoring requirements to show adherence to the Title 22 limits.

Las Vegas, Nevada, and Clark County Sanitation District provide 90 mgd of reclaimed water to supply 35 percent of the water demand in power generating stations operated by the Nevada Power Company. The Nevada Power Company receives secondary effluent and provides lime softening, filtration, and disinfection on site [Water Pollution Control Federation, 1989].

The Palo Verde Nuclear Generating Station (PVNGS) is the largest nuclear power plant in the nation. The plant is located in the desert, approximately 55 miles west of Phoenix, Arizona. The facility uses reclaimed water for cooling purposes and has zero discharge. The source of the cooling water is two secondary wastewater treatment plants, located in Phoenix and Tolleson, Arizona. The PVNGS utilizes about 90 mgd of reclaimed water that receives additional treatment by trickling filters to reduce ammonia, lime/soda ash softening to reduce scale- and corrosion-causing constituents, and filtration to reduce suspended solids. Two 467-acre evaporation ponds dispose of liquid waste from blowdown [Blackson and Moreland, 1998].

Boiler Feed Water

The Wyodak Power Plant near Gillette, Wyoming, uses 0.4 mgd of reclaimed water for boiler make-up, dust suppression, and other small-volume plant uses. Secondary effluent from Gillette is piped approximately 5 miles to a water treatment facility that includes chlorination, softening, activated carbon adsorption, pH adjustment, sand filtration, cartridge filtration, reverse osmosis, dechlorination, recarbonation, and ion exchange demineralization [Breistein and Tucker, 1986].

Three industries in Odessa, Texas, have used approximately 2.5 mgd of municipal wastewater for cooling tower make-up and boiler feed for over 20 years. Secondary effluent is treated by lime softening prior to use by the industries. The reclaimed water is used directly for cooling tower make-up, and water used for boiler feed is treated by two-bed demineralization before use [Water Pollution Control Federation, 1989].

Process Water

Two paper mills use tertiary treated effluent from the Los Angeles County (California) Sanitation Districts' Pomona Water Reclamation Plant as process water. The Garden State Paper Company uses 3 mgd of reclaimed water during newsprint reprocessing, and the Simpson Paper Company uses 1 mgd during the manufacture of high quality paper for stationery and wrappings. Treatment includes biological oxidation, alum coagulation, filtration, and disinfection to achieve a total coliform of ≤2.2 total coliform organisms/100 ml.

The Hampton Roads Sanitation District (HRSD), Virginia has been supplying 0.5 mgd of nitrified secondary effluent from the York River Treatment Plant to Giant Industries' Yorktown since 2002. Reclaimed water is used for the following service water applications: cooling; crude oil desalting; coke cutting; miscellaneous uses such as rinsing and chemical mixing; charge water for the fire protection system when it is not in use (York River water would be used during actual firefighting); and irrigation of trees. The reclaimed water limits include the following: COD <40 mg/L; TSS <10 mg/L; Ammonia (NH_3) <2.0 mg/L; P <2.0 mg/L; turbidity <5 NTU; fecal coliform <200/100 ml; chlorine residual ≥0.5 mg/L; and pH 6.0 – 9.0 [Crook, 2004].

Stack Gas Scrubbing

The Tampa Electric Company (Florida) has been using reclaimed water since 1984 for stack gas scrubbing at its Big Bend Station. Approximately 0.2 mgd of tertiary-treated effluent from the Sun City Wastewater Treatment Plant is stored in two 6-million gallon storage tanks at the treatment plant and rechlorinated prior to being pumped 12 miles to the Big Bend facility for use as scrubber water in the flue gas desulfurization system. A minimum chlorine residual of 0.1 mg/L in conjunction with a turbidity of 5.0 NTU is used as a guideline to provide reasonable assurance that the reclaimed water is adequately disinfected. Wastewater generated from the flue gas desulfurization system enters the in-plant recycle system for further reuse within the plant for floor and equipment washdown and other applications [Rogers, Stone and Sheffield, 1992].

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Section 3
Inventory of Major WWTPs and Potential Industrial Reuse Demands

This section reviews the historical water use in the state for major industrial users in context with municipal wastewater treatment plants' (WWTPs') location and production capacity. A more in-depth review of industries in proximity to reclaimed water suppliers is provided for each individual watershed. General information on the existing water sources in the watersheds and areas that may be prone to water supply problems is also provided. The Minneapolis/St. Paul metro area is examined on a WWTP basis, where industries located within a one- and five-mile radius of each existing metro area WWTP are identified.

A brief summary of the industrial reuse customer inventory sets the framework for the evaluation of the inventory in the next stage of the project. In Task 2, the industries or areas where water reuse could have the most impact will be identified and further analyzed to explore treatment requirements, costs, and implementation issues.

3.1 Statewide Inventory

Industry Water Use

The nine industrial water use categories used by MDNR in their Appropriations Permit database are subdivided in the database into the following:

- Power Generation
  - Hydropower
  - Steam power cooling – once through
  - Steam power cooling – wet tower
  - Steam power cooling – ponds
  - Steam power other than cooling
  - Nuclear power plant
  - Power generation (miscellaneous not fitting other categories)

- Industrial Processing
  - Agricultural processing (food & livestock)
  - Pulp and paper processing
  - Mine processing (not sand & gravel washing)
  - Sand and gravel washing
  - Industrial process cooling once-through
  - Petroleum-chemical processing, ethanol
  - Metal processing
  - Non-metallic processing (rubber, plastic, glass)
  - Industrial processing

The majority of water used in the power industry category in Minnesota is surface water used for once-through cooling at steam power generation plants, as indicated in Figures 3.1 and 3.2. The next largest use is for nuclear plant cooling water, followed by other steam power non-cooling water uses. Almost all of the water used by this category is supplied by surface waters, as indicated in Table 3.1.

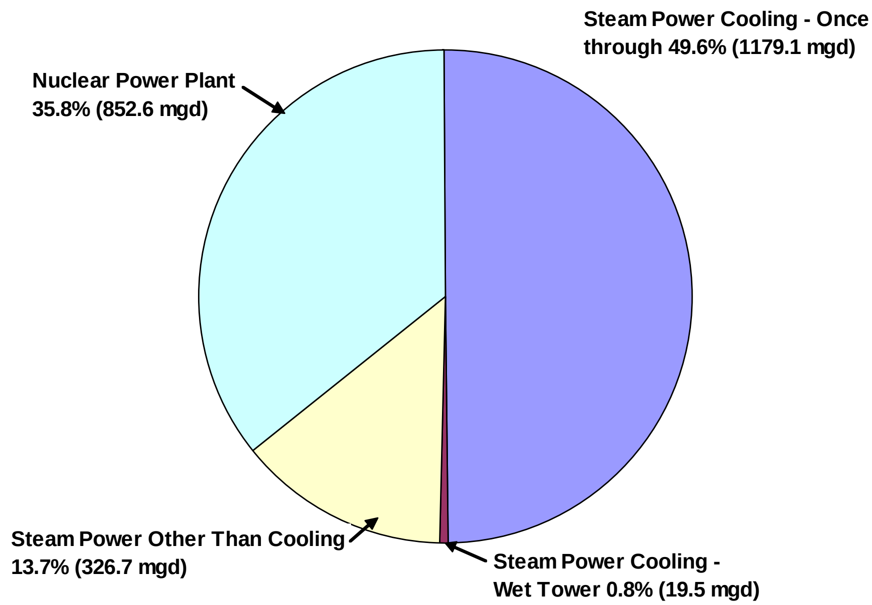


Figure 3.1. Power Generation Facilities Water Use, 2004
Source: MDNR, 2004

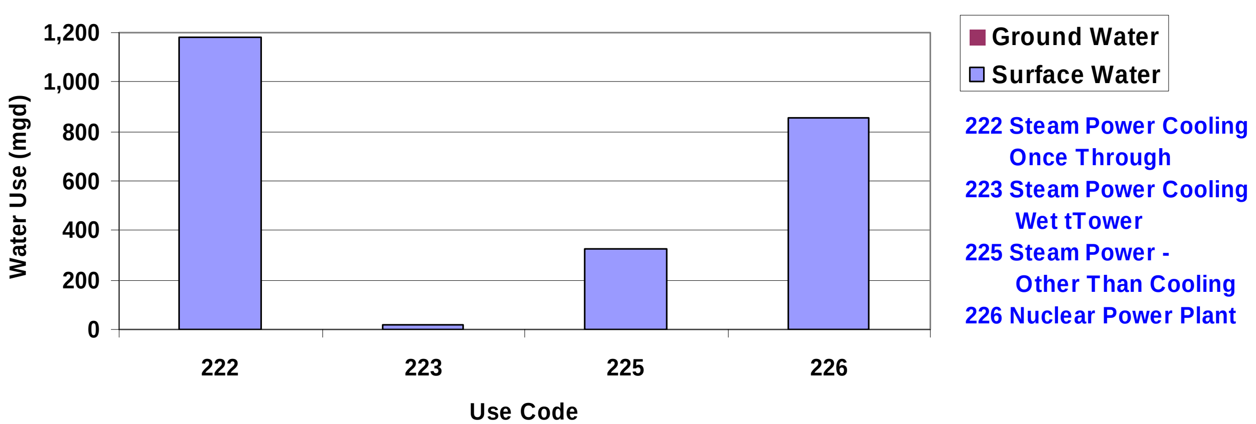


Figure 3.2. Power Generation Facilities Water Use, 2004
Source:MDNR, 2004

Table 3.1. Power Generation Facilities Water Use in Minnesota, 2004

	Water Use, mgd		
Category	**Ground Water**	**Surface Water**	**Total**
Hydropower	0	0.12	0.1
Steam power cooling – once through	0.30	1178.75	1179.1
Steam power cooling – wet tower	0.98	18.47	19.5
Steam power other than cooling	1.36	325.35	326.7
Nuclear power plant	0.14	852.44	852.6
Power generation	0.85	0.01	0.9
Total	3.6	2375.0	2378.7

Source: MDNR, 2004

Mine processing and pulp and paper processing are the largest water users under the industrial processing category, as listed in Table 3.2 and illustrated in Figures 3.3 and 3.4. While these industries predominantly use surface water supplies the next largest water use category is agricultural processing, which relies primarily on higher quality ground water supplies. Appendix A provides the detailed statistics on industrial water use in Minnesota for 2000 – 2004.

Table 3.2. Industrial Processing Water Use in Minnesota, 2004

	Water Use, mgd		
Category	**Ground Water**	**Surface Water**	**Total**
Agricultural processing (food & livestock)	25.2	0.1	25.3
Pulp and paper processing	2.3	80.3	82.6
Mine processing (not sand & gravel washing)	0.5	296.5	297.0
Sand and gravel washing	3.8	7.5	11.3
Industrial process cooling once-through	5.8	0.5	6.3
Petroleum-chemical processing, ethanol	10.9	0.4	11.3
Metal processing	3.9	0.0	3.9
Non-metallic processing (rubber, plastic, glass)	3.0	0.0	3.0
Industrial processing	1.0	0.0	1.0
Total	56.3	385.4	441.7

Source: MDNR, 2004

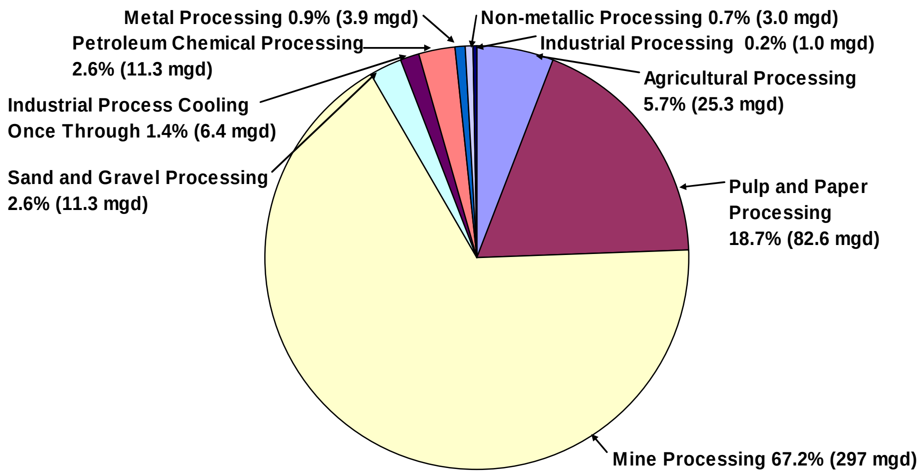


Figure 3.3. Industrial Processing Water Use in 2004

Source: MNDR, 2004

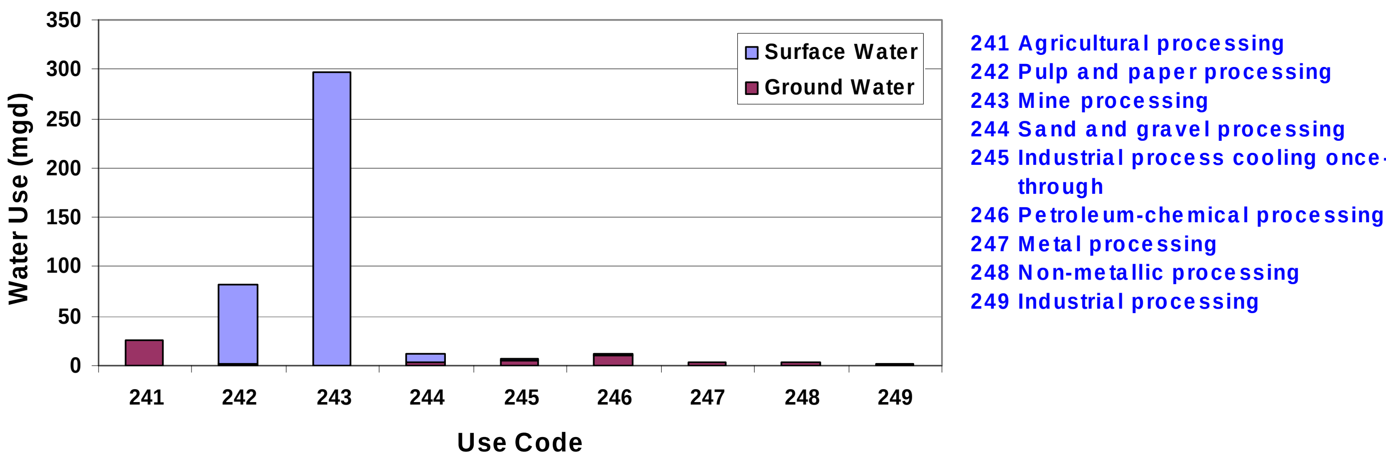


Figure 3.4. Industrial Processing by Use Code in 2004

Source: MNDR, 2004

Wastewater Treatment Plants

The state of Minnesota has nearly 600 municipal WWTPs permitted for discharge to surface waters, as indicated in Figure 3.5. While the majority of permitted WWTPs have capacities of less than 1 mgd, the majority of effluent discharged comes from the 11 WWTPs whose capacities exceed 10 mgd. Thus, the greatest potential for maximizing industrial reuse may lie in the vicinity of these larger plants. In contrast, numerous reuse systems – perhaps numbering in the hundreds – would be required to take full advantage of the treated effluent resource.

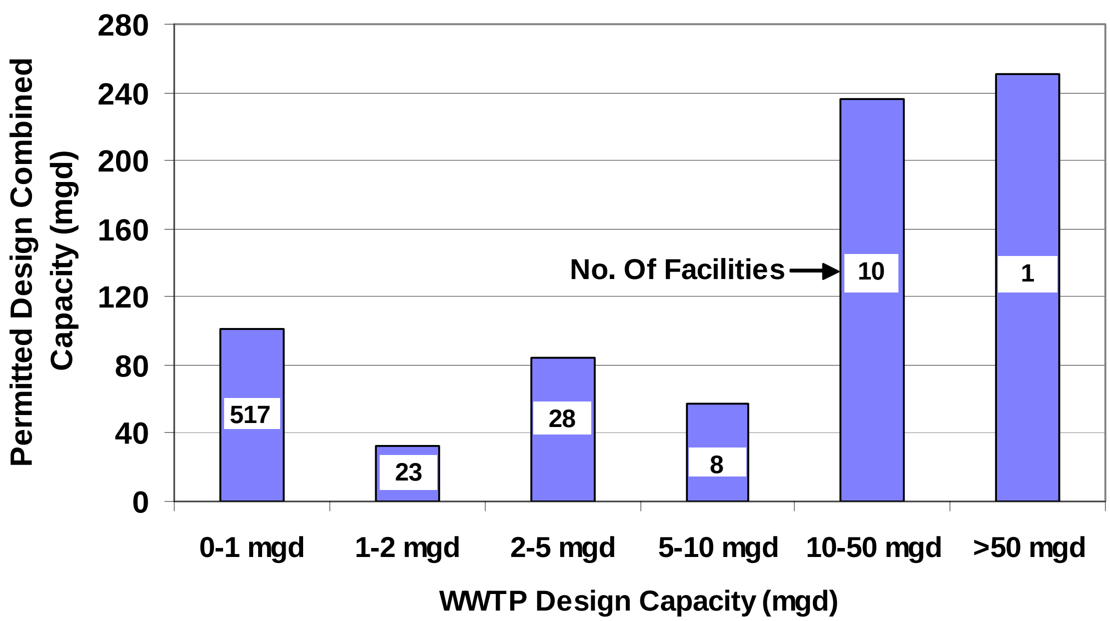


Figure 3.5. Capacity and Number of Municipal WWTPs in Minnesota
Source: MPCA, 2005

Proximity of Industries to WWTPs

While an understanding of the industrial water users throughout the state is helpful in assessing industrial water demands, these industries must be located near a WWTP for reclaimed water to be an economically viable supply.

A statewide map of industries, the relative volume of water they use, and the proximity to larger WWTPs (Figure 3.6) gives a synopsis of potential industrial opportunities. A more detailed review is provided on an individual watershed basis in the following subsections. Figure 3.6 presents all the permitted MDNR industrial water users for the state by category. The power generation industry subcategories were all grouped under the general heading of power generation, as shown by the purple color in Figure 3.6. The relative volume of water used by these industries is depicted by the size of the symbol. Circles represent ground water-using industries and squares are surface water users.

Major WWTPs (over 1 mgd design capacity) are identified by the triangles on Figure 3.6, with relative size shown for each facilty's design capacity. While it may be feasible for smaller plants (with design capabilities less than 1 mgd) to supply industry's reclaimed water, this initial analysis focused on opportunities associated with larger WWTPs. Larger treatment facilities are more likely to have the staff and municipal infrastructure to support treatment upgrades and the administrative role that is required. The next phase of work may consider smaller WWTPs if there appears to be a close correlation between a specific WWTP effluent supply and major industrial water demands in that area.

3.2 Watershed Inventories

Overview

The inventory of industrial water users and municipal wastewater treatment plants is summarized below for each of the ten major watersheds in Minnesota, depicted in Figure 3.7a. As discussed in Section 1, the data presented are only for industries with permits for water withdrawal. These industries are referenced as "major" industrial water users. Industries that use a municipal water supply ("waterworks") for their water source are not represented in this analysis. This inventory is based on existing industries and WWTPs. Task 2 will incorporate forecasts of industrial and population growth to identify future water reuse opportunities.

The industrial reuse customer inventory for each watershed is presented through four main exhibits:

- Map of major industrial water use and major WWTPs (over 1 mgd design capacity)

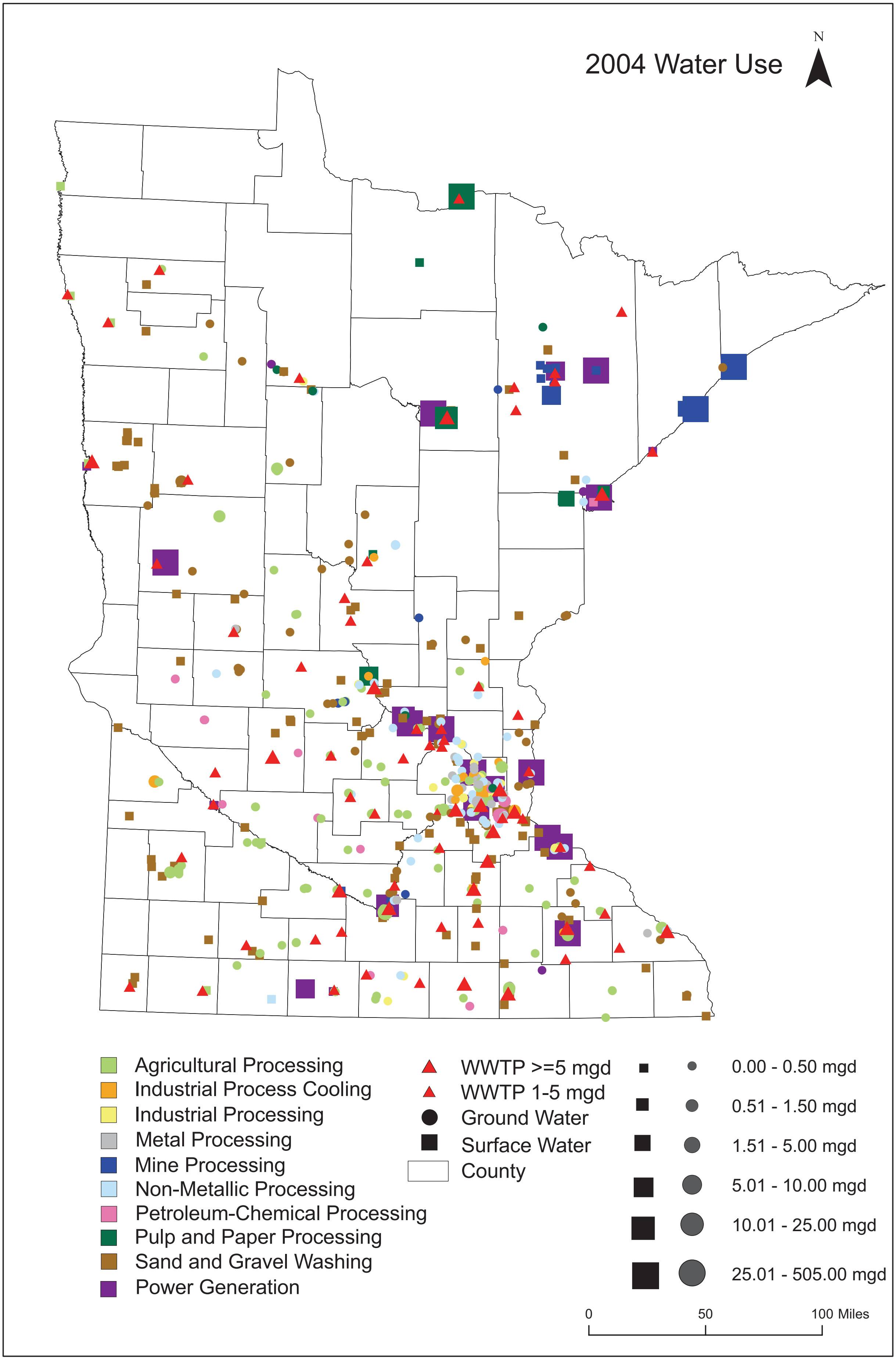
- Statistics on industrial water use (Source: DNR Appropriations Permit Program, 2004)

- List of WWTPs, their design capacity (based on their NPDES Permit average wet weather flow unless otherwise stated) and historic flows (Source: MPCA Dischargers Database [2005] based on Discharge Monitoring Reports submitted by each facility in requirements with their NPDES Permit). Appendix C contains the complete list of WWTPs with design capacities greater than 1 mgd.

- List of industries, their water use, and their proximity to a WWTP
    - Appendix C contains the complete industry lists for all watersheds. In the Minnesota River, Mississippi River – Headwaters and Lower Mississippi River watersheds, the distance between an industry and a WWTP was determined for industries within a 5-mile radius. A 10-mile radius was used for the other watersheds.

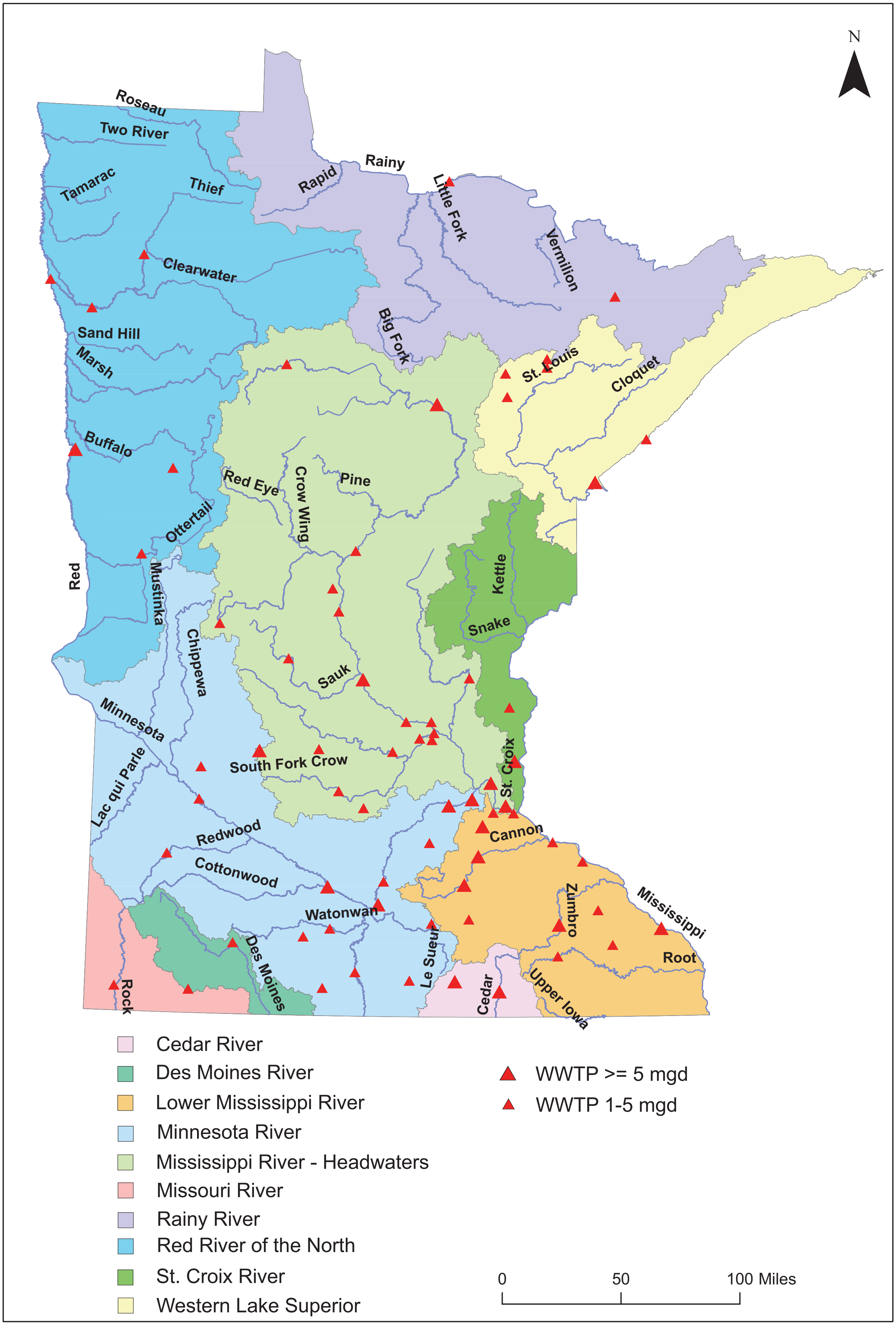
    - Summary industry lists are provided in this section for watersheds with larger numbers of industries. The summaries list the industries that are closest to a WWTP, within a defined radius. The radius varies with each watershed, and is

Figure 3.6. Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Figure 3.7a. Minnesota Watersheds



the radius (to the nearest mile) that captures the top 30-40 industries. Appendix C provides the complete list.

The facility design capacities and flows are included to compare industrial water demand to the reclaimed water supply available in a watershed. It is also useful to compare the historic WWTP flow to the plant's design capacity. Facilities with discharge flows significantly less than the design capacity indicate: (1) the area is planning for growth or (2) there was a change in the area's industries that caused a decrease in flow to the WWTP and/or the movement of residents from the area.

Both of these cases provide an incentive for industries to locate in these areas and benefit from industrial reuse. New growth areas provide the ability to locate and install conveyance and other infrastructure more economically. Plants with excess capacity related to the closing of an industry in the area, provide available treatment capacity for an industry's waste load. The industry might avoid the costs for their own treatment facilities and the permitting associated with an independent discharge to the receiving waters. If water supply problems exist in the area, reuse can also be factored into the planning and provide another positive reason for an industry to locate in this community.

Conversely, a facility with current discharge flows near the design capacity, may be a preferred community for new industry. Assuming the area will experience some growth, communities with facilities treating flows within 80% of design capacity will be planning for a wastewater treatment expansion. The design for the expanded facilities can incorporate the treatment requirements to deliver reclaimed water to existing or new industries – providing economic incentives for an industry looking for a water supply, as well as the municipality.

Distances between WWTPs and industries were approximated. It is assumed that the wells used by the industry are close to the facilities that use the water supply. This may not always be the case. 'Distance' is used as a general criterion to evaluate the feasibility of specific water reuse applications, recognizing that distance will affect transmission costs.

Along with the information on existing industries and WWTPs, a synopsis of basin and regional factors related to industrial growth is provided. Water supply availability is reviewed on a regional level using the MDNR's classification of Minnesota into six ground water areas. The areas are categorized by the general availability of ground water in the bedrock and two overlying sediment layers classified as surficial sands and buried sands, shown in Figure 3.7b. Appendix D contains the classification system and supporting documentation (MDNR, 2005). Additional information on quantity and quality of ground water is summarized from the MPCA's regional ground water profiles (MPCA, 1995). The statewide assessment of susceptibility to ground water contamination (MPCA, 1989), as shown in Figure 3.7c, is also used to identify ground water supply issues. These assessments by MDNR and MPCA provide higher level indicators of ground water quantity and quality concerns that can be applied uniformly across the state.

In addition to water supply quantity and quality factors that would lead an industry to consider use of reclaimed water, relevant watershed issues are summarized. Those watersheds undergoing more extensive planning with impending Total Maximum Daily Loads (TMDLs) are identified. This is of particular importance to municipalities or industries negotiating new NPDES permits. With more stringent discharge criteria, municipalities may look to reuse options, where existing industries or future industries in the area may be likely reuse partners and collectively the watershed can reduce loadings.

Cedar River

Industrial Water Use

Industries in the Cedar River watershed primarily use ground water. As shown in Figures 3.8a and 3.8b and Table 3.8a, only 0.08 mgd of the 4.13 mgd of industrial water used in 2004 was from a surface supply and it was used for sand and gravel washing. The majority of the industrial water use in this watershed is for agricultural processing industries, specifically Hormel Foods Corporation in Austin. Ventura Foods in the Albert Lea area has a permit for water withdrawal, but has not used their permitted source the past few years and previously used less than 100 mgy. Agra Resources Coop used over 0.5 mgd of water in 2004, and the other ground water use was by Austin Utilities for cooling water.

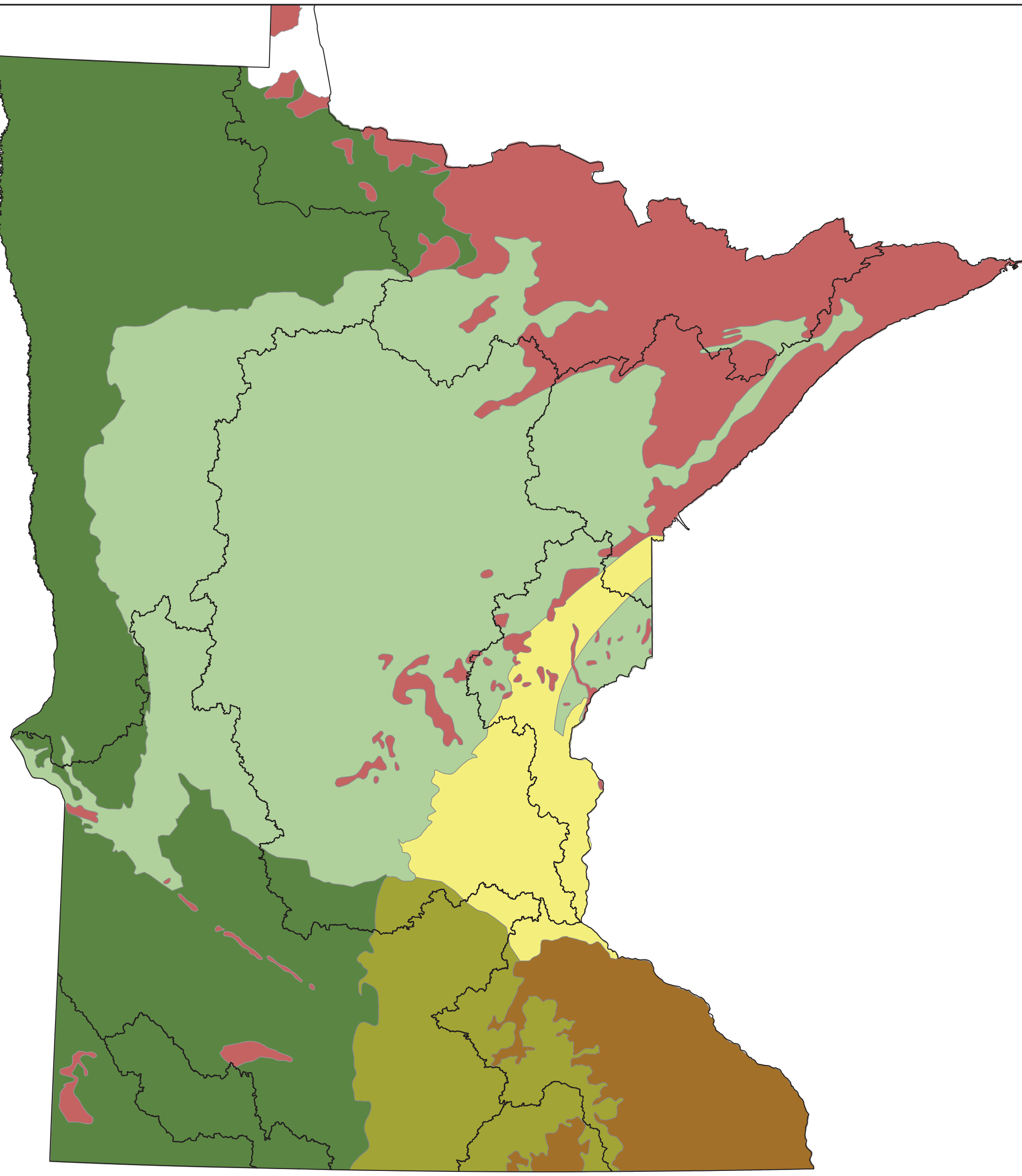
WWTPs

There are two municipal WWTPs in this watershed with design capacities greater than 1 mgd: Austin WWTP and Albert Lea WWTP. Table 3.8b summarizes the design capacity and historic flows for these facilities. These WWTPs discharged nearly 10 mgd in 2005 into the Cedar River watershed. Both of these facilities were designed to handle heavy industrial loads, which have fluctuated over the years with the variable production of the local industries. The design capacities listed in Table 3.8b, as reported in the MPCA database, show plenty of capacity for growth. The listed design capacity may be based on a standard domestic load and not a load with a significant low flow/high organic concentration contribution. Task 2 will examine additional data for these WWTPs and followup to confirm the design capacities. WWTPs in this watershed with design capacities less than 1 mgd have a combined design capacity of 2.6 mgd.

Industries and Proximity to WWTPs

Figure 3.8c presents the location of the industries and WWTPs in the Cedar River watershed. Table 3.8c lists the various industries and their distance from the closer of the two WWTPs. Two of the sand and gravel companies are located more than 5 miles from a WWTP and one is about 1.5 miles from the Austin WWTP; all use surface water. Hormel Foods processing plant and administrative offices are located near the Austin WWTP; their water supply wells are 2 and 3.5 miles from the Austin WWTP.

Figure 3.7b. Ground Water Availability in Minnesota

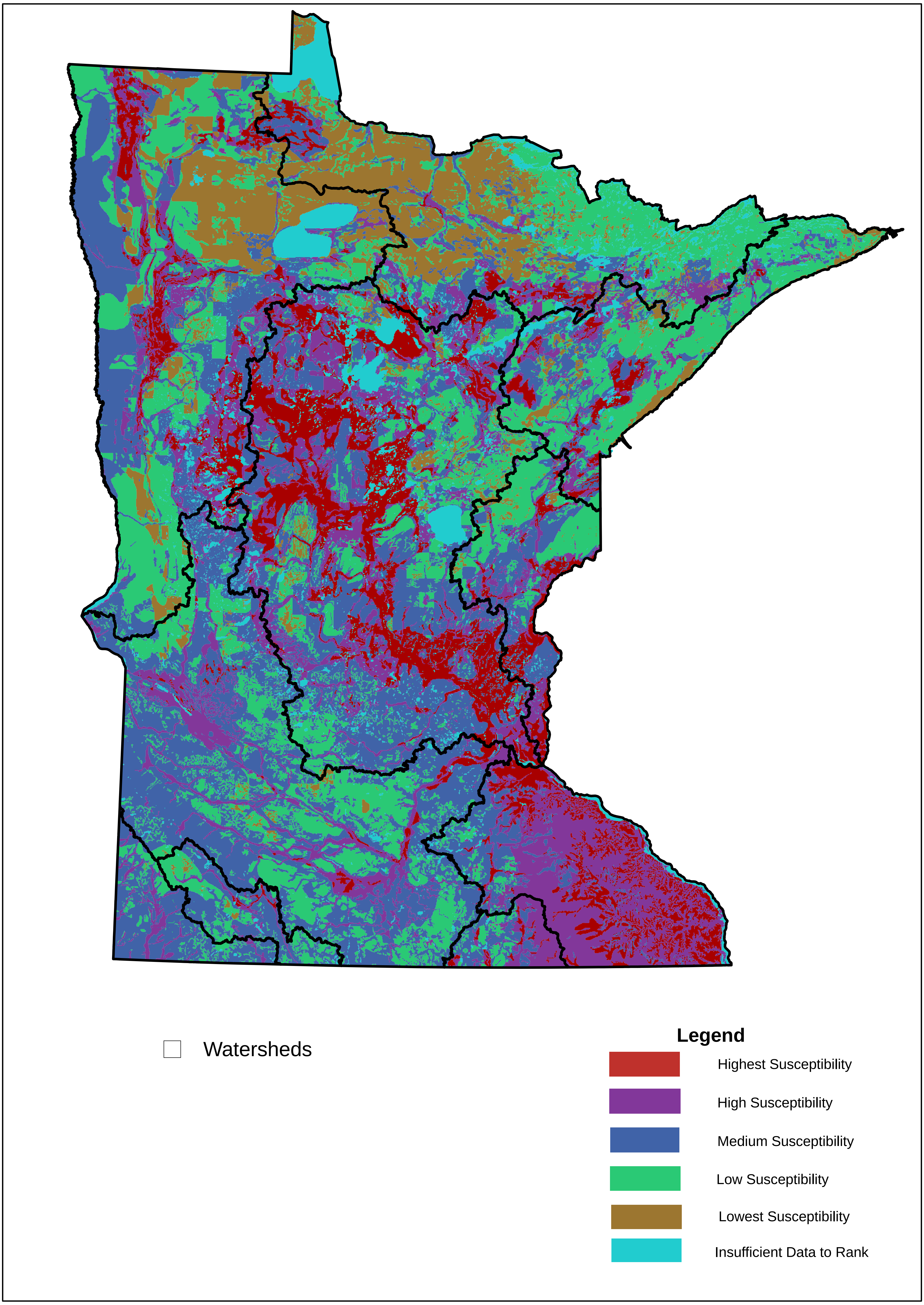


☐ Watersheds

	General Availability of Ground Water by Source		
Area	Surficial Sands	Buried Sands	Bedrock
1	Moderate	Moderate	Good
2	Limited	Moderate	Good
3	Limited	Limited	Good
4	Good	Moderate	Limited
5	Moderate	Limited	Limited
6	Limited	Limited	Limited

Source: Groundwater Provinces Data, Minnesota DNR, 2005

Figure 3.7c. Ground Water Contamination Susceptibility in Minnesota



Source: MPCA, 1989 (with updates in 2005)

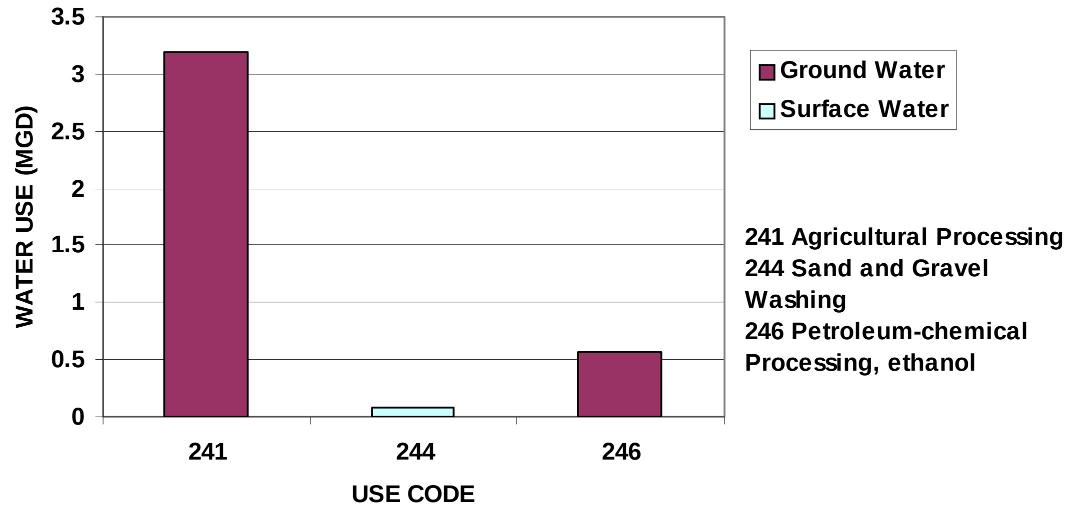


Figure 3.8a. Industrial Processing Water Use in the Cedar River Watershed, 2004

Source: MDNR, 2004

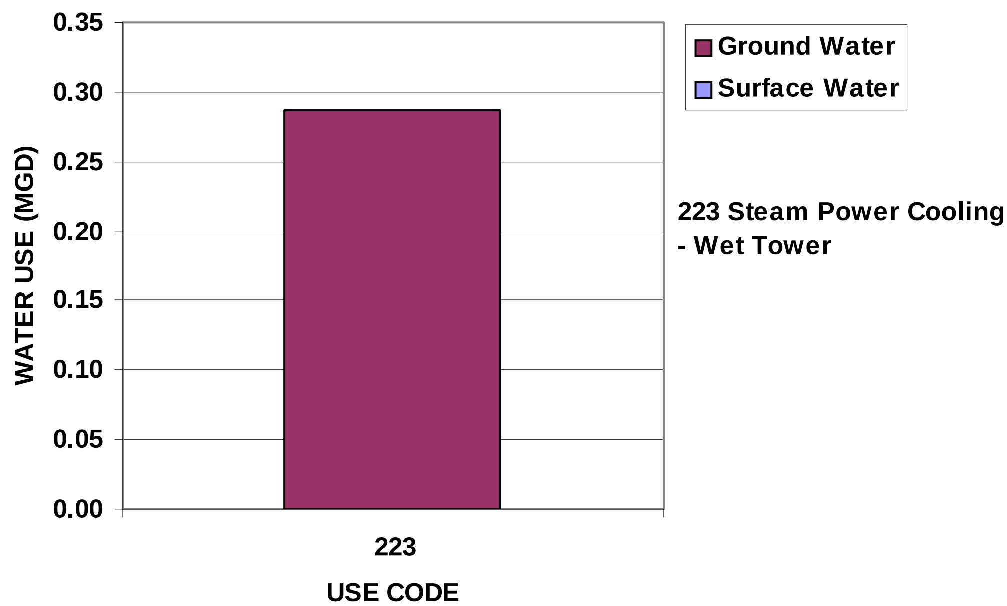


Figure 3.8b. Power Generation Water Use in the Cedar River Watershed, 2004

Source: MDNR, 2004

Table 3.8a. Industrial Water Use in the Cedar River Watershed

Industry Category	2004 Water Use, mgd		
	Ground Water	Surface Water	Total
Agricultural Processing	3.20	0.00	3.20
Petroleum - Chemical Processing, Ethanol	0.56	0.00	0.56
Sand & Gravel Washing	0.00	0.08	0.08
Steam Power Cooling - Wet Tower	0.29	0.00	0.29
Total	4.05	0.08	4.13

Source: MDNR, 2004

Table 3.8b. WWTPs in the Cedar River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Albert Lea WWTP	18.380	4.233	23.0%
Austin WWTP	8.475	5.42	64.0%
Total	26.855	9.653	36.0%

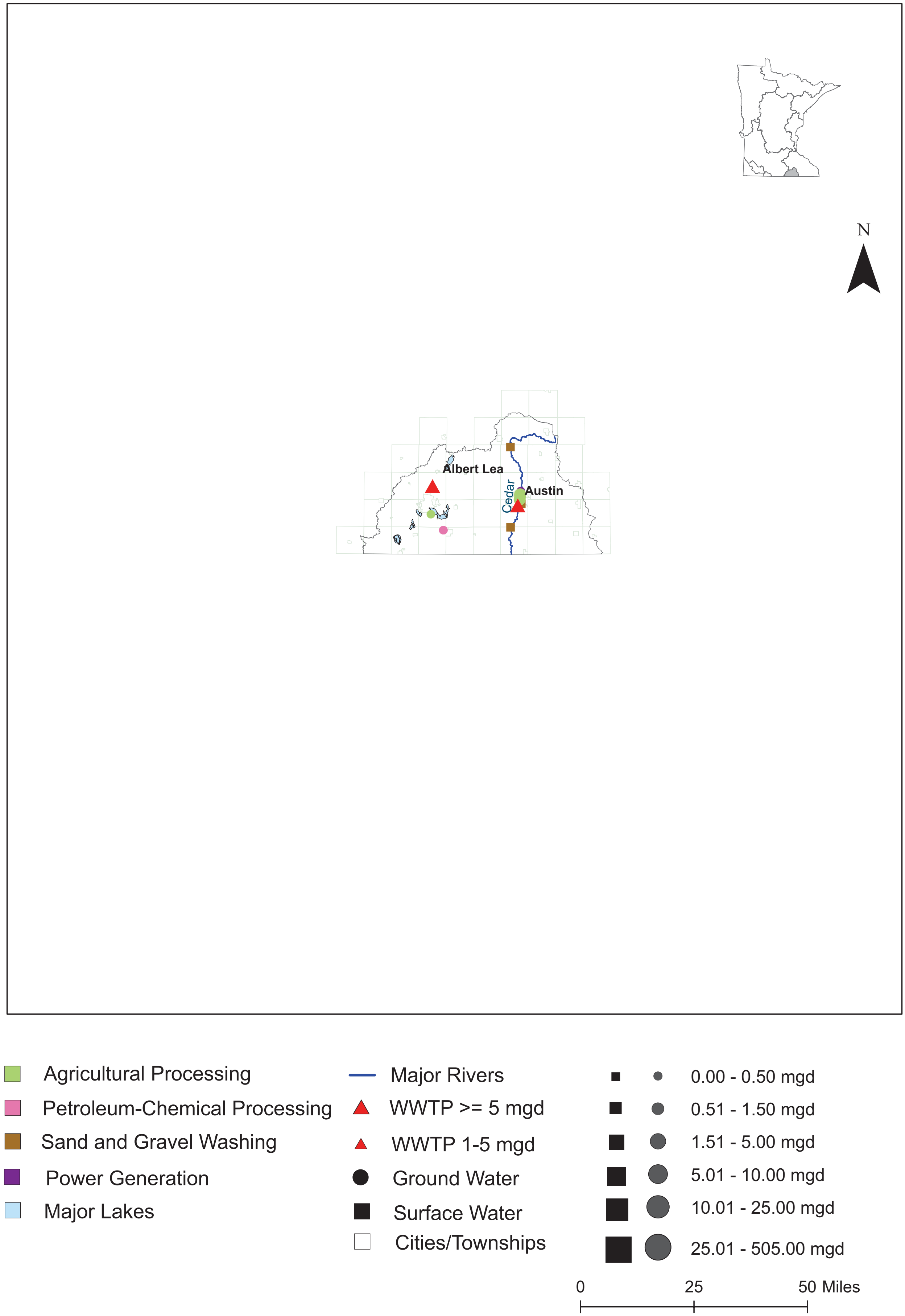
Source: MPCA, 2005

Table 3.8c. Industries in the Cedar River Watershed

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
HORMEL FOODS CORP	G	0.000	2.0	Austin	Agricultural Processing
HORMEL FOODS CORP	G	0.681	2.0	Austin	Agricultural Processing
HORMEL FOODS CORP	G	1.183	3.5	Austin	Agricultural Processing
HORMEL FOODS CORP	G	1.334	3.5	Austin	Agricultural Processing
VENTURA FOODS LLC	G	0.000	5.7	Albert Lea	Agricultural Processing
AGRA RESOURCES COOP	G	0.183	9.7	Albert Lea	Petroleum - Chemical Processing
AGRA RESOURCES COOP	G	0.208	9.7	Albert Lea	Petroleum - Chemical Processing
AGRA RESOURCES COOP	G	0.172	9.7	Albert Lea	Petroleum - Chemical Processing
BISHOP EXCAVATING INC	S	0.000	>10	Austin	Sand and Gravel Washing
ULLAND BROTHERS INC	S	0.060	1.5	Austin	Sand and Gravel Washing
ULLAND BROTHERS, INC	S	0.020	5.0	Austin	Sand and Gravel Washing
AUSTIN UTILITIES	G	0.287	4.0	Austin	STEAM POWER COOLING - WET TOWER

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Figure 3.8c. Cedar River Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

The Agra Resources Coop is within 2 miles of the Albert Lea WWTP. The Austin Utilities power facility location is within 5 miles of the WWTP and could be closer depending on its proximity to the permitted wells.

Factors Influencing Potential for Industrial Reuse

The majority of the Cedar River watershed is in Ground Water Area 2 of the state, which has a good bedrock aquifer supply and limited water bearing surficial sands and moderate availability of water in the buried sand aquifers. The southern edge of the watershed is part of the karst area of Ground Water Area 3, where ground water supplies are strongly linked to surface supplies. Contamination susceptibility varies over the watershed with a higher potential in the eastern sections and areas of lower susceptibility interspersed with areas rated with highest susceptibility in the mid- and western regions of the watershed. Occasional well interferences have been noted, but the public water supplies have had no problems. The agricultural practices of the area have led to nitrate contamination which could affect the Prairie du Chien-Jordan aquifer as well as surficial aquifers. Agricultural drainage wells have polluted deeper ground water.

Des Moines River

Industrial Water Use

There is little permitted water used for industrial purposes in the Des Moines River watershed. Of the 0.66 mgd used in 2004, the majority was for agricultural processing industries, specifically PM Windom, Worthington Rendering, and the City of Heron Lake. Sand and gravel operations collectively withdrew 0.1 mgd from surface waters in 2004. Table 3.9a and Figure 3.9a summarize the industrial water use for the Des Moines River watershed. There were no water withdrawals related to power generator facilities.

In Heron Lake, located southwest of Windom, a 50 million gallon capacity ethanol plant is under construction and scheduled for completion by April 2007. A wastewater treatment plant expansion has also been bid for construction.

WWTPs

There are two municipal WWTPs in this watershed with design capacities greater than 1 mgd: Windom WWTP and Worthington WWTP. Table 3.9b summarizes the design capacity and historic flows for the plants. These WWTPs, with a design capacity total of 5.8 mgd, discharged over 3 mgd in 2005. WWTPs in this watershed with design capacities less than 1 mgd have a combined design capacity of 3.1 mgd. As with Heron Lake discussed previously and below, smaller WWTPs in proximity to an industry may be a potential supplier of reclaimed water. With over 30% of the watershed's wastewater treatment system capacity in facilities less than 1 mgd, and the agricultural industry potential in this area, smaller WWTPs should be evaluated more closely in Task 2.

Table 3.9a. Industrial Water Use in the Des Moines River Watershed

Industry Category	2004 Water Use, mgd		
	Ground Water	Surface Water	Total
Agricultural Processing	0.56	0.00	0.56
Sand & Gravel Washing	0.00	0.10	0.10
Total	0.56	0.10	0.66

Source: MDNR, 2004

Table 3.9b. WWTPs in the Des Moines River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Windom WWTP	1.830	1.074	58.7%
Worthington WWTP	4.000	1.992	49.8%
Total	5.830	3.066	52.6%

Source: MPCA, 2005

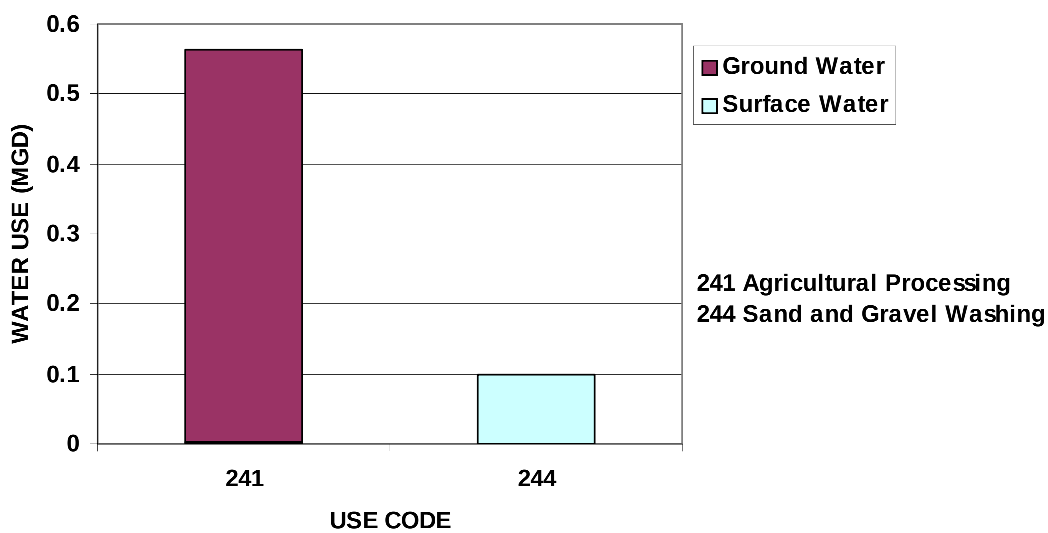


Figure 3.9a Industrial Processing Water Use in the Des Moines River Watershed, 2004

Source: MDNR, 2004

Industries and Proximity to WWTPs

Figure 3.9b presents the location of the industries and WWTPs in the Des Moines River watershed. Table 3.9c lists the various industries and their distance from the closer of the two WWTPs. The agricultural processing industries are all located within 3 miles of a WWTP. The Heron Lake WWTP is not shown because its design capacity of 0.1 mgd is less than 1 mgd. The ethanol plant and wastewater treatment plant modifications for Heron Lake will be investigated further in Task 2. One sand and gravel business is located about 4 miles from the Windom WWTP, while the other businesses are located more than 10 miles from a WWTP.

Table 3.9c. Industries in the Des Moines River Watershed

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
HERON LAKE, CITY OF	G	0.089	9.6	Windom	Agricultural Processing
HERON LAKE, CITY OF	G	0.098	9.6	Windom	Agricultural Processing
PM WINDOM	G	0.200	6.5	Windom	Agricultural Processing
PM WINDOM	G	0.077	6.5	Windom	Agricultural Processing
PM WINDOM	G	0.098	6.5	Windom	Agricultural Processing
WORTHINGTON RENDERING	S	0.003	1.7	Worthington	Agricultural Processing
WILLETT GRAVEL CO	S	0.001	>10	Windom	Non-Metallic Processing
MUECKE SAND & GRAVEL, R A	S	0.100	>10	Windom	Sand and Gravel Washing
WINDOM READY MIX INC	S	0.000	3.3	Windom	Sand and Gravel Washing
WINDOM READY MIX INC	S	0.000	7.1	Windom	Sand and Gravel Washing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Factors Influencing Potential for Industrial Reuse

The Des Moines River watershed is in Ground Water Area 5, represented by limited bedrock and buried sand aquifers and moderate producing surficial sand aquifers. The water quality of the buried sand and gravel and Cretaceous aquifers often yield water of poor natural quality, typically high in sulfate and total dissolved solids. The highest yielding aquifers in this region are mostly narrow, channel outwash deposits which are susceptible to contamination, notably nitrates. Many residents rely on rural water supply systems because domestic wells are contaminated with nitrates. The area around Worthington and the central portion of the watershed is typically less susceptible to contamination than the other areas.

Water quantity of appropriate quality has been an issue for potable water suppliers of this watershed. The cities of Luverne and Worthington, the Lincoln-Pipestone Rural Water System and Rock County Rural Water System are working with communities in South Dakota and Iowa to provide another source of water to the Des Moines and Missouri River watersheds in Minnesota's borders: the Lewis and Clark Rural Water System.

The Lewis and Clark Rural Water System will draw water from a well system near the Missouri River southwest of Vermillion, South Dakota. The water will be diverted, treated and distributed through a network of pipelines, pump stations, interconnections and storage reservoirs to service connections with each of the 15 municipalities and 5 rural water systems of South Dakota, Iowa, and Minnesota that are currently members of the Lewis & Clark Rural Water System. The system is designed for a maximum capacity of 27.2 mgd with an average delivery of 19.6 mgd. This project has been pursued over the past two decades and construction was initiated in Minnesota in 2005.

Lower Mississippi River

Industrial Water Use

The Lower Mississippi River watershed has a diverse base of industries, as summarized in Table 3.10a and Figures 3.10a and 3.10b. The largest water use is related to power generation facilities (nuclear power plant, steam power cooling and miscellaneous power generation uses): averaging 578 mgd in 2004, of which all but 1 mgd was obtained from surface water supplies. The Prairie Island Nuclear Plant used over 500 mgd in 2004 and another 70 mgd was used for once-through cooling at the Xcel facility near Red Wing and the Rochester Public Utilities plant. There are several agricultural processing facilities in this watershed with a combined water use of 2.9 mgd in 2004. Flint Hills Resources withdrew 7 mgd from its set of wells for processing of petrochemical products.

Table 3.10a. Industrial Water Use in the Lower Mississippi River Watershed

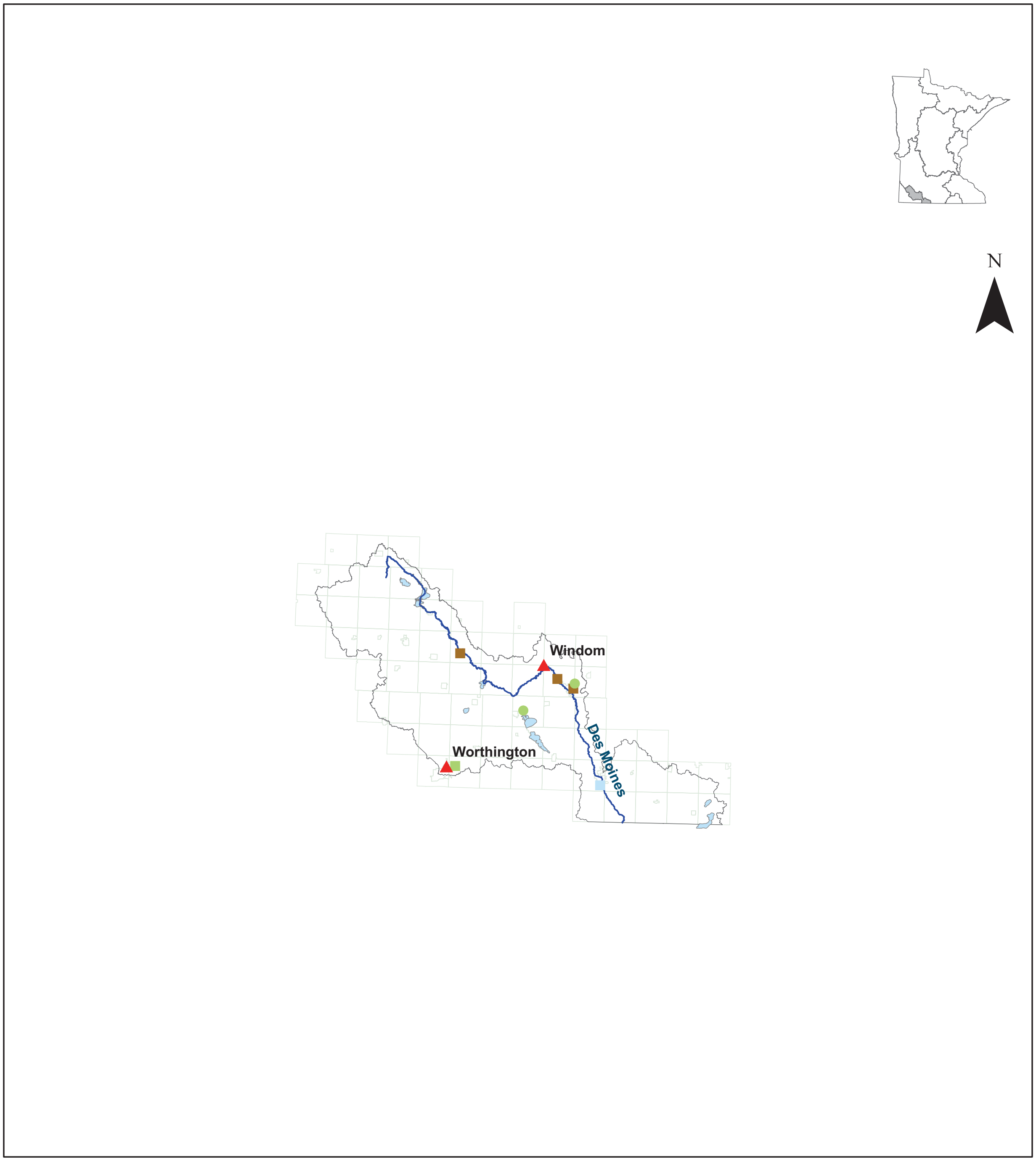
Industry Category	2004 Water Use, mgd		
	Ground Water	Surface Water	Total
Agricultural Processing	2.89	0.00	2.89
Industrial Process Cooling - Once Through	0.38	0.01	0.39
Metal Processing	0.70	0.00	0.70
Non-Metallic Processing	1.02	0.00	1.02
Nuclear Power Plant	0.09	505.84	505.93
Petroleum - Chemical Processing, ethanol	7.00	0.00	7.00
Power Generation	0.55	0.00	0.55
Sand & Gravel Washing	0.27	1.58	1.85
Steam Power Cooling - Once Through	0.00	71.38	71.38
Steam Power Cooling - Wet Tower	0.41	0.00	0.41
Total	13.31	578.81	592.12

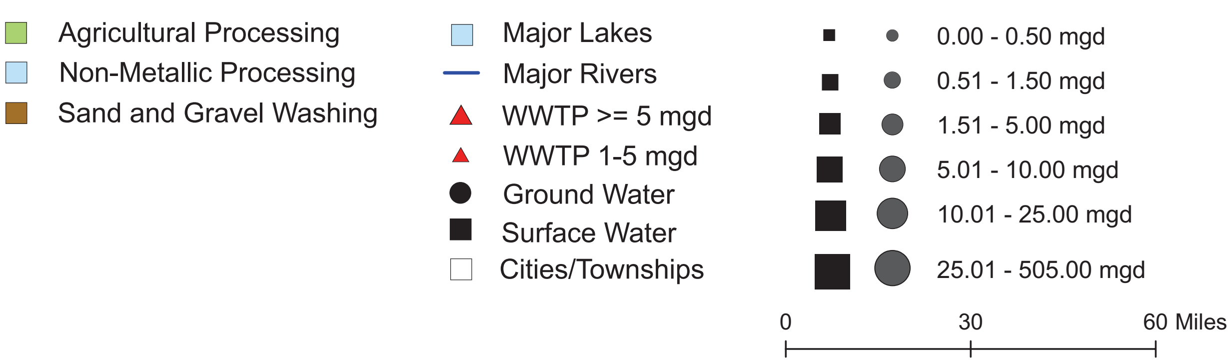
Source: MDNR, 2004

WWTPs

There are 12 municipal WWTPs in this watershed with design capacities greater than 1 mgd. Table 3.10b summarizes the design capacity and historic flows for the plants. There are three facilities within 70% of the design capacity: Owatonna, Plainview-Elgin, and Rochester. Rochester is nearing completion of construction for an expansion to 24

Figure 3.9b. Des Moines River Watershed Industrial Reuse Customer Inventory





Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

mgd. In 2005, approximately 40 mgd of treated wastewater was discharged into the Lower Mississippi River watershed from these 12 facilities. Smaller WWTPs account for 16% of the combined capacity of WWTPs discharging to surface waters in the Lower Mississippi River watershed. This would equate to an annual average flow of 15 mgd if these rural communities grew to use the full capacity of their WWTPs.

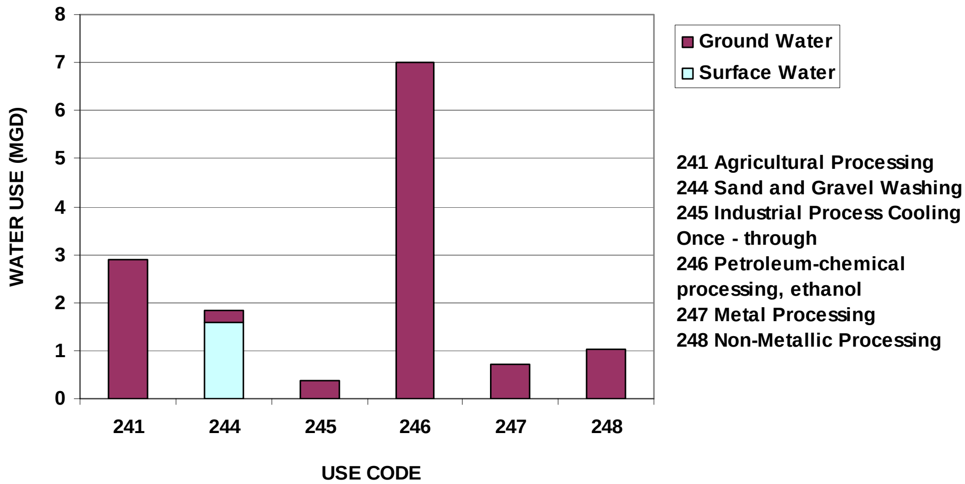


Figure 3.10a. Industrial Processing Water Use in the Lower Mississippi River Watershed, 2004

Source: MDNR, 2004

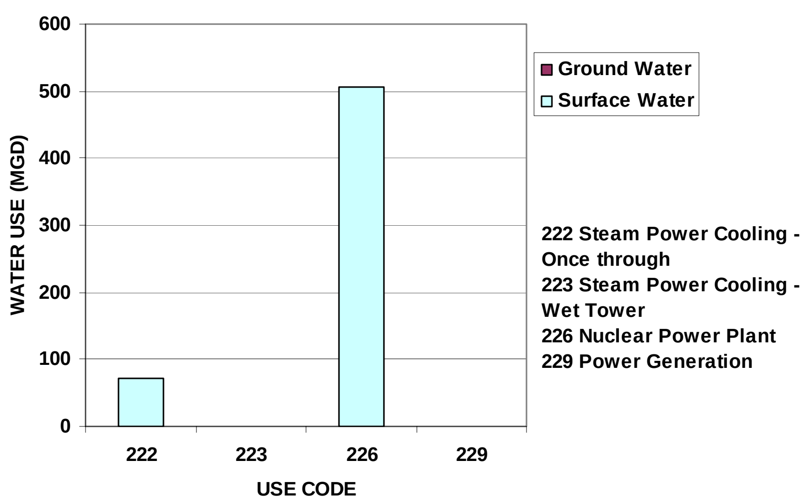


Figure 3.10b. Power Generation Water Use in the Lower Mississippi River Watershed, 2004

Source: MDNR, 2004

Table 3.10b. WWTPs in the Lower Mississippi River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Faribault WWTP	7.0	3.697	52.8%
Lake City WWTP	1.52	0.558	36.7%
Met Council - Empire WWTP*	24	8.458	35.2%
Met Council - Rosemount WWTP*	1.3	0.903	69.5%
Northfield WWTP	5.20	2.067	39.8%
Owatonna WWTP	5.0	3.531	70.6%
Plainview-Elgin Sanitary District WWTP	1.421	1.053	74.1%
Red Wing WWTP	4.0	2.057	51.4%
Rochester Water Reclamation Plant	19.1	13.462	70.5%
Stewartville WWTP	1.111	0.531	47.8%
Whitewater River Regional WWTP	1.12	0.701	62.6%
Winona WWTP	6.5	3.947	60.7%
Total	77.27	40.965	53.0%

* The Rosemount WWTP is located in the Lower Mississippi River Watershed, but discharges into the Mississippi River-Headwaters watershed. In 2007 the Empire WWTP will move its discharge near the Rosemount WWTP discharge and the Rosemount WWTP will be phased out.

Source: MPCA, 2005

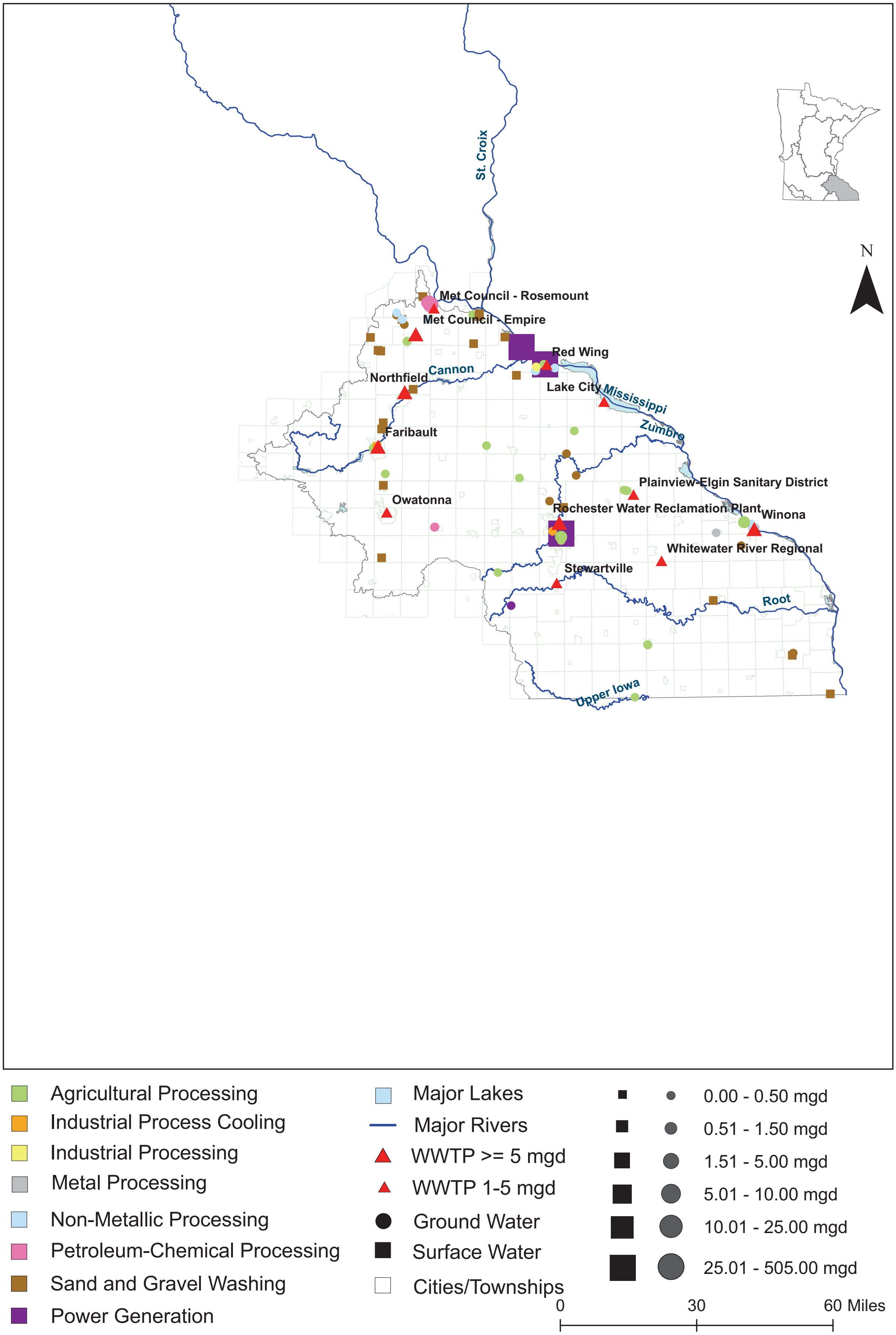
Industries and Proximity to WWTPs

A total of 56 industries are permitted to withdraw ground and/or surface water in the Lower Mississippi River watershed and 25 of these are located within 4 miles of a larger municipal WWTP. Figure 3.10c presents the location of the industries and WWTPs in the Lower Mississippi River watershed. Table 3.10c summarizes the industries within a 4 mile radius of a WWTP. Appendix C provides the full industry list.

Winona has the largest number of industries in close proximity to its WWTP. Water is used for metal processing by Badger Foundry Company and Peerless Chain Company, non-metallic processing by RTP Company, industrial process cooling by Cytec Engineered Materials, and agricultural processing by International Malting Company. Red Wing and Faribault are two other cities with multiple industries within proximity to their WWTP.

There are several agricultural processing facilities within 4 miles of a WWTP. The larger agricultural processing water users are Associated Milk Producers near the Rochester WRP (2.7 mgd), International Malting Co. (1 mgd) in the Winona area, and Marigold Foods (0.3 mgd) near the Met Council's Empire WWTP.

Figure 3.10c. Lower Mississippi River Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Table 3.10c. Industries in the Lower Mississippi River Watershed Within 4 Miles of a WWTP

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ARCHER DANIELS MIDLAND CO	G	0.206	1.0	Red Wing	Agricultural Processing
ASSOCIATED MILK PRODUCERS	G	0.696	2.7	Rochester WRP	Agricultural Processing
HORMEL FOODS CORP	G	0.272	1.0	Fairbault	Agricultural Processing
IFP INC	G	0.012	1.0	Fairbault	Agricultural Processing
INTERNATIONAL MALTING CO LLC	G	0.238	3.3	Winona	Agricultural Processing
INTERNATIONAL MALTING CO LLC	G	0.726	3.3	Winona	Agricultural Processing
LAKESIDE FOODS INC	G	0.075	3.0	Plainview - Elgin	Agricultural Processing
MARIGOLD FOODS INC	G	0.162	2.0	MetC-Empire	Agricultural Processing
MARIGOLD FOODS INC	G	0.157	2.0	MetC-Empire	Agricultural Processing
PLAINVIEW MILK PROD COOP	G	0.191	3.0	Plainview - Elgin	Agricultural Processing
PROTEIN INGREDIENT TECHNOLOGIES INC	G	0.052	2.0	Fairbault	Agricultural Processing
SENECA FOODS CORP	G	0.049	4.0	Rochester WRP	Agricultural Processing
CYTEC ENGINEERED MATERIALS	G	0.077	3.3	Winona	Industrial Process Cooling - Once Through
FARIBAULT WOOLEN MILL COMPANY	S	0.006	1.0	Fairbault	Industrial Process Cooling - Once Through
KERRY BIOFUNCTIONAL INGREDIENTS INC	G	0.298	2.5	Rochester WRP	Industrial Process Cooling - Once Through
BADGER FOUNDRY CO	G	0.052	1.0	Winona	Metal Processing
BADGER FOUNDRY CO	G	0.373	1.0	Winona	Metal Processing
PEERLESS CHAIN COMPANY	G	0.266	1.0	Winona	Metal Processing
8TH AND JEFFERSON LLC	G	0.001	1.0	Winona	Non-Metallic Processing
GENOVA INC	G	0.139	1.0	Fairbault	Non-Metallic Processing
RTP COMPANY	G	0.177	2.5	Winona	Non-Metallic Processing
RTP COMPANY	G	0.259	2.5	Winona	Non-Metallic Processing
S B FOOT TANNING CO	G	0.135	2.6	Red Wing	Non-Metallic Processing
S B FOOT TANNING CO	G	0.172	2.6	Red Wing	Non-Metallic Processing
USG INTERIORS INC	G	0.034	2.3	Red Wing	Non-Metallic Processing
USG INTERIORS INC	G	0.001	2.3	Red Wing	Non-Metallic Processing
FRANKLIN HEATING STATION	G	0.136	4.0	Rochester WRP	POWER GENERATION
FRANKLIN HEATING STATION	G	0.367	4.0	Rochester WRP	POWER GENERATION
BARSNESS CONSTRUCTION & EXCA	S	0.000	2.3	Northfield	Sand and Gravel Washing
CEMSTONE PRODUCTS	G	0.011	3.8	MetC-Empire	Sand and Gravel Washing
NSP CO DBA XCEL ENERGY	S	44.763	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
ROCHESTER PUBLIC UTILITIES	S	26.622	3.0	Rochester WRP	STEAM POWER COOLING - ONCE THROUGH
ROCHESTER PUBLIC UTILITIES	G	0.405	3.0	Rochester WRP	STEAM POWER COOLING - WET TOWER

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Flint Hills Resources is the largest non-power related industrial water user in this watershed. Approximately 7 mgd was pumped from its well field in 2004 for its total facility use. They are in the process of system modifications to reuse their process water rather than add an additional well. Municipal WWTP effluent use at Flint Hills Resources was evaluated during the facility planning stages of the Met Council's Empire WWTP expansion; the outfall for this plant will be moved to discharge into the Upper Mississippi River watershed and will be within 2 miles of Flint Hills Resources. While earlier discussions on reclaimed water from Empire were not pursued because of water quality issues, notably high chlorides in the Empire WWTP effluent, it is possible that potential future Flint Hills Resources expansions could consider this source. Also, the industrial areas along the outfall could benefit from this potential 24 mgd source of reclaimed water. More detailed investigations of this area will be conducted in Task 2.

Factors Influencing Potential for Industrial Reuse

The majority of the Lower Mississippi River watershed has a good bedrock source water supply that most communities rely on as their primary water source. Most of the watershed is in Ground Water Area 3 of the state, with eastern regions in Area 2 and the northern reaches in Area 1. All three areas have a reliable and productive bedrock aquifer.

Area 3 has extensive near-surface karst areas that result in aquifers being vulnerable to contamination. There is wide-spread nitrate contamination in near-surface aquifers as well occurrences of pesticides and other contaminants. The susceptibility to contamination index places this watershed in the medium to highest range. Area 2 on the western edge of the watershed has a more productive buried sand aquifer, but still limited surficial sand aquifers. The northern watershed, in Area 1, has a reliable supply for all three general aquifer levels.

Portions of the Lower Mississippi River watershed will be affected by the TMDL for Lake Pepin. The planning process on this TMDL has established preliminary targets of phosphorus and solids loading reductions of one-half into Lake Pepin. While nonpoint sources are significant contributions to this load, it is likely that most point sources will be considered for loading reductions.

Minnesota River

Industrial Water Use

With the exception of water for once through cooling of Xcel Energy's power plant, industrial water use in the watershed is dominated by the demands of the agricultural processing industry. As shown in Figures 3.11a and 3.11b and Table 3.11a, over 60% of the ground water withdrawals were for agricultural processing facilities. While the watershed houses a diverse set of industries, most of the other industries have fairly small demands.

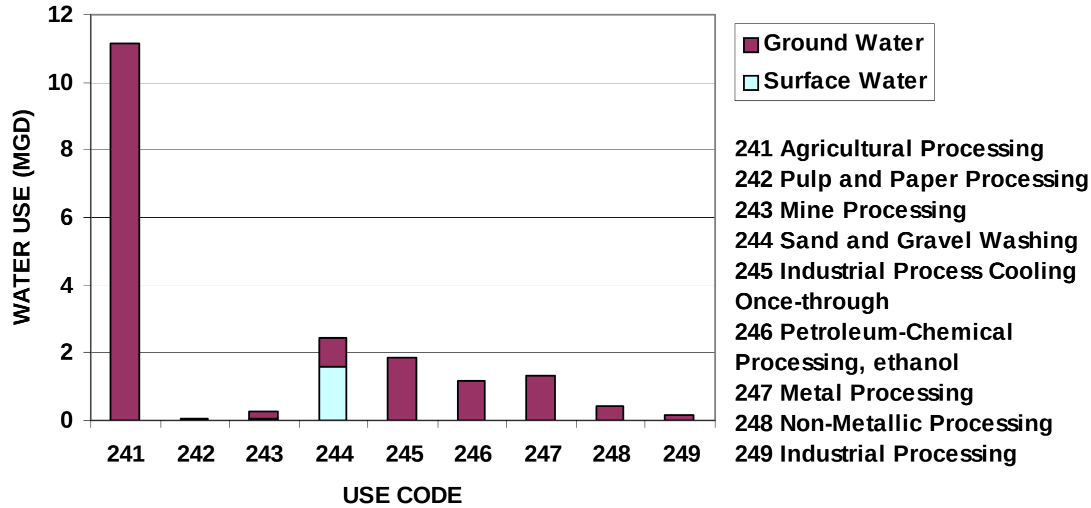


Figure 3.11a. Industrial Processing Water Use in the Minnesota River Watershed, 2004

Source: MDNR, 2004

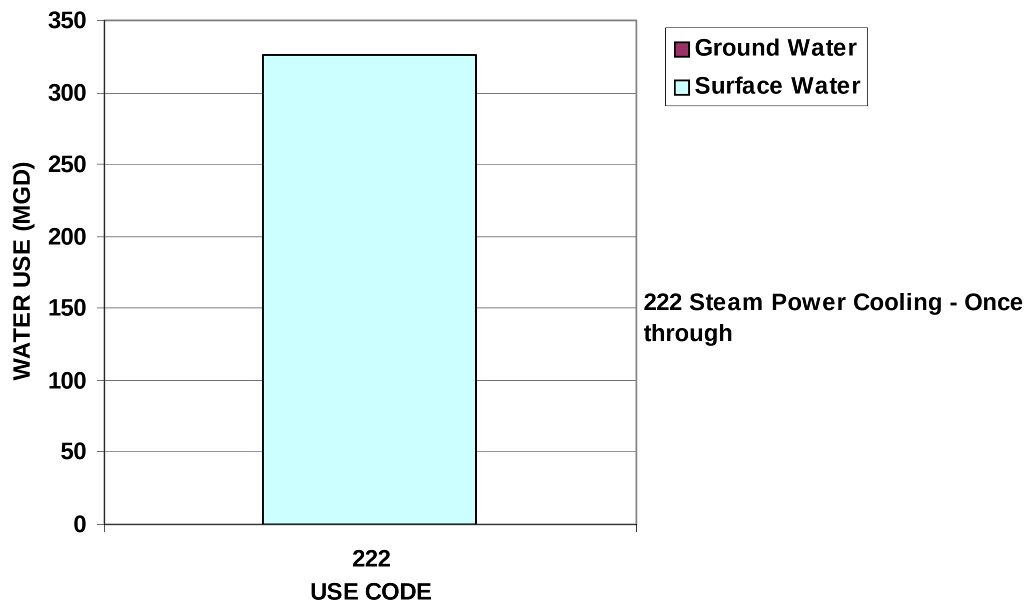


Figure 3.11b. Power Generation Water Use in the Minnesota River Watershed, 2004

Source: MDNR, 2004

Table 3.11a. Industrial Water Use in the Minnesota River Watershed

Industry Category	2004 Water Use, mgd		
	Ground Water	Surface Water	Total
Agricultural Processing	11.14	0.00	11.14
Industrial Process Cooling - Once Through	1.88	0.00	1.88
Industrial Processing	0.17	0.00	0.17
Metal Processing	1.31	0.00	1.31
Mine Processing	0.20	0.04	0.24
Non-Metallic Processing	0.43	0.00	0.43
Petroleum - Chemical Processing, ethanol	1.18	0.00	1.18
Pulp and Paper Processing	0.05	0.00	0.05
Sand and Gravel Washing	0.83	1.62	2.45
Steam Power Cooling - Once Through	0.11	326.00	326.11
Total	17.30	327.66	344.96

Source: MDNR, 2004

WWTPs

There are 15 municipal WWTPs in the Minnesota River watershed with design capacities greater than 1 mgd. As shown in Table 3.11b, there are 3 plants with rated capacities greater than 10 mgd: Met Council's Blue Lake and Seneca WWTPs and the Mankato WWTP. These 15 WWTPs discharged 73 mgd in 2005. The smaller WWTPs in the watershed have a combined design capacity of nearly 23 mgd, representing approximately 15% of the WWTP capacity in the watershed.

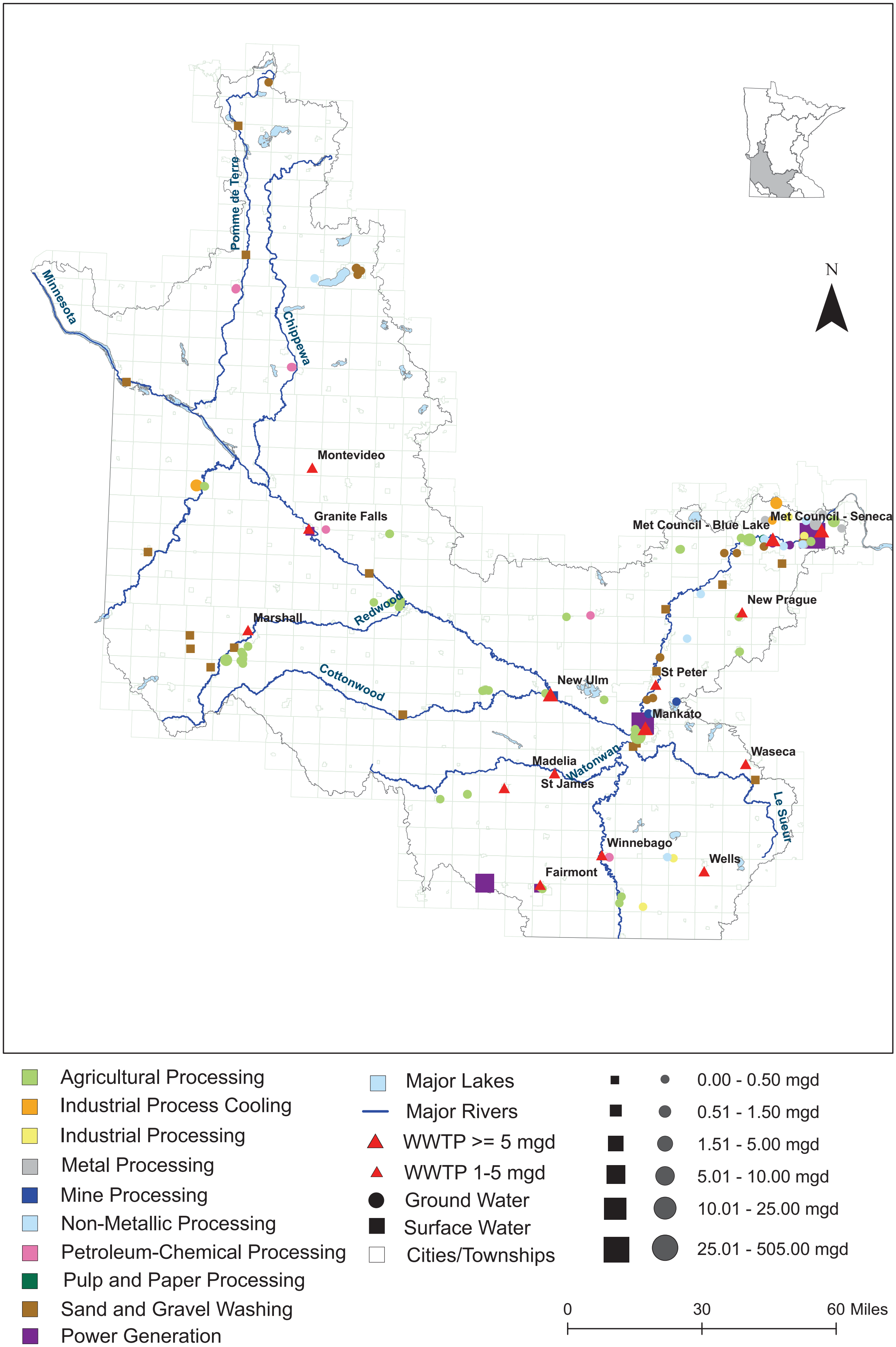
Industries and Proximity to WWTPs

As shown on Figure 3.11c, there are many industries of various categories residing in the Minnesota River watershed. Table 3.11c lists the various industries that are within five miles of a WWTP. Mankato has the largest number of industries in proximity of its WWTP. There are a variety of industry types utilizing ground water supplies that could be candidate industries for Mankato, in addition to the near completed construction of their project with Calpine Corporation (for 6 mgd of reclaimed water). There are several sand and gravel washing operations in St. Peter, but they are four to five miles away.

Factors Influencing Potential for Industrial Reuse

The Minnesota River watershed has a diverse geology that provides for three different ground water areas. Ground Water Area 5 covers the central to western reaches of the watershed. It is characterized with limited bedrock aquifers, moderate surficial sand aquifers and limited buried sand aquifers. In the north parts of the watershed, the surficial and buried sand aquifers are more productive. The eastern portions are characterized by Ground Water Area 2, which has good bedrock aquifers, moderate buried sand aquifers, and limited surfical aquifers. Well interference has occurred in some areas. The ground water contamination susceptibility of this

Figure 3.11c. Minnesota River Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

watershed varies from low to high. Surficial sand aquifers have shown nitrate contamination.

The Minnesota River watershed dischargers will be affected by the TMDL for the Minnesota River and the downstream Lake Pepin TMDL. The agricultural practices and natural characteristics of this watershed have contributed to making it a significant contributor to phosphorus and solids loadings at Lake Pepin. This watershed will be an integral part of the TMDL process and receiving stream discharge limits could push some municipalities to consider wastewater reuse.

Table 3.11b. WWTPs in the Minnesota River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Fairmont WWTP	3.9	1.595	41%
Granite Falls WWTP	1.111	0.477	43%
Madelia WWTP	1.31	0.907	69%
Mankato WWTP	11.25	6.861	61%
Marshall WWTP	4.5	2.5180	56%
Met Council - Blue Lake WWTP	37	28.420	77%
Met Council - Seneca WWTP	38	23.353	60%
Montevideo WWTP	3.0	1.083	36%
New Prague WWTP	1.378	0.662	48%
New Ulm WWTP	6.77	2.582	38%
St James WWTP	2.960	1.032	35%
St Peter WWTP	4.0	1.170	29%
Waseca WWTP	3.5	1.580	45%
Wells Easton Minnesota Lake WWTP	1.088	0.516	47%
Winnebago WWTP	1.7	0.592	35%
Total	122.47	73.348	60%

Source: MPCA, 2005

Note: Willmar WWTP discharges into the Minnesota River, but the facility resides in the Mississippi River-Headwaters. It is included with Mississippi River-Headwaters watershed summary.

Mississippi River-Headwaters (Upper)

Industrial Water Use

The Mississippi River-Headwaters or Upper Mississippi River watershed has the most diverse set of potential reuse industries, as shown in Table 3.12a and Figures 3.12a and 3.12b. Cooling water, mainly for once-through systems for steam power and nuclear power facilities, is the dominant use of water by industries, totaling about 800 mgd. The largest water users, outside of the power generation industry, are for pulp and paper processing at Blandin Paper Company, Grand Rapids and International Paper Company, St. Cloud. However, since both use Mississippi River water and the municipality's use river water as their source, there is no added benefit to the ground water supply systems in those communities if they were reclaimed water customers. Agricultural processing industries were the largest user of ground water, using 6.5 mgd in 2004. Metal processing, petroleum/chemical processing, and smaller pulp & paper facilities withdrew around 2 mgd each from the local aquifers in 2004.

Table 3.11c. Industries in the Minnesota River Watershed Within 4 Miles of a WWTP

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
FAIRMONT FOODS OF MINNESOTA	G	0.032	1.4	Fairmont	Agricultural Processing
FAIRMONT, CITY OF	S	0.409	1	Fairmont	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	S	0.008	1	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
CENEX HARVEST STATES COOPERATIVES	G	3.578	2	Mankato	Agricultural Processing
WIS-PAK OF MANKATO INC	G	0.371	2.5	Mankato	Agricultural Processing
VETTER STONE CO	G	0.200	3.9	Mankato	Mine Processing
MINNESOTA QUARRIES INC	G	0.117	1	Mankato	Sand and Gravel Washing
NSP CO DBA XCEL ENERGY	G	0.000	1	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	S	21.581	1	Mankato	STEAM POWER COOLING - ONCE THROUGH
ANCHOR GLASS CONTAINER CORP	G	0.067	2.0	METC- Blue Lake	Non-Metallic Processing
GREENMAN TECHNOLOGIES OF MN	G	0.002	2.7	METC- Blue Lake	Non-Metallic Processing
INLAND PAPERBOARD & PACKAGING INC	G	0.050	2.0	METC- Blue Lake	Pulp and Paper Processing
NSP CO DBA XCEL ENERGY	G	0.000	1.0	METC- Blue Lake	STEAM POWER COOLING - WET TOWER
SHAKOPEE GRAVEL INC	G	0.001	2.5	METC- Blue Lake	Sand and Gravel Washing
COCA-COLA BOTTLING MW	G	0.706	3.7	METC- Seneca	Agricultural Processing
CYPRESS SEMICONDUCTOR	G	0.853	2.5	METC- Seneca	Metal Processing
NSP CO DBA XCEL ENERGY	S	295.460	2.5	METC- Seneca	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	G	0.112	2.5	METC- Seneca	STEAM POWER COOLING - ONCE THROUGH
PEPSI COLA BOTTLING CO	G	0.321	2.9	METC- Seneca	Agricultural Processing
POLARFAB LLC	G	0.265	2.4	METC- Seneca	Non-Metallic Processing
SURMODICS INC	G	0.003	4.0	METC- Seneca	Industrial Processing
ANCHOR GLASS CONTAINER CORP	G	0.067	2.0	METC- Blue Lake	Non-Metallic Processing
GREENMAN TECHNOLOGIES OF MN	G	0.002	2.7	METC- Blue Lake	Non-Metallic Processing
INLAND PAPERBOARD & PACKAGING INC	G	0.050	2.0	METC- Blue Lake	Pulp and Paper Processing
ASSOCIATED MILK PRODUCERS	G	0.000	1	New Prague	Agricultural Processing
AUGUST SCHELL BREWERY	G	0.000	1.5	New Ulm	Agricultural Processing
NEW ULM QUARTZITE QUARRY	S	0.042	1.3	New Ulm	Mine Processing
SOUTHERN MINNESOTA CONSTRUCTION CO	G	0.150	4	St Peter	Sand and Gravel Washing
UNIMIN MINNESOTA CORP	S	0.000	2.5	St Peter	Sand and Gravel Washing
CORN PLUS	G	0.136	1	Winnebago	Petroleum - Chemical Processing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Table 3.12a. Industrial Water Use in the Mississippi River Headwaters Watershed

	2004 Water Use, mgd		
Industry Category	**Ground Water**	**Surface Water**	**Total**
Agricultural Processing	6.49	0.00	6.49
Hydropower	0.00	0.12	0.12
Industrial Process Cooling - Once Through	3.58	0.51	4.09
Industrial Processing	0.87	0.00	0.87
Metal Processing	1.88	0.00	1.88
Mine Processing	0.24	0.00	0.24
Non-Metallic Processing	0.95	0.00	0.95
Nuclear Power Plant	0.05	346.60	346.65
Petroleum - Chemical Processing, ethanol	2.13	0.00	2.13
Power Generation	0.31	0.01	0.32
Pulp and Paper Processing	2.17	26.84	29.01
Sand and Gravel Washing	1.13	2.56	3.69
Steam Power Cooling - Once Through	0.19	544.49	544.68
Steam Power Cooling - Wet Tower	0.18	18.47	18.65
Steam Power Other than Cooling	1.36	0.00	1.36
Total	21.53	939.60	961.13

Source: MDNR, 2004

WWTPs

As the most populated watershed, the Mississippi River-Headwaters watershed has the largest number of the WWTPs greater than 1 mgd and processes the most wastewater. In 2005, the WWTPs in this watershed discharged collectively 230 mgd from the 22 facilities in its borders. Table 3.12b lists the watersheds, their design capacity, and 2005 discharge volume. The Met Council's Metropolitan WWTP, located in downtown St. Paul, provides treatment for the majority of the central and northern part of the metro area. It processed approximately 190 mgd of wastewater in 2005. Discussion of this and other Met Council facilities is reserved for Section 3.4.

The next largest municipal discharger on the upper Mississippi River is the St. Cloud WWTP, which discharged 10 mgd in 2005, followed by several plants discharging 2 to 4 mgd. Several of these facilities are nearing capacity, indicated by flows exceeding 70% of the design capacity. These include Alexandria, Brainerd, Litchfield, Melrose, Met Council-Metro WWTP, St. Cloud and Willmar. Many of these municipalities are in the planning, design, or construction phase of an expansion. Task 2 will evaluate this in more detail.

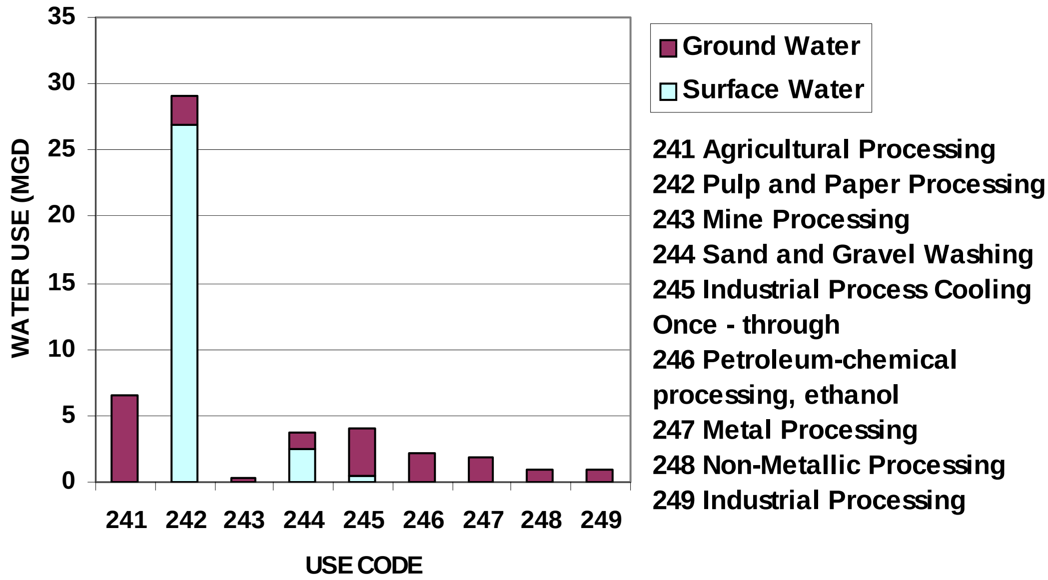


Figure 3.12a. Industrial Processing Water Use in the Mississippi River Headwaters Watershed, 2004

Source: MDNR, 2004

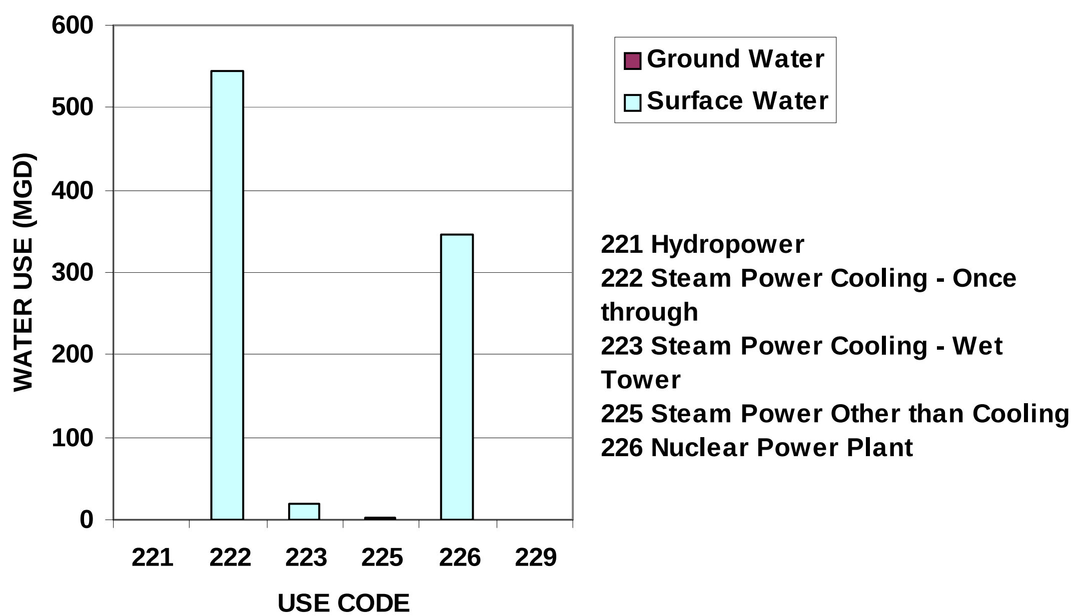


Figure 3.12b. Power Generation Water Use in the Mississippi River Headwaters Watershed, 2004

Source: MDNR, 2004

Table 3.12b. WWTPs in the Mississippi River Headwaters Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Alexandria Lake Area Sanitary District	3.750	2.906	77.5%
Bemidji WWTP	2.500	1.056	42.2%
Brainerd WWTP	3.130	2.438	77.9%
Buffalo WWTP	3.600	1.628	45.2%
Cambridge WWTP	1.920	0.847	44.1%
Camp Ripley WWTP	1.440	0.115	8.0%
Elk River WWTP	2.200	1.186	53.9%
Glencoe WWTP	2.600	0.69	26.5%
Grand Rapids WWTP	15.200	7.33	48.2%
Hutchinson WWTP	4.270	2.574	60.3%
Litchfield WWTP	1.900	1.513	79.6%
Little Falls WWTP	2.4	1.182	49.3%
Melrose WWTP	2.5	2.001	80.0%
Met Council - Eagles Point WWTP	10.0	2.34	23.0%
Met Council - Hastings WWTP	2.9	1.592	54.9%
Met Council - Metropolitan WWTP	251	187.018	74.5%
Monticello WWTP	2.360	1.189	50.4%
Otsego WWTP East	1.650	0.206	12.5%
Rogers WWTP	1.602	0.769	48.0%
St Cloud WWTP	13.000	10.358	79.7%
St Michael WWTP	2.445	0.834	34.1%
Willmar WWTP	5.040	3.81	75.6%
Total	337.4	233.6	69.2%

Source: MPCA, 2005

Industries and Proximity to WWTPs

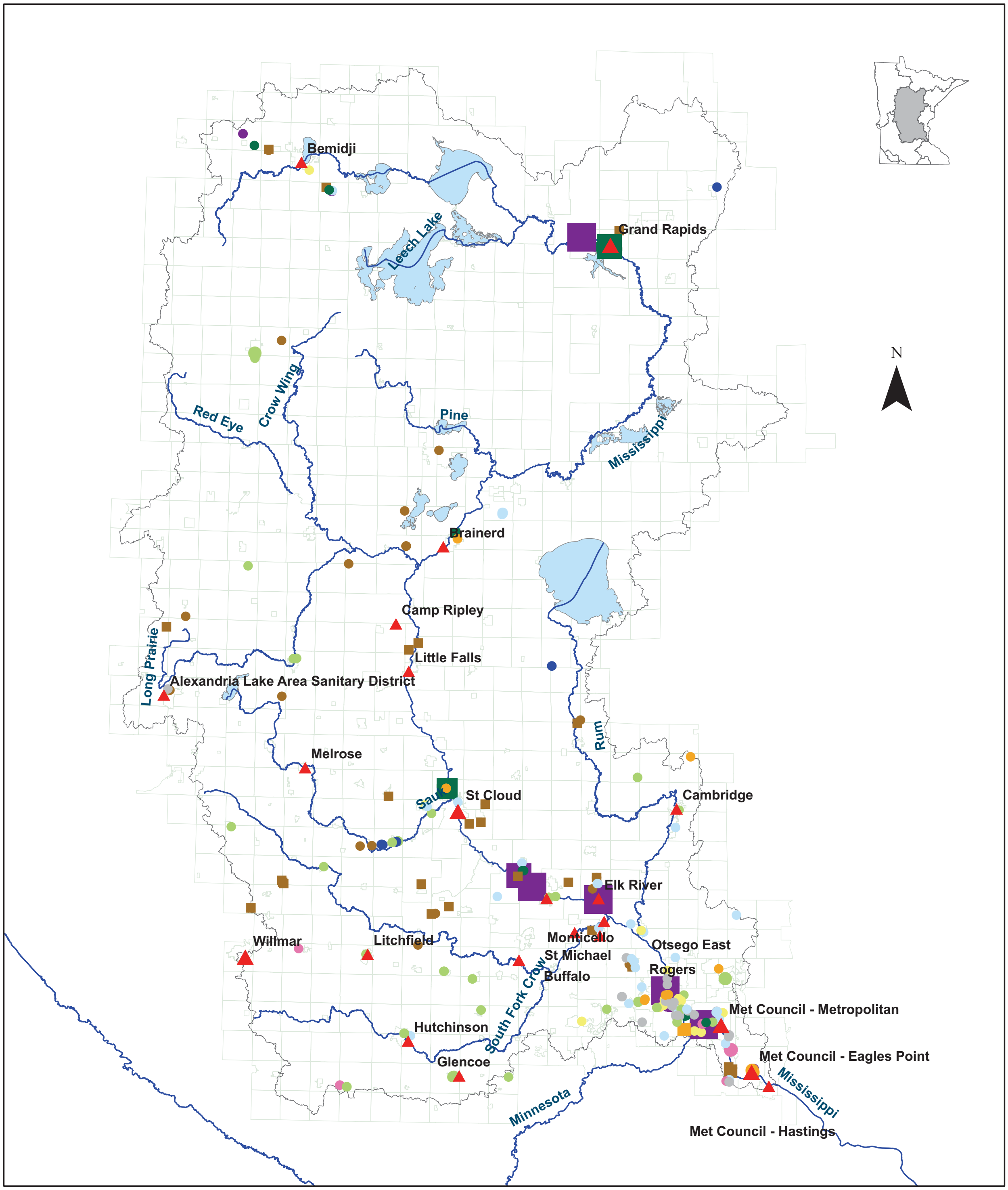
The watershed inventory displayed in Figure 3.12c shows the WWTPs in relation to the various industries in the watershed. The inventory shows that there are several WWTPs with industries in close proximity and most of these are agricultural processing industries. Examples include Seneca Foods in Glencoe, Burn Philip Food Ingredients in Hutchinson, Northern Food & Dairy in Alexandria, all of which have WWTPs within 1.5 miles of their operations. Table 3.12c lists industries within 4 miles of a WWTP. The complete list of industries in the Mississippi River-Headwaters watershed is in Appendix C.

Table 3.12c. Industries in the Mississippi River Headwaters Watershed Within 4 Miles of a WWTP

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
OPTA FOOD INGREDIENTS INC	G	0.200	1.00	Cambridge	Agricultural Processing
ELK RIVER, CITY OF	S	0.006	1.00	Elk River	POWER GENERATION
GREAT RIVER ENERGY	G	0.054	1.00	Elk River	STEAM POWER - OTHER THAN COOLING
GREAT RIVER ENERGY	S	34.728	1.00	Elk River	STEAM POWER COOLING - ONCE THROUGH
ASSOCIATED MILK PRODUCERS	G	0.024	1.00	Glencoe	Agricultural Processing
SENECA FOODS CORP	G	0.478	1.00	Glencoe	Agricultural Processing
BURN PHILP FOOD INGREDIENTS	G	0.917	1.00	Hutchinson	Agricultural Processing
FIRST DISTRICT ASSOC	G	0.126	1.00	Litchfield	Agricultural Processing
DECHENE CORP	G	0.004	1.00	Monticello	Agricultural Processing
NORTHERN FOOD & DAIRY INC	G	0.000	1.50	Alexandria Lake Area SD	Agricultural Processing
LEE, MARK	G	0.001	1.50	Alexandria Lake Area SD	Sand and Gravel Washing
ALEXANDRIA EXTRUSION CO	G	0.004	1.50	Alexandria Lake Area SD	Metal Processing
NORTHERN FOOD & DAIRY INC	G	0.310	1.50	Alexandria Lake Area SD	Agricultural Processing
BLANDIN PAPER CO	S	16.680	1.50	Grand Rapids	Pulp and Paper Processing
BAUERLY BROTHERS INC	G	0.004	1.50	Hutchinson	Non-Metallic Processing
EWING FARMS INC	G	0.004	1.50	Monticello	Agricultural Processing
AGGREGATE INDUSTRIES-NCR INC	G	0.009	2.00	Rogers	Non-Metallic Processing
HASSAN SAND & GRAVEL INC	S	0.041	2.00	Rogers	Sand and Gravel Washing
JERRYS ICE SERVICE	G	0.008	2.50	Bemidji	Industrial Processing
GRANITE CITY READY MIX	S	0.259	2.50	St Cloud	Sand and Gravel Washing
BARTON SAND AND GRAVEL CO	G	0.000	2.90	Elk River	Sand and Gravel Washing
XCEL OPTICAL COMPANY	G	0.005	3.00	St Cloud	Non-Metallic Processing
BARTON SAND & GRAVEL	G	0.089	3.50	Elk River	Sand and Gravel Washing
POTLATCH CORPORATION	S	0.007	3.50	Grand Rapids	Pulp and Paper Processing
NSP CO DBA XCEL ENERGY	S	132.737	3.70	METC - Metro	STEAM POWER COOLING - ONCE THROUGH
3M COMPANY	G	2.788	2.00	METC- Eagles Point	Industrial Process Cooling Once Thru
LSP-COTTAGE GROVE LP	G	0.000	2.00	METC- Eagles Point	POWER GENERATION
CAPTAIN KENS FOODS INC	G	0.009	2.30	METC- Metropolitan	Agricultural Processing
CEMSTONE PRODUCTS	G	0.007	2.30	METC- Metropolitan	Non-Metallic Processing
NORTH STAR STEEL MINNESOTA	G	0.177	2.50	METC- Metropolitan	Metal Processing
NORTHERN MALLEABLE IRON CO	G	0.038	3.00	METC- Metropolitan	Metal Processing
NRG ENERGY CENTER INC	G	0.204	3.10	METC- Metropolitan	Pulp and Paper Processing
D & D LAND LLC	G	0.000	3.30	METC- Metropolitan	Non-Metallic Processing
3M COMPANY	G	0.322	3.40	METC- Metropolitan	Non-Metallic Processing
CEMSTONE PRODUCTS	G	0.004	3.60	METC- Metropolitan	Industrial Processing
NSP CO DBA XCEL ENERGY	S	132.737	3.70	METC- Metropolitan	STEAM POWER COOLING - ONCE THROUGH
ELK RIVER RED-E-MIX INC	G	0.006	3.90	Elk River	Non-Metallic Processing
BAUERLY BROTHERS INC	G	0.005	4.00	Cambridge	Non-Metallic Processing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Figure 3.12c. Mississippi River - Headwaters Watershed Industrial Reuse Customer Inventory



Agricultural Processing
Industrial Process Cooling
Industrial Processing
Metal Processing
Mine Processing
Non-Metallic Processing
Petroleum-Chemical Processing
Pulp and Paper Processing
Sand and Gravel Washing
Power Generation

Major Lakes
Major Rivers
WWTP >= 5 mgd
WWTP 1-5 mgd
Ground Water
Surface Water
Cities/Townships

0.00 - 0.50 mgd
0.51 - 1.50 mgd
1.51 - 5.00 mgd
5.01 - 10.00 mgd
10.01 - 25.00 mgd
25.01 - 505.00 mgd

0 25 50 Miles

Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Factors Influencing Potential for Industrial Reuse

The northern three-quarters of the Mississippi River-Headwaters watershed is in Ground Water Area 4, known for good surficial aquifers, less reliable buried sand aquifers, and a limited supply from the bedrock. Well interference problems have been experienced in this area. The southern end, in the 7-county metro area through St. Cloud has a reliable bedrock supply and moderate bearing surficial and buried sand aquifers. The susceptibility for contamination index rates this watershed as medium to highest in the mid-watershed regions, with low susceptibility areas interspersed through the north and eastern parts of the watershed. As with the Minnesota River watershed, ground water supply and quality is highly variable across the watershed and site-specific conditions must be considered in evaluating the adequacy of the water supply.

The Mississippi River-Headwaters watershed has similar surface water issues as the Lower Mississippi River and Minnesota River, particularly in relation to the Lake Pepin TMDL. Like these two watersheds, the metro area has a tremendous influence on the quality of the water leaving the watershed. Municipal and industrial dischargers in this watershed will be an integral part of the solution to meeting the water quality goals downstream.

Missouri River

Industrial Water Use

There are only two industries in the Missouri River with a permit to withdraw water. Both are sand and gravel washing operations that use surface water. In 2004 only one of these businesses withdrew water for an annual average of 0.06 mgd, as shown in Table 3.13a.

Table 3.13a. Industrial Water Use in the Missouri River Watershed

	2004 Water Use, mgd		
Industry Category	**Ground Water**	**Surface Water**	**Total**
Sand and Gravel Washing	0.00	0.06	0.06
Total	0.00	0.06	0.06

Source: MDNR, 2004

WWTPs

The Luverne WWTP is the only facility with a capacity greater than 1 mgd and discharged nearly 0.9 mgd in 2005, as shown in Table 3.13b. The Luverne WWTP is operating at about 60% of its design capacity. The combined capacity of the smaller WWTPs in the watershed is 2.0 mgd.

Table 3.13b. WWTPs in the Missouri River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Luverne WWTP	1.500	0.865	57.7%
Total	1.500	0.865	57.7%

Source: MPCA, 2005

Industries and Proximity to WWTPs

While both sand and gravel washing operations are within 5 miles of the Luverne WWTP, as shown on Figure 3.13b and in Table 3.13a, their limited water use and use of a surface water supply do not make them a good candidate for reclaimed water. Given this is a limited water supply area, Task 2 work may be directed at looking at the industries using a municipal water supply.

Table 3.13c. Industries in the Missouri River Watershed

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
NORTHERN CON-AGG INC	S	0.000	5.0	Luverne	Sand and Gravel Washing
NORTHERN CON-AGG INC	S	0.061	2.5	Luverne	Sand and Gravel Washing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Factors Influencing Potential for Industrial Reuse

Like the Des Moines River watershed, the water supply in the Missouri River watershed is lacking in quality and quantity. This part of the state is in Ground Water Area 5 known for a limited supply in the bedrock and buried sand aquifers and only a moderate supply in the surficial aquifer. Some areas of this watershed are in Area 6 which has limited supplies in all the aquifer levels. The surficial aquifers in this area have been classified as medium to high for susceptibility to contamination, with some pockets of less concern. Similar issues exist here as described for the Des Moines River watershed.

Rainy River Watershed

Industrial Water Use

The least populated watershed of the state, the Rainy River, has few industries with a water appropriations permit. As shown in Table 3.14a and Figure 3.14a, the pulp and paper industry is the largest water user, dominated by Boise White Paper near the NKASD plant. Of the 47 mgd used in 2004, less than 0.2 mgd was used for the other two types of industry, mine processing and sand and gravel washing. Boise White Paper uses only a surface water supply for its industrial uses. Potlach Corporation uses ground water supplies totaling less than 0.07 mgd.

Figure 3.13b. Missouri River Watershed Industrial Reuse Customer Inventory

Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Table 3.14a. Industrial Water Use in the Rainy River Watershed

Industry Category	2004 Water Use, mgd		
	Ground Water	**Surface Water**	**Total**
Mine Processing	0.00	0.01	0.01
Pulp and Paper Processing	0.07	46.70	46.77
Sand and Gravel Washing	0.00	0.14	0.14
Total	0.07	46.85	46.92

Source: MDNR, 2004

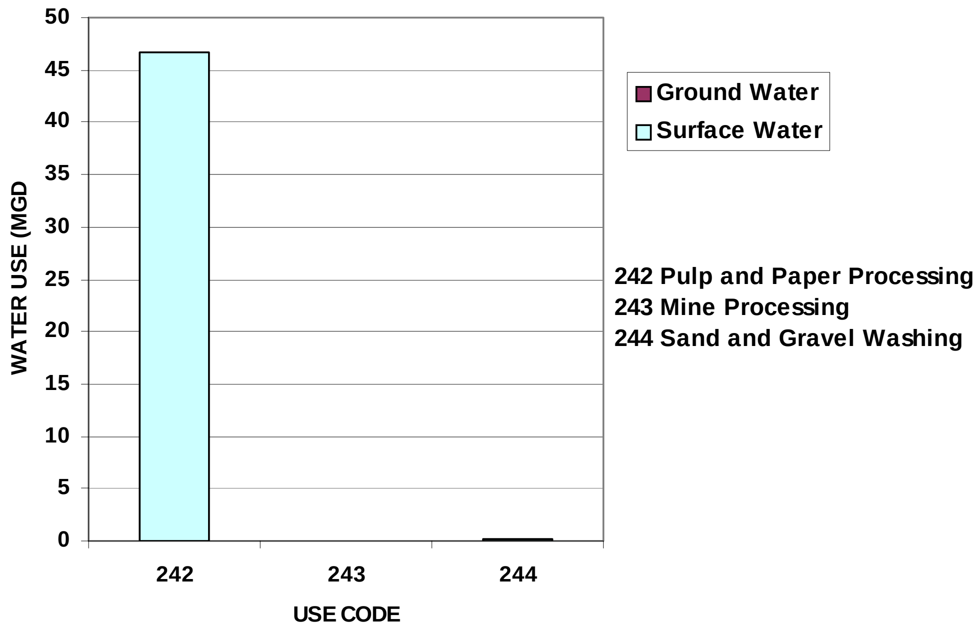


Figure 3.14a. Industrial Processing Water Use in the Rainy River Watershed, 2004

Source: MDNR, 2004

WWTPs

There are two municipal WWTPs in this watershed with design capacities greater than 1 mgd: NKASD in International Falls and the Ely WWTP. Table 3.14b summarizes the design capacity and historic flows for the plants. These WWTPs discharged nearly 2 mgd in 2005. There are also several smaller WWTPs that discharge to surface waters with a combined design capacity of 3.3 mgd. This compares to a total WWTP capacity of 7.1 mgd for the watershed. Depending on the location of the industry it is possible that a smaller WWTP could provide an adequate reclaimed water supply.

Table 3.14b. WWTPs in the Rainy River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
NKASD WWTP	2.3	1.264	55.0%
Ely WWTP	1.5	0.688	45.9%
Total	3.8	1.952	51.4%

Source: MPCA, 2005

Industries and Proximity to WWTPs

The largest industry is located in International Falls and in close proximity (2.3 miles) to the WWTP, as shown on Figure 3.14c. There are no industries in Ely that have their own water permits.

Table 3.14c. Industries in the Rainy River Watershed

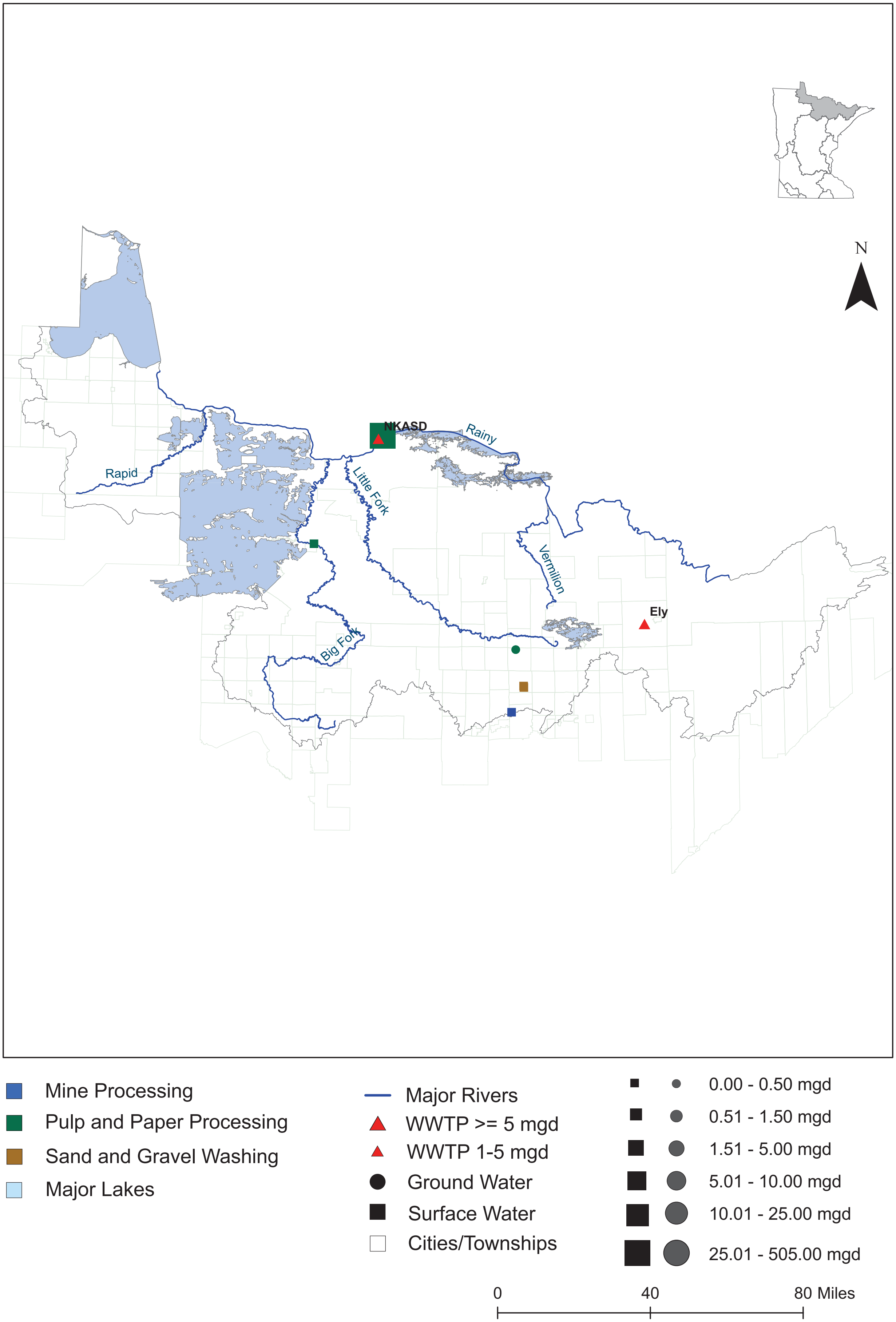
Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
UNITED STATES STEEL CORP	S	0.010	>10	Ely	Mine Processing
BOISE WHITE PAPER LLC	S	46.684	2.3	NKASD	Pulp and Paper Processing
KNAEBLE TIMBER INC	S	0.018	>10	NKASD	Pulp and Paper Processing
POTLATCH CORPORATION	G	0.067	>10	Ely	Pulp and Paper Processing
SEPPI BROS CONCRETE	S	0.136	>10	Ely	Sand and Gravel Washing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Factors Influencing Potential for Industrial Reuse

Ground water supplies are limited in the central and eastern portions of the Rainy River watershed. This area is Ground Water Area 3 and is dominated by glacial aquifers that are commonly thin and limited in their extent and yield. The bedrock aquifers also have limited yield; there are no large-scale regional aquifers. Ground water movement in much of the area is difficult to define because of the fractured nature of the bedrock. In the west (Area 4) and north (Area 5) portions of the watershed, the ground water supply in the surficial aquifers are less shallow and have moderate to good yields. This area can be dominated by connections to wetlands and contamination of surface aquifers has occurred. However, overall this watershed has a lowest to low susceptibility to contamination index, except along the southern border and interspersed areas in the watershed.

Figure 3.14b. Rainy River Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

The Rainy River watershed is a heavily forested area, which like much of Minnesota, values its water resources for recreational purposes. Voyageurs National Park and the Boundary Waters Canoe Area are located here, as are several of the states most famous walleye fisheries and prized trout streams. Basin planning has been ongoing in this watershed to maintain protection of Minnesota's water resources and coordinate planning with Canada, into which the waterways flow, with nearly 60% of the watershed in Canada's borders. The Rainy River Basin Plan, (MPCA, 2004) outlines various goals and activities to monitor, evaluate and implement projects where improvements are needed. No specific watershed initiatives were noted that would influence the use of reclaimed water in this area for industry. The driver will most likely be insufficient ground water supplies, in areas lacking a higher quality surface water supply. It is anticipated that surface water supplies could be of higher quality than reclaimed water, but will be location and industry specific.

Red River of the North

Industrial Water Use

Major industries in the Red River of the North watershed are limited to three industry types, as depicted in Figures 3.15a and 3.15b. As detailed in Table 3.15a, less than 2.2 mgd of ground water supplies were withdrawn for use by agricultural processing facilities and sand and gravel washing businesses in 2004. The Otter Tail Power Company in Thief River Falls has the largest industrial water demand, using over 50 mgd of surface water.

Table 3.15a. Industrial Water Use in the Red River of the North Watershed

	2004 Water Use, mgd		
Industry Category	**Ground Water**	**Surface Water**	**Total**
Agricultural Processing	0.91	0.09	1.00
Power Generation	0.00	54.43	54.43
Sand & Gravel Washing	1.26	0.69	1.95
Total	2.17	55.21	57.38

Source: MDNR, 2004

WWTPs

The six WWTPs in the area (with a capacity greater than 1 mgd) have a combined treatment capacity of nearly 20 mgd (Table 3.15b). In 2005, the combined discharge of the plants was 12 mgd. Four of these plants are nearing capacity: Crookston, East Grand Forks, Fergus Falls and Thief River Falls.

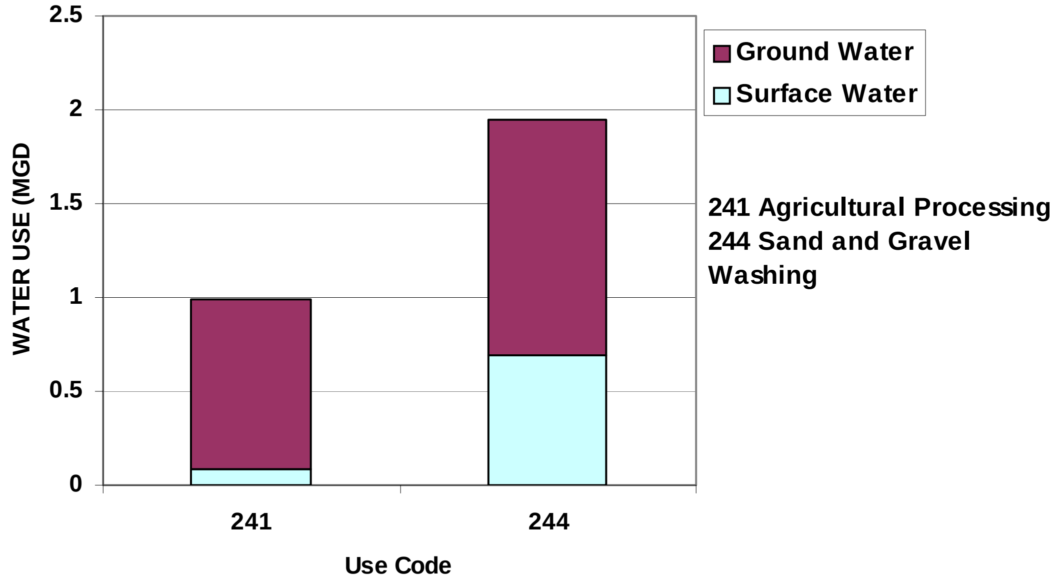


Figure 3.15a. Industrial Processing Water Use in the Red River of the North Watershed, 2004

Source: MDNR. 2004

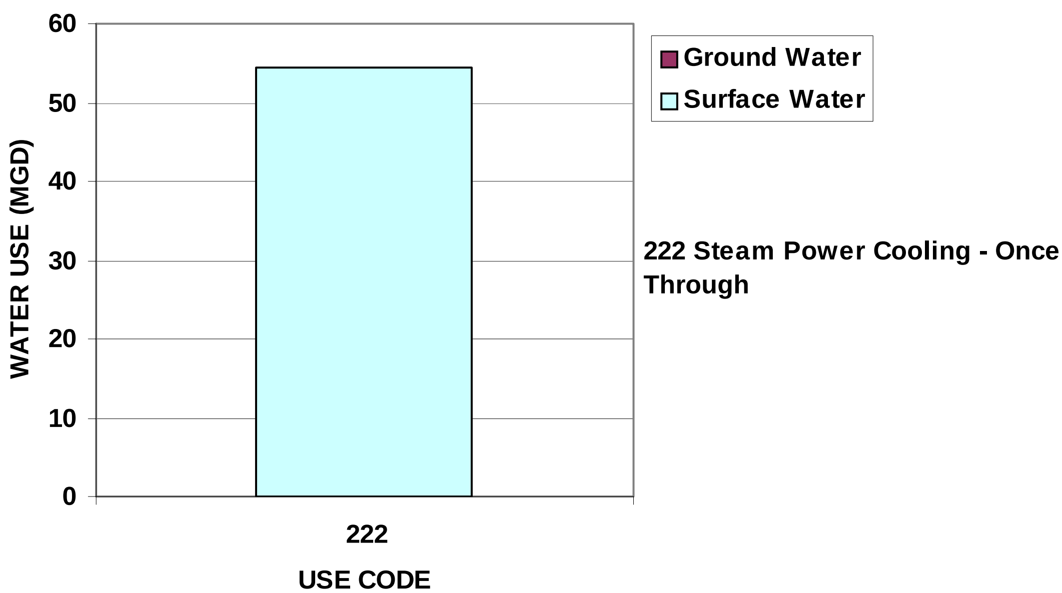


Figure 3.15b. Power Generation Water Use in the Red River of the North Watershed, 2004

Source: MDNR. 2004

Table 3.15b. WWTPs in the Red River of the North Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Crookston WWTP	1.400	1.117	79.8%
Detroit Lakes WWTP	3.000	1.256	41.9%
East Grand Forks WWTP	1.400	1.193	85.2%
Fergus Falls WWTP	2.810	1.909	67.9%
Moorhead WWTP	9.000	4.753	52.8%
Thief River Falls WWTP	2.140	1.447	67.6%
Total	19.750	11.675	59.1%

Source: MPCA, 2005

Industries and Proximity to WWTPs

Of the four municipal WWTPs approaching design capacity, Crookston has the closest potential industrial reuse customer (Figure 3.15c and Table 3.15c). The American Crystal Sugar facility is approximately 1 mile from the WWTP. There is also an American Crystal Sugar facility adjacent to the Moorhead WWTP.

Factors Influencing Potential for Industrial Reuse

Limited ground water supplies occur through much of the Red River Valley. The majority of this watershed is in Ground Water Area 5, noted for low yielding bed and buried sand aquifers. The surficial sand aquifers provide the best yields and quality. However, overpumping of these aquifers can cause the upward flow of poorer quality ground water from the lower aquifers, known for high total dissolved solids. In addition, the surficial aquifers have recharge zones that are susceptible to contamination. The larger communities in the area, such as Moorhead, use both ground and surface water supplies for their potable water supply. The Buffalo aquifer water levels were gradually declining until water treatment operations went online to treat more Red River water. This dual supply approach has been necessary to sustain the water supply aquifers of this part of the Red River watershed.

Basin planning efforts initiated in the mid-1990s continue to guide the watershed protection initiatives for the Red River of the North watershed communities. Ammonia limits imposed in late 1990s led to improvements in the treatment processes for WWTPs in the watershed. The initiatives of neighboring states and Canada, which is downstream, will also affect the discharge requirements placed on WWTPs in this Minnesota watershed.

Table 3.15c. Industries in the Red River of the North Watershed within 10 Miles of a WWTP

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
AMERICAN CRYSTAL SUGAR CO	S	0.000	1	Moorhead	Agricultural Processing
AMERICAN CRYSTAL SUGAR CO	S	0.010	1.2	Crookston	Agricultural Processing
MOORHEAD PUBLIC SERVICE	S	0.000	1.5	Moorhead	STEAM POWER COOLING - ONCE THROUGH
AMERICAN CRYSTAL SUGAR CO	S	0.000	2	East Grand Forks	Agricultural Processing
NORTHERN PRIDE INC	G	0.000	2.6	Thief River Falls	Agricultural Processing
ROCK RIDGE RESOURCES	S	0.000	3	Detroit Lakes	Sand and Gravel Washing
ROCK RIDGE RESOURCES	G	0.666	3	Detroit Lakes	Sand and Gravel Washing
OTTER TAIL POWER CO	S	54.428	3.5	Fergus Falls	STEAM POWER COOLING - ONCE THROUGH
OTTER TAIL POWER CO	G	0.000	3.5	Fergus Falls	STEAM POWER COOLING - WET TOWER
MNDAK CONCRETE INC	S	0.034	7.5	Thief River Falls	Sand and Gravel Washing
MNDAK CONCRETE INC	G	0.025	7.5	Thief River Falls	Sand and Gravel Washing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

St. Croix River

Industrial Water Use

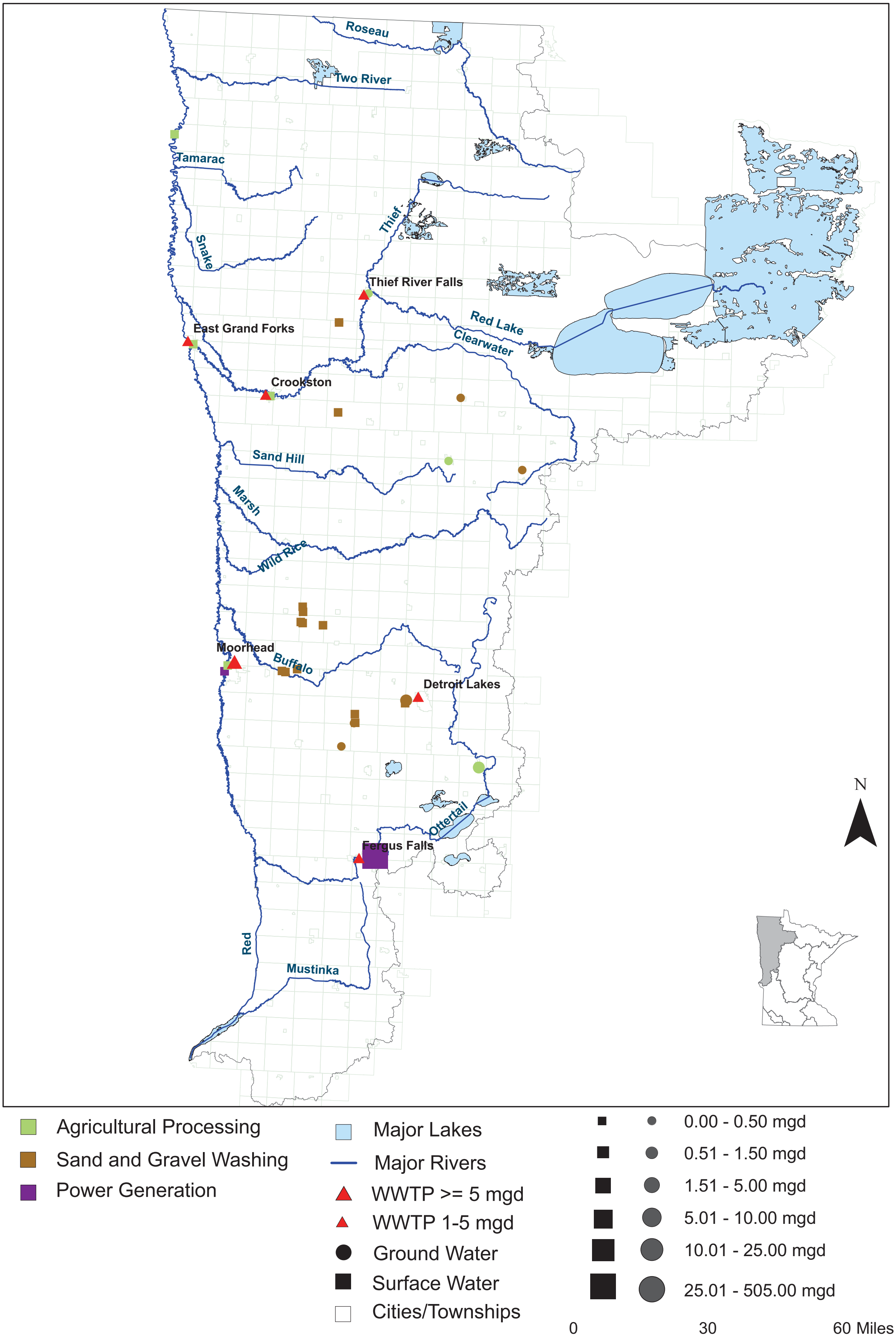
The largest industrial water user in the St. Croix River watershed is Xcel Energy, which used 325 mgd of water from the St. Croix River in 2004. The other permitted industrial water users include several sand and gravel companies and Andersen Corporation for window production. Nearly 1 mgd of ground water was used by these industries in 2004. Figures 3.16a and 3.16b and Table 3.16a summarize the industrial water use for the St. Croix watershed.

Table 3.16a. Industrial Water Use in the St. Croix River Watershed

Industry Category	2004 Water Use, mgd		
	Ground Water	Surface Water	Total
Non-Metallic Processing	0.59	0.00	0.59
Sand & Gravel Washing	0.33	0.35	0.68
Steam Power Other than Cooling	0.00	325.35	325.35
Total	0.92	325.70	326.62

Source: MDNR, 2004

Figure 3.15c. Red River of the North Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

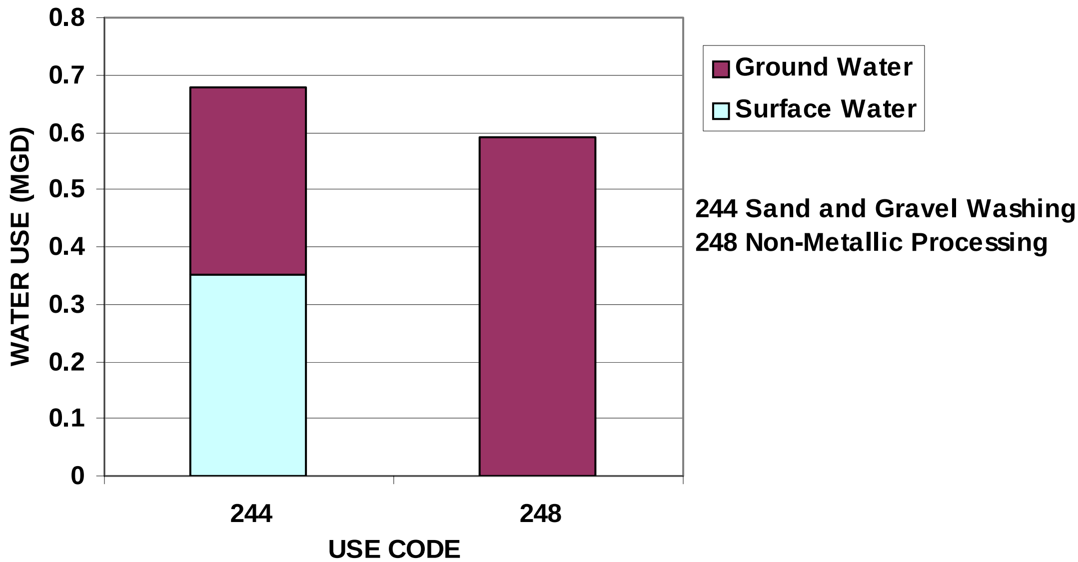


Figure 3.16a. Industrial Processing Water Use in the St. Croix Watershed, 2004

Source: MDNR. 2004

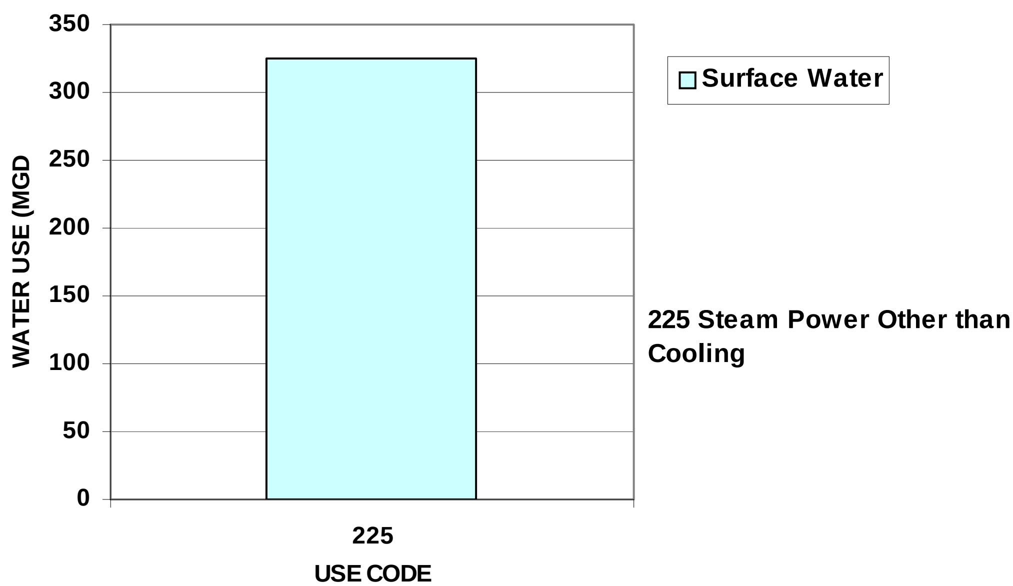


Figure 3.16b. Power Generation Water Use in the St. Croix Watershed, 2004

Source: MDNR. 2004

WWTPs

There are two municipal WWTPs in this watershed with design capacities greater than 1 mgd: Chisago Lakes Joint STC and Metro Council's St. Croix Valley WWTP. Table 3.16b summarizes the design capacity and historic flows for the plant. These WWTPs discharged 3.9 mgd in 2005. There are also smaller WWTPs that discharge to surface waters with a combined design capacity of 5.2 mgd.

Table 3.16b. WWTPs in the St. Croix River Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Chisago Lakes Joint STC	1.26	0.756	60.0%
Met Council - St Croix Valley WWTP	4.5	3.126	69.5%
Total	5.76	3.882	67.4%

Source: MPCA, 2005

Industries and Proximity to WWTPs

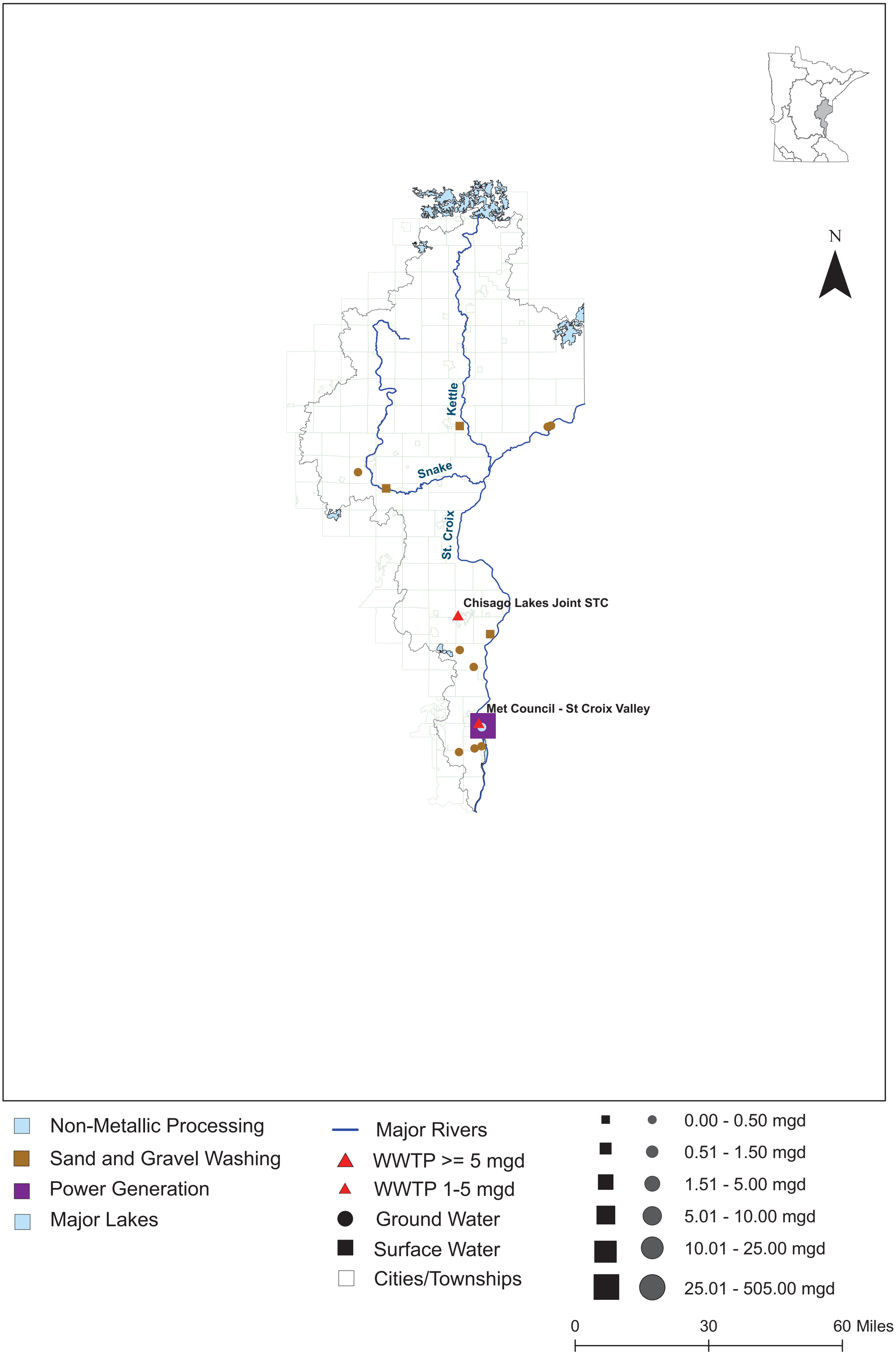
Figure 3.16c presents the location of the industries and WWTPs in the St. Croix River watershed. Table 3.16c lists the various industries and their distance from the closer of the two WWTPs. The sand and gravel companies are all located a considerable distance from a WWTP, the closest is 5 miles away. Andersen Corporation, which used approximately 0.6 mgd of ground water in 2004, is within 1 mile of the Met Council St. Croix Valley WWTP. The Xcel Energy facility is also within 1 mile of this WWTP.

Factors Influencing Potential for Industrial Reuse

This watershed resides in Ground Water Area 1 of the state, which has a good bedrock aquifer supply and moderate bearing surficial sand and buried sand aquifers. As development continues around the metro area, supply pressures will be placed on ground water resources in the metro area and fringe areas to the north. Water quality has not been an issue, in general, for this area. The St. Croix supply as a surface water is superior to other major waterways of the area. Low-level contamination of upper aquifers has occurred from spills and general effects of urbanization. Areas developing with private individual sewage treatment systems (ISTSs) or clustered systems have the increased risk of nitrate and pathogen contamination.

Rapid population growth and accompanying land-use changes have affected the water resources of the St. Croix River Basin. The St. Croix Basin Water Resources Planning Team (St. Croix Basin Team), working with recently completed nutrient and sediment research, has recommended a 20-percent reduction in total phosphorus loading within the St. Croix Basin. This is based on a 39-percent projected population growth in the St. Croix Basin by the year 2020. The St. Croix basin will also be part of the Lake Pepin TMDL which is projected to require a 50% reduction in solids and phosphorus loads from upstream sources.

Figure 3.16c. St. Croix River Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Table 3.16c. Industries in the St. Croix River Watershed

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ANDERSEN CORPORATION	G	0.591	4	METC St. Croix Valley	NON-METALLIC PROCESSING
AGGREGATE INDUSTRIES-NCR INC	G	0.135	5	METC St. Croix Valley	SAND & GRAVEL WASHING
AGGREGATE INDUSTRIES-NCR INC	S	0.315	9	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
AGGREGATE INDUSTRIES-NCR INC	G	0.092	9	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BARTON SAND & GRAVEL	G	0.004	8	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BARTON SAND & GRAVEL	G	0.004	7	METC St. Croix Valley	SAND & GRAVEL WASHING
BAUERLY BROTHERS INC	S	0.000	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BAUERLY BROTHERS INC	G	0.005	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BLACK DIAMOND INC	G	0.079	8	METC St. Croix Valley	SAND & GRAVEL WASHING
BRACHT BROS INC	G	0.001	>10	METC St. Croix Valley	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	G	0.013	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	G	0.007	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	G	0.002	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
STAFNE AND AND GRAVEL LLC	S	0.037	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
NSP CO DBA XCEL ENERGY	S	325.347	5	METC St. Croix Valley	STEAM POWER - OTHER THAN COOLING

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Western Lake Superior Watershed

Industrial Water Use

Industries in the Western Lake Superior watershed rely on the high quality surface water of Lake Superior and other surface sources for most of their needs. Only 0.15 mgd of ground water was withdrawn from this watershed by industries, as indicated in Table 3.17a. The heavy water demands of the mining industry dwarf the other uses except for cooling water for steam power facilities, as shown in Figure 3.17a. Nearly 300 mgd water was used by mining facilities in 2004 *(Note: water used by the power industry specifically for mining activities is noted as a mining water use).* As indicated in Figure 3.17b, 180 mgd of surface water was used for once through cooling water systems for steam power facilities. Pulp and paper processing, chemical processing, sand and gravel washing, and a concrete products industry were the other industry types residing in the Western Lake Superior watershed.

Table 3.17a. Industrial Water Use in the Western Lake Superior Watershed

	2004 Water Use, mgd		
Industry Category	**Ground Water**	**Surface Water**	**Total**
Mine Processing	0.01	296.51	296.52
Non-metallic Processing	0.01	0.00	0.01
Petroleum - Chemical Processing, ethanol	0.00	0.43	0.43
Pulp and Paper Processing	0.00	6.78	6.78
Sand and Gravel Washing	0.01	0.30	0.31
Steam Power Cooling - Once through	0.00	182.35	182.35
Steam Power Cooling - Wet Tower	0.12	0.00	0.12
Total	0.15	486.37	486.52

Source: MDNR, 2004

WWTPs

The six major WWTPs in the Western Lake Superior watershed discharged 45 mgd of treated wastewater in 2005, as summarized in Table 3.17b. Approximately 85% of this wastewater was processed at the Western Lake Superior Sanitary District (WLSSD) near downtown Duluth. The other WWTPs have capacities between 1 and 5 mgd. It is estimated that the capacity for the smaller wastewater treatment systems, less than 1 mgd, is about 7 mgd.

Table 3.17b. WWTPs in the Western Lake Superior Watershed

Facility Name	Design Capacity, mgd	2005 Ann Avg Flow, mgd	Flow as % of Design Capacity
Eveleth WWTP	1.000	0.645	64.5%
Hibbing WWTP North Plant	3.200	0.000	0.0%
Hibbing WWTP South Plant	2.000	2.573	128.7%
Two Harbors WWTP	1.600	0.701	43.8%
Virginia WWTP	4.300	2.182	50.7%
WLSSD WWTP	48.800	38.797	79.5%
Total	60.900	44.898	73.7%

Source: MPCA, 2005

Industries and Proximity to WWTPs

The WWTP and industry combinations in this watershed have some favorable reuse options. Communities on the iron range are within 10 miles of several industries as listed in Table 3.17c. The Western Lake Superior Sanitary District (WLSSD) also has several industries within 10 miles including mine processing, sand and gravel washing, and it is expected that there are industries in the industrial area adjacent to the WWTP that use a potable supply.

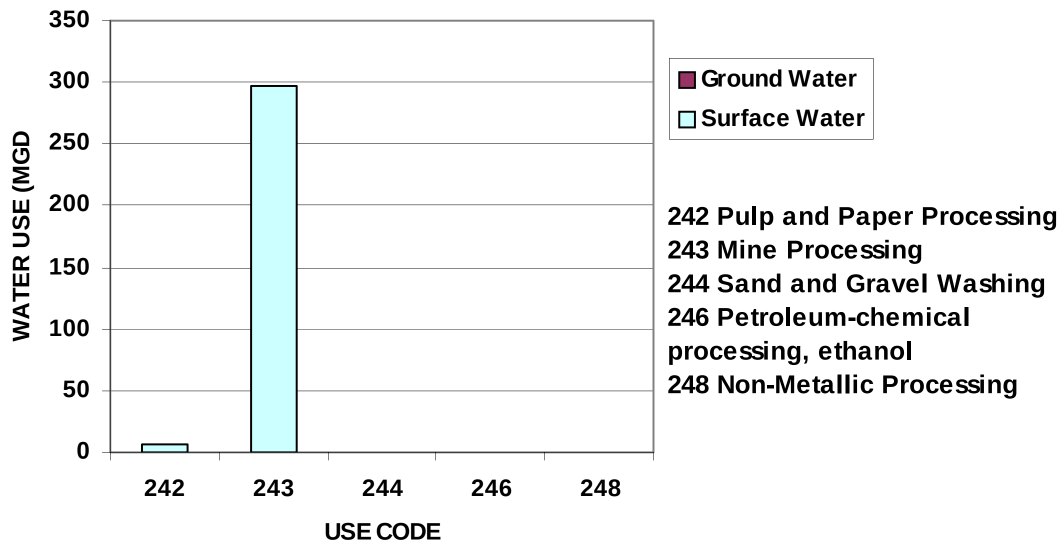


Figure 3.17a. Industrial Processing Water Use in the Western Lake Superior Watershed, 2004

Source: MDNR. 2004

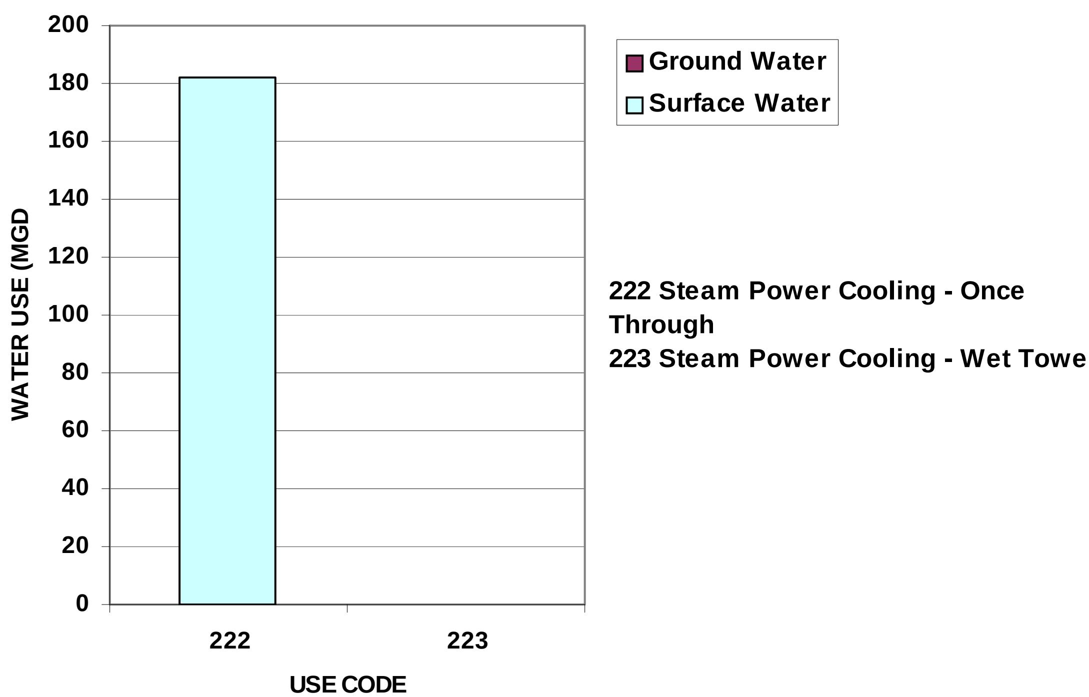


Figure 3.17b. Power Generation Water Use in the Western Lake Superior Watershed, 2004

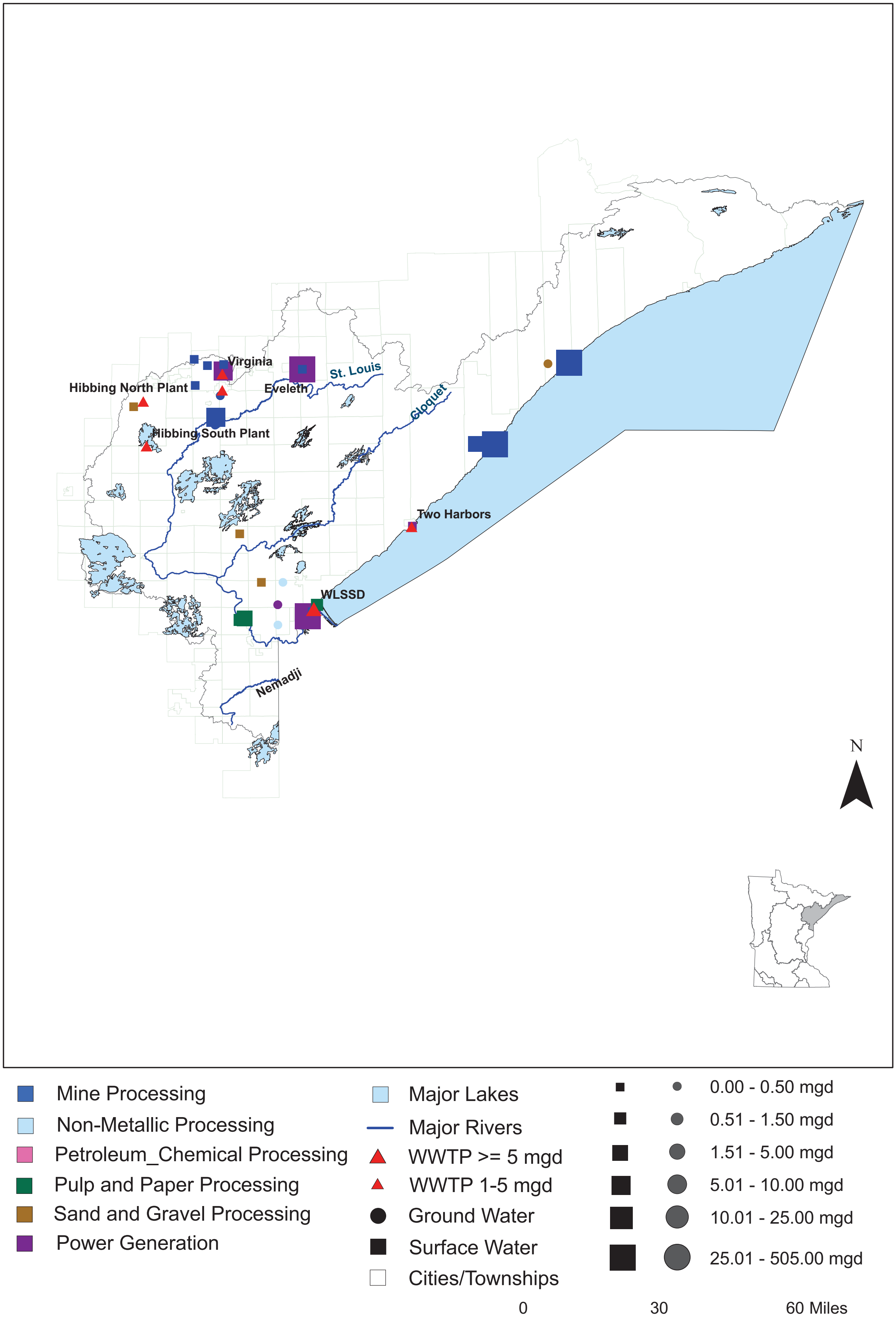
Source: MDNR. 2004

Table 3.17c. Industries in the Western Lake Superior Watershed Within 10 Miles of a WWTP

Industry Name	Source*	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
UNITED TACONITE LLC	G	0.000	1.2	Eveleth	Mine Processing
UNITED TACONITE LLC	S	6.575	6.3	Eveleth	Mine Processing
SEPPI BROS CONCRETE	S	0.115	2.5	Hibbing North Plant	Sand and Gravel Washing
TWO HARBORS, CITY OF	S	0.002	1.0	Two harbors	STEAM POWER COOLING - ONCE THROUGH
UNITED TACONITE LLC	G	0.000	1.5	Virginia	Mine Processing
VIRGINIA PUBLIC UTILITIES	S	7.915	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
VIRGINIA PUBLIC UTILITIES	S	2.038	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
VIRGINIA PUBLIC UTILITIES	S	0.276	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
ISPAT INLAND MINING	S	0.000	3.5	Virginia	Mine Processing
UNITED STATES STEEL CORP	S	0.000	4.0	Virginia	Mine Processing
UNITED STATES STEEL CORP	S	0.000	6.0	Virginia	Mine Processing
UNITED STATES STEEL CORP	S	0.010	7.5	Virginia	Mine Processing
ELK RIVER CONCRETE PRODUCTS	G	0.001	9.0	Virginia	Non-Metallic Processing
DULUTH, MISSABE & IRON RANGE RAIL	S	0.002	1.5	WLSSD	Mine Processing
GEORGIA PACIFIC CORP	S	1.228	1.6	WLSSD	Pulp and Paper Processing
MINNESOTA POWER	S	43.716	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	S	0.537	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	S	0.013	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	G	0.102	3.5	WLSSD	STEAM POWER COOLING - WET TOWER
TATE & LYLE CITRIC ACID INC	S	0.429	5.0	WLSSD	Petroleum - Chemical Processing
UNITED TACONITE LLC	G	0.000	7.0	WLSSD	Mine Processing
UNITED TACONITE LLC	G	0.009	7.0	WLSSD	Mine Processing
MINNESOTA POWER	G	0.000	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
MINNESOTA POWER	G	0.001	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
MINNESOTA POWER	G	0.014	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
ARROWHEAD CONCRETE WORKS	G	0.005	9.9	WLSSD	Non-Metallic Processing

* G=Ground Water; S=Surface Water
Source: MDNR, 2004

Figure 3.17c. Western Lake Superior Watershed Industrial Reuse Customer Inventory



Source: Minnesota DNR Water Appropriations Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)

Factors Influencing Potential for Industrial Reuse

The Western Lake Superior watershed has similar water availability indices as described for the Rainy River watershed. The northern half is in Area 6 and the south half is in Area 4. Both of these areas have limited bedrock aquifers. The north half has limited water supplies in all three aquifer zones, while the south half has productive surifical aquifers and less productive buried sand aquifers. The north half of the watershed is the least prone to ground water contamination, while the south half has some pockets of medium to highest susceptibility of contamination.

Limitations on pollutant discharges will continue to be a focus for this watershed. This region of Minnesota is a treasured recreation area and also provides resources for the state's mining and forest industries. The Lake Superior Basin Plan, completed in 2004, provides recommendations for policy and initiatives to enhance and protect this watershed and the industries that contribute to the economic vitality of the area. The partnerships and mandates associated with the Great Lakes Water Quality Agreement and related programs are expected to continue to influence the management of the watershed in response to the region's growth. One example is the Zero Discharge Demonstration Program, which is devoted to the goal of zero discharge of nine persistent bioaccumulative toxic substances.

3.3 Metro Area Inventory

The range of industries in the Minneapolis/St. Paul metro area provides a perspective on the full range of industries that can be present in a community. Unlike the analysis of industrial demands outside the metro area, the inventory for the metro area includes industries that use a municipal potable supply and/or withdraw from ground or surface waters at lower thresholds than required for an appropriations permit (1 mgy or 100,000 gpd). The Met Council monitors all industries that discharge to the metro area regional sewer system. The database for the industrial users permitted by the Met Council was used to identify the industry, the type of industry, the facility location, and the amount of water that enters the facility. Some industrial users may consume most of this supply and others may discharge all of it to the sewer system. The water use data evaluated for this project is the industrial water demand – what comes into a facility.

Metro Area Overview

The industrial customer inventory for the metro area is represented by a diversity of industries and a prevalence of potential industrial reuse customers along the river corridors. Figure 3.18 presents the industries with water permits (MDNR appropriation permits) and Figure 3.19a locates the larger set of industries in the metro area, represented by the Met Council's Industrial User permit program.

The Met Council database provides for a more detailed categorization of the industries, as shown in the legend for the Figure 3.19a. These industry categories are documented with subcategories in Appendix E. Figure 3.19a also identifies if the industry obtains its water from a municipal (potable) source or another source, which typically would be through a DNR appropriations permit. The other source could be ground water (well), surface water or a combination of both. The municipal designation was rolled up to include any industry that uses a municipal supply. An industry could also have another supply through a DNR appropriations permit.

The Met Council database includes any discharger to the sewer system and the term 'industrial discharger' covers a wide designation of industries. Some dischargers use little water, such as landfill leachate systems, and mainly collect and treat water for discharge. The inventory assembled for this project includes only those industry categories that have a water demand. The Met Council Industrial Dischargers Permit database does not include all industries in the area, because some have their own treatment systems and discharge permits.

The industries in the metro area discharging to the sewer system, as shown in Figure 3.19b, had a combined water demand of 65 mgd in 2005. The largest water users were food industries, at 15 mgd, followed by the metal products industries at 10 mgd. Water used in the electronic products and paper/packaging industries and for power/steam/air conditioning and health care facilities, all had category totals over 5 mgd.

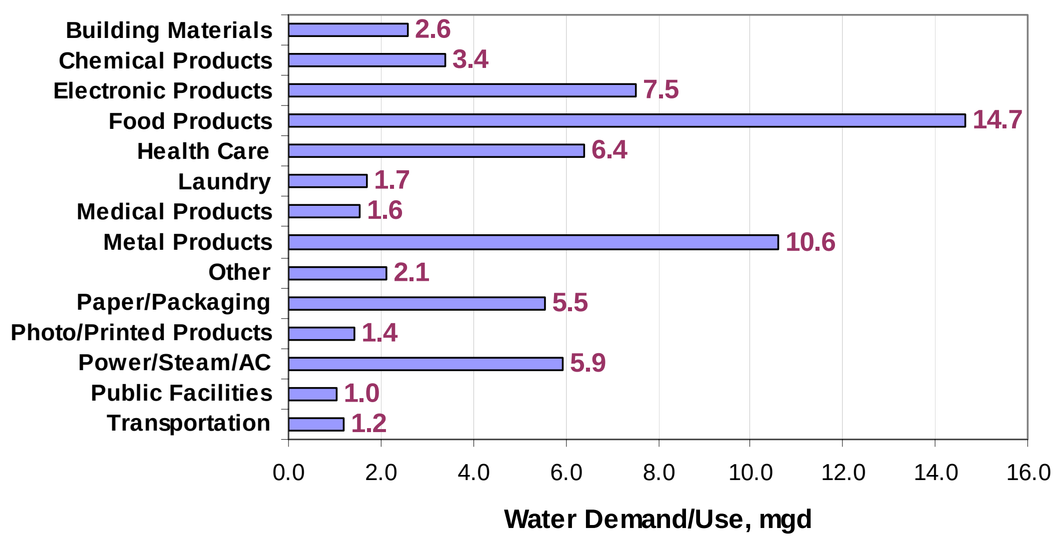
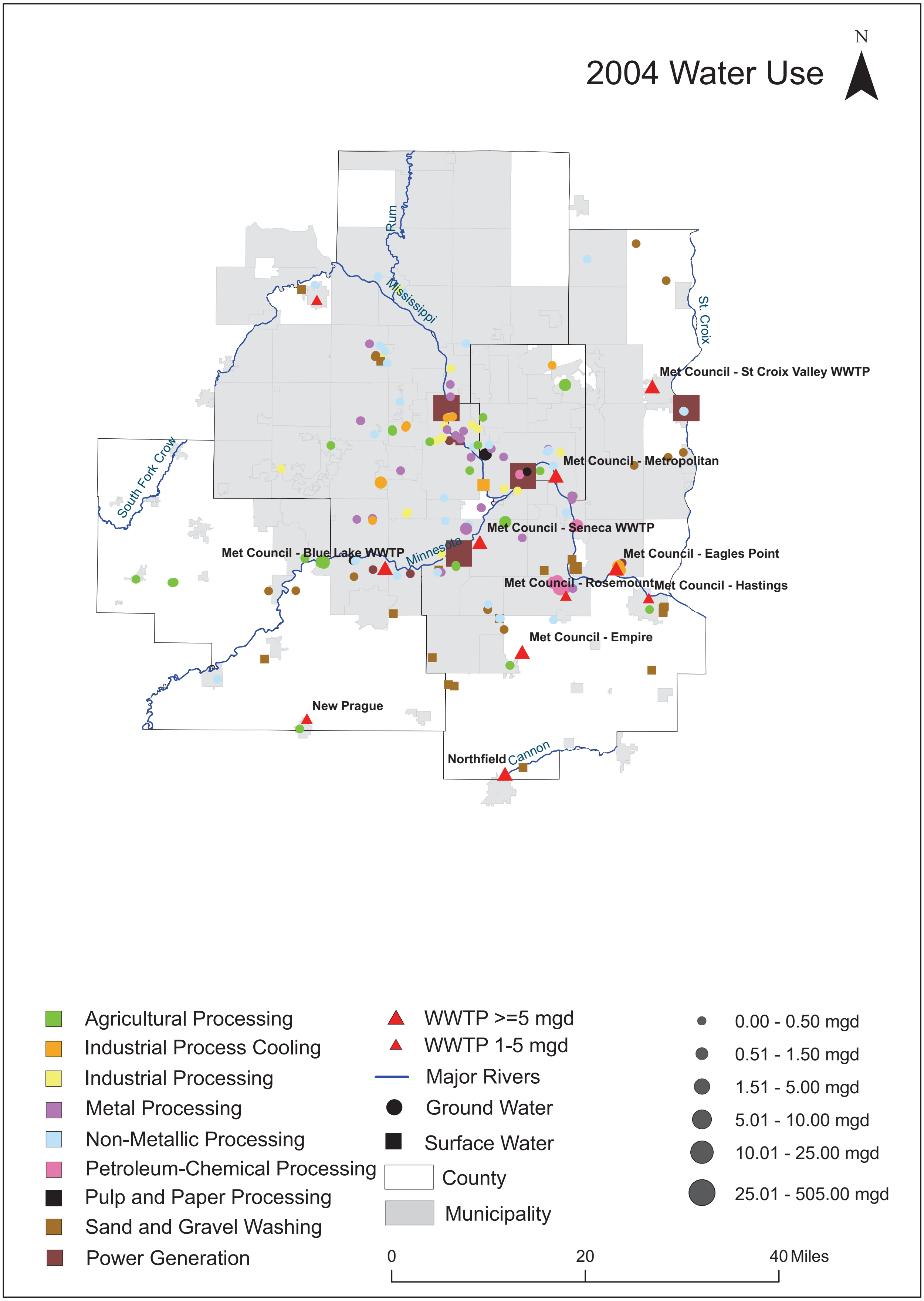


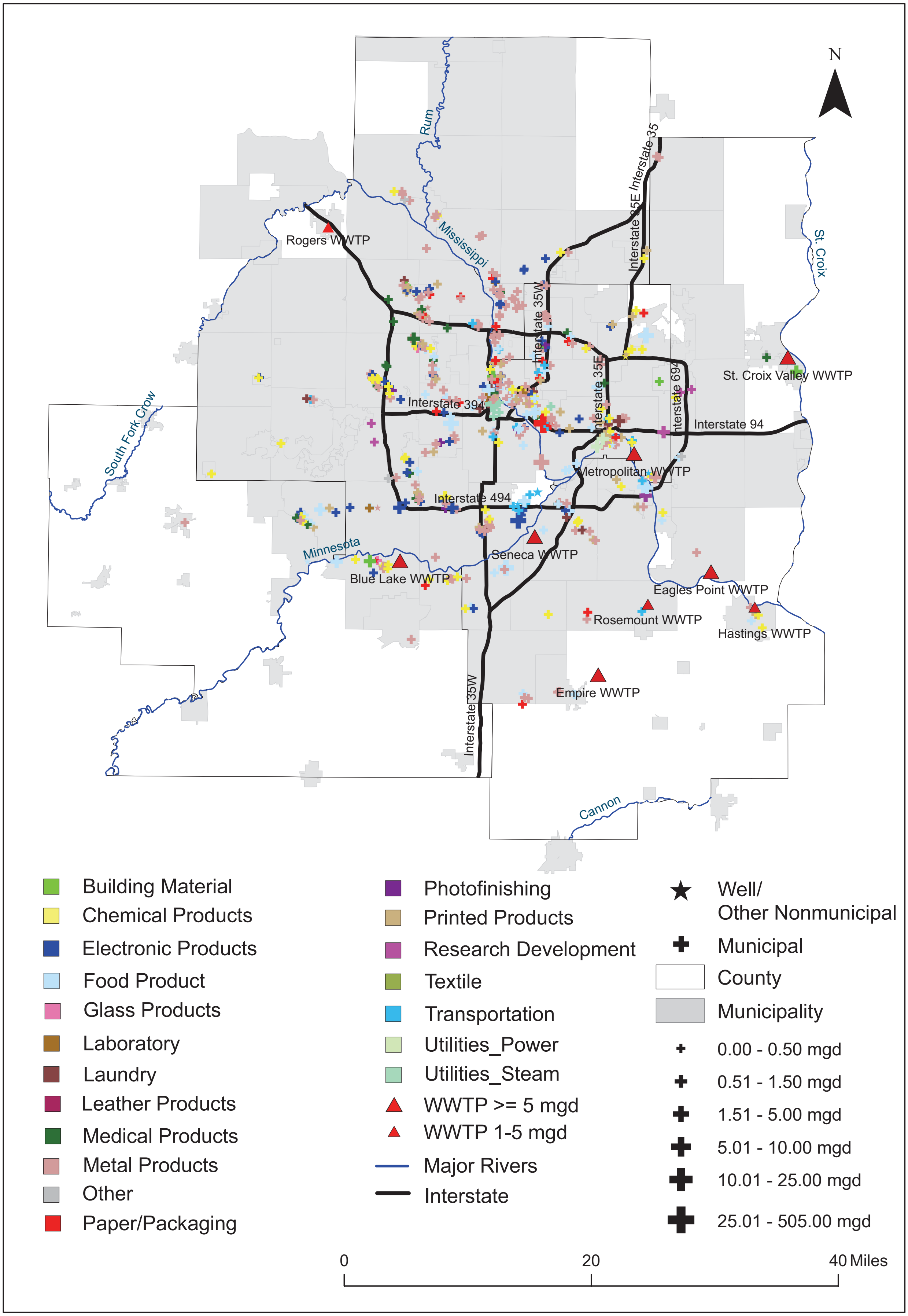
Figure 3.19b. Metro Area Industrial Water Demand, 2005
Source: Met Council Industrial Discharge Permit Program, 2005

Figure 3.18 Metro Area Industrial Reuse Customer Inventory - DNR Water Appropriation Permits



Source: Minnesota DNR Water Appropriation Permits (Withdrawls greater than 1mgy or 10,000 gpd)

Figure 3.19a. Metro Area Industrial Reuse Customer Inventory - MCES Industrial Dischargers



Source: Metropolitan Council Industrial Dischargers Permit Program, 2005

The inventory for the metro area is restricted to the Met Council plants and Rogers WWTP (since it resides in the seven county area). Information is provided on a plant-basis organized by watershed. The following sections summarize the industries within 1- and 5-miles zones of the plant. These zones are represented as circles on the maps. A brief summary of the range of flows for the industries in these two zones is provided, followed by a list of the industries. The purpose of this inventory is to define the 'universe' of potential industrial reuse customers. Task 2 will apply selected criteria to rank and identify industrial reuse customers for a more detailed analysis.

Minnesota River Watershed WWTPs

The Blue Lake and Seneca WWTPs reside in the Minnesota River watershed. Both of these facilities are in the design phase of process improvements and expansion. The plants are currently rated at 37 and 39 mgd, respectively.

A variety of industries are located within a 5-mile radius of the Blue Lake WWTP, as shown on Figure 3.20. Table 3.18 lists all these industries and identifies the water source. Non-metallic and metal processing facilities are the most abundant type of industry. The water demand for industries near the Blue Lake WWTP is 0.13 mgd for nonpotable (not supplied by a municipal water supply system and obtained through an appropriations permit) ground water, and 3.8 mgd for a combination of potable and nonpotable supplies. The largest water user in the 5-mile zone was ADC Telecommunications Inc for metal processing. They used 1.44 mgd of municipal water in 2005. Prior Lake Aggregates, a sand and gravel washing business, had the second highest demand with 0.4 mgd. There were no facilities within a 1-mile radius.

The Seneca WWTP has a larger number of industries within a five-mile radius and one food processing industry, Best Brands, within 1 mile of the plant. Figure 3.21 shows these industries spatially and Table 3.19 lists the industries. The metal processing category has the largest number of facilities, but most have demands less than 0.05 mgd, except for Polar Semiconductor Inc, which used 1.7 mgd in 2005 and Cypress Semi-Conductor, which used 2 mgd in 2005. The food products industries in the 5-mile zone had the next largest demand. The total demand for the industries permitted by Met Council was 9.7 mgd in 2005. Other industries within the 5-mile zone include some that do not discharge to the Met Council sewers, but are large water users, such as Xcel Energy. Nearly 300 mgd of nonpotable supply was used by industries in the 5-mile zone of the Seneca Plant, of which 2.7 mgd was ground water.

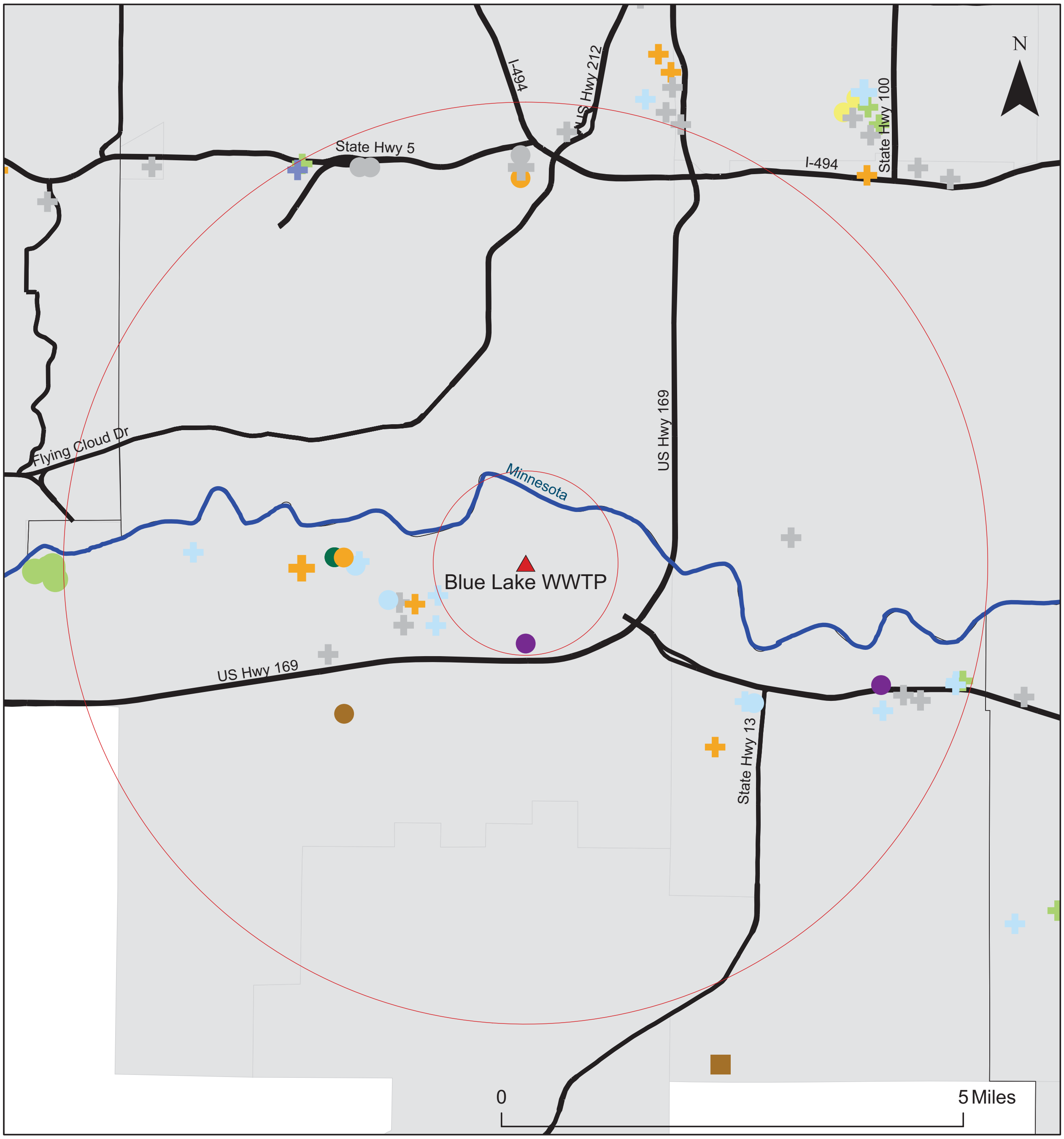
Table 3.18. Blue Lake WWTP Industries Within a 5 Mile Radius

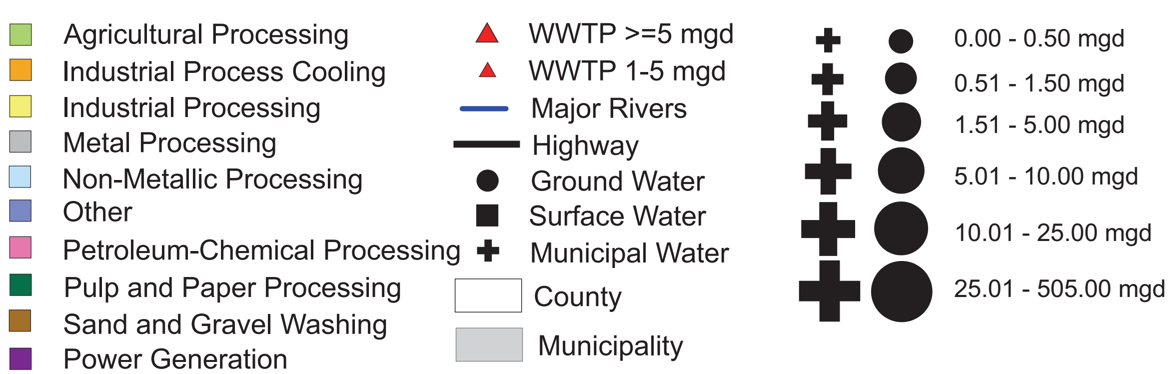
Industry Name	DNR Permit	Water Source *	Industry Category - DNR	MCES Business Category
ADC Telecommunications Inc		M	Metal Processing	Metal Products
Anchor Glass Container Corp	x	G; M&G	Non-Metallic Processing	
B.F. Nelson Corporation		M	Industrial Processing	Paper/Packaging
Birchwood Laboratories Inc		M&G	Other	Laboratory
Cargill Inc-Process Development		M	Agricultural Processing	Food Products
Certainteed Corp		M	Industrial Processing	Building Material
Chaska Chemical Co Inc		M	Non-Metallic Processing	Chemical Products
Conklin Co		M	Non-Metallic Processing	Chemical Products
Continental Machines		M	Metal Processing	Metal Products
Degussa Building Systems (0964)		M	Non-Metallic Processing	Chemical Products
Detector Electronics Corp		M	Metal Processing	Metal Products
E A Sween Co dba Deli Express		M	Agricultural Processing	Food Products
Eaton Corp	x	G	Metal Processing	
Eaton MDH Inc, Eden Prairie Pl		G	Metal Processing	Metal Products
Fremont Industries Inc		G	Non-Metallic Processing	Chemical Products
Greenman Technologies of MN	x	G; M&G	Non-Metallic Processing	Chemical Products
Inland Paperboard & Packaging Inc	x	G	Pulp and Paper Processing	
Koch Material Company	x	G	Stean Power - Other than Cooling	
NatureWorks LLC		M	Non-Metallic Processing	Chemical Products
Novus Inc		M	Non-Metallic Processing	Chemical Products
NSP CO DBA Xcel Energy	x	G	Steam Power Cooling – Wet Tower	
NVE Corp		M	Metal Processing	Electronic Product
Rosemount Inc	x	G; M&G	Industrial Process Cooling Once - through; Metal Processing	Electronic Product
Rubber Industries Inc		M	Non-Metallic Processing	Chemical Products
Seagate Technology LLC		M+	Metal Processing	Electronic Produc
Shakopee Gravel Inc	x	G	Sand & Gravel Washing	
Shakopee Valley Printing		M	Industrial Processing	Printed Products
Temple-Inland*		G	Industrial Processing	Paper/Packaging
Toro Co		M	Metal Processing	Metal Products
NSP CO DBA Xcel Energy	x	G	Steam Power Cooling – Wet Tower	

* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: M+: Municipal and Other Sources.

** Industry located with 1 mile of the WWTP.

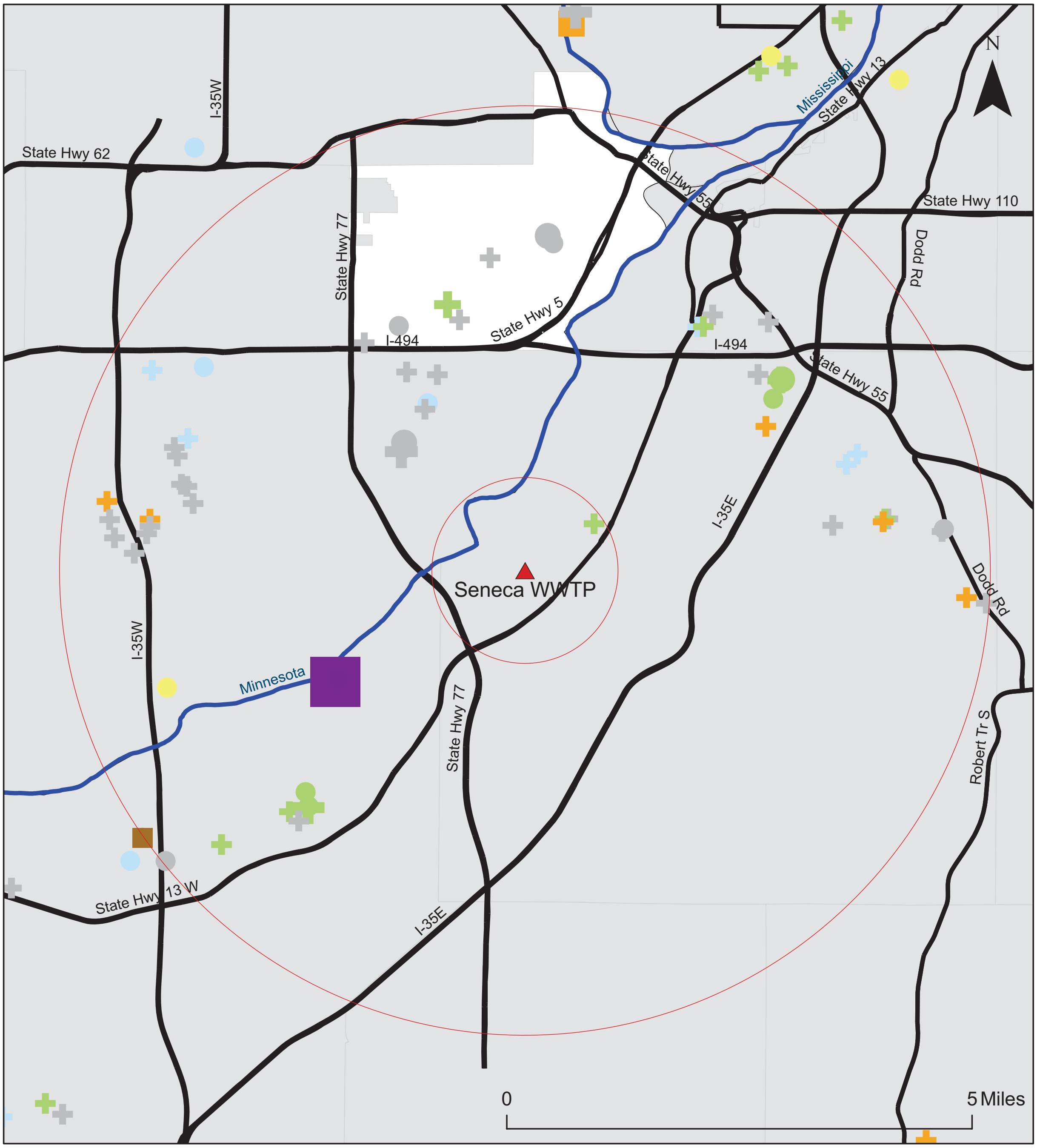
Figure 3.20. Blue Lake WWTP - Industries within 1 and 5 mile Radii





Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Figure 3.21. Seneca WWTP - Industries within 1 and 5 mile Radii



Agricultural Processing
Industrial Process Cooling
Industrial Processing
Metal Processing
Non-Metallic Processing
Other
Petroleum-Chemical Processing
Pulp and Paper Processing
Sand and Gravel Washing
Power Generation

WWTP >=5 mgd
WWTP 1-5 mgd
Major Rivers
Highway
Ground Water
Surface Water
Municipal Water
County
Municipality

0.00 - 0.50 mgd
0.51 - 1.50 mgd
1.51 - 5.00 mgd
5.01 - 10.00 mgd
10.01 - 25.00 mgd
25.01 - 505.00 mgd

Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Table 3.19. Seneca WWTP Industries Within a 5 mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Best Brands Inc**		M	Agricultural Processing	Food Products
Added Value Technology		M	Metal Processing	Electronic Products
Aspen Equipment Co		M	Metal Processing	Metal Products
Better Parts Co		M	Metal Processing	Metal Products
Bo-Decor Metal Finishing Inc		M	Metal Processing	Metal Products
BSM/CORAM North America, Inc.		M	Metal Processing	Metal Products
Buddy's Kitchen Inc		M	Agricultural Processing	Food Products
Cintas Corp - Eagan		M	Industrial Processing	Laundry
Coca - Cola Bottling MW	x	G	Agricultural Processing	
Cypress Semiconductor	x	G, M&G	Metal Processing	
Domino's National Commissary C		M	Agricultural Processing	Food Products
Donaldson Co Inc		M	Metal Processing	Metal Products
Ecolab Inc		M	Non-Metallic Processing	Chemical Products
FMS Corp		M	Metal Processing	Metal Products
General Dynamics Advanced Info		M	Metal Processing	Electronic Produc
Gopher Resource Corp	x	G, M+	Metal Processing	
Hitchcock Industries Inc		M	Metal Processing	Metal Products
Holnamic	x	G	Metal Processing	
Huebsch Laundry Co		M	Industrial Processing	Laundry
Interstate Detroit Diesel		M	Metal Processing	Transportation
KIK Minnesota		M	Non-Metallic Processing	Chemical Products
Leeann Chin Inc		M	Agricultural Processing	Food Products
Litho Technical Service		M	Industrial Processing	Printed Products
Lloyd's Barbeque Co		M	Agricultural Processing	Food Products
LSG/Sky Chef		M+	Agricultural Processing	Food Products
Metro Transit		M	Metal Processing	Transportation
Metropolitan Airports Commissi		M+	Metal Processing	Transportation
Micro Parts Inc		M	Metal Processing	Metal Products
Micron Molding Inc	x	G	Non-Metallic Processing	
Midwest Coca Cola Bottling Inc		M&G	Agricultural Processing	Food Products
Minnesota Knitting Mills		M	Non-Metallic Processing	Textiles
Morrissey Inc		M	Metal Processing	Metal Products
Northwest Airlines Inc	x	G	Metal Processing	
Northwest Airlines Inc (MB) 20		G	Metal Processing	Transportation
Northwest Airlines Inc (OB)		M	Metal Processing	Transportation
NSP CO DBA Xcel Energy	x	G, S	Steam Power Cooling – Once Through	
Pepsi Bottling Group LLC		M&G	Agricultural Processing	Food Products
Pepsi Cola Bottling Co	x	G	Agricultural Processing	
Polar Semiconductor Inc		M&G	Metal Processing	Electronic Produc
Polarfab LLC	x	G	Non-Metallic Processing	
Printed Circuits Inc		M	Metal Processing	Electronic Produc
Release Coatings of Minneapoli		M	Non-Metallic Processing	Chemical Products
Rosemount Aerospace Inc		M	Metal Processing	Electronic Produc
Servisair & Shell Fuel Service		M+	Metal Processing	Transportation

Table 3.19. Seneca WWTP Industries Within a 5 mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Skyline Exhibits		M+	Metal Processing	Metal Products
Spruce Co		M	Industrial Processing	Laundry
Sunburst Chemicals Inc		M	Non-Metallic Processing	Chemical Products
Surmodics Inc	x	G	Industrial Processing	
Tempco Mfg Co Inc		M	Metal Processing	Metal Products
Thermo King Corp		M	Metal Processing	Metal Products
Thomson West - Eagan Productio		M+	Industrial Processing	Printed Products
Valmont / Applied Coating Tech		M	Metal Processing	Metal Products
Ziegler Inc		M	Metal Processing	Metal Products

* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: M+: Municipal and Other Sources; S: Surface Water.
** Industry located with 1 mile of the WWTP.

Mississippi River Watershed WWTPs

The WWTPs that discharge to the Mississippi River-Headwaters watershed from upstream to downstream include: Rogers, Metropolitan, Rosemount, Eagles Point, and Hastings. The Empire WWTP currently discharges to the Vermillion River, a part of the Lower Mississippi River watershed. Upon completion of facility and interceptor construction, the discharge will move to a new discharge point on the Mississippi River in the vicinity of the existing Rosemount WWTP discharge.

The 1.6 mgd Rogers WWTP has only two industries within a 5-mile radius (both located within 1 mile) of the plant with a total demand of 0.05 mgd. Figure 3.22 and Table 3.20 identify these industries as sand and gravel washing businesses, one of which does other processing operations.

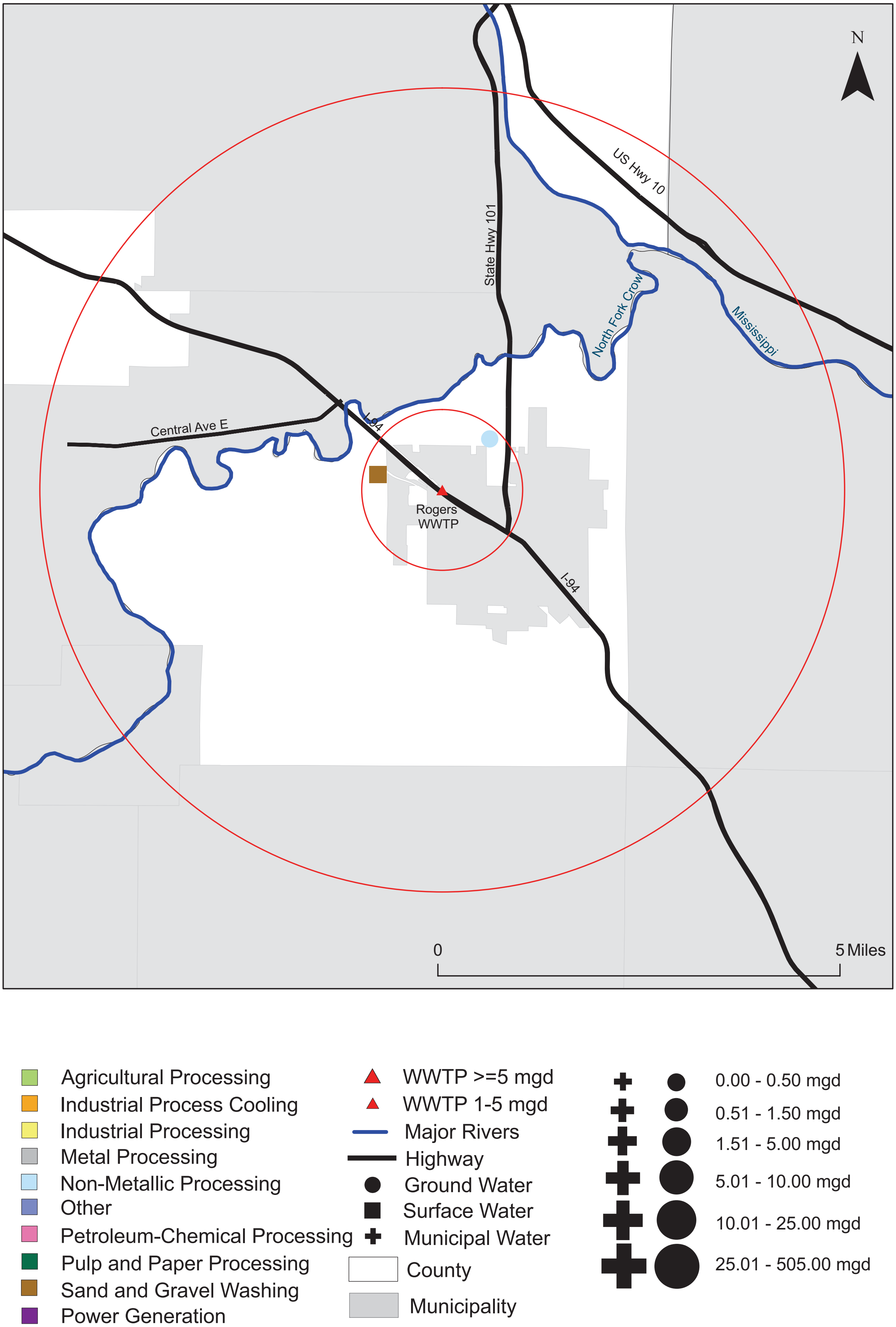
Table 3.20 Rogers WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Aggregate Industries_NCR Inc.**	x	G	Non-Metallic Processing	
Hassen Sand & Gravel Inc. **	x	S	Sand & Gravel Washing	

* G: Ground Water; S: Surface Water.
** Industry located with 1 mile of the WWTP.

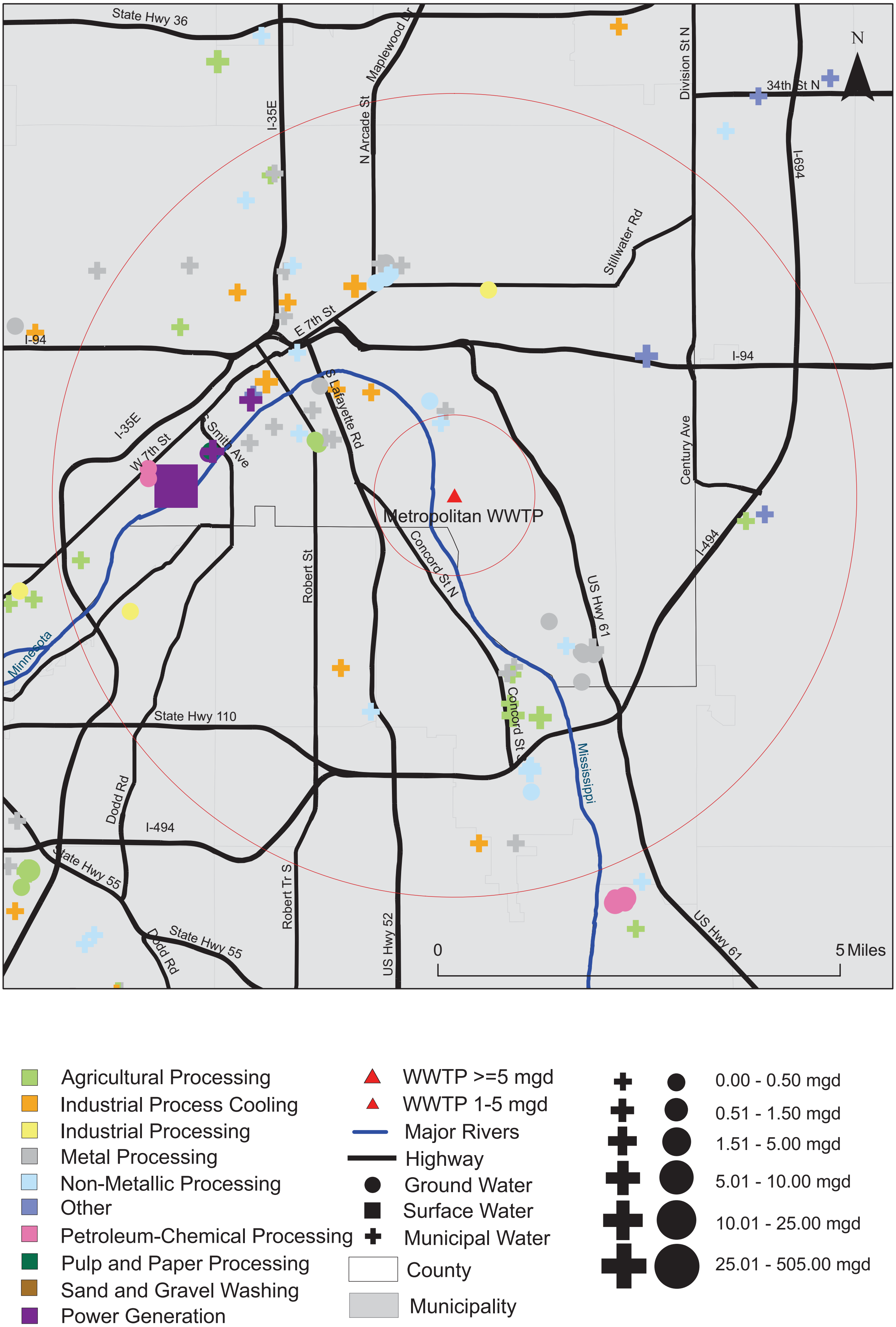
The largest WWTP in Minnesota, the 250 mgd Metropolitan (Metro) WWTP, has a diversity of industries within a 5-mile radius of the plant, as shown on Figure 3.23. A chemical company, Hawkins Chemical, with a demand of 0.1 mgd, is located within 1 mile of the plant. In the 5-mile zone around the plant, the industrial water demand is 0.96 mgd for nonpotable supply, and 17 mgd for combined municipal and nonpotable supplies. Table 3.21 lists these facilities and their industry type.

Figure 3.22. Rogers WWTP - Industries within 1 and 5 mile Radii



Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Figure 3.23. Metropolitan WWTP - Industries within 1 and 5 mile Radii



Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Table 3.21. Metropolitan WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
3M Co		M	Metal Processing	Metal Products
3M Co - 3M Center		M	Other	Research & Develop
3M Company	x	G	Non-Metallic Processing	
A W Beadblasting Co		M	Metal Processing	Metal Products
ADDCO Inc		M	Metal Processing	Metal Products
Americraft Carton Inc		M	Industrial Processing	Paper/Packaging
Anamax Corp (0273)		M+	Agricultural Processing	Food Products
Bix Produce Co		M	Agricultural Processing	Food Products
C & H Chemical Inc		M	Non-Metallic Processing	Chemical Products
Captain Kens Foods Inc	x	G	Agricultural Processing	
Canadian Pacific Railway		M+	Metal Processing	Transportation
Cemstone Products	x	G	Industrial Processing; Non-Metallic Processing	
Central Livestock Association		M+	Agricultural Processing	Food Products
D & D Land LLC	x	G	Non-Metallic Processing	
Dakota Premium Foods LLC		M	Agricultural Processing	Food Products
Dean Foods Woodbury		M	Agricultural Processing	Food Products
Diamond Products Co		M+	Non-Metallic Processing	Chemical Products
District Energy St Paul Inc		M	Other	Utilities-Steam&A
ECOLAB Inc	x	G	Industrial Processing	
Ecowater Corp		M	Other	Other
Fox Packaging Inc		M	Non-Metallic Processing	Chemical Products
G & K Services		M	Industrial Processing	Laundry
Gerdau Ameristeel US Inc - St		M&G	Metal Processing	Metal Products
Gopher State Ethanol LLC	x	G	Petroleum or Chemical Processing, Ethanol	
Gross-Given Mfg Co		M	Metal Processing	Metal Products
Hawkins Chemical Inc**		M	Non-Metallic Processing	Chemical Products
Health Systems Cooperative Lau		M	Industrial Processing	Laundry
IonBond Inc		M	Non-Metallic Processing	Chemical Products
J & L Wire Cloth Co Inc		M	Metal Processing	Metal Products
Metro Transit		M	Metal Processing	Transportation
Modernistic Inc		M	Industrial Processing	Printed Products
Molex Inc Copper Flex Products		M	Metal Processing	Metal Products
North Star Steel Minnesota	x	G	Metal Processing	
North Star Steel St Paul	x	G	Metal Processing	
Northern Malleable Iron Co	x	G	Metal Processing	
Northern Screw Machine Co		M	Metal Processing	Metal Products
NRG Energy Center Inc	x	G	Pulp and Paper Processing	
NSP CO DBA Xcel Energy	x	G, S	Steam Power - Other than Cooling; Steam Power Cooling - Once Through	
NSP, dba Xcel Energy (0576)		M&G	Power Generation	Utilities-Power
Old Home Foods Inc		M+	Agricultural Processing	Food Products
Rexam Beverage Can		M	Metal Processing	Metal Products

Table 3.21. Metropolitan WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Sexton Printing Inc		M	Industrial Processing	Printed Products
South St Paul Truck Wash		M	Metal Processing	Transportation
St Paul Cogeneration LLC		M&G	Power Generation	Utilities-Power
St Paul Pioneer Press Dispatch		M; M&G	Industrial Processing	Printed Products
Stock Yards Meat Packing Co		M	Agricultural Processing	Food Products
Summit Brewing Co		M	Agricultural Processing	Food Products
Travel Tags		M	Industrial Processing	Printed Products
Twin City Hide Inc (0048)		M	Non-Metallic Processing	Leather Products
Twin City Tanning Co (0784)		M	Non-Metallic Processing	Leather Products
Univar USA Inc		M	Non-Metallic Processing	Chemical Products
Upper River Services Inc		M+	Metal Processing	Transportation
Versa Iron & Machine		M&G	Metal Processing	Metal Products
Viking Drill & Tool Inc		M	Metal Processing	Metal Products
Waterous Co		M	Metal Processing	Metal Products
Wipaire Inc		M	Metal Processing	Metal Products

* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: M+: Municipal and Other Sources; S: Surface Water

** Industry located with 1 mile of the WWTP.

The Rosemount WWTP will be phased out by 2007, as the outfall from the expanded Empire WWTP is brought online. The information is still summarized because the outfall from Empire will be able to serve these areas with treated effluent when the facility is abandoned. There are four facilities within a 1-mile radius of Rosemount and five more within a five-mile radius. Municipal water demand was 0.07 and nonpotable water demand was 7.7 mgd in 2004. Figure 3.24 show these industries spatially and Table 3.22 lists the facilities and their industry type.

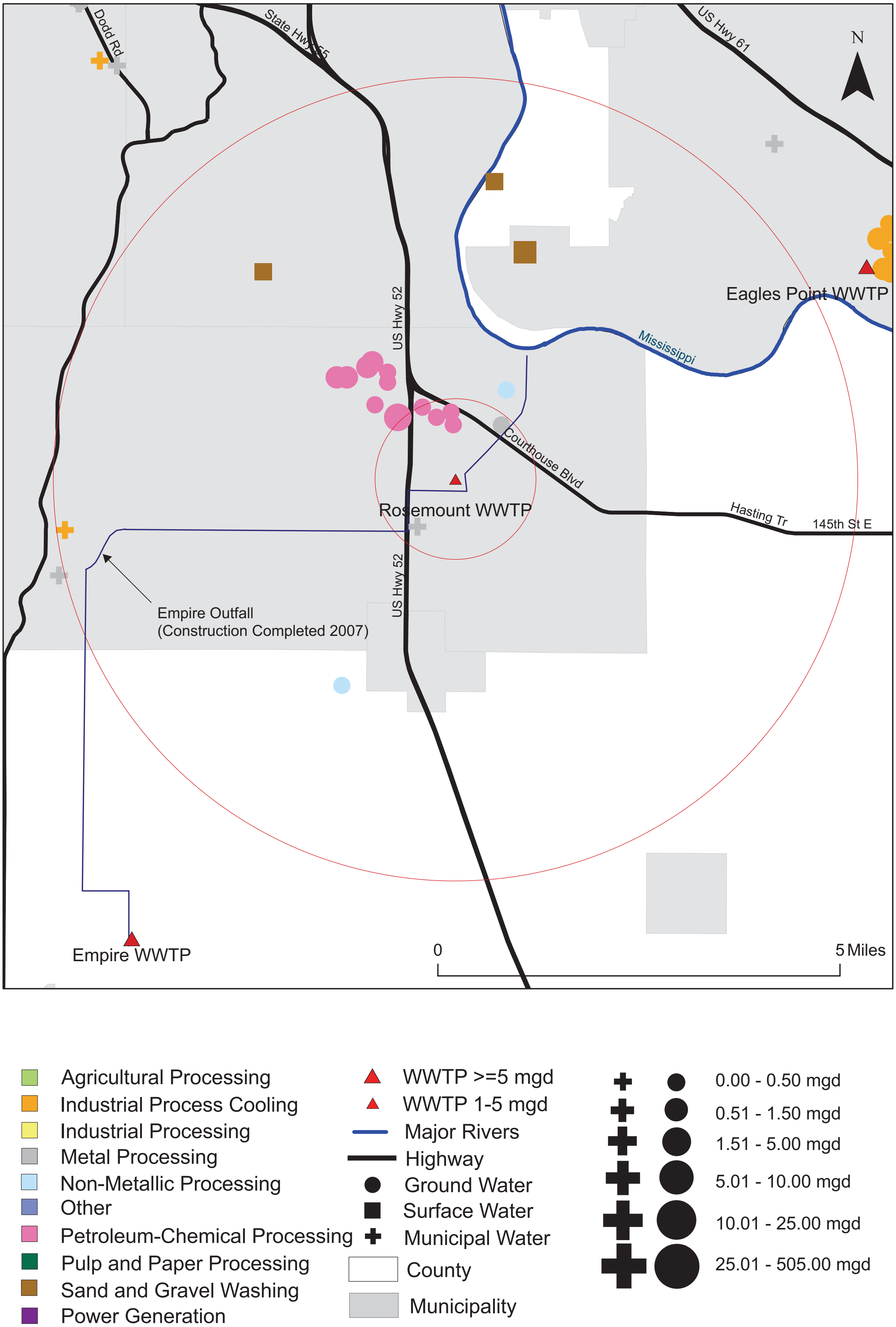
Table 3.22. Rosemount WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Aggregate Industries-NCR Inc	x	S	Sand & Gravel Washing	
Bituminous Roadways Inc	x	S	Sand & Gravel Washing	
Continental Nitrogen & Resources**	x	G	Petroleum or Chemical Processing, Ethanol	
CF Industries Inc	x	G	Non-Metallic Processing	
Flint Hills Resources LP**	x	G	Petroleum or Chemical Processing, Ethanol	
Greif Bros Corp		M	Industrial Processing	Paper/Packaging
NRG Processing Solutions LLC	x	G	Non-Metallic Processing	
Spectro Alloys Corp**	x	G	Metal Processing	
Wayne Transports Inc**		M&G	Metal Processing	Transportation

* M: Municipal; G: Ground Water; S: Surface Water

** Industry located with 1 mile of the WWTP.

Figure 3.24. Rosemount WWTP - Industries within 1 and 5 mile Radii



Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

As described previously in the Lower Mississippi River Watershed Inventory section, Flint Hills Resources is one of the high water demand industries in the watershed, withdrawing nearly 6 mgd in 2004, and previous discussions with Met Council on wastewater reuse opportunities have occurred. The industry with the next largest water use near Rosemount WWTP is Aggregate Industries, with a demand of 1.1 mgd.

The Eagles Point WWTP, which was expanded to 10 mgd in 2003, is situated near a 3M chemical facility which uses most of the 2.8 mgd ground water supply for industrial process cooling (once-through). Figure 3.25 shows the well field for 3M within the 1-mile radius and the other industries in the area. The other industries within a 5-mile radius of the plant used 1.13 mgd in 2004. Over 1 mgd of surface water was used by Aggregate Industries. Table 3.23 lists the industries.

Table 3.23. Eagles Point WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
3M Company**	x	G	Industrial Process Cooling Once Through	
Advance Corp #1258		M	Metal Processing	Metal Products
Aggregate Industries - NCR Inc	x	S	Sand & Gravel Washing	
CF Industries	x	G	Non-Metallic Processing	
HD Hudson Mfg Co		M	Metal Processing	Metal Products
LSP-Cottage Grove LP**	x	G	Power Generation	
Spectro Alloys Corp	x	G	Metal Processing	

* M: Municipal; S: Surface Water.; G: Ground Water
** Industry located with 1 mile of the WWTP

The Hastings WWTP has several industries within a 5-mile radius, as shown on Figure 3.26. There is a 0.05 mgd industrial water demand within 1 mile of the plant, for the facilities listed in Table 3.24. In a 5-mile zone, there are agricultural processing industries with a combined demand of 0.04 mgd and sand and gravel washing operations that rely primarily on surface water supplies.

The Empire WWTP was expanded from 9 mgd to 24 mgd and will have a new discharge to the Mississippi River in the vicinity of the one currently used by the Rosemount WWTP. Figure 3.27 identifies the industries near the plant and Table 3.25 lists those within a 5-mile radius. The outfall for the Empire WWTP to the Mississippi River is also shown on the figure. The list of industries in Table 3.25 is restricted to the radius around the plant, but could be broadened to include industries along the outfall, which would include those in the Rosemount WWTP proximity. The industry with the largest water demand near the Empire WWTP is Marigold Foods, which uses 0.32 mgd of ground water supplied by its own well field. Another Food Product industry, Kemps, has a demand of 0.25 mgd. The other industries in the area have a combined demand of 0.42 mgd.

Table 3.24. Hasting WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
3M Company	x	G	Industrial Process Cooling Once Through	
Aggregate Industries - NCR Inc	x	S	Sand & Gravel Washing	
Barton Sand & Gravel	x	S	Sand & Gravel Washing	
Con Agra Flour Milling Co	x	G	Agricultural Processing	
Hastings Coop Creamery		M	Agricultural Processing	Food Products
H D Hudson Mfg Co**		M	Metal Processing	Metal Products
Intek Plastics Inc**		M	Non-Metallic Processing	Chemical Products
LSP-Cottage Grove LP	x	G	Power Generation	
Intek Plastics Inc**		M	Non-Metallic Processing	Chemical Products

* M: Municipal; G: Ground Water; S: Surface Water.
** Industry located with 1 mile of the WWTP.

Table 3.25. Empire WWTP Industries Within a 5 Mile Radius

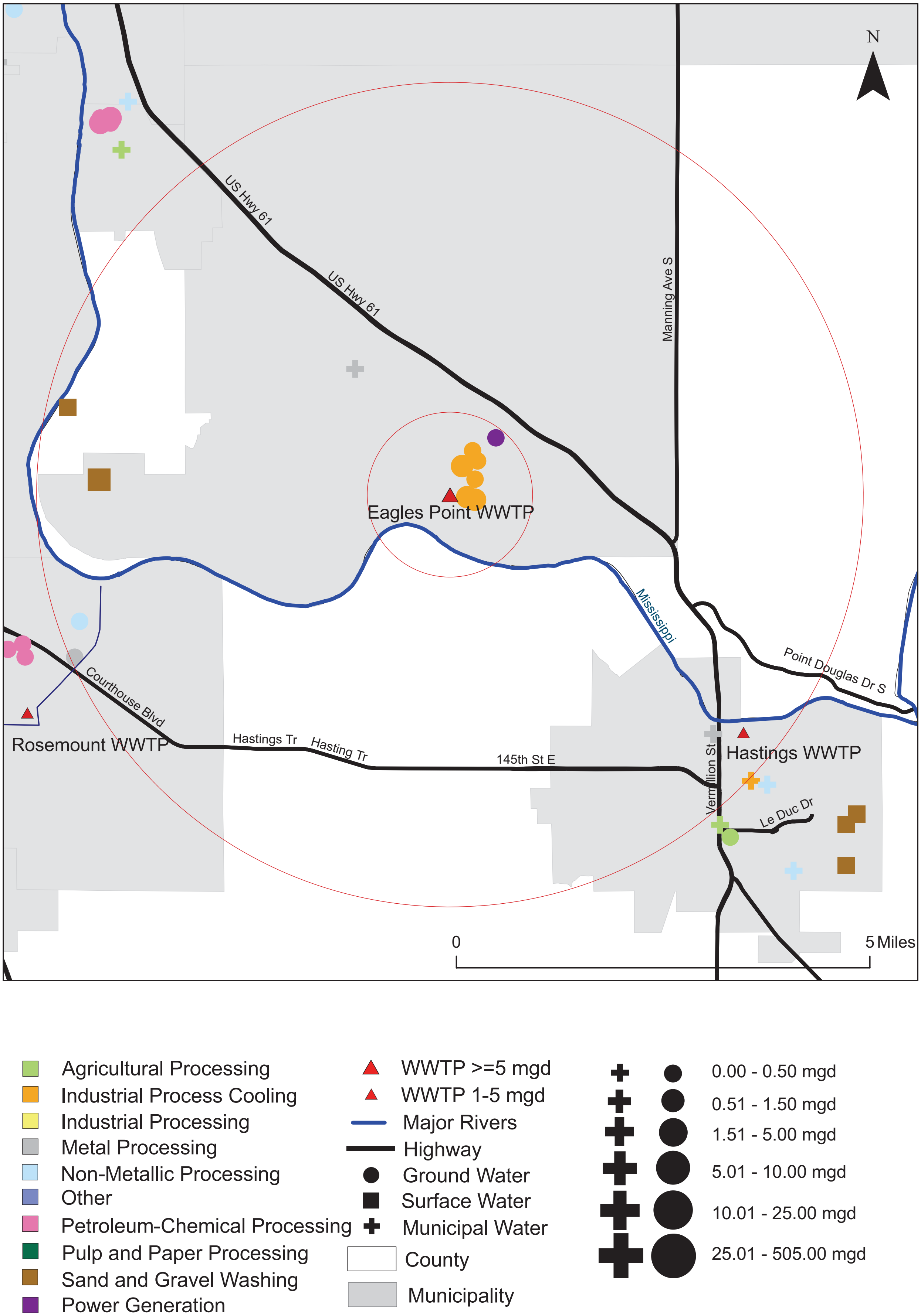
Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Aggregate Industries - NCR Inc	x	G; S	Non-Metallic Processing; Sand & Gravel Washing	
Cannon Equipment		M	Metal Processing	Metal Products
Cemstone Products	x	G	Sand & Gravel Washing	
J I T Powder Coating		M	Metal Processing	Metal Products
Kemps LLC		M&G	Agricultural Processing	Food Products
Marigold Foods Inc	x	G	Agricultural Processing	
NRG Processing Solutions LLC	x	G	Non-Metallic Processing	
Performance Industrial Coating		M	Metal Processing	Metal Products
Valmont/Lexington		M	Metal Processing	Metal Products

* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: S: Surface Water.

St. Croix River Watershed WWTP

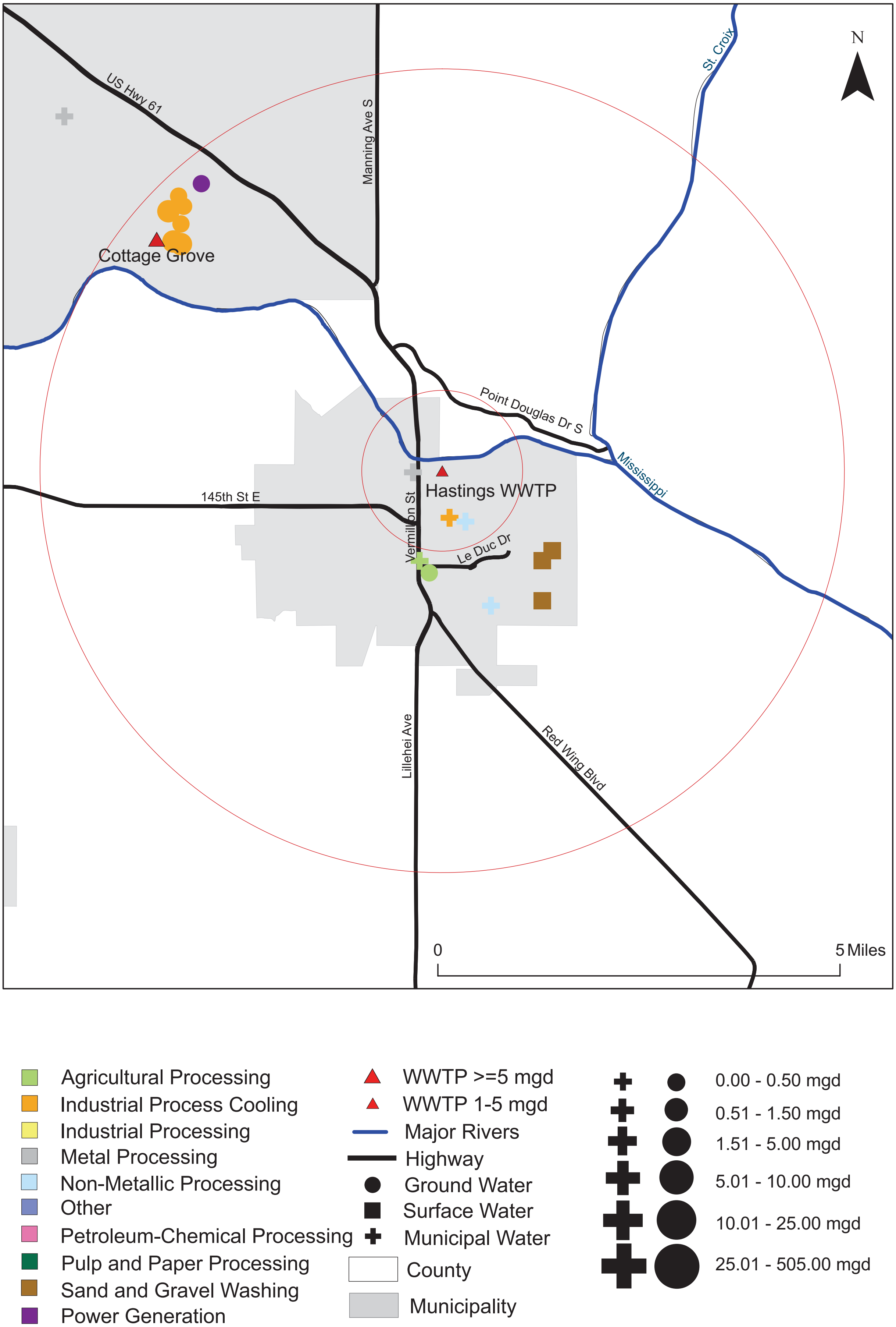
The only WWTP with a capacity greater than 1 mgd in the St. Croix River watershed, resident to the seven county metro area, is the Met Council St. Croix Valley WWTP. As shown on Figure 3.28, there are a few industries within 5 miles of this 5.8 mgd facility. Table 3.26 lists the four industries. As discussed under the Watershed Inventory subsection, the largest demand in the watershed is for cooling water for the Xcel Energy steam power plant. The Andersen Corporation has the next highest demand, using 0.5 mgd of nonpotable supply and 0.5 mgd of municipal supply for the needs at their facility. The other industries have a combined demand of 0.025 mgd.

Figure 3.25. Eagles Point WWTP - Industries within 1 and 5 mile Radii



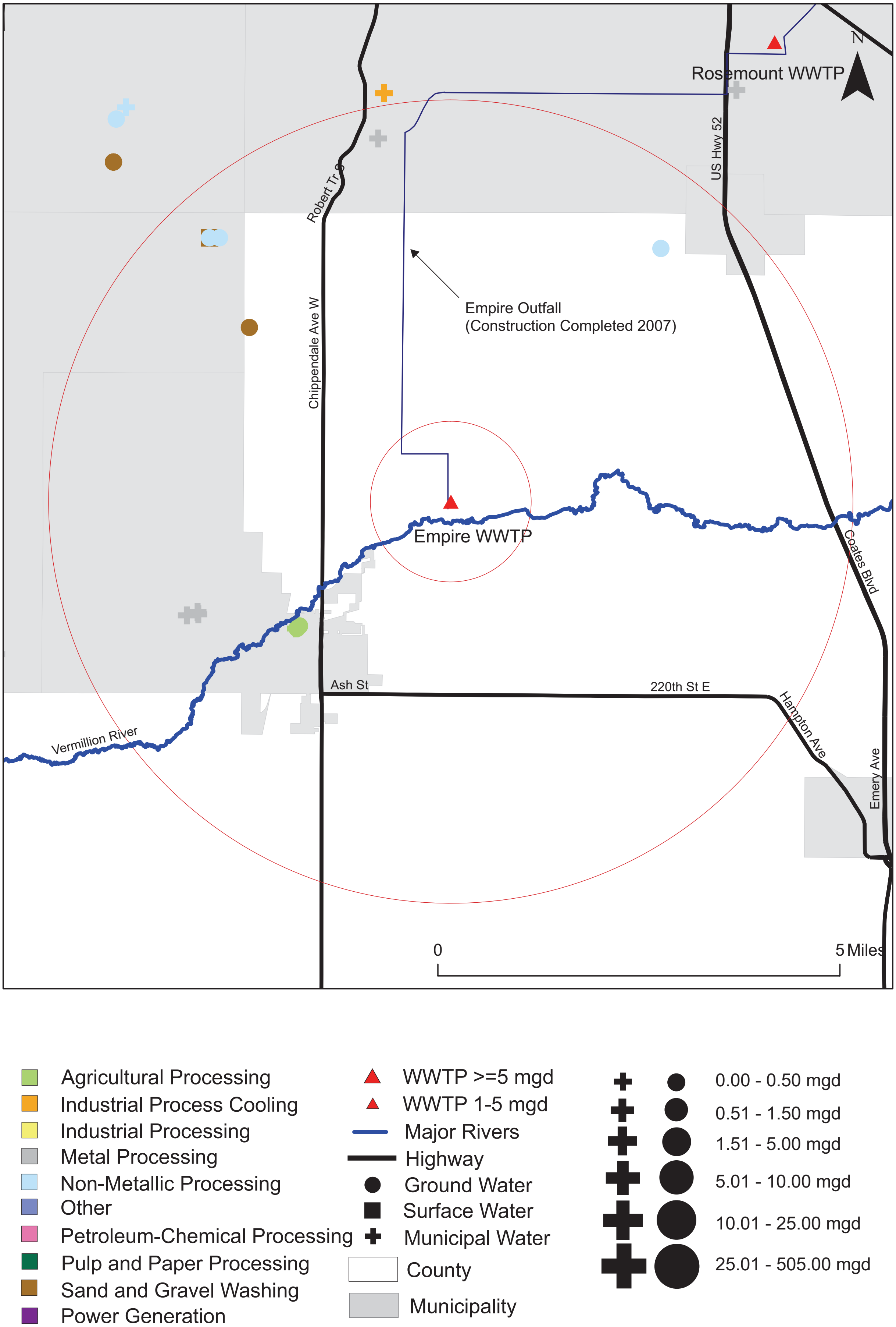
Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Figure 3.26. Hastings WWTP - Industries within 1 and 5 mile Radii



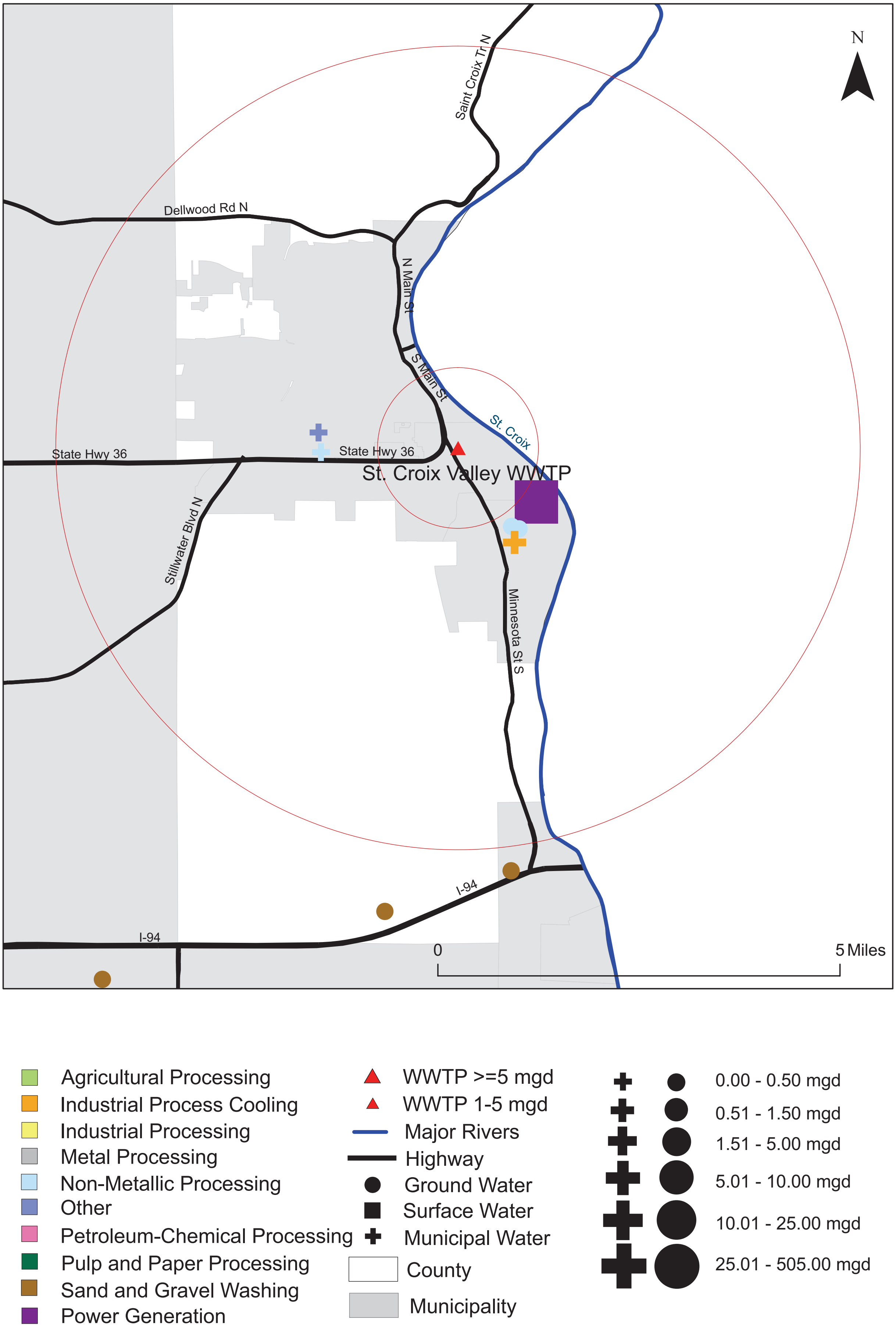
Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Figure 3.27. Empire WWTP - Industries within 1 and 5 mile Radii



Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Figure 3.28. St. Croix Valley WWTP - Industries within 1 and 5 mile Radii



Sources: Minnesota DNR Water Appropriation Permit Program, 2004 (Withdrawls greater than 1 mgy or 10,000 gpd)
Metropolitan Council Industrial Dischargers Permit Program, 2005

Table 3.26. St Croix Valley WWTP Industries Within a 5 Mile Radius

Industry Name	DNR Permit	Water Source*	Industry Category - DNR	MCES Business Category
Andersen Corporation**	x	M&G	Non-Metallic Processing	Building Materials
DiaSorin Inc**		M	Non-Metallic Processing	Medical Products
NSP CO DBA Xcel Energy	x	S	Steam Power - Other Than Cooling	
Sterling Water Inc dba Culliga		M	Other	Other

* M: Municipal; G: Ground Water; M & G: Municipal and Ground Water: S: Surface Water.
** Listed under Non-Metallic Processing for the industry code of the DNR database.

3.4 Inventory Summary

Ground Water Supply

The availability of higher quality ground water, typically sought first for municipal and industrial purposes, is a key factor in planning for growth in most of Minnesota. The summary of watershed inventories presented in Table 3.27 shows there are several areas of the state with limited ground water supplies. These areas are in the Des Moines River and Missouri River watersheds, in the southwest part of the state, northwestern Minnesota in parts of the Red River of the North watershed, and in the Rainy River and Western Lake Superior watersheds, in north central and northeastern Minnesota.

There are also community-specific water supply limitations in quality and quantity, as seen in the southwest and northwest metro areas, that are restricting withdrawals from certain aquifers. Ground water contamination is found throughout the state and certain aquifer characteristics make some aquifers a less reliable supply, as in the karst area of the Lower Mississippi River watershed. In general, the water quality of an area and susceptibility to contamination must be assessed on a site specific basis and is not a good indicator of regional water supply limitations.

Supply vs. Demand

The comparison of historic ground water use by industries and WWTP effluent discharge flows indicates that each watershed currently processes enough wastewater to supply these industrial needs, but as the spatial inventories demonstrated, the industries are not usually in proximity to WWTPs. The annual WWTP (greater than 1 mgd design capacity) discharges totaled 425 mgd, while total industrial water demand was 445 mgd (excludes power generation industry) and industrial ground water demand totaled 60 mgd.

The statewide assessment of industrial demand performed under this project includes only major users that have their own permitted water supply, based on a compilation of the DNR Appropriations Permit database. There are also industries that use significant quantities of water provided by a municipal water system and these industries are not captured in the inventory. The metro area analysis included industries that use a municipal (potable) water supply (only or in combination with a DNR permitted supply) and provided a more detailed categorization of industry types, based on a compilation of the Met Council's Industrial Discharger (User) database.

Table 3.27. Industrial Water Reuse Inventory Summary by Watershed

Watershed	Ground Water	Surface Water	Total	Total Without Power Facilities*	Larger WWTP Capacity (WWTPs > 1 mgd)	Smaller WWTP Capacity (WWTPs < 1 mgd)	Larger WWTP Discharge Flow, 2005	No. of Industry Categories with Water Permits	Ground Water Availability	Ground Water Contamination Susceptibility
	2004 Industrial Water Use, mgd				mgd	mgd	mgd	No.	✓=Favors Recycling	
Cedar River	4.1	0.1	4.1	4.1	26.9	2.6	9.7	4	No Factor	No Factor
Des Moines River	0.56	0.16	0.7	0.7	5.8	3.1	3.1	2	✓	No Factor
Lower Mississippi River	13.3	578.8	592.1	14.9	77.3	15.8	41.0	10	No Factor	✓
Minnesota River	17.3	327.7	345.0	19.0	123.5	22.4	73.4	10	No Factor	Potential Factor
Mississippi River-Headwaters	21.5	939.6	961.1	51.3	337.4	31.5	233.6	15	No Factor	No Factor
Missouri River	0	0.1	0.1	0.1	1.5	2.0	0.7	1	✓	No Factor
Rainy River	<0.1	46.9	46.9	46.92	3.8	3.3	2.0	3	✓	No Factor
Red River of the North	2.2	55.2	57.4	3.0	19.8	7.9	11.7	3	✓	No Factor
St. Croix River	0.9	325.7	326.6	1.3	5.8	5.2	3.9	3	No Factor	No Factor
Western Lake Superior	0.2	486.4	486.5	304.2	60.9	6.9	44.9	7	✓	No Factor
TOTAL	60	2,760	2,820	445	663	100	425			

* Excludes surface water uses for power generation facilities.

The Met Council database provided a single data source for a regional inventory of industries and their water demand. A more accurate method to identify potential industries for a specific WWTP is the analysis of water billing records, which typically provide enough detail to also assess any industrial seasonal water demands.

While the inventories performed on a state and watershed basis for this study do not include all potential industrial water users, they do provide an indication of the types of industries in the area and the types of industries that may be attracted to the area. If it is assumed that the degree of diversity of industries in the watersheds does not change (number of industry categories represented as listed in Table 3.27), then one would expect to see a similar diversity in the future. Diversity of industries is an indicator of areas that may be more advantageous for wastewater reuse. Given the capital and O&M costs associated with supplying reclaimed water, and that costs per gallon supplied typically decrease with increased supply, municipalities in areas with multiple industrial customers will be more likely to invest in facilities for wastewater reuse. If some industries have seasonal or weekly production schedules, the fluctuations can be dampened by having a more diverse set of customers.

As indicated in Table 3.27, the watersheds with the most diverse (therefore, potential) industrial reuse customers are the larger watersheds that have larger population centers. The diversity criterion is only an indicator and has limitations with the data set used in this study. Smaller communities may have other industries that are not captured by the DNR database.

Areas with industries that have the highest ground water use are possibly better candidates for water reuse, particularly if there are local supply issues. From Table 3.27, the watersheds with the greatest demand for ground water by major industries are also those with the greatest land area: Mississippi River-Headwaters, Minnesota River and Lower Mississippi River. These watersheds also have the largest reclaimed water supply. While these watersheds do not have regional water supply issues like those in the southwest and northeast of Minnesota, local issues and the proximity of a diversity of industries may provide a community-specific fit for use of reclaimed water by industries.

The other criterion used to assess areas that may favor water reuse by industries, was the WWTP location and capacity. The more industries closer to the plant, the more favorable a customer they are for reclaimed water. Capacity can be an indicator in its comparison to the current plant flow rates. Plants approaching capacity may be planning for expansion and any treatment modifications could roll in requirements for reclaimed water. Conversely, plants with excess capacity and limited growth potential in the area, may attract industry for its treatment capacity, and if supply is an issue, water reuse options could be explored. This criteria is not applicable on a broad watershed basis. However, specific WWTPs are noted in the watershed discussion on factors influencing potential for industrial reuse.

As discussed throughout this technical memorandum, the factors that promote and result in a water reuse application are very site specific. The inventory of industry water demand and WWTP supply has been evaluated with broad criteria in this document: ground water quality and quantity, pollutant discharge limitations for receiving streams, industry diversity, available supply to meet demand, and the WWTP capacity and location. Under Task 2 of the project, the evaluation of wastewater reuse opportunities in Minnesota will expand to consider treatment requirements, new facility construction, operation and maintenance needs, costs, and the range of issues associated with implementation of facilities and practices to use treated, municipal for beneficial uses.

3.5 References

Minnesota Department of Natural Resources (MDNR), 2004. Minnesota Water Appropriations Permit Program. Data summarized through 2004 were obtained from the MDNR website in March 2006. (This Technical Memorandum uses the 2004 annual volume reported to DNR, presented as the average annual water use in million gallons per day (mgd)). The Permit Information Report (MS Excel) was created 6/23/2005 and the ArcView shape files were created 12/19/2005.

Minnesota Department of Natural Resources (MDNR), 2005. *Where is Ground Water and Is it Available for Use?* MDNR Fact Sheet on Ground-Water Sustainability, 2 pages.

Minnesota Pollution Control Agency (MPCA), 2005. Minnesota Discharge Monitoring Report Data Summary. Data summarized for dischargers in 2003-2005 were obtained via CD from the MPCA in April 2006. (This Technical Memorandum uses the 2005 annual discharge volume reported to MPCA, presented as the average annual water discharged in million gallons per day (mgd)). The ArcView shape files were obtained from the MPCA website download link "MPCA Water Quality Monitoring Stations" at http://www.pca.state.mn.us/data/edaWater/index.cfm.

Minnesota Pollution Control Agency (MPCA), 1995. Regional Ground Water Profiles. Developed by the Interagency Ground Water Coordination Group. Available at: http://www.pca.state.mn.us/water/gwprofiles.html.

Minnesota Pollution Control Agency (MPCA), 1989. Statewide Evaluation of Ground Water Contamination Susceptibility. GIS files for map updated in 2005: metadata not complete for this publication.

Metropolitan Council, 2005. Metropolitan Council Industrial Dischargers Permit Program. Data summarized for dischargers to the Metropolitan Council sewer system, under the agency's Pretreatment Program, were obtained in May 2006. (This Technical Memorandum uses the 2005 annual volume of incoming water reported to Metropolitan Council, presented as the average annual water demand in million gallons per day (mgd)). The ArcView shape files were obtained from the Metropolitan Council website (2002) and updates provided by Metropolitan Council staff (May 2006).

Appendix A

DNR Appropriations Permit Data Analysis Documentation

Water Use Code Categories
Minnesota Department of Natural Resources Water Appropriations Permit Program

WATERWORKS
- 211 Municipal
- 212 Private waterworks
  (trailer courts, small housing units)
- 213 Commercial and Institutional
  (business, industry, hospital)
- 214 Cooperative waterworks
- 215 Fire protection
- 216 Campgrounds, waysides, highway rest areas
- 217 Rural Water Districts
- 219 Waterworks

POWER GENERATION
- 221 Hydropower
- 222 Steam power cooling-once through
- 223 Steam power cooling-wet tower
- 224 Steam power cooling-ponds
- 225 Steam power other than cooling
- 226 Nuclear power plant
- 229 Power generation

AIR CONDITIONING
- 231 Commercial building A/C
- 232 Institutions (school, hospital)
- 233 Heat pumps
- 234 Coolant pumps
- 235 District heating
- 239 Once-through heating or A/C
- 238 Air conditioning

INDUSTRIAL
- 241 Agricultural processing (food & livestock)
- 242 Pulp and paper processing
- 243 Mine processing (not sand & gravel washing)
- 244 Sand and gravel washing
- 245 Industrial process cooling once-through
- 246 Petroleum-chemical processing, ethanol
- 247 Metal processing
- 248 Non-metallic processing (rubber, plastic, glass)
- 249 Industrial processing

TEMPORARY
- 251 Construction (non-dewatering)
- 252 Construction (dewatering)
- 253 Pipeline & tank testing
- 254 Landscape watering
- 255 Pollution containment
- 256 Water level maintenance
- 257 Livestock waste treatment
- 258 Temporary ag irrigation
- 259 Temporary

Water Use Code Categories
Minnesota Department of Natural Resources Water Appropriations Permit Program

WATER LEVEL MAINTENANCE
- 261 Basin (lake) level
- 262 Mine dewatering
- 263 Quarry dewatering
- 264 Sand/gravel pit dewatering
- 265 Tile drainage and pumped sumps
- 266 Dewatering
- 269 Water level maintenance

SPECIAL CATEGORIES
- 271 Pollution containment
- 272 Aquaculture (hatcheries, fisheries)
- 273 Snow making
- 274 Peat fire control
- 275 Livestock watering
- 276 Pipeline and tank testing
- 277 Sewage treatment
- 279 Special Categories

NON-CROP IRRIGATION
- 281 Golf course
- 282 Cemetery
- 283 Landscaping
- 284 Sod farms
- 285 Nursery
- 286 Orchard
- 289 Non-crop irrigation

MAJOR CROP IRRIGATION
- 290 Major crop irrigation
- 296 Wild rice irrigation

Minnesota Water Use for All Categories, 2000-2004
Source: DNR Appropriations Permit Data

CATEGORY	CATEGORY CODE	Sum Of USE_2004 (MGY)	Sum Of USE_2004 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	2492.95	6.83	0.2
INDUSTRIAL PROCESSING	2	161205.9	441.66	11.8
MAJOR CROP IRRIGATION	3	73901.55	202.47	5.4
NON-CROP IRRIGATION	4	9431.6	25.84	0.7
POWER GENERATION	5	868251.05	2378.77	63.4
SPECIAL CATEGORIES	6	12165.45	33.33	0.9
TEMPORARY	7	1788.5	4.9	0.1
WATER LEVEL MAINTENANCE	8	36562.05	100.17	2.7
WATERWORKS	9	202888.9	555.86	14.8
Total			3749.8	

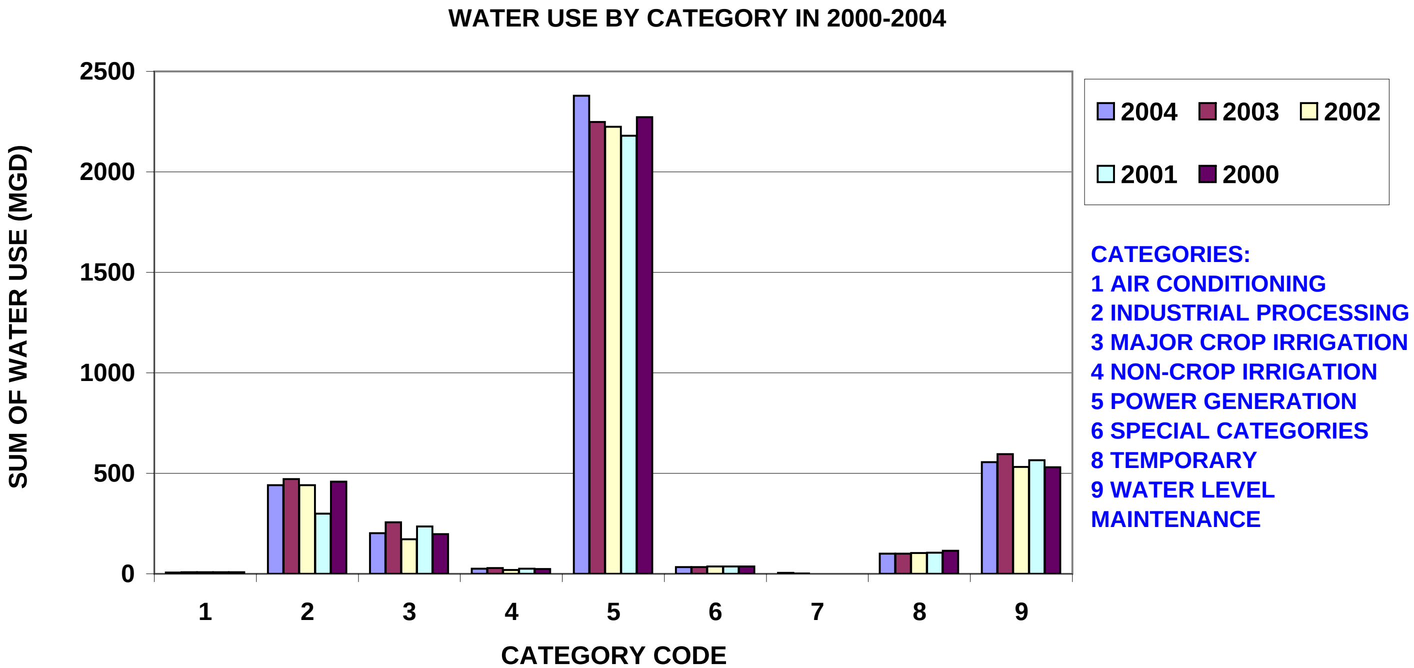
CATEGORY	CATEGORY CODE	Sum Of USE_2003 (MGY)	Sum Of USE_2003 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	2638.95	7.23	0.2
INDUSTRIAL PROCESSING	2	171874.85	470.89	12.6
MAJOR CROP IRRIGATION	3	93600.6	256.44	6.8
NON-CROP IRRIGATION	4	10694.5	29.3	0.8
POWER GENERATION	5	820720.75	2248.55	60.1
SPECIAL CATEGORIES	6	12234.8	33.52	0.9
TEMPORARY	7	719.05	1.97	0.1
WATER LEVEL MAINTENANCE	8	36729.95	100.63	2.7
WATERWORKS	9	217342.9	595.46	15.9
Total			3744.0	

CATEGORY	CATEGORY CODE	Sum Of USE_2002 (MGY)	Sum Of USE_2002 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3007.6	8.24	0.2
INDUSTRIAL PROCESSING	2	160928.5	440.9	12.5
MAJOR CROP IRRIGATION	3	62725.25	171.85	4.9
NON-CROP IRRIGATION	4	6880.25	18.85	0.5
POWER GENERATION	5	811836.65	2224.21	62.9
SPECIAL CATEGORIES	6	13129.05	35.97	1.0
TEMPORARY	7	25.55	0.07	0.0
WATER LEVEL MAINTENANCE	8	37638.8	103.12	2.9
WATERWORKS	9	194391.7	532.58	15.1
Total			3535.8	

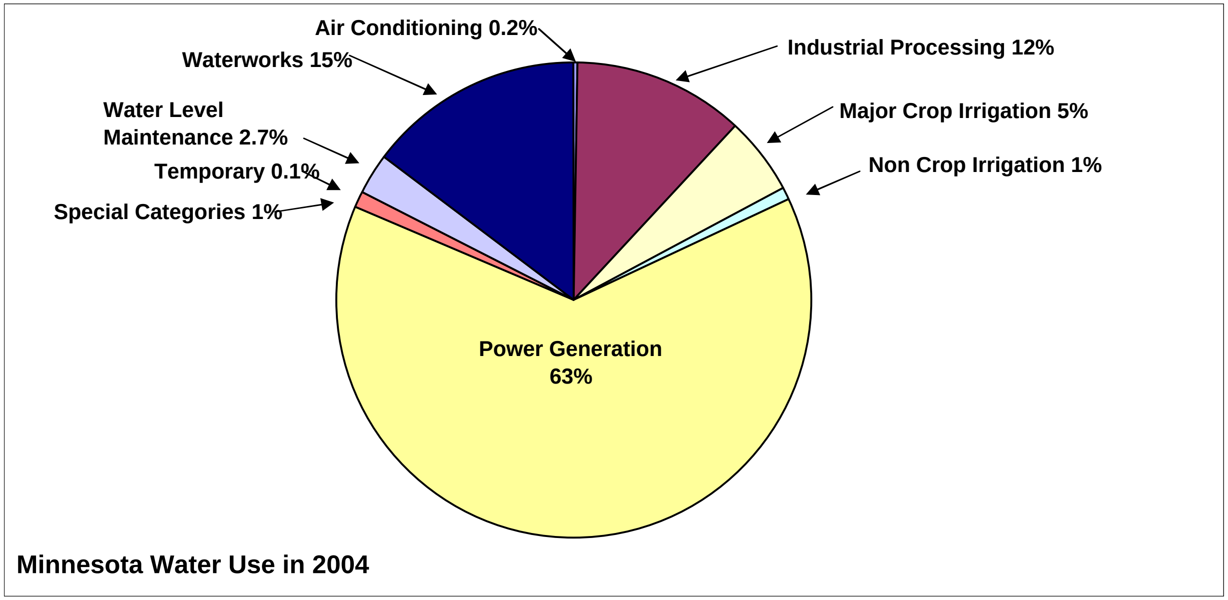
CATEGORY	CATEGORY CODE	Sum Of USE_2001 (MGY)	Sum Of USE_2001 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3179.15	8.71	0.3
INDUSTRIAL PROCESSING	2	109339.4	299.56	8.7
MAJOR CROP IRRIGATION	3	85997.65	235.61	6.8
NON-CROP IRRIGATION	4	9044.7	24.78	0.7
POWER GENERATION	5	795634.3	2179.82	63.1
SPECIAL CATEGORIES	6	13286	36.4	1.1
TEMPORARY	7	0	0	0.0
WATER LEVEL MAINTENANCE	8	38354.2	105.08	3.0
WATERWORKS	9	206590	566	16.4
Total			3456.0	

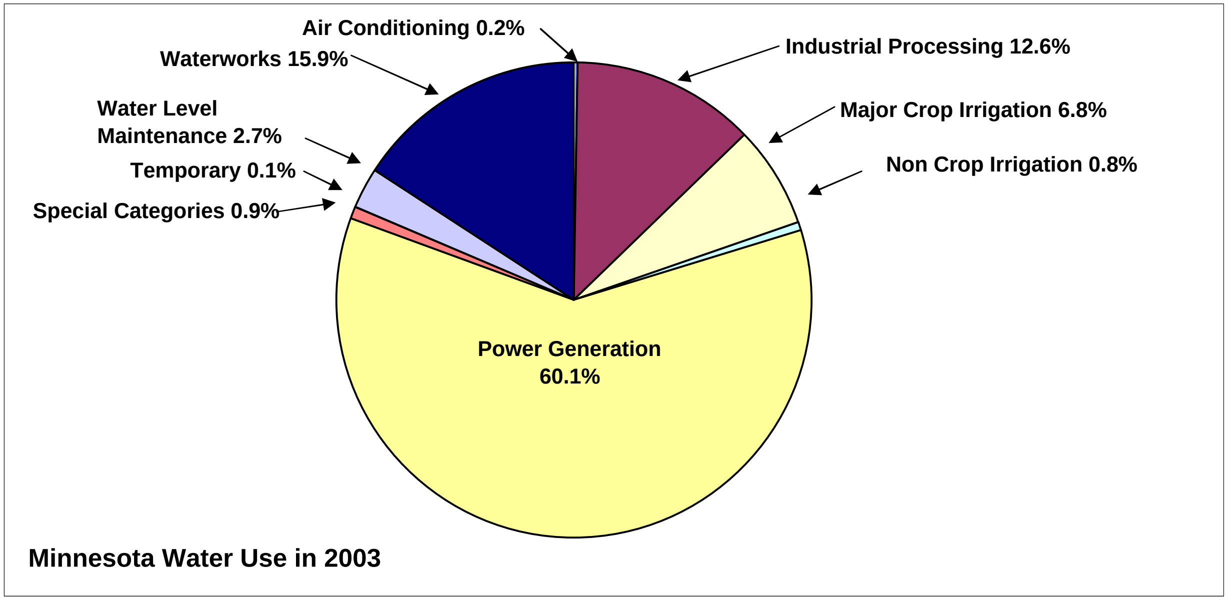
Minnesota Water Use for All Categories, 2000-2004
Source: DNR Appropriations Permit Data

CATEGORY	CATEGORY CODE	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3066	8.4	0.2
INDUSTRIAL PROCESSING	2	167556.9	459.06	12.6
MAJOR CROP IRRIGATION	3	72207.95	197.83	5.4
NON-CROP IRRIGATION	4	8519.1	23.34	0.6
POWER GENERATION	5	829250.8	2271.92	62.4
SPECIAL CATEGORIES	6	13245.85	36.29	1.0
TEMPORARY	7	0	0	0.0
WATER LEVEL MAINTENANCE	8	41737.75	114.35	3.1
WATERWORKS	9	193464.6	530.04	14.6
Total			3641.2	

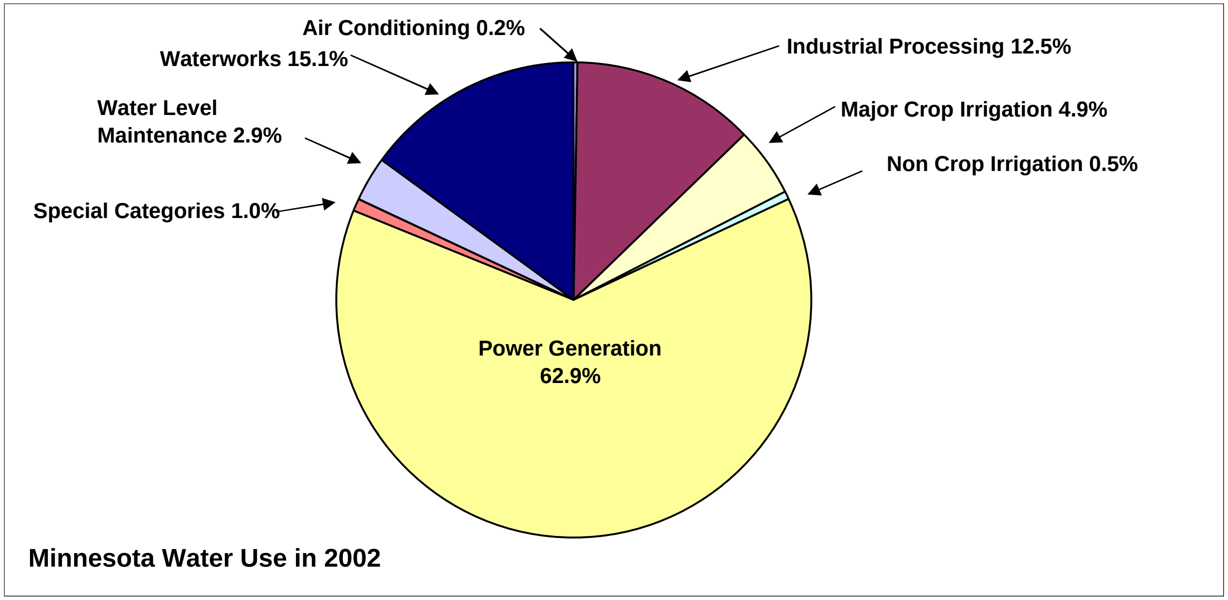


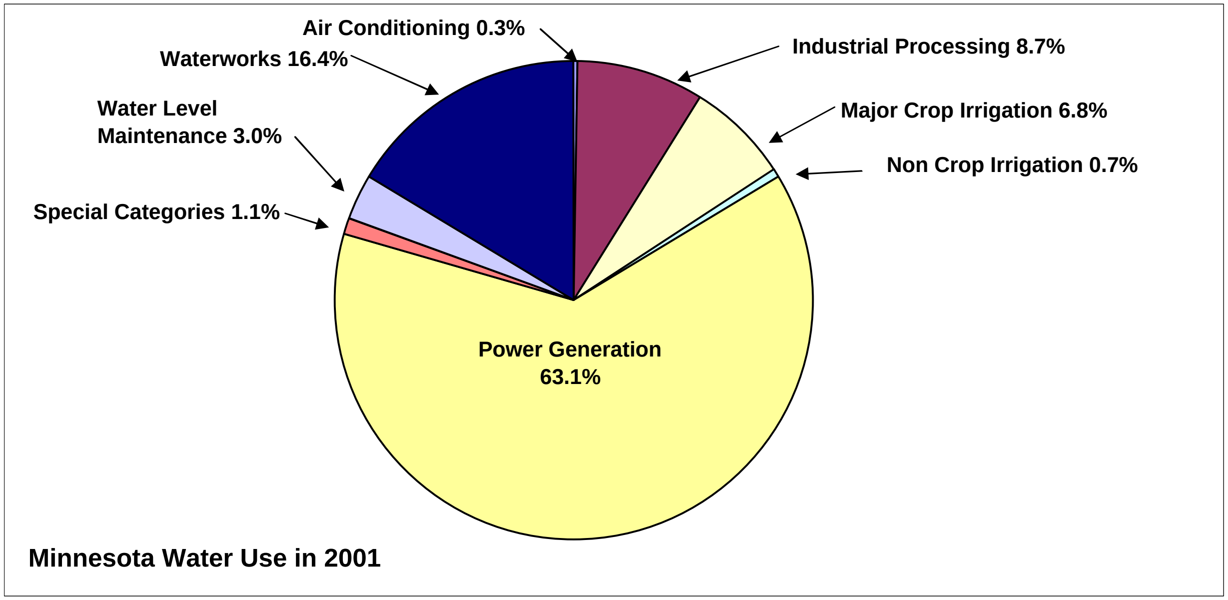
Minnesota Water Use for All Categories, 2000-2004
Source: DNR Appropriations Permit Data



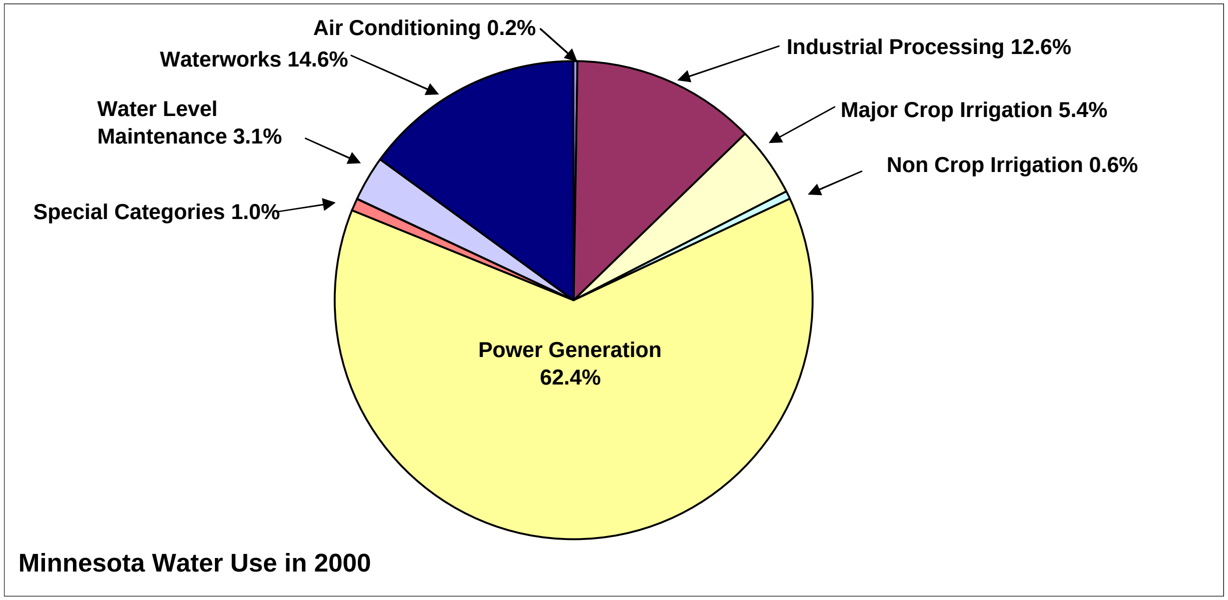


Minnesota Water Use for All Categories, 2000-2004
Source: DNR Appropriations Permit Data





Minnesota Water Use for All Categories, 2000-2004
Source: DNR Appropriations Permit Data



Minnesota Water Use, 2000-2004 - Statistics Without Power Generation
Source: DNR Appropriations Permit Data

CATEGORY	CATEGORY CODE	Sum Of USE_2004 (MGY)	Sum Of USE_2004 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	2492.95	6.83	0.5
INDUSTRIAL PROCESSING	2	161205.9	441.66	32.2
MAJOR CROP IRRIGATION	3	73901.55	202.47	14.8
NON-CROP IRRIGATION	4	9431.6	25.84	1.9
SPECIAL CATEGORIES	5	12165.45	33.33	2.4
TEMPORARY	6	1788.5	4.9	0.4
WATER LEVEL MAINTENANCE	7	36562.05	100.17	7.3
WATERWORKS	8	202888.9	555.86	40.5
POWER GENERATION	9	868251.05	2378.77	
Total Without Power Generation			1371.1	

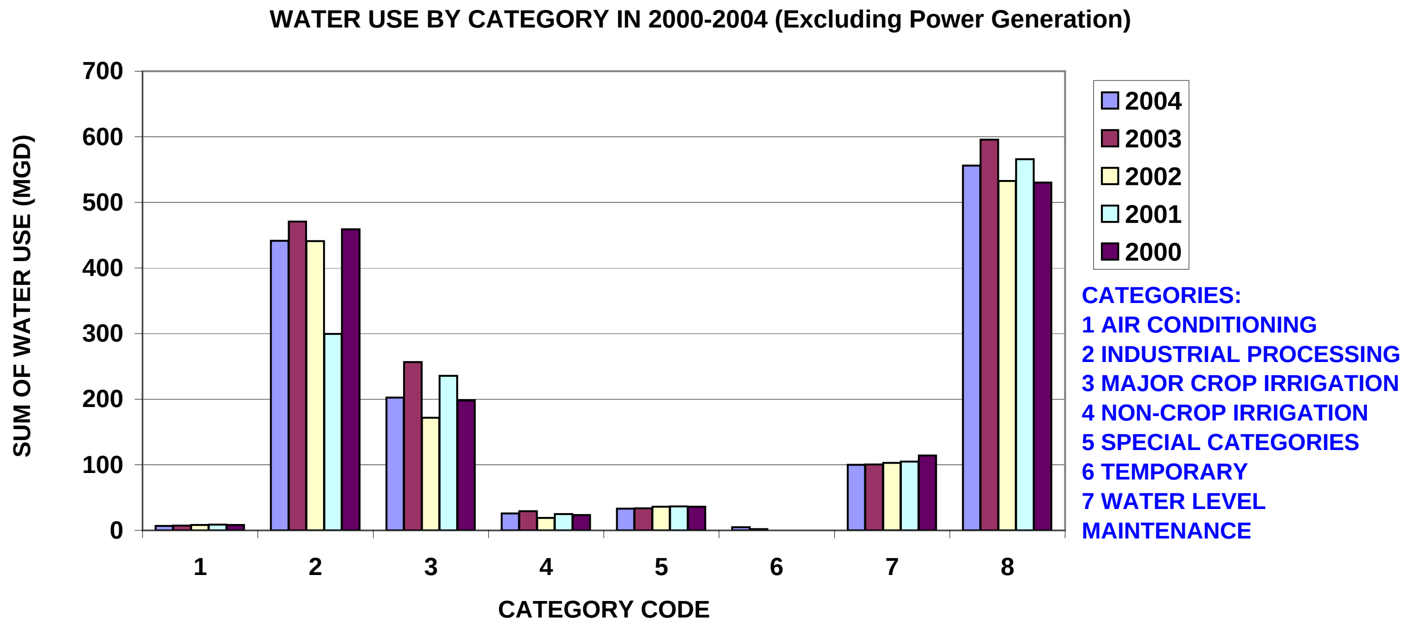
CATEGORY	CATEGORY CODE	Sum Of USE_2003 (MGY)	Sum Of USE_2003 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	2638.95	7.23	0.5
INDUSTRIAL PROCESSING	2	171874.85	470.89	31.5
MAJOR CROP IRRIGATION	3	93600.6	256.44	17.1
NON-CROP IRRIGATION	4	10694.5	29.3	2.0
SPECIAL CATEGORIES	6	12234.8	33.52	2.2
TEMPORARY	7	719.05	1.97	0.1
WATER LEVEL MAINTENANCE	8	36729.95	100.63	6.7
WATERWORKS	9	217342.9	595.46	39.8
POWER GENERATION	5	820720.75	2248.55	150.4
Total Without Power Generation			1495.4	

CATEGORY	CATEGORY CODE	Sum Of USE_2002 (MGY)	Sum Of USE_2002 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3007.6	8.24	0.6
INDUSTRIAL PROCESSING	2	160928.5	440.9	33.6
MAJOR CROP IRRIGATION	3	62725.25	171.85	13.1
NON-CROP IRRIGATION	4	6880.25	18.85	1.4
SPECIAL CATEGORIES	6	13129.05	35.97	2.7
TEMPORARY	7	25.55	0.07	0.01
WATER LEVEL MAINTENANCE	8	37638.8	103.12	7.9
WATERWORKS	9	194391.7	532.58	40.6
POWER GENERATION	5	811836.65	2224.21	169.6
Total Without Power Generation			1311.6	

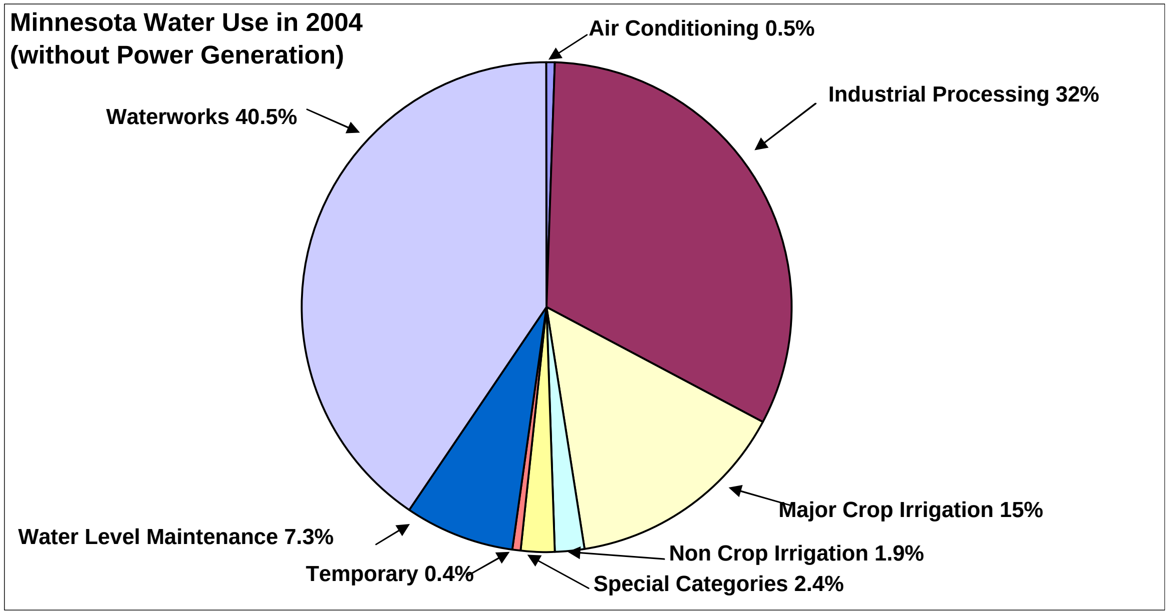
CATEGORY	CATEGORY CODE	Sum Of USE_2001 (MGY)	Sum Of USE_2001 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3179.15	8.71	0.7
INDUSTRIAL PROCESSING	2	109339.4	299.56	23.5
MAJOR CROP IRRIGATION	3	85997.65	235.61	18.5
NON-CROP IRRIGATION	4	9044.7	24.78	1.9
SPECIAL CATEGORIES	6	13286	36.4	2.9
TEMPORARY	7	0	0	0.0
WATER LEVEL MAINTENANCE	8	38354.2	105.08	8.2
WATERWORKS	9	206590	566	44.4
POWER GENERATION	5	795634.3	2179.82	170.8
Total Without Power Generation			1276.1	

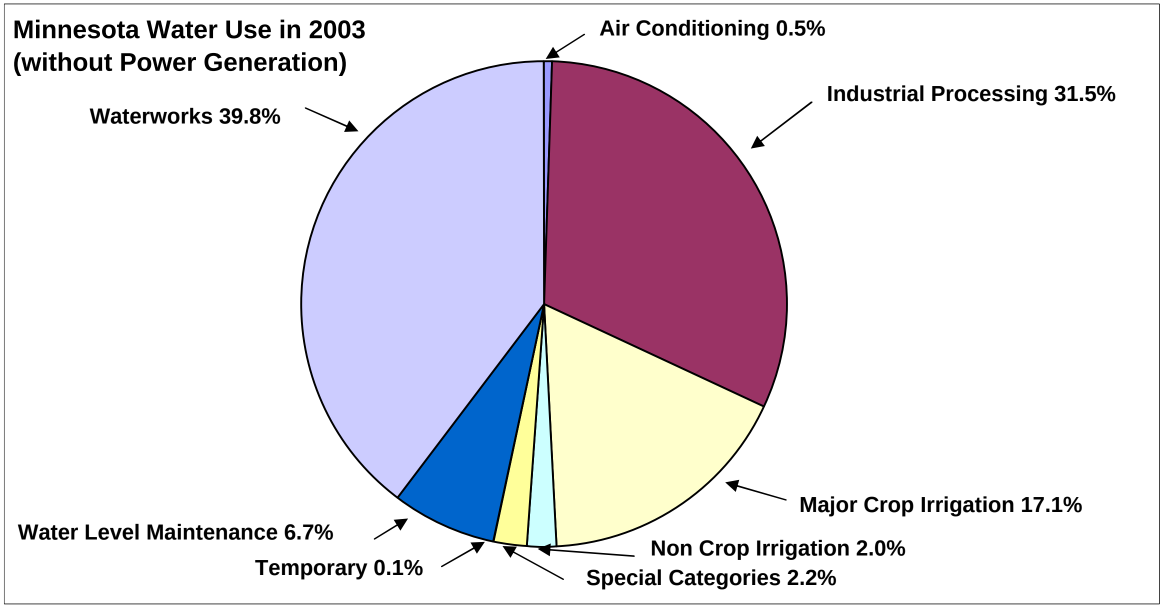
Minnesota Water Use, 2000-2004 - Statistics Without Power Generation
Source: DNR Appropriations Permit Data

CATEGORY	CATEGORY CODE	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of the Total Water Use
AIR CONDITIONING	1	3066	8.4	0.6
INDUSTRIAL PROCESSING	2	167556.9	459.06	33.5
MAJOR CROP IRRIGATION	3	72207.95	197.83	14.4
NON-CROP IRRIGATION	4	8519.1	23.34	1.7
SPECIAL CATEGORIES	6	13245.85	36.29	2.7
TEMPORARY	7	0	0	0.0
WATER LEVEL MAINTENANCE	8	41737.75	114.35	8.4
WATERWORKS	9	193464.6	530.04	38.7
POWER GENERATION	5	829250.8	2271.92	165.9
Total Without Power Generation			1369.3	

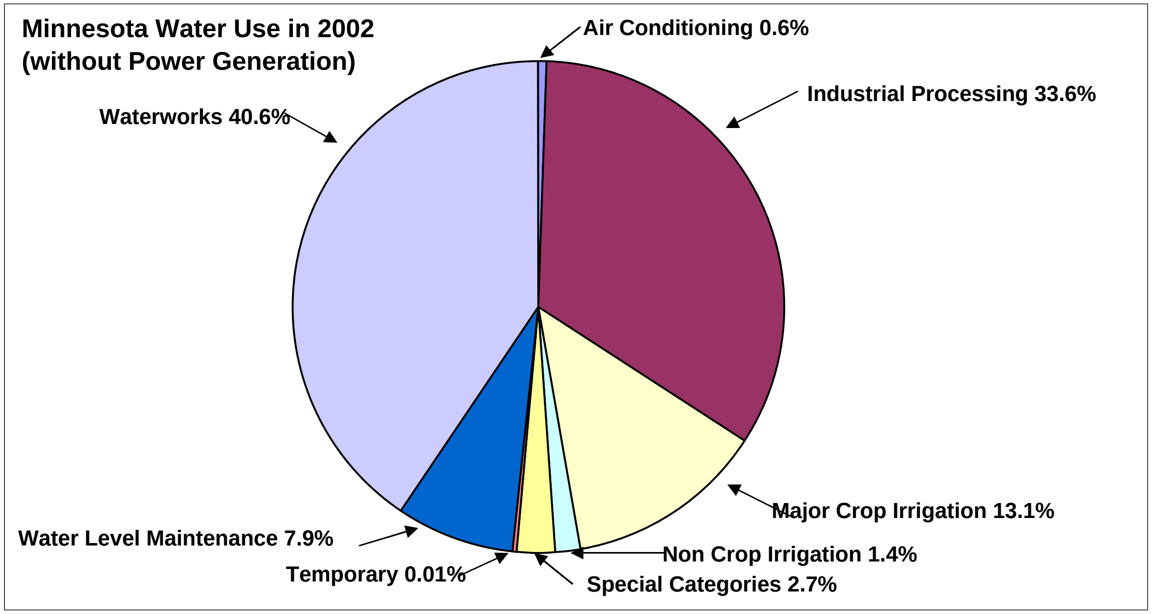


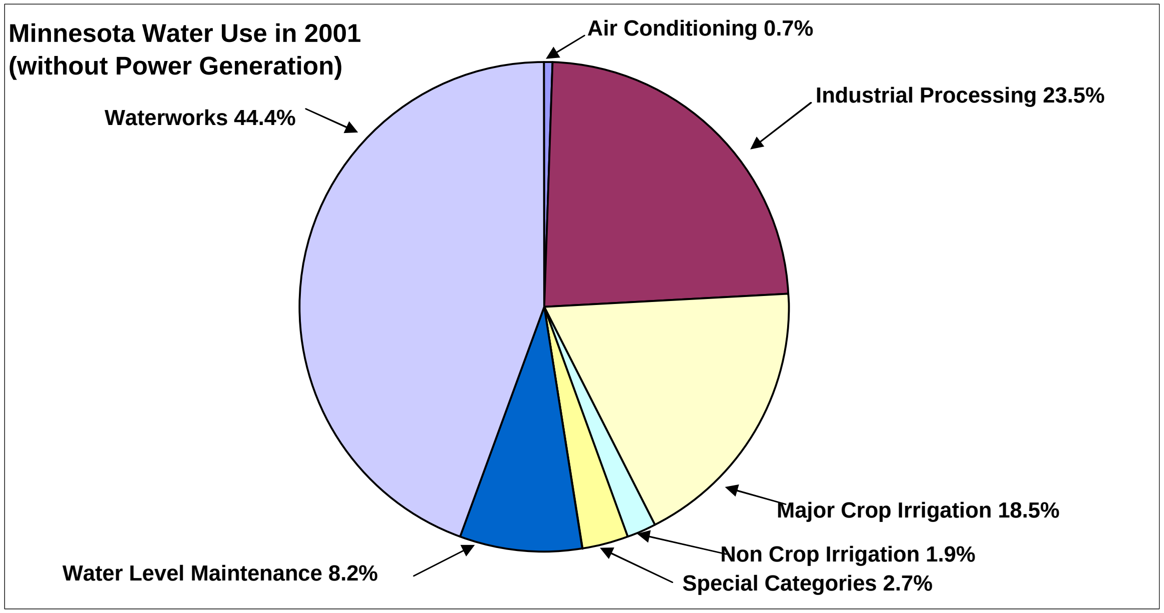
Minnesota Water Use, 2000-2004 - Statistics Without Power Generation
Source: DNR Appropriations Permit Data



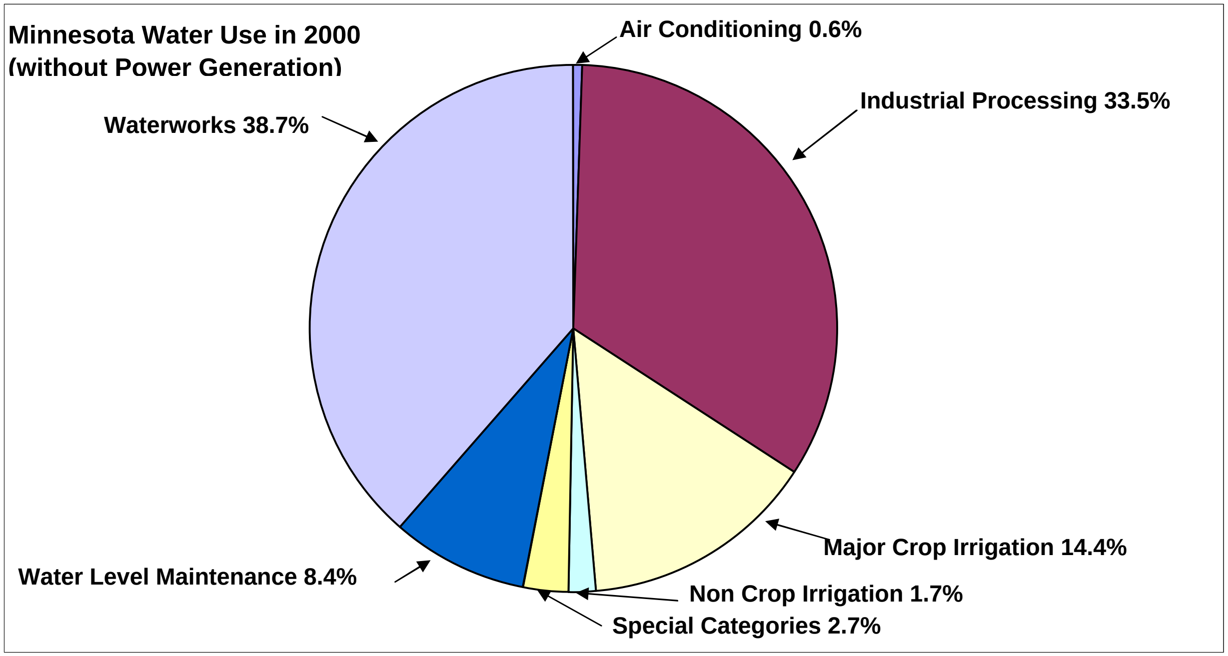


Minnesota Water Use, 2000-2004 - Statistics Without Power Generation
Source: DNR Appropriations Permit Data





Minnesota Water Use, 2000-2004 - Statistics Without Power Generation
Source: DNR Appropriations Permit Data



Minnesota Power Generation Facilities Water Use, 2000-2004

CATEGORY	USE_CODE	Sum Of USE_2004 (MGY)	Sum Of USE_2004 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
POWER GENERATION	221	43.8	0.1	0.0	0	0.12	0.0	43.8
POWER GENERATION	222	430353.25	1179.1	49.6	0.3	1178.75	109.5	430243.8
POWER GENERATION	223	7099.25	19.5	0.8	0.98	18.47	357.7	6741.6
POWER GENERATION	225	119249.15	326.7	13.7	1.36	325.35	496.4	118752.8
POWER GENERATION	226	311191.7	852.6	35.8	0.14	852.44	51.1	311140.6
POWER GENERATION	229	313.9	0.9	0.0	0.85	0.01	310.3	3.7
total		868207.25	2378.7	100.0	3.6	2375.0		

CATEGORY	USE_CODE	Sum Of USE_2003 (MGY)	Sum Of USE_2003 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
POWER GENERATION	221	47.45	0.1	0.0	0	0.13	0.0	47.5
POWER GENERATION	222	402481.85	1102.7	49.0	0.43	1102.26	157.0	402324.9
POWER GENERATION	223	7537.25	20.7	0.9	1.06	19.59	386.9	7150.4
POWER GENERATION	225	101199.9	277.3	12.3	1.22	276.04	445.3	100754.6
POWER GENERATION	226	309049.15	846.7	37.7	0.11	846.6	40.2	309009.0
POWER GENERATION	229	405.15	1.1	0.0	1.1	0.01	401.5	3.7
total		820673.3	2248.4					

CATEGORY	USE_CODE	Sum Of USE_2002 (MGY)	Sum Of USE_2002 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
POWER GENERATION	221	10.95	0.0	0.0	0	0.03	0.0	11.0
POWER GENERATION	222	377691.05	1034.8	46.5	0.31	1034.46	113.2	377577.9
POWER GENERATION	223	8037.3	22.0	1.0	0.92	21.1	335.8	7701.5
POWER GENERATION	225	100192.5	274.5	12.3	1.17	273.33	427.1	99765.5
POWER GENERATION	226	325463.2	891.7	40.1	0.11	891.57	40.2	325423.1
POWER GENERATION	229	441.65	1.2	0.1	1.21	0	441.7	0.0
total		811825.7	2224.2					

CATEGORY	USE_CODE	Sum Of USE_2001 (MGY)	Sum Of USE_2001 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
POWER GENERATION	221	0	0.0	0.0	0	0	0.0	0.0
POWER GENERATION	222	375548.5	1028.9	47.2	0.33	1028.57	120.5	375428.1
POWER GENERATION	223	7774.5	21.3	1.0	1.09	20.21	397.9	7376.7
POWER GENERATION	225	98845.65	270.8	12.4	1.09	269.72	397.9	98447.8
POWER GENERATION	226	313078.75	857.8	39.3	0.12	857.63	43.8	313035.0
POWER GENERATION	229	386.9	1.1	0.0	1.05	0.01	383.3	3.7
total		795634.3	2179.8					

CATEGORY	USE_CODE	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
POWER GENERATION	221	0	0.0	0.0	0	0	0.0	0.0
POWER GENERATION	222	385578.7	1056.4	46.5	0.5	1055.88	182.5	385396.2
POWER GENERATION	223	8365.8	22.9	1.0	1.41	21.51	514.7	7851.2
POWER GENERATION	225	105981.4	290.4	12.8	1.03	289.33	376.0	105605.5
POWER GENERATION	226	328927.05	901.2	39.7	0.11	901.06	40.2	328886.9
POWER GENERATION	229	397.85	1.1	0.0	1.09	0	397.9	0.0
total		829250.8	2271.9					

Minnesota Power Generation Facilities Water Use, 2000-2004

UseCode by Year

Power Generation UseCode 222	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
222	2004	430353.25	1179.1	49.6	0.3	1178.75	109.5	430243.8
222	2003	402481.85	1102.7	49.0	0.43	1102.26	156.95	402324.9
222	2002	377691.05	1034.8	46.5	0.31	1034.46	113.15	377577.9
222	2001	375548.5	1028.9	47.2	0.33	1028.57	120.45	375428.1
222	2000	385578.7	1056.4	46.5	0.5	1055.88	182.5	385396.2

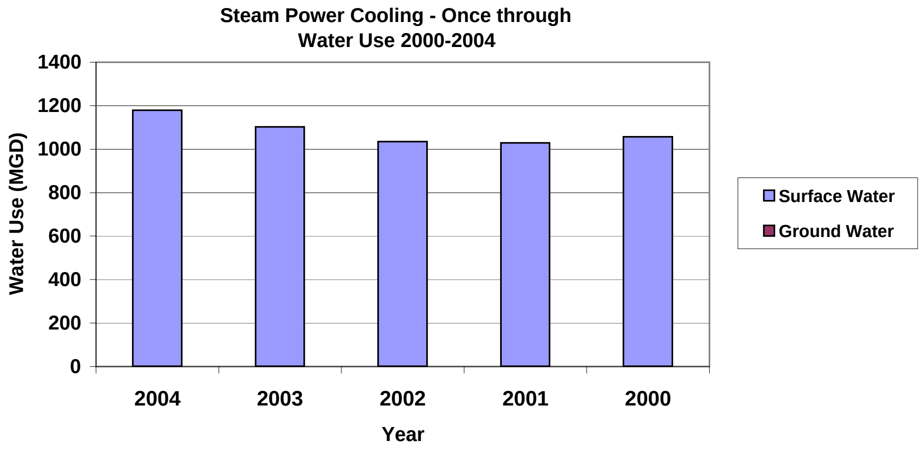
Power Generation UseCode 223	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
223	2004	7099.25	19.45	0.8	0.98	18.47	357.7	6741.55
223	2003	7537.25	20.65	0.9	1.06	19.59	386.9	7150.35
223	2002	8037.3	22.02	1.0	0.92	21.1	335.8	7701.5
223	2001	7774.5	21.3	1.0	1.09	20.21	397.85	7376.65
223	2000	8365.8	22.92	1.0	1.41	21.51	514.65	7851.15

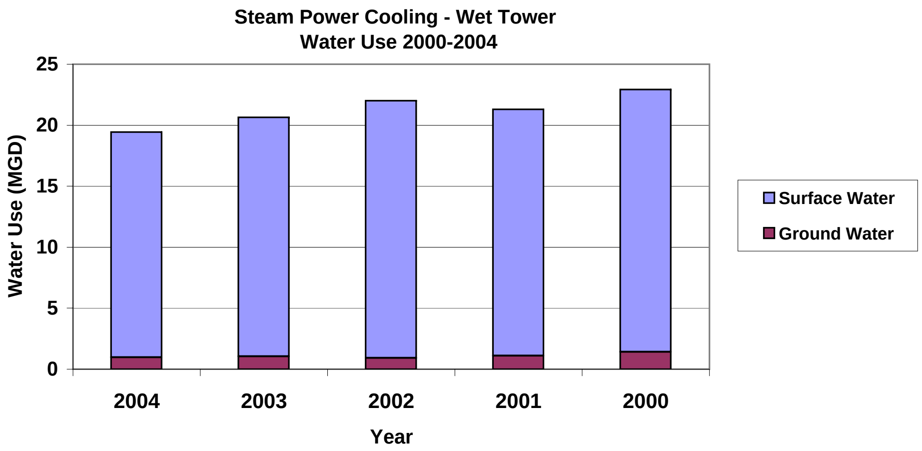
Power Generation UseCode 225	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
225	2004	119249.15	326.71	13.7	1.36	325.35	496.4	118752.8
225	2003	101199.9	277.26	12.3	1.22	276.04	445.3	100754.6
225	2002	100192.5	274.5	12.3	1.17	273.33	427.05	99765.45
225	2001	98845.65	270.81	12.4	1.09	269.72	397.85	98447.8
225	2000	105981.4	290.36	12.8	1.03	289.33	375.95	105605.5

Power Generation UseCode 226	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
226	2004	311191.7	852.58	35.8	0.14	852.44	51.1	311140.6
226	2003	309049.15	846.71	37.7	0.11	846.6	40.15	309009
226	2002	325463.2	891.68	40.1	0.11	891.57	40.15	325423.1
226	2001	313078.75	857.75	39.3	0.12	857.63	43.8	313035
226	2000	328927.05	901.17	39.7	0.11	901.06	40.15	328886.9

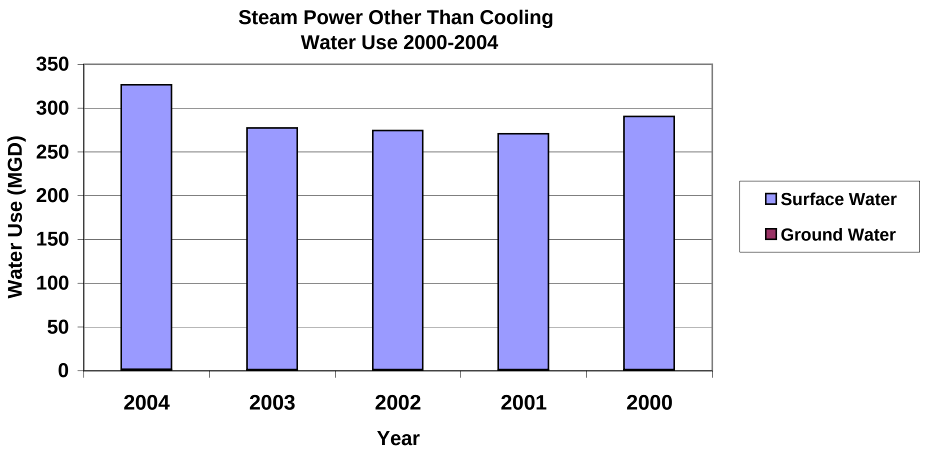
Power Generation UseCode 229	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
229	2004	313.9	0.86	0.0	0.85	0.01	310.25	3.65
229	2003	405.15	1.11	0.0	1.1	0.01	401.5	3.65
229	2002	441.65	1.21	0.1	1.21	0	441.65	0
229	2001	386.9	1.06	0.0	1.05	0.01	383.25	3.65
229	2000	397.85	1.09	0.0	1.09	0	397.85	0

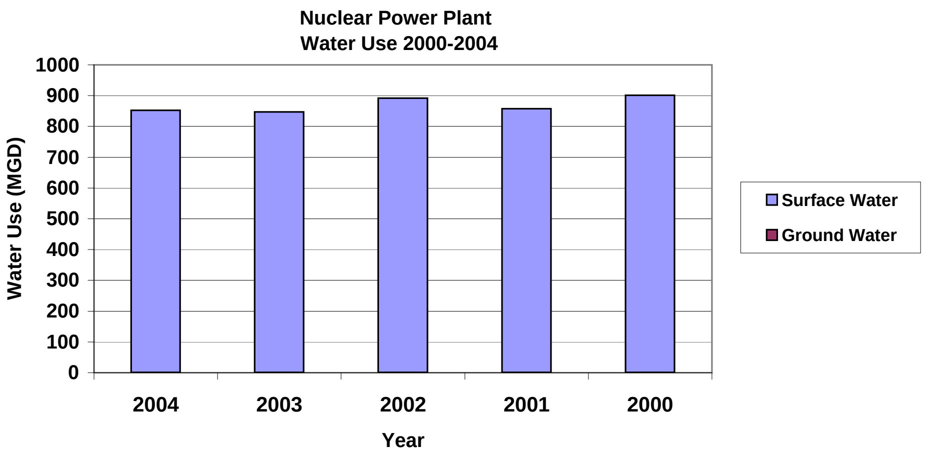
Minnesota Power Generation Facilities Water Use, 2000-2004



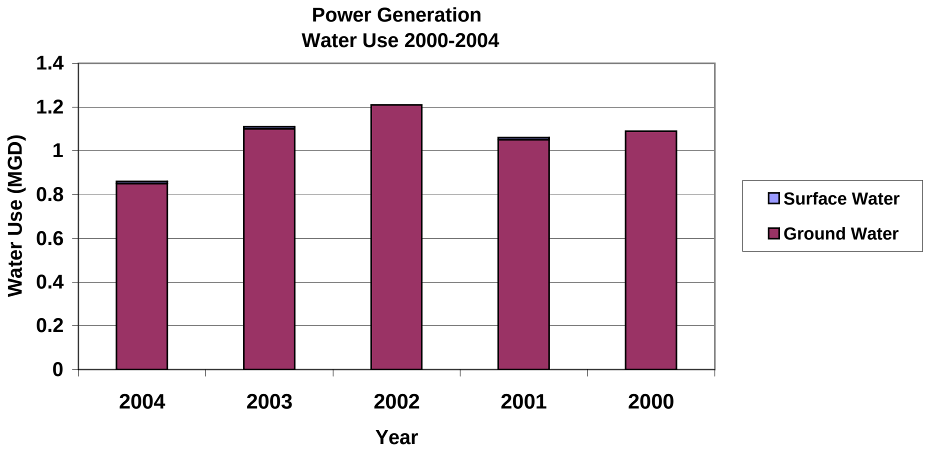


Minnesota Power Generation Facilities Water Use, 2000-2004





Minnesota Power Generation Facilities Water Use, 2000-2004



Minnesota Industrial Processing Facility Water Use, 2000-2004

CATEGORY	USE_CODE	Sum Of USE_2004 (MGY)	Sum Of USE_2004 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
INDUSTRIAL PROCESSING	241	9216.25	25.3	5.7	25.2	0.1	9183.4	32.9
INDUSTRIAL PROCESSING	242	30149	82.6	18.7	2.3	80.3	835.9	29313.2
INDUSTRIAL PROCESSING	243	108401.35	297.0	67.2	0.5	296.5	164.3	108237.1
INDUSTRIAL PROCESSING	244	4113.55	11.3	2.6	3.8	7.5	1387.0	2726.6
INDUSTRIAL PROCESSING	245	2314.1	6.3	1.4	5.8	0.5	2124.3	189.8
INDUSTRIAL PROCESSING	246	4131.8	11.3	2.6	10.9	0.4	3974.9	157.0
INDUSTRIAL PROCESSING	247	1412.55	3.9	0.9	3.9	0.0	1412.6	0.0
INDUSTRIAL PROCESSING	248	1087.7	3.0	0.7	3.0	0.0	1087.7	0.0
INDUSTRIAL PROCESSING	249	379.6	1.0	0.2	1.0	0.0	379.6	0.0
total		161205.9	441.7		56.3	385.4	20549.5	140656.4

CATEGORY	USE_CODE	Sum Of USE_2003 (MGY)	Sum Of USE_2003 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
INDUSTRIAL PROCESSING	241	8665.1	23.7	5.0	23.56	0.18	8599.4	65.7
INDUSTRIAL PROCESSING	242	29798.6	81.6	17.3	2.39	79.25	872.4	28926.3
INDUSTRIAL PROCESSING	243	119665.25	327.9	69.6	0.39	327.46	142.4	119522.9
INDUSTRIAL PROCESSING	244	3876.3	10.6	2.3	3.12	7.50	1138.8	2737.5
INDUSTRIAL PROCESSING	245	2153.5	5.9	1.3	5.30	0.60	1934.5	219.0
INDUSTRIAL PROCESSING	246	4657.4	12.8	2.7	12.05	0.71	4398.3	259.2
INDUSTRIAL PROCESSING	247	1445.4	4.0	0.8	3.96	0.00	1445.4	0.0
INDUSTRIAL PROCESSING	248	1233.7	3.4	0.7	3.38	0.00	1233.7	0.0
INDUSTRIAL PROCESSING	249	379.6	1.0	0.2	1.04	0.00	379.6	0.0
total		171874.85	470.9		55.2	415.7	20144.4	151730.5

CATEGORY	USE_CODE	Sum Of USE_2002 (MGY)	Sum Of USE_2002 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
INDUSTRIAL PROCESSING	241	8581.15	23.5	5.3	23.48	0.03	8570.2	11.0
INDUSTRIAL PROCESSING	242	32036.05	87.8	19.9	2.83	84.94	1033.0	31003.1
INDUSTRIAL PROCESSING	243	106711.4	292.4	66.3	0.27	292.09	98.6	106612.9
INDUSTRIAL PROCESSING	244	3770.45	10.3	2.3	2.61	7.72	952.7	2817.8
INDUSTRIAL PROCESSING	245	2204.6	6.0	1.4	5.59	0.45	2040.4	164.3
INDUSTRIAL PROCESSING	246	4314.3	11.8	2.7	11.32	0.50	4131.8	182.5
INDUSTRIAL PROCESSING	247	1438.1	3.9	0.9	3.94	0.00	1438.1	0.0
INDUSTRIAL PROCESSING	248	1518.4	4.2	0.9	4.16	0.00	1518.4	0.0
INDUSTRIAL PROCESSING	249	354.05	1.0	0.2	0.97	0.00	354.1	0.0
total		160928.5	440.9		55.2	385.7	20137.1	140791.5

CATEGORY	USE_CODE	Sum Of USE_2001 (MGY)	Sum Of USE_2001 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
INDUSTRIAL PROCESSING	241	8566.55	23.5	7.8	23.46	0.01	8562.9	3.7
INDUSTRIAL PROCESSING	242	32269.65	88.4	29.5	3.00	85.41	1095.0	31174.7
INDUSTRIAL PROCESSING	243	54830.3	150.2	50.1	0.29	149.93	105.9	54724.5
INDUSTRIAL PROCESSING	244	3489.4	9.6	3.2	2.92	6.64	1065.8	2423.6
INDUSTRIAL PROCESSING	245	2394.4	6.6	2.2	6.02	0.54	2197.3	197.1
INDUSTRIAL PROCESSING	246	4536.95	12.4	4.1	11.82	0.61	4314.3	222.7
INDUSTRIAL PROCESSING	247	1394.3	3.8	1.3	3.82	0.00	1394.3	0.0
INDUSTRIAL PROCESSING	248	1481.9	4.1	1.4	4.06	0.00	1481.9	0.0
INDUSTRIAL PROCESSING	249	375.95	1.0	0.3	1.03	0.00	376.0	0.0
total		109339.4	299.6		56.4	243.1	20593.3	88746.1

Minnesota Industrial Processing Facility Water Use, 2000-2004

CATEGORY	USE_CODE	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
INDUSTRIAL PROCESSING	241	8435.15	23.1	5.0	23.10	0.01	8431.5	3.7
INDUSTRIAL PROCESSING	242	36007.25	98.7	21.5	2.87	95.78	1047.6	34959.7
INDUSTRIAL PROCESSING	243	109295.6	299.4	65.2	0.30	299.14	109.5	109186.1
INDUSTRIAL PROCESSING	244	3723	10.2	2.2	2.92	7.28	1065.8	2657.2
INDUSTRIAL PROCESSING	245	2328.7	6.4	1.4	5.74	0.64	2095.1	233.6
INDUSTRIAL PROCESSING	246	4343.5	11.9	2.6	11.34	0.56	4139.1	204.4
INDUSTRIAL PROCESSING	247	1470.95	4.0	0.9	4.03	0.00	1471.0	0.0
INDUSTRIAL PROCESSING	248	1529.35	4.2	0.9	4.19	0.00	1529.4	0.0
INDUSTRIAL PROCESSING	249	423.4	1.2	0.3	1.16	0.00	423.4	0.0
total		167556.9	459.1		55.7	403.4	20312.3	147244.7

USE_CODE by YEAR

INDUSTRIAL PROCESSING

USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
241	2004	9216.25	25.25	5.7	25.16	0.09	9183.4	32.85
241	2003	8665.1	23.74	5.0	23.56	0.18	8599.4	65.7
241	2002	8581.15	23.51	5.3	23.48	0.03	8570.2	10.95
241	2001	8566.55	23.47	7.8	23.46	0.01	8562.9	3.65
241	2000	8435.15	23.11	5.0	23.1	0.01	8431.5	3.65

INDUSTRIAL PROCESSING

USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
242	2004	30149	82.6	18.70	2.29	80.31	835.85	29313.15
242	2003	29798.6	81.64	17.34	2.39	79.25	872.35	28926.25
242	2002	32036.05	87.77	19.91	2.83	84.94	1032.95	31003.1
242	2001	32269.65	88.41	29.51	3	85.41	1095	31174.65
242	2000	36007.25	98.65	21.49	2.87	95.78	1047.55	34959.7

INDUSTRIAL PROCESSING

USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
243	2004	108401.35	296.99	67.24	0.45	296.54	164.25	108237.1
243	2003	119665.25	327.85	69.62	0.39	327.46	142.35	119522.9
243	2002	106711.4	292.36	66.31	0.27	292.09	98.55	106612.85
243	2001	54830.3	150.22	50.15	0.29	149.93	105.85	54724.45
243	2000	109295.6	299.44	65.23	0.3	299.14	109.5	109186.1

INDUSTRIAL PROCESSING

USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
244	2004	4113.55	11.27	2.55	3.8	7.47	1387	2726.55
244	2003	3876.3	10.62	2.26	3.12	7.5	1138.8	2737.5
244	2002	3770.45	10.33	2.34	2.61	7.72	952.65	2817.8
244	2001	3489.4	9.56	3.19	2.92	6.64	1065.8	2423.6
244	2000	3723	10.2	2.22	2.92	7.28	1065.8	2657.2

INDUSTRIAL PROCESSING

USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
245	2004	2314.1	6.34	1.44	5.82	0.52	2124.3	189.8
245	2003	2153.5	5.9	1.25	5.3	0.6	1934.5	219
245	2002	2204.6	6.04	1.37	5.59	0.45	2040.35	164.25
245	2001	2394.4	6.56	2.19	6.02	0.54	2197.3	197.1
245	2000	2328.7	6.38	1.39	5.74	0.64	2095.1	233.6

Minnesota Industrial Processing Facility Water Use, 2000-2004

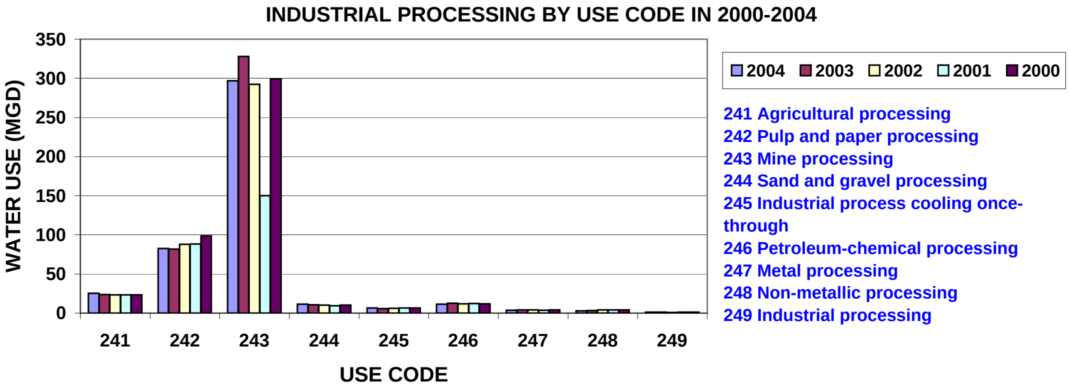
INDUSTRIAL PROCESSING USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
246	2004	4131.8	11.3	2.56	10.9	0.4	3974.9	157.0
246	2003	4657.4	12.76	2.71	12.05	0.71	4398.25	259.15
246	2002	4314.3	11.82	2.68	11.32	0.5	4131.8	182.5
246	2001	4536.95	12.43	4.15	11.82	0.61	4314.3	222.65
246	2000	4343.5	11.9	2.59	11.34	0.56	4139.1	204.4

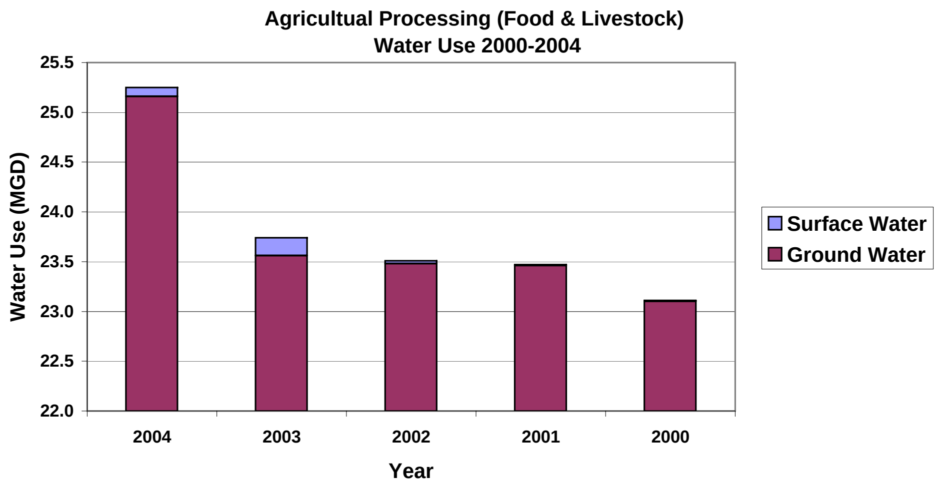
INDUSTRIAL PROCESSING USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
247	2004	1412.55	3.87	0.88	3.87	0	1412.55	0
247	2003	1445.4	3.96	0.84	3.96	0	1445.4	0
247	2002	1438.1	3.94	0.89	3.94	0	1438.1	0
247	2001	1394.3	3.82	1.28	3.82	0	1394.3	0
247	2000	1470.95	4.03	0.88	4.03	0	1470.95	0

INDUSTRIAL PROCESSING USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
248	2004	1087.7	2.98	0.67	2.98	0	1087.7	0
248	2003	1233.7	3.38	0.72	3.38	0	1233.7	0
248	2002	1518.4	4.16	0.94	4.16	0	1518.4	0
248	2001	1481.9	4.06	1.36	4.06	0	1481.9	0
248	2000	1529.35	4.19	0.91	4.19	0	1529.35	0

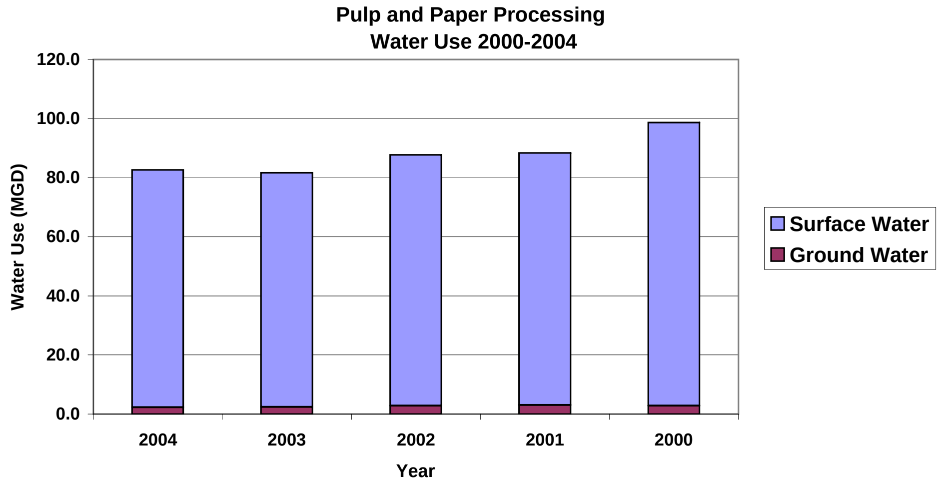
INDUSTRIAL PROCESSING USE_CODE	Year	Sum Of USE_2000 (MGY)	Sum Of USE_2000 (MGD)	Percentage of total	Ground water (MGD)	Surface water (MGD)	Ground water (MGY)	Surface water (MGY)
249	2004	379.6	1.04	0.24	1.04	0	379.6	0
249	2003	379.6	1.04	0.22	1.04	0	379.6	0
249	2002	354.05	0.97	0.22	0.97	0	354.05	0
249	2001	375.95	1.03	0.34	1.03	0	375.95	0
249	2000	423.4	1.16	0.25	1.16	0	423.4	0

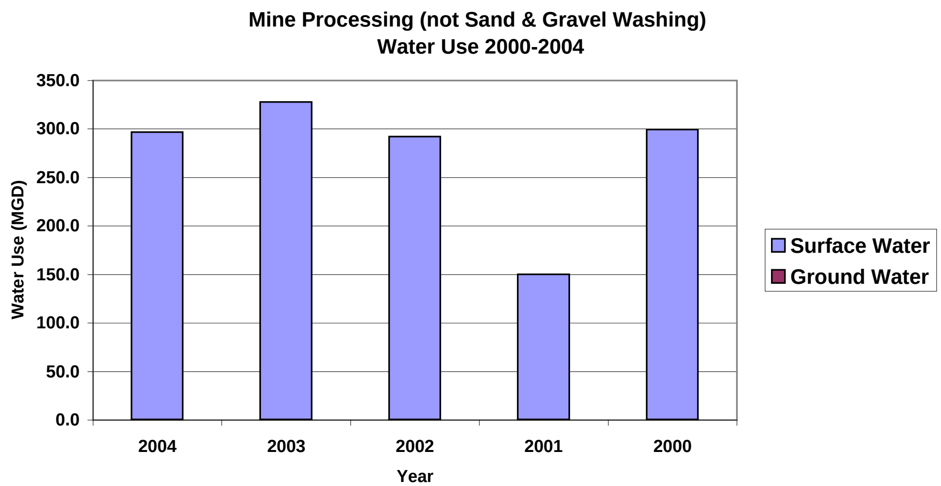
Minnesota Industrial Processing Facility Water Use, 2000-2004



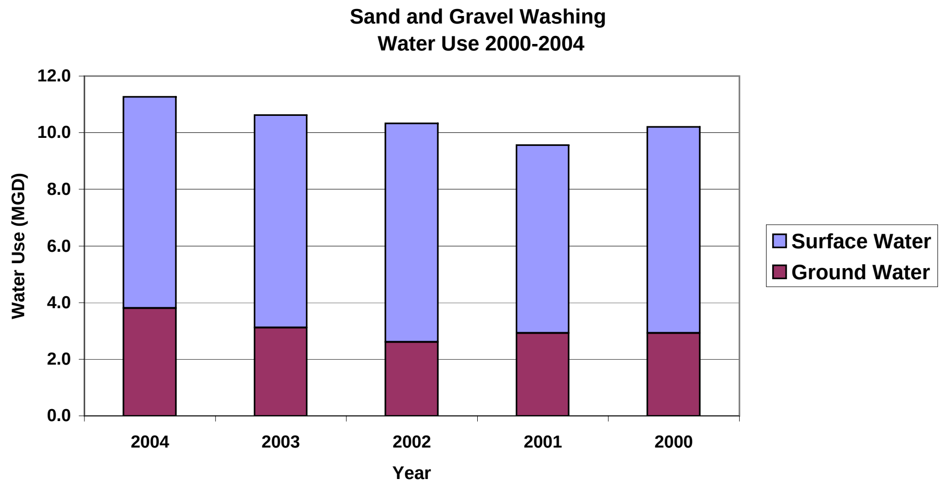


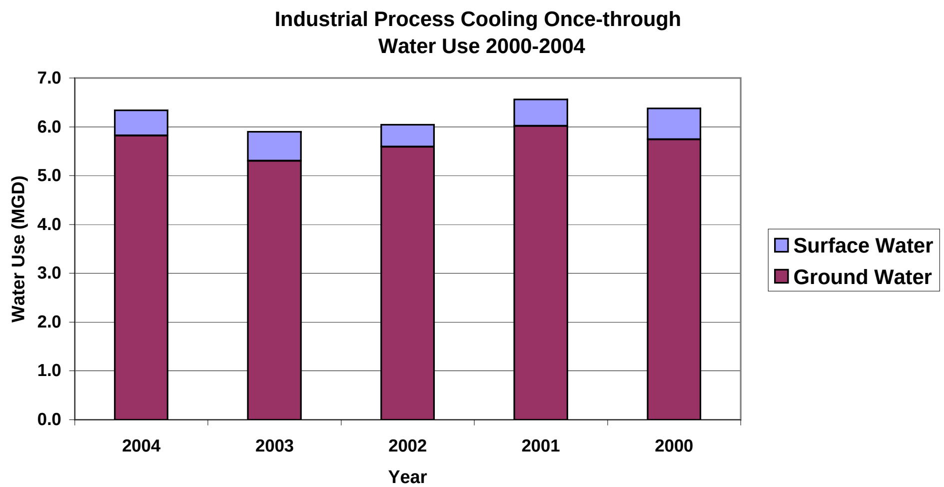
Minnesota Industrial Processing Facility Water Use, 2000-2004



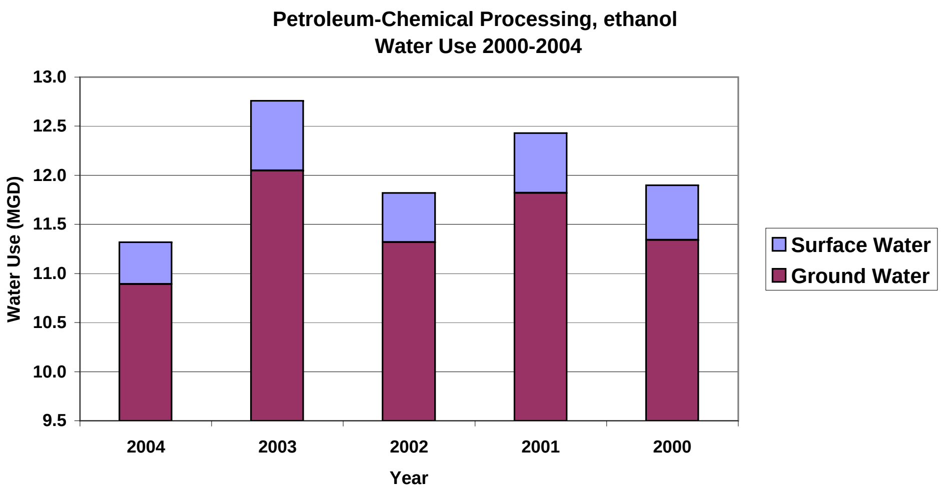


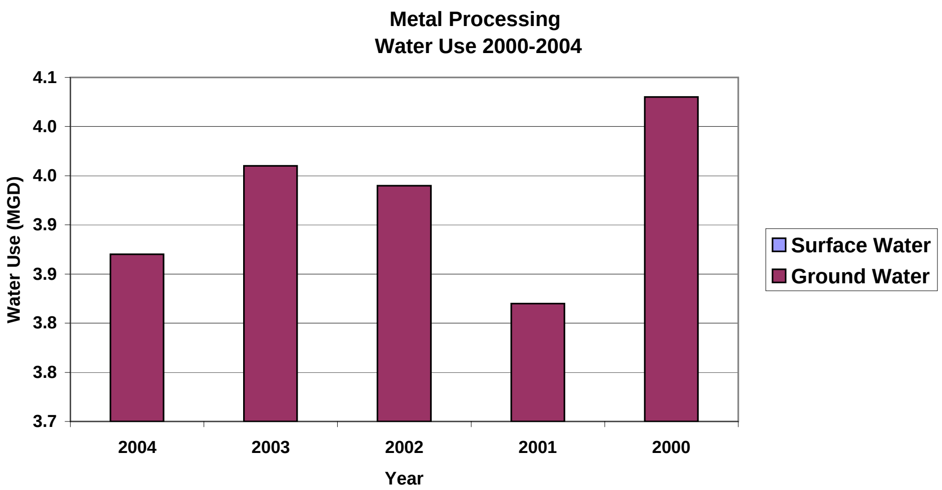
Minnesota Industrial Processing Facility Water Use, 2000-2004



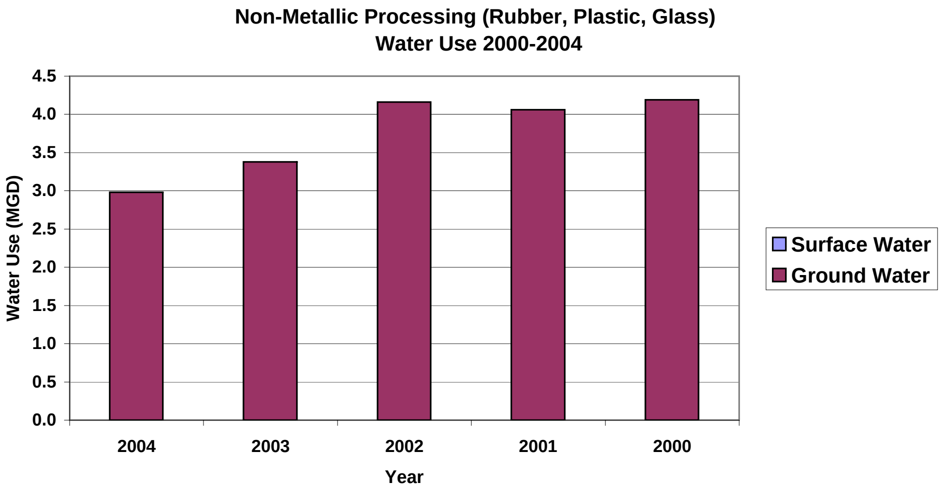


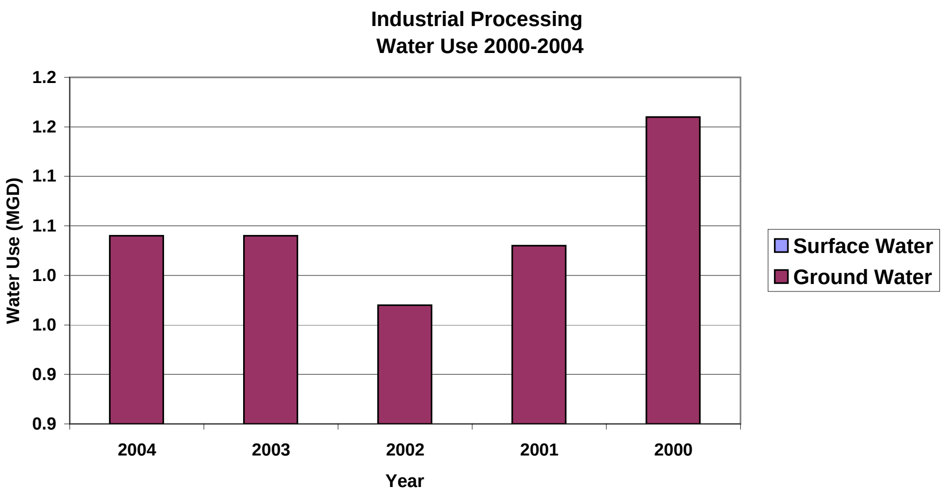
Minnesota Industrial Processing Facility Water Use, 2000-2004





Minnesota Industrial Processing Facility Water Use, 2000-2004





Appendix B
Status of Water Reuse Regulations and Guidelines

Overview

There are no federal regulations governing water reclamation and reuse in the United States; regulations are developed and implemented at the state government level. The lack of federal regulations has resulted in differing standards among states that have developed water reuse regulations. In the 1990s, several states adopted or revised their respective regulations, and it was common practice to base reuse criteria on those of states that had comprehensive regulations, guidelines, and background information to support them. The *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 1992], which were published in 1992 (revised in 2004), were also used as a resource by states that had limited or no regulations or guidelines. Since then, there has been increased interest in water reuse in several states that previously did not have water reuse regulations.

At present, no states have regulations that cover all potential uses of reclaimed water, but several states have extensive regulations that prescribe requirements for a wide range of end uses of the reclaimed water. Other states have regulations or guidelines that focus on land treatment of wastewater effluent, emphasizing additional treatment or effluent disposal rather than beneficial reuse, even though the effluent may be used for irrigation of agricultural sites or public access lands.

Minnesota is one of several states that have not developed state water reuse criteria. Currently, the State of Minnesota uses California's *Water Recycling Criteria* [State of California, 2000a] to evaluate water reuse projects on a case-by-case basis, as summarized in Table 1.

The status and summary of water reclamation and reuse regulations and guidelines in the United States as of 2004 have been documented in the EPA *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 2004] and are provided in Table 2. The absence of state regulations and guidelines for specific reuse applications does not necessarily prohibit those applications; many states evaluate specific types of water reuse on a case-by-case basis. Based on the data in Table 2, 25 states have adopted regulations regarding the use of reclaimed water, 16 states have guidelines or design standards, and 9 states have no regulations or guidelines. These data are somewhat misleading, as they include regulations and guidelines directed at land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse.

The number of states with regulations or guidelines for each type of reuse is summarized in Table 3, which has been adapted from the U.S. EPA *Guidelines for Water Reuse*. As indicated in Table 3, agricultural and landscape irrigation represent the reclaimed water uses most commonly regulated, and many states have implemented regulations that apply only to those types of use. As noted above, these data include state regulations that pertain to land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse.

Table 1. 2000 California Water Recycling Criteria

Type of Use	Total Coliform Limits[a]	Treatment Required
Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers	▪ None required	▪ Oxidation
Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	▪ ≤23/100 ml [a] ▪ ≤240/100 ml in more than one sample in any 30-day	▪ Oxidation ▪ Disinfection
Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries	▪ ≤2.2/100 ml [a] ▪ ≤23/100 ml in more than one sample in any 30-day period	▪ Oxidation ▪ Disinfection
Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	▪ ≤2.2/100 ml [a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation[h] ▪ Filtration[i] ▪ Disinfection
Nonrestricted recreational impoundments	▪ ≤2.2/100 ml [a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation ▪ Clarification[j] ▪ Filtration[i] ▪ Disinfection
Ground water recharge by spreading	▪ Case-by-case evaluation	▪ Case-by-case evaluation

[a] Based on running 7-day median; daily sampling is required.
[b] No contact between reclaimed water and edible portion of crop.
[c] Food crops that undergo commercial pathogen-destroying prior to human consumption.
[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.
[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.
[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.
[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.
[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 nephelometric turbidity units (NTU) for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.
[i] The turbidity after filtration through filter media cannot exceed an average of 2 NTU within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.
[j] Not required if reclaimed water is monitored for enteric viruses, *Giardia*, and *Cryptosporidium*.

Source: Adapted from State of California [2000a].

Table 2. Summary of State Reuse Regulations and Guidelines for Nonpotable Reuse Applications

State	Regulations	Guidelines	No Regulations or Guidelines	Unrestricted Nonpotable Urban Uses	Restricted Nonpotable Urban Uses	Agricultural Irrigation of Food Crops	Agricultural Irrigation of Non-Food Crops	Unrestricted Recreational Impoundments	Restricted Recreational Impoundments	Environmental Uses	Industrial Uses
Alabama		●			●		●				
Alaska	●						●				
Arizona	●			●	●	●	●		●		
Arkansas		●		●	●	●	●				
California	●			●	●	●	●	●	●		●
Colorado	●			●	●						●
Connecticut			●								
Delaware	●			●	●		●				
Florida	●			●	●	●	●			●	●
Georgia		●		●	●		●				
Hawaii		●		●	●	●	●		●		●
Idaho	●			●	●	●	●				
Illinois	●			●	●		●				
Indiana	●			●	●	●	●				
Iowa	●				●		●				
Kansas		●		●	●	●	●				
Kentucky			●								
Louisiana			●								
Maine			●								
Maryland		●			●		●				
Massachusetts		●		●	●		●				
Michigan	●					●	●				
Minnesota			●								
Mississippi			●								
Missouri	●				●		●				
Montana		●		●	●	●	●				
Nebraska	●				●		●				
Nevada	●			●	●	●	●	●	●		
New Hampshire			●								
New Jersey		●		●	●	●	●				●
New Mexico		●		●	●	●	●				
New York		●					●				
North Carolina	●			●	●						●
North Dakota		●		●	●		●				
Ohio		●		●	●		●				
Oklahoma	●				●	●	●				
Oregon	●			●	●	●	●	●	●		●
Pennsylvania		●					●				
Rhode Island			●								
South Carolina	●			●	●		●				
South Dakota		●		●	●		●			●	
Tennessee	●			●	●		●				
Texas	●			●	●	●	●	●	●		●
Utah	●			●	●	●	●	●	●		●
Vermont	●						●				
Virginia			●								
Washington		●		●	●	●	●	●	●	●	●
West Virginia	●					●	●				
Wisconsin	●						●				
Wyoming	●			●	●	●	●				

Source: Adapted from U.S. Environmental Protection Agency [2004].

Table 3. Number of States with Reuse Regulations or Guidelines for Different Types of Use

Type of Use	Number of States with Regulations or Guidelines	Description
Unrestricted urban water reuse Irrigation Toilet flushing Fire protection Construction Landscape impoundment Street cleaning	28 28 10 9 9 11 6	Irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences. Toilet flushing, air conditioning, fire protection, construction, cleansing, ornamental fountains, and aesthetic impoundments.
Restricted urban water reuse	34	Irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.
Agricultural irrigation of food crops	21	Irrigation of food crops which are intended for human consumption. Food crop is to be processed. Food crop is consumed uncooked.
Agricultural irrigation of nonfood crops	40	Irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
Unrestricted recreational water reuse	7	An impoundment of water in which no limitations are imposed on body-contact water recreation activities.
Restricted recreational water reuse	9	An impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
Environmental water reuse	3	Reclaimed water used to create manmade wetlands, enhance natural wetlands, and to sustain stream flows.
Industrial water reuse	9	Reclaimed water used in industrial facilities primarily for cooling system makeup water, boiler-feed water, process water, and general washdown and cleansing.
Ground water Recharge	5	Using via infiltration basins, percolation ponds or injection wells, reclaimed water is used to recharge ground water aquifers.
Indirect Potable Reuse	5	The intentional discharge of highly treated reclaimed water into surface waters or ground water that will be used as a source of potable water supply.

Adapted from U.S. Environmental Protection Agency [2004].

The standards in states having the most reuse experience tend to be more stringent than those in states with fewer reuse projects. States that have water reuse regulations or guidelines typically set standards for reclaimed water quality and specify minimum treatment requirements, although a few states, such as Texas and New Mexico, do not prescribe treatment processes and rely solely on water quality limits.

Regulatory Requirements for Nonpotable Uses of Reclaimed Water

In the past, most state water reuse regulations were developed in response to a need to regulate a growing number of water reuse projects in the particular state. Recently, some states that currently have few reuse projects have taken a proactive approach and have adopted criteria, which tend to encourage implementation of projects. Arizona, California, Florida, and Texas, which have had comprehensive criteria for a number of years, have revised their water reuse regulations within the last ten years to reflect additional reclaimed water uses, advances in wastewater treatment technology, and increased knowledge in the areas of microbiology and public health protection.

Common Uses

The variations and inconsistencies among state regulations are illustrated in Table 4, which includes examples of several states' reclaimed water standards for uses ranging from fodder crop irrigation to toilet and urinal flushing in buildings.

Water reuse regulations focus on public health implications of using the water, and water quality criteria not related to health protection usually are not included in water reuse regulations. Most states with extensive water reuse experience have comparable, conservatively-based water quality criteria or guidelines. Arguments for less restrictive standards are most often predicated upon a lack of documented health hazards rather than upon any certainty that hazards are small or nonexistent. In the absence of definitive epidemiological data and a unified interpretation of scientific and technical data on pathogen exposures, selection of water quality limits will continue to be somewhat subjective and inconsistent among the states. Regulatory requirements for some nonpotable uses of reclaimed water not included in Table 4 are discussed below.

Wetlands

In most cases, the primary intent in applying reclaimed water to wetlands is to provide additional treatment of effluent prior to discharge or reuse, although wetlands are sometimes created solely for environmental enhancement. In such cases, secondary treatment is usually acceptable as influent to the wetland system. Very few states have regulations that specifically address the use of reclaimed water for creation of artificial wetlands or the restoration or enhancement of natural wetlands. Where there are no regulations, regulatory agencies prescribe requirements on a case-by-case basis. In addition to state requirements, natural wetlands, which are considered waters of the United States, are protected under EPA's NPDES Permit and Water Quality Standards programs. Constructed wetlands built and operated for the purpose of wastewater treatment generally are not considered waters of the United States.

Table 4. Examples of State Water Reuse Criteria for Selected Nonpotable Applications

State	Fodder Crop Irrigation[1]		Processed Food Crop Irrigation[2]		Food Crop Irrigation[3]		Restricted Recreational Impoundments[4]	
	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required
Arizona	▪ 1,000 fecal coli/100 ml	▪ Secondary	Not covered	Not covered	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection
California	Not specified	▪ Oxidation	Not specified	▪ Oxidation	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[5] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml	▪ Oxidation ▪ Disinfection
Colorado	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered
Florida	▪ 200 fecal coli/100 ml ▪ 20 mg/L CBOD[6] ▪ 20 mg/l TSS[7]	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	Use prohibited	Use prohibited	▪ No detect. fecal coli/ 100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection
New Mexico (Policy)	▪ 1,000 fecal coli/100 ml ▪ 75 mg/L TSS ▪ 30 mg/L BOD[6]	Not specified	Not covered	Not covered	Use Prohibited	Use Prohibited	▪ 100 fecal coli/100 ml ▪ 30 mg/L BOD ▪ 30 mg/L TSS	Not specified
Utah	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection
Texas	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	Use prohibited	Use prohibited	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified
Washington	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/ 100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml	▪ Oxidation ▪ Disinfection

[1] In some states more restrictive requirements apply where milking animals are allowed to graze on pasture irrigated with reclaimed water.
[2] Physical or chemical processing sufficient to destroy pathogenic microorganisms. Less restrictive requirements may apply where there is no direct contact between reclaimed water and the edible portion of the crop.
[3] Food crops eaten raw where there is direct contact between reclaimed water and the edible portion of the crop.
[4] Recreation is limited to fishing, boating, and other nonbody contact activities.
[5] Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.
[6] CBOD – carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD
[7] TSS – total suspended solids

Table 4. Examples of State Water Reuse Criteria for Selected Nonpotable Applications (cont'd)

State	Restricted Access Irrigation[1]		Unrestricted Access Irrigation[2]		Toilet Flushing[3]		Industrial Cooling Water[4]	
	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required
Arizona	▪ 200 fecal coli/100 ml	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 2 NTU	▪ Oxidation ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Filtration ▪ Disinfection	Not covered	Not covered
California	▪ 23 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Coagulation[4] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/ 100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[5] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[4] ▪ Filtration ▪ Disinfection
Colorado	▪ 126 *E.coli*/100 ml ▪ 3 NTU	▪ Secondary ▪ Disinfection	▪ 126 *E.coli*/100 ml ▪ 3 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	Not covered	Not covered	▪ 126 *E.coli*/100 ml ▪ 3 NTU	▪ Secondary ▪ Filtration ▪ Disinfection
Florida	▪ 200 fecal coli/100 ml ▪ 20 mg/L CBOD[6] ▪ 20 mg/l TSS[7]	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection
New Mexico (Policy)	▪ 200 fecal coli/100 ml ▪ 30 mg/L BOD[6] ▪ 30 mg/L TSS	Not specified	If within 100 ft of dwelling: ▪ 5 fecal coli/100 ml ▪ 10 mg/L BOD ▪ 3 NTU	Not specified	▪ 100 fecal coli/100 ml ▪ 30 mg/L BOD ▪ 30 mg/L TSS	Not specified	Not covered	Not covered
Utah	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/ 100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/TSS	▪ Secondary ▪ Disinfection
Texas	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified	▪ 20 fecal coli/100 ml ▪ 3 NTU ▪ 5 mg/L BOD or CBOD	Not specified	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified
Washington	▪ 23 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/ 100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection

1 Classification varies by state; generally includes irrigation of cemeteries, freeway medians, restricted access golf courses, and similar restricted access areas.
2 Includes irrigation of parks, playgrounds, schoolyards, residential lawns, and similar unrestricted access areas.
3 Not allowed in single-family residential dwelling units.
4 Cooling towers where a mist is created that may reach populated areas.
5 Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.
6 CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD
7 TSS – total suspended solids

In the few states that have adopted regulations for reclaimed water use in wetlands, requirements vary based on type of wetland system and degree of public access. For example, Washington requires that reclaimed water discharged to natural wetlands where there is no expected human contact with the water must meet Class D reclaimed water standards (secondary treatment and not more than 240 total coliform (coli)/100 ml), while discharges to natural or constructed wetlands providing human contact recreational or educational beneficial uses must meet Class A reclaimed water standards (tertiary treatment and not more than 2.2 total coli/100 ml in the reclaimed water). Reclaimed water discharged to any wetland system in Washington cannot exceed the following water quality limits: 20 mg/L biochemical oxygen demand (BOD); 20 mg/L total suspended solids (TSS); 3 mg/L total Kjeldahl nitrogen (as N); and 1 mg/L total phosphorus (as P).

Industrial Uses Other than Cooling

Due to the myriad of industrial processes that use water, regulatory agencies generally prescribe water reuse requirements for industrial applications other than cooling on an individual case basis. Reclaimed water from conventional wastewater treatment processes is of adequate quality for many industrial applications that can tolerate water of less than potable quality. Industrial uses of reclaimed water include cooling, process water, stack scrubbing, boiler feed, wash water, transport of material, and as an ingredient in a nonfood-related product.

Regulatory considerations for reuse of water in industrial applications include generation of aerosols, safety of manufactured products, and associated food and beverage production. For example, Florida regulations address the use of reclaimed water for food processing at industrial facilities. Florida's reuse rule specifically prohibits the use of reclaimed water in the manufacture or processing of food or beverage for human consumption where the reclaimed water will be incorporated into or come in contact with the food or beverage product. Similarly, Washington standards do not allow the use of reclaimed water for food preparation and prohibit its use in food or drink for humans. While many industrial uses require water of higher chemical quality than that typically present in reclaimed water, e.g., computer chip manufacturing requires reverse osmosis treatment to produce ultra-pure wash water, water reuse regulations are intended to provide health protection and only include requirements to attain that end.

Miscellaneous Nonpotable Uses

While all states that have water reuse regulations or guidelines include criteria for crop and/or landscape irrigation, some include requirements for less common uses of reclaimed water, such as flushing sanitary sewers, street cleaning, dust control, soil compaction, making concrete, snowmaking, decorative fountains, commercial laundries, commercial car washes, equipment washing, and fire protection systems. For these and similar uses, the various state standards impose wastewater treatment process requirements, reclaimed water quality limits, and design and operational requirements reflective of the degree of human exposure to the water that are in concert with other more common uses of reclaimed water. For example, secondary treatment with a minimal level of disinfection is acceptable for uses where there is little or no expected human contact with the water, such as flushing sanitary sewers or making concrete. Conversely, uses such as snowmaking and vehicle washing are likely to result in contact with the reclaimed water, and tertiary treatment with a high level of disinfection is usually required.

Treatment, Water Quality, and Other Requirements

Treatment Process Requirements

With few exceptions, state water reuse regulations prescribe treatment unit process requirements. Where expected exposure is incidental or not likely, a low level of wastewater treatment is usually acceptable and undisinfected or disinfected secondary treated effluent may be allowed dependent on the type of use. In most states, the definition of secondary treatment means that neither the BOD (total BOD) nor TSS exceed 30 mg/L. A few states use the term "oxidized wastewater" to define secondary treated wastewater, where oxidized wastewater is defined as wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen. Most state regulations do not require a specific type of secondary treatment; e.g., conventional activated sludge, extended aeration activated sludge, lagoon systems, and other types of secondary treatment may be acceptable. Where public exposure to reclaimed water used for nonpotable applications is expected to occur, tertiary treatment usually is required. Different types of acceptable tertiary treatment may include sand filtration, multi-media filtration, membranes, or other methods shown to be effective in reducing particulate and organic matter.

BOD, TSS, and Turbidity Requirements

Most states specify wastewater treatment processes and reclaimed water quality limits for TSS and/or turbidity, total or fecal coliforms, and disinfection. States that have regulations for potable reuse also include limits on chemical constituents that include, but are not limited to, the U.S. EPA drinking water standards. For uses of reclaimed water that require a high quality product water, BOD and TSS limits as low as 5 mg/L are specified in some states. These limits are applicable where filtration or other tertiary treatment processes are used to remove some objectionable constituents and prepare the water for disinfection. Daily sampling for BOD and TSS, using composite samples is usually required, although less frequent sampling is allowed in some states. Not all states include limits for BOD and TSS, and several states specify turbidity requirements in lieu of TSS. Turbidity limits generally are required only for tertiary treated reclaimed water where human contact is expected or likely. Where required, most states require that turbidity be continuously monitored. The compliance point for turbidity usually is just prior to disinfection.

Where specified, limits on turbidity in reclaimed water after filtration range from 1 to 10 nephelometric turbidity units (NTU), with 2 NTU being a common requirement. California specifies different turbidity requirements depending on type of tertiary treatment. Where media filtration is the tertiary treatment process, turbidity after filtration cannot exceed an average of 2 NTU within any 24-hour period, cannot exceed 5 NTU more than 5 percent of the time within a 24-hour period, and cannot exceed 10

NTU at any time. Where membranes are used in lieu of media filtration, turbidity cannot exceed 0.2 NTU more than 5 percent of the time within a 24-hour period and cannot exceed 0.5 NTU at any time.

Coliform Bacteria Limits

Most states use fecal coliform organisms as the indicator organism for microbial pathogens in reclaimed water, while a few states use total coliform. Fecal or total coliform limits depend on use of the water and are highly variable among states. Arizona, Florida, and some other states' regulations are similar to, or based on, the EPA *Guidelines for Water Reuse* and use fecal coliform organisms as the indicator organism. In those states regulations typically require that reclaimed water have no detectable fecal coliform/100 ml for high level nonpotable applications and not exceed 200 fecal coliform/100 ml for uses where human contact is minimal.

States that use total coliform as the indicator organism require that total coliform organisms not exceed 2.2/100 ml for high level uses and either 23 or 240/100 ml for uses where there is no or minimal human contact with the water. Higher single sample maximum coliform limits are allowed in several states. Regulatory compliance varies in different states, but usually is based on median or geometric mean values over a given time period. Coliform samples are usually required to be collected on a daily basis during peak flow conditions to represent the most demanding treatment facility operating conditions. Less frequent coliform sampling is allowed in some states. Several states require that coliform analyses be conducted using the multiple tube fermentation technique with the results expressed as the most probable number (MPN), while others allow use of the membrane filter (MF) technique. A few states do not specify which enumeration technique to use, and some states allow the use of either the MPN or MF methods.

The draft revisions of the Minnesota water quality standards include *Escherichia coli* (*E. coli*). While indicator organisms in water reuse criteria do not necessarily have to be the same as those in waste discharge requirements, it is likely that *E. coli* will be part of the evaluation of water reuse criteria for Minnesota.

Limits and Monitoring for Pathogenic Protozoa

At present, no states have set limits on pathogenic organisms for any nonpotable reuse application, but at least two states require monitoring for specific pathogens under certain circumstances. In an effort to learn more about the possible presence of protozoan pathogens in reclaimed water that receives tertiary treatment and a high level of disinfection, Florida's reuse rules contain parasite monitoring requirements. Facilities (ith capacities of 1.0 mgd and larger are required to sample their reclaimed water for *Giardia* and *Cryptosporidium* at least once every two years. Smaller facilities must sample at least once every five years. Samples are required to be taken following the disinfection process.

California requires that reclaimed water used for nonrestricted recreational impoundments be monitored for enteric viruses, *Giardia*, and *Cryptosporidium* if tertiary treatment does not include a sedimentation process between the chemical coagulation and filtration processes. Monthly sampling is required for the first year of operation, and quarterly sampling is required during the second year of operation. Sampling may be discontinued after the second year of operation with approval of the California Department of Health Services (DHS).

Currently, there are no states with monitoring requirements for other pathogens.

Disinfection Requirements

Where chlorine is used as the disinfectant, several states require continuous monitoring of chlorine residual and specify both the chlorine residual and contact time that must be met, particularly for reclaimed water uses where human contact with the water is likely to occur. Required chlorine residuals and disinfection contact times differ substantially from state-to-state ranging from 1 to 5 mg/L and 15 to 90 minutes at peak flow, respectively. Where UV is used for disinfection, most states do not specify UV dosage or design or operating conditions, although some state regulations require compliance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* [National Water Research Institute, 2003].

While the need to maintain a chlorine residual in reclaimed water distribution systems to prevent odors, slimes, and bacterial regrowth was recognized early in the development of dual water systems [Okun, 1979], only in the last decade or so have regulatory agencies begun to require such residuals. A few states now require maintenance of a chlorine residual (typically 0.5 or 1.0 mg/L) in distribution systems carrying reclaimed water. Facilities using UV disinfection will need to add chlorination facilities to meet residual requirements.

Treatment Facility Reliability

Some states have adopted treatment reliability requirements to insure that inadequately treated reclaimed water is not reused. Generally, requirements consist of alarms warning of power failure or failure of essential unit processes, automatic standby power sources, emergency storage or disposal provisions, and the provision that each treatment process be equipped with multiple units or a back-up unit. Reliability requirements for California and Florida are presented below as examples.

California Requirements. California's *Water Recycling Criteria* provide design and operational considerations covering alarms, power supply, emergency storage and disposal, wastewater treatment processes, and chemical supply, storage and feed facilities. For treatment processes, a variety of reliability features are acceptable. For example, for all biological treatment processes one of the following is required: (1) alarm (failure and power loss) and multiple units capable of producing oxidized wastewater (i.e., secondary treatment) with one unit not in operation; (2) alarm (failure and power loss) and short-term (at least 24 hours) storage or disposal provisions and stand-by replacement equipment; or (3) alarm (failure and power loss) and long-term (at least 20 days) storage or disposal provisions. Similar reliability requirements apply to other treatment processes.

Florida Requirements. Florida requires Class I reliability as defined by the U.S. EPA [U.S. Environmental Protection Agency, 1974] at water reclamation facilities where filtration and high-level disinfection are provided. Class I reliability requires multiple treatment units or back-up units and a secondary power source. In addition, a minimum of 1 day of reject storage is required to store reclaimed water of unacceptable quality for additional treatment. Florida also requires staffing at the water reclamation facility 24 hours/day, 7 days/week or 6 hours/day, 7 days/week as long as reclaimed water is delivered to the reuse system only during periods when a qualified operator is present. Operator presence can be reduced to 6 hours/day if additional reliability features are provided.

Storage Requirements

Current regulations and guidelines regarding storage requirements are primarily based upon the need to limit or prevent surface water discharge and are not related to storage required to meet diurnal or seasonal variations in supply and demand. Storage requirements vary from state to state and are generally dependent upon geographic location, climate, and site conditions. A minimum storage volume equal to 3 days of the average design flow is typical in water-short states with warm climates, while more than 200 days of storage are required in some northern states because of the high number of non-irrigation days due to high rainfall or freezing temperatures.

Most states that specify storage requirements do not differentiate between operational and seasonal storage. The majority of states that have storage requirements in their regulations or guidelines require that a water balance be performed on the water reuse system, taking into account all inputs and outputs of water to the system based on a specified rainfall recurrence interval.

Reclaimed Water Application Rates

Most state regulations do not include requirements or recommendations regarding reclaimed water irrigation application rates, as these are generally based on plant or crop irrigated and site-specific conditions. Of the states that do recommend application rates, the maximum recommended hydraulic loading rate typically is 2 inches/wk).

Ground Water Monitoring

Ground water monitoring is often required when reclaimed water is used for irrigation or for impoundments that are not sealed to prevent seepage. In general, the ground water monitoring programs require that one well be placed hydraulically upgradient of the water reuse site to assess background and incoming ground water conditions within the aquifer in question and one or more wells be placed hydraulically down gradient of the reuse site to monitor compliance with ground water quality requirements. Ground water monitoring programs associated with reclaimed water irrigation generally focus on water quality in shallow aquifers. Sampling parameters and frequency of sampling are generally considered on a case-by-case basis.

Setback Distances

Many states have established setback distances between reclaimed water use areas and surface waters, potable water supply wells, or areas accessible to the public. Setbacks are usually required where reclaimed water is used for spray irrigation, cooling water in towers, and other areas where spray or mist is formed. Setbacks may also be required at irrigation or impoundment sites to prevent percolated reclaimed water from reaching potable water supply wells. Setback distances vary depending on the quality of reclaimed water, type of reuse, method of application, and purpose of the setback, e.g., to avoid human contact with the water or protect potable water sources from contamination. Setback distances, where required, vary considerably from state-to-state, and range from 50 feet to as much and 800 feet. Some states do not require setback distances from irrigated areas to areas accessible to the public if a high level of treatment and disinfection is provided.

Cross Connection Control

Cross connection control regulations to prevent interconnecting reclaimed and potable water pipelines are included in some state water reuse criteria. Regulations often address: identification of transmission and distribution lines and appurtenances via color-coding, taping, or other means; separation of reclaimed water and potable water lines; allowable pressures; surveillance; and backflow prevention devices. At use areas that receive both potable and reclaimed water, backflow prevention devices are usually required on the potable water supply line to each site to reduce the potential of contaminating the potable drinking water system in the event of a cross-connection at a use area. Direct connections between reclaimed water and potable water lines are not allowed in any state.

California's Water Recycling Criteria require compliance with the California Department of Health Services cross connection control regulations [State of California, 2000b]. Those regulations require that water systems serving residences through a dual water system that uses reclaimed water for landscape irrigation must, as a minimum, be protected by a double check valve assembly backflow preventer. The same requirement applies to a public water system in buildings using reclaimed water in a separate piping system within buildings for fire protection. A reduced pressure principle backflow prevention device is required as a minimum to protect the potable system at sites other than those mentioned above. An air gap separation is required where a public water system is used to supplement a reclaimed water supply.

California's criteria for dual plumbed systems within buildings include the following requirements:

- Internal use of reclaimed water within any individually-owned residential unit, including multiplexes or condominiums is prohibited;

- Submission of a report that includes a detailed description of the intended use area, plans and specifications, and cross connection control provisions and testing procedures;

- Testing for possible cross connections at least every four years;
- Notification of any incidence of backflow from the reclaimed water system into the potable water system within 24 hours of discovery;
- Conformance to the DHS cross connection control regulations; and
- Facilities that produce or process food products or beverages can use reclaimed water internally only for fire suppression systems.

State Regulations for Indirect Potable Reuse

There are no direct potable reuse projects in the United States, and no states have developed regulations allowing such use. From a regulatory standpoint, few states have addressed the challenge of developing regulations for indirect potable reuse. California and Florida are in the forefront of developing discrete criteria relating to planned indirect potable reuse of reclaimed water. Some of the other states rely on U.S. EPA's Underground Injection Control regulations to protect potable ground water basins, while some states prohibit indirect potable reuse altogether. There are no federal regulations that specifically address potable reuse of reclaimed water.

State of California

The existing California *Water Recycling Criteria* include general requirements for ground water recharge of domestic water supply aquifers by surface spreading. The regulations state that reclaimed water used for ground water recharge of domestic water supply aquifers by surface spreading "shall be at all times of a quality that fully protects public health" and that DHS recommendations "will be based on all relevant aspects of each project, including the following factors: treatment provided; effluent quality and quantity; spreading area operations; soil characteristics; hydrogeology; residence time; and distance to withdrawal." Until more definitive criteria are adopted, proposals to recharge ground water by either surface spreading or injection will be evaluated on a case-by-case basis, although draft ground water recharge criteria described below will guide DHS decisions. California has prepared draft criteria for ground water recharge (the most recent being in 2004), which are summarized in Table 5.

State of Florida

Florida's water reuse rules pertaining to ground water recharge and indirect potable reuse are summarized in Table 6. Although not specifically designated as indirect potable reuse systems, ground water recharge projects located over potable aquifers could function as an indirect potable reuse system. If more than 50 percent of the wastewater applied to the systems is collected after percolation, the systems are considered to be effluent disposal systems and not beneficial reuse. Loading to these systems is limited to 9 inches/day. For systems having higher loading rates or a more direct connection to an aquifer than normally encountered, reclaimed water must receive secondary treatment, filtration, disinfection, and must meet primary and secondary drinking water standards.

Table 5. California Draft Ground Water Recharge Regulations

Contaminant Type	Type of Recharge	
	Surface spreading	**Subsurface injection**
Pathogenic Microorganisms		
Filtration	≤ 2 NTU	
Disinfection	5-log virus inactivation [a], ≤ 2.2 total coliform per 100 ml	
Retention time underground	6 months	12 months
Horizontal separation [b]	500 ft	2000 ft
Regulated Contaminants		
Drinking water standards	Meet all drinking water MCLs [c] (except nitrogen) and new federal and state regulations as they are adopted	
Total nitrogen	▪ Level specified by DHS for existing project with no RWC increase ▪ ≤5 mg/L for new project or increased RWC at existing project ▪ Or NO_2 [d] and NO_3 [d] consistently met in mound (blending allowed)	
Unregulated Contaminants		
TOC [e] in filtered wastewater	TOC ≤ 16 mg/L in any portion of the filtered wastewater not subjected to reverse osmosis (RO) treatment	
TOC in recycled water	RO treatment as needed to achieve: ▪ TOC level specified by DHS for existing project with no RWC increase ▪ TOC ≤ (0.5 mg/L)/RWC (new project or increased RWC at existing project) ▪ Compliance point is in recycled water or mound [f] (no blending)	100% RO treatment to achieve: ▪ TOC level specified by DHS for existing project with no RWC increase ▪ TOC ≤ (0.5 mg/L)/RWC (new project or increased RWC at existing project)
Recycled water contribution (RWC)	≤ 50 % subject to above requirements 50-100 % subject to additional requirements	

[a] The virus log reduction requirement may be met by a combination of removal and inactivation.
[b] May be reduced upon demonstration via tracer testing that the required detention time will be met at the proposed alternative distance.
[c] MCL=maximum contaminant level.
[d] NO_2=nitrite and NO_3=nitrate
[e] TOC=total organic carbon
[f] If mound monitoring approved.

Source: Adapted from California Department of Health Services [2004].

Table 6. Florida Water Reuse Rules for Ground Water Recharge and Indirect Potable Reuse

Type of Use	Water Quality Limits	Treatment Required
Ground water recharge via rapid infiltration basins (RIBs)	▪ 200 fecal coli/100 ml ▪ 20 mg/L $CBOD_5$ ▪ 20 mg/L TSS ▪ 12 mg/L NO_3 (as N)	▪ Secondary ▪ Disinfection
Ground water recharge via RIBs in unfavorable conditions	▪ No detectable fecal coli/100 ml ▪ 20 mg/L $CBOD_5$ ▪ 5.0 mg/L TSS ▪ Primary[a] & secondary drinking water standards ▪ 10 mg/L total N	▪ Secondary ▪ Filtration ▪ Disinfection
Ground water recharge or injection to ground waters having TDS < 3000 mg/L	▪ No detectable total coli/100 ml ▪ 20 mg/L$CBOD_5$ ▪ 5.0 mg/L TSS ▪ 3.0 mg/L TOC ▪ 0.2 mg/L TOX[b] ▪ 10 mg/L total N ▪ Primary[a] & secondary drinking water standards	▪ Secondary ▪ Filtration ▪ Disinfection ▪ Multiple barriers for control of pathogens & organics ▪ Pilot testing required
Ground water recharge or injection to ground waters having TDS 3,000-10,000 mg/L	▪ No detectable total coli/100 ml ▪ 20 mg/L$CBOD_5$ ▪ 5.0 mg/L TSS ▪ 10 mg/L total N ▪ Primary drinking water standards[a]	▪ Secondary ▪ Filtration ▪ Disinfection
Indirect potable reuse: discharge to Class I surface waters (used for public water supply)	▪ No detectable total coli/100 ml ▪ 20 mg/L$CBOD_5$ ▪ 5.0 mg/L TSS ▪ 3.0 mg/L TOC ▪ 10 mg/L total N ▪ Primary[a] & secondary drinking water standards ▪ WQBELs[c] may apply	▪ Secondary ▪ Filtration ▪ Disinfection

[a] Except for asbestos.
[b] TOX = total organic halogen.
[c] WQBELs are water quality based effluent limitations to ensure that water quality standards in a receiving body of water will not be violated.

Source: Adapted from Florida Department of Environmental Protection [1999].

The Florida regulations include requirements for planned indirect potable reuse by injection into water supply aquifers and augmentation of surface supplies. A minimum horizontal separation distance of 500 feet is required between reclaimed water injection wells and potable water supply wells. The injection regulations pertain to G-I, G-II, and F-I ground waters, all of which are classified as potable aquifers. Reclaimed water must meet G-II ground water standards prior to injection. G-II ground water standards are, for the most part, primary and secondary drinking water standards. Florida considers discharges to Class I surface waters (public water supplies) as indirect potable reuse. Discharges less than 24 hours travel time upstream from Class I waters are also considered as indirect potable reuse. Outfalls for surface water discharges cannot be located within 500 feet of existing or approved potable water intakes within Class I surface waters. Pilot testing is required prior to implementation of injection or surface water augmentation projects.

Other States

In some states, regulations addressing indirect potable reuse are independent from the state's water reuse regulations. For example, the use of reclaimed water for ground water recharge in Arizona is regulated under statutes and administrative rules administered by the Arizona Department of Environmental Quality (ADEQ) and the Arizona Department of Water Resources (ADWR). Several different permits are required by these agencies prior to implementation of a ground water recharge project. In general, ADEQ regulates ground water quality and ADWR manages ground water supply. All aquifers in Arizona currently are classified for drinking water protected use, and the state has adopted National Primary Drinking Water Maximum Contaminant Levels (MCLs) as aquifer water quality standards. These standards apply to all ground water in saturated formations that yield more than 5 gallons per day (gpd) of water. Any ground water recharge project involving injection of reclaimed water into an aquifer is required to demonstrate compliance with aquifer water quality standards at the point of injection.

Regulation Mandates

States such as California and Florida have regulations that mandate water reuse under certain conditions. The Florida Water Policy [Florida Department of Environmental Protection, 1995] establishes a mandatory reuse program that is actively enforced. The policy requires that the state's water management districts identify water resource caution areas that have water supply problems that have become critical or are anticipated to become critical within the next 20 years. State legislation requires preparation of water reuse feasibility studies for treatment facilities located within the water resource caution areas, and a "reasonable" amount of reclaimed water use from municipal wastewater treatment facilities is required within the designated water resource caution areas unless reuse is not economically, environmentally, or technically feasible. Water reuse also may be required outside of designated water resource caution areas if reclaimed water is readily available, reuse is economically, environmentally, and technologically feasible, and rules governing the imposition of requirements for reuse have been adopted in those areas by the water management district having jurisdiction.

In California, laws and regulations exist that mandate water reuse under certain conditions. Section 13550 of the California Water Code states that the use of potable domestic water for nonpotable uses, including, but not limited to, cemeteries, golf courses, highway landscaped areas, and industrial and irrigation uses, is a waste or an unreasonable use of the water if reclaimed water is available which meets certain conditions [California State Water Resources Control Board, 2000]. The conditions are:

the source of reclaimed water is of adequate quality for these uses and is available for these uses; reclaimed water may be furnished for these uses at a reasonable cost to the user; after concurrence with the State Department of Health Services, the use of reclaimed water from the proposed source will not be detrimental to public health; and use of reclaimed water for these uses will not adversely affect downstream water rights, will not degrade water quality, and is determined not to be injurious to plant life, fish and wildlife. The Water Code mandates that no person or public agency shall use water from any source or quality suitable for potable domestic use for nonpotable uses if suitable reclaimed water is available and meets the conditions stated above. Other sections of the code allow for mandating reclaimed water use for irrigation of residential landscaping, industrial cooling applications, and toilet and urinal flushing in nonresidential buildings. Some local jurisdictions in the state have taken action to require the use of reclaimed water is certain situations.

U.S. EPA Guidelines for Water Reuse

In recognition of the increasing role of water reuse as an integral component of the nation's water resources management – and to facilitate the orderly planning, design, and implementation of water reuse projects – the U.S. Environmental Protection Agency (EPA), in conjunction with the U.S. Agency for International Development, published *Guidelines for Water Reuse* in 1992 [U.S. Environmental Protection Agency, 1992]. The U.S. EPA took the position that national water reuse standards were not necessary and comprehensive guidelines, coupled with flexible state regulations, would foster increased consideration and implementation of water reuse projects. The guidelines were updated in 2004 [U.S. Environmental Protection Agency, 2004] to include technological advances, research data, and other information generated in the last decade. The guidelines address various aspects of water reuse and include recommended treatment processes, reclaimed water quality limits, monitoring frequencies, setback distances, and other controls for various water reuse applications. The suggested guidelines for wastewater treatment and reclaimed water quality are presented in Appendix A.

It is explicitly stated in the *Guidelines for Water Reuse* that the recommended treatment unit processes and water quality limits presented in the guidelines "are not intended to be used as definitive water reclamation and reuse criteria. They are intended to provide reasonable guidance for water reuse opportunities, particularly in states that have not developed their own criteria or guidelines." [U.S. Environmental Protection Agency, 2004].

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Appendix C
Watershed Inventory Data

Table 3.8a. Industrial Water Use in the Cedar River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	3.20	0.00	3.20
Petroleum - Chemical Processig, ethanol	0.56	0.02	0.58
Sand & Gravel Washing	0.00	0.08	0.08
Steam Power Cooling - Wet Tower	0.29	0.00	0.29
Total	4.05	0.10	4.15

Table 3.8b. WWTPs in the Cedar River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Albert Lea WWTP	18.380			4.233
Austin WWTP	8.475			5.42
Total	26.855			9.653

Table 3.8c. Industries in the Cedar River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
HORMEL FOODS CORP	Ground Water	0.000	2.0	Austin	Agricultural Processing
HORMEL FOODS CORP	Ground Water	0.681	2.0	Austin	Agricultural Processing
HORMEL FOODS CORP	Ground Water	1.183	3.5	Austin	Agricultural Processing
HORMEL FOODS CORP	Ground Water	1.334	3.5	Austin	Agricultural Processing
VENTURA FOODS LLC	Ground Water	0.000	5.7	Albert Lea	Agricultural Processing
AGRA RESOURCES COOP	Ground Water	0.183	9.7	Albert Lea	Petroleum - Chemical Processing
AGRA RESOURCES COOP	Ground Water	0.208	9.7	Albert Lea	Petroleum - Chemical Processing
AGRA RESOURCES COOP	Ground Water	0.172	9.7	Albert Lea	Petroleum - Chemical Processing
BISHOP EXCAVATING INC	Surface Water	0.000	>10	Austin	Sand and Gravel Washing
ULLAND BROTHERS INC	Surface Water	0.060	1.5	Austin	Sand and Gravel Washing
ULLAND BROTHERS, INC	Surface Water	0.020	5.0	Austin	Sand and Gravel Washing
AUSTIN UTILITIES	Ground Water	0.287	4.0	Austin	STEAM POWER COOLING - WET TOWER

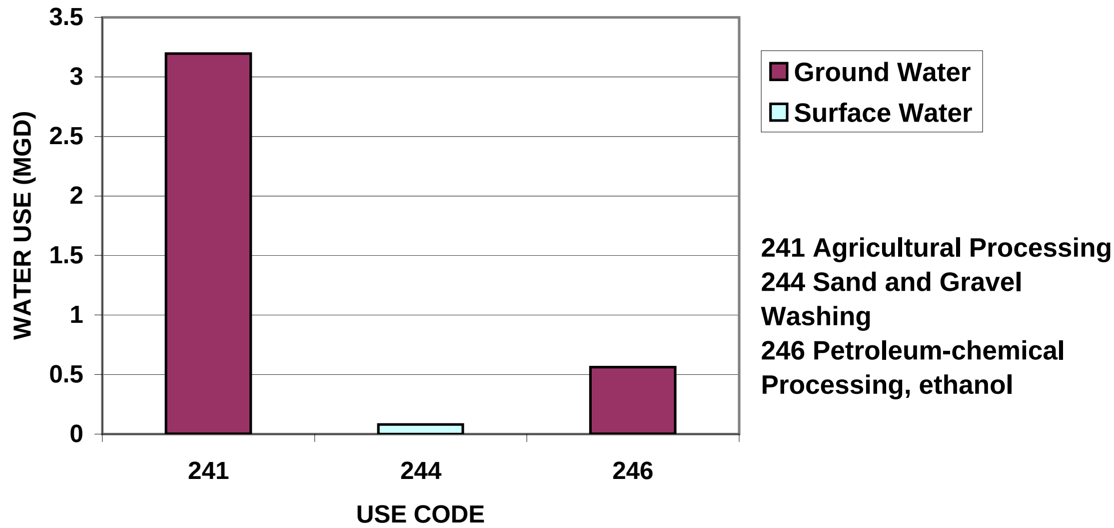


Figure 3.8a. Industrial Processing Water Use in the Cedar River Watershed, 2004

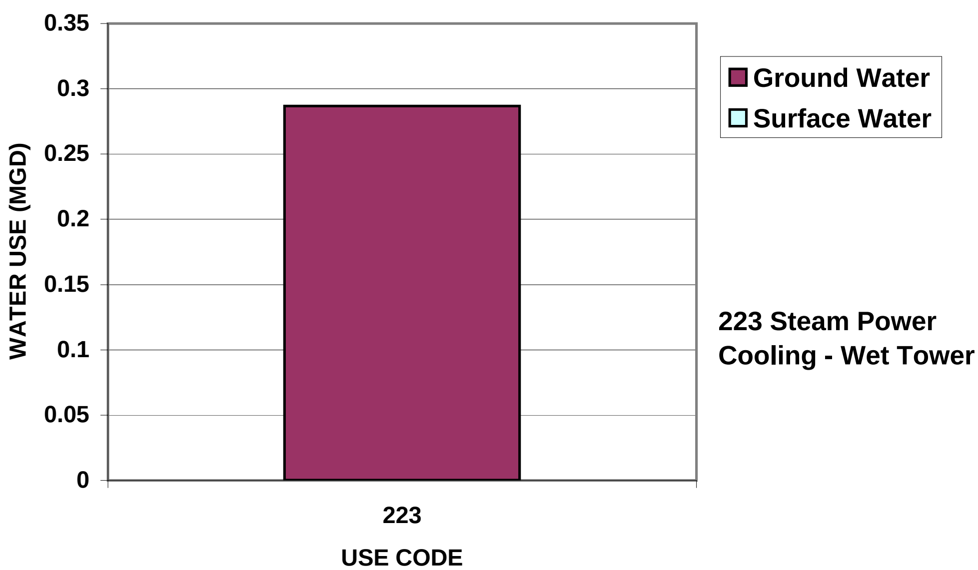


Figure 3.8b. Power Generation Water Use in the Cedar River Watershed, 2004

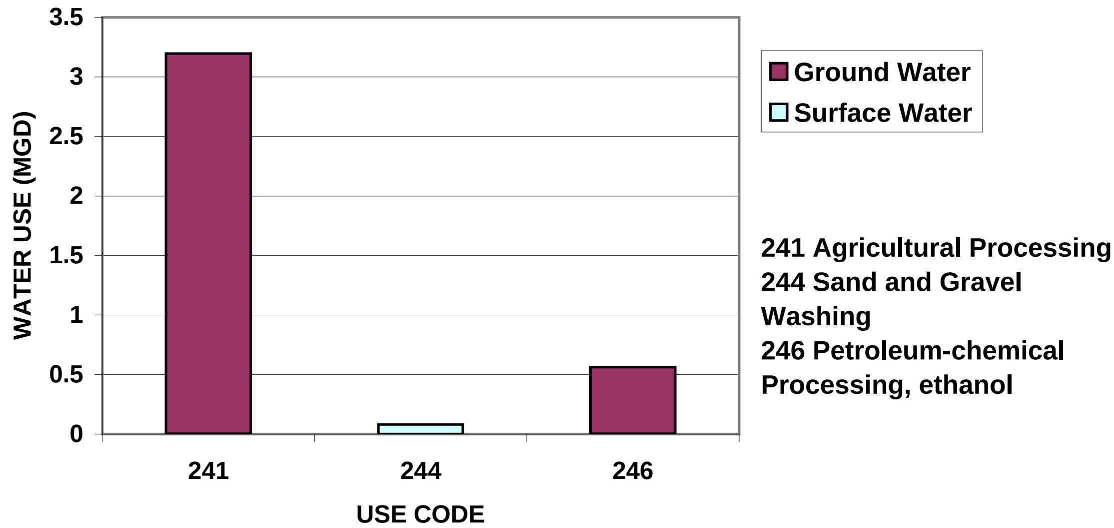


Figure 3.8a. Industrial Processing Water Use in the Cedar River Watershed, 2004

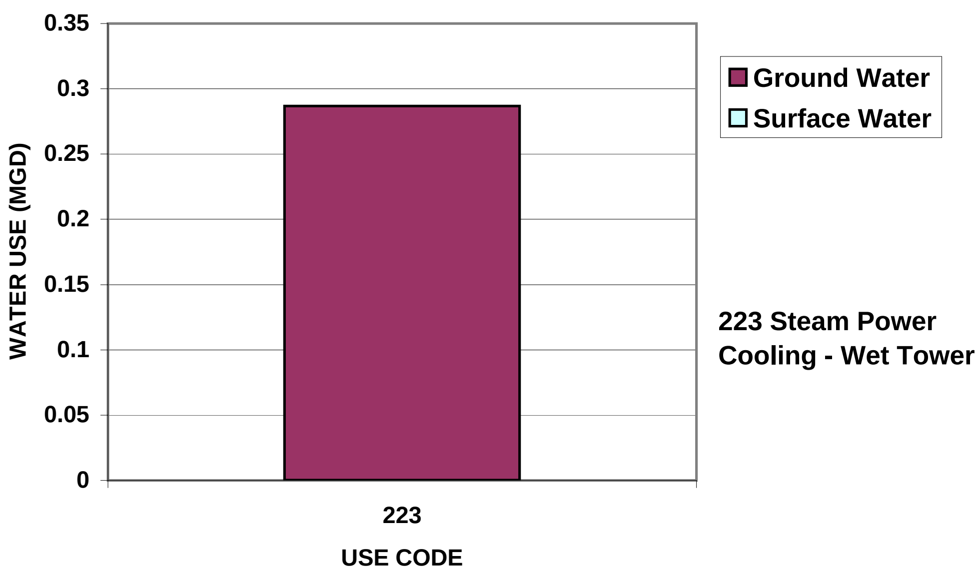


Figure 3.8b. Power Generation Water Use in the Cedar River Watershed, 2004

Table 3.9a. Industrial Water Use in the Des Moines River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	0.56	0.00	0.56
Sand & Gravel Washing	0.00	0.10	0.10
Total	0.56	0.10	0.66

Table 3.9b. WWTPs in the Des Moines River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Windom WWTP	1.830			1.074
Worthington WWTP	4.000			1.992
Total	5.830			3.066

Table 3.9c. Industries in the Des Moines River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
HERON LAKE, CITY OF	Ground Water	0.089	9.6	Windom	Agricultural Processing
HERON LAKE, CITY OF	Ground Water	0.098	9.6	Windom	Agricultural Processing
PM WINDOM	Ground Water	0.200	6.5	Windom	Agricultural Processing
PM WINDOM	Ground Water	0.077	6.5	Windom	Agricultural Processing
PM WINDOM	Ground Water	0.098	6.5	Windom	Agricultural Processing
WORTHINGTON RENDERING	Surface Water	0.003	1.7	Worthington	Agricultural Processing
WILLETT GRAVEL CO	Surface Water	0.001	>10	Windom	Non-Metallic Processing
MUECKE SAND & GRAVEL, R A	Surface Water	0.100	>10	Windom	Sand and Gravel Washing
WINDOM READY MIX INC	Surface Water	0.000	3.3	Windom	Sand and Gravel Washing
WINDOM READY MIX INC	Surface Water	0.000	7.1	Windom	Sand and Gravel Washing

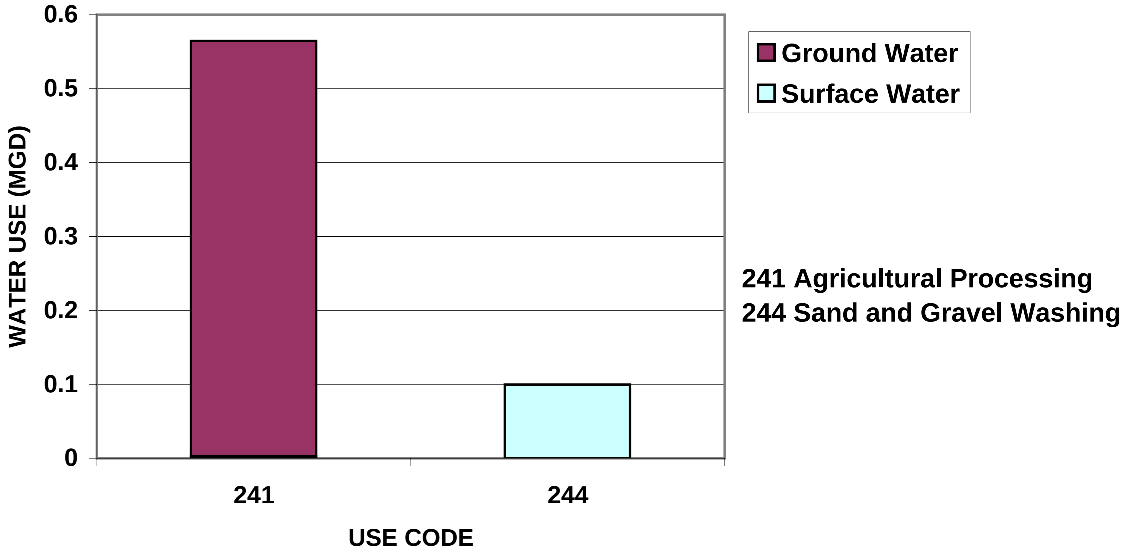


Figure 3.9a Industrial Processing Water Use in the Des Moines River Watershed, 2004

Table 3.10a. Industrial Water Use in the Lower Mississippi River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	2.89	0.00	2.89
Industrial Process Cooling - Once Through	0.38	0.01	0.39
Metal Processing	0.70	0.00	0.70
Non-Metallic Processing	1.02	0.00	1.02
Nuclear Power Plant	0.09	505.84	505.93
Petroleum - Chemical Processing, ethanol	7.00	0.00	7.00
Power Generation	0.55	0.00	0.55
Sand & Gravel Washing	0.27	1.58	1.85
Steam Power Cooling - Once Through	0.00	71.38	71.38
Steam Power Cooling - Wet Tower	0.41	0.00	0.41
Total	13.31	578.81	592.12

Table 3.10b. WWTPs in the Lower Mississippi River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd			Flow as % of Design Capacity
		2003	2004	2005	2005
Faribault WWTP	7.000			3.697	53%
Lake City WWTP	1.520			0.558	37%
Met Council - Empire WWTP*	24.000			8.458	35%
Met Council - Rosemount WWTP*	1.300			0.903	69%
Northfield WWTP	5.200			2.067	40%
Owatonna WWTP	5.000			3.531	71%
Plainview-Elgin Sanitary District WWTP	1.421			1.053	74%
Red Wing WWTP	4.000			2.057	51%
Rochester Water Reclamation Plant	19.100			13.462	70%
Stewartville WWTP	1.111			0.531	48%
Whitewater River Regional WWTP	1.120			0.701	63%
Winona WWTP	6.500			3.947	61%
Total	77.272			40.965	53%

* Design capacity changed per MCES instructions

Table 3.10d. Industries in the Lower Mississippi River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ARCHER DANIELS MIDLAND CO	Ground Water	0.206	1.0	Red Wing	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.603	2.7	Rochester WWTP/Water Reclamation Plant	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.092	2.7	Rochester WWTP/Water Reclamation Plant	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.001	2.7	Rochester WWTP/Water Reclamation Plant	Agricultural Processing
CON AGRA FLOUR MILLING CO	Ground Water	0.018	1.5	Met Council - Hastings	Agricultural Processing
FOREMOST FARMS USA	Ground Water	0.009	>10	Stewartville	Agricultural Processing
FOREMOST FARMS USA	Ground Water	0.005	>10	Stewartville	Agricultural Processing
GRANGER CO-OP CREAMERY	Ground Water	0.004	>10	Stewartville	Agricultural Processing
HORMEL FOODS CORP	Ground Water	0.272	1.0	Fairbault	Agricultural Processing
IFP INC	Ground Water	0.012	1.0	Fairbault	Agricultural Processing
INTERNATIONAL MALTING CO LLC	Ground Water	0.238	3.3	Winona	Agricultural Processing
INTERNATIONAL MALTING CO LLC	Ground Water	0.726	3.3	Winona	Agricultural Processing
LAKESIDE FOODS INC	Ground Water	0.075	3.0	Plainview - Elgin Sanitary District	Agricultural Processing
LAND O LAKES INC	Ground Water	0.008	9.2	Lake City	Agricultural Processing
LAND O LAKES INC	Ground Water	0.000	>10	Plainview - Elgin Sanitary District	Agricultural Processing
MAPLE ISLAND INC	Ground Water	0.002	>10	Plainview - Elgin Sanitary District	Agricultural Processing
MARIGOLD FOODS INC	Ground Water	0.162	2.0	Met Council - Empire	Agricultural Processing
MARIGOLD FOODS INC	Ground Water	0.157	2.0	Met Council - Empire	Agricultural Processing
PLAINVIEW MILK PROD COOP	Ground Water	0.191	3.0	Plainview - Elgin Sanitary District	Agricultural Processing
PROTEIN INGREDIENT TECHNOLOGIES INC	Ground Water	0.052	2.0	Fairbault	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.049	4.0	Rochester WWTP/Water Reclamation Plant	Agricultural Processing
TURKEY STORE COMPANY	Ground Water	0.009	5.5	Fairbault	Agricultural Processing
CYTEC ENGINEERED MATERIALS INC	Ground Water	0.004	3.3	Winona	Industrial Process Cooling - Once Through
CYTEC ENGINEERED MATERIALS INC	Ground Water	0.073	3.3	Winona	Industrial Process Cooling - Once Through
FARIBAULT WOOLEN MILL COMPANY	Surface Water	0.006	1.0	Fairbault	Industrial Process Cooling - Once Through
KERRY BIOFUNCTIONAL INGREDIENTS INC	Ground Water	0.298	2.5	Rochester WWTP/Water Reclamation Plant	Industrial Process Cooling - Once Through
S B FOOT TANNING CO	Ground Water	0.000	3.2	Red Wing	Industrial Processing
S B FOOT TANNING CO	Ground Water	0.000	3.2	Red Wing	Industrial Processing
BADGER FOUNDRY CO	Ground Water	0.052	1.0	Winona	Metal Processing
BADGER FOUNDRY CO	Ground Water	0.373	1.0	Winona	Metal Processing
PEERLESS CHAIN COMPANY	Ground Water	0.266	1.0	Winona	Metal Processing
TECHNICAL DIE CASTING INC	Ground Water	0.010	9.3	Winona	Metal Processing
8TH AND JEFFERSON LLC	Ground Water	0.001	1.0	Winona	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.015	5.0	Met Council - Empire	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.009	5.0	Met Council - Empire	Non-Metallic Processing
GENOVA INC	Ground Water	0.139	1.0	Fairbault	Non-Metallic Processing
HANSON PIPE & PRODUCTS MN INC	Ground Water	0.078	7.5	Met Council - Empire	Non-Metallic Processing
NRG PROCESSING SOLUTIONS LLC	Ground Water	0.000	5.6	Met Council - Empire	Non-Metallic Processing
RTP COMPANY	Ground Water	0.177	2.5	Winona	Non-Metallic Processing
RTP COMPANY	Ground Water	0.259	2.5	Winona	Non-Metallic Processing
S B FOOT TANNING CO	Ground Water	0.135	2.6	Red Wing	Non-Metallic Processing
S B FOOT TANNING CO	Ground Water	0.172	2.6	Red Wing	Non-Metallic Processing
USG INTERIORS INC	Ground Water	0.034	2.3	Red Wing	Non-Metallic Processing
USG INTERIORS INC	Ground Water	0.001	2.3	Red Wing	Non-Metallic Processing

Table 3.10d. Industries in the Lower Mississippi River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
NSP CO DBA XCEL ENERGY	Ground Water	0.051	6.1	Red Wing	NUCLEAR POWER PLANT
NSP CO DBA XCEL ENERGY	Ground Water	0.036	6.1	Red Wing	NUCLEAR POWER PLANT
NSP CO DBA XCEL ENERGY	Surface Water	505.836	6.1	Red Wing	NUCLEAR POWER PLANT
NSP CO DBA XCEL ENERGY	Ground Water	0.000	6.1	Red Wing	NUCLEAR POWER PLANT
AL-CORN CLEAN FUEL	Ground Water	0.000	>10	Owatonna	Petroleum - Chemical Processing
AL-CORN CLEAN FUEL	Ground Water	0.000	>10	Owatonna	Petroleum - Chemical Processing
AL-CORN CLEAN FUEL	Ground Water	0.000	>10	Owatonna	Petroleum - Chemical Processing
AL-CORN CLEAN FUEL	Ground Water	0.387	>10	Owatonna	Petroleum - Chemical Processing
CONTINENTAL NITROGEN & RESOURCES	Ground Water	0.000	1.6	Met Council - Rosemount	Petroleum - Chemical Processing
CONTINENTAL NITROGEN & RESOURCES	Ground Water	0.085	1.6	Met Council - Rosemount	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.960	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.660	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	1.048	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	1.407	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.000	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.329	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	1.661	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.465	8.5	Met Council - Empire	Petroleum - Chemical Processing
FLINT HILLS RESOURCES LP	Ground Water	0.000	8.5	Met Council - Empire	Petroleum - Chemical Processing
FRANKLIN HEATING STATION	Ground Water	0.136	4.0	Rochester WWTP/Water Reclamation Plant	POWER GENERATION
FRANKLIN HEATING STATION	Ground Water	0.367	4.0	Rochester WWTP/Water Reclamation Plant	POWER GENERATION
GREAT RIVER ENERGY	Ground Water	0.001	>10	Stewartville	POWER GENERATION
NSP CO DBA XCEL ENERGY	Ground Water	0.042	6.1	Red Wing	POWER GENERATION
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	6.8	Red Wing	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.320	5.0	Met Council - Empire	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.472	10.0	Red Wing	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	>10	Met Council - Empire	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	2.0	Met Council - Hastings	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	2.0	Met Council - Hastings	Sand and Gravel Washing
BARSNESS CONSTRUCTION & EXCAVATION	Surface Water	0.000	2.3	Northfield	Sand and Gravel Washing
BARTON SAND & GRAVEL	Surface Water	0.002	9.0	Met Council - Empire	Sand and Gravel Washing
BARTON SAND & GRAVEL	Surface Water	0.004	>10	Met Council - Empire	Sand and Gravel Washing
BITUMINOUS ROADWAYS INC	Surface Water	0.004	4.0	Met Council - Rosemount	Sand and Gravel Washing
BONANZA GRAIN INC	Ground Water	0.005	>10	Winona	Sand and Gravel Washing
BONANZA GRAIN INC	Surface Water	0.025	>10	Winona	Sand and Gravel Washing
CEMSTONE PRODUCTS	Ground Water	0.011	3.8	Met Council - Empire	Sand and Gravel Washing
FISCHER SAND & AGGREGATE	Ground Water	0.163	6.5	Met Council - Empire	Sand and Gravel Washing
FISCHER SAND & AGGREGATE	Ground Water	0.000	6.5	Met Council - Empire	Sand and Gravel Washing
FISCHER SAND & AGGREGATE	Ground Water	0.000	6.5	Met Council - Empire	Sand and Gravel Washing
MATHY CONSTRUCTION CO	Surface Water	0.000	4.3	Rochester WWTP/Water Reclamation Plant	Sand and Gravel Washing
MATHY CONSTRUCTION CO	Ground Water	0.009	4.5	Winona	Sand and Gravel Washing
MEDFORD PROPERTIES	Surface Water	0.224	8.5	Fairbault	Sand and Gravel Washing
MILESTONE MATERIALS	Ground Water	0.006	>10	Lake City	Sand and Gravel Washing
OWATONNA CONSTRUCTION CO INC	Surface Water	0.202	7.7	Northfield	Sand and Gravel Washing

Table 3.10d. Industries in the Lower Mississippi River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
PATTERSON QUARRIES	Ground Water	0.024	>10	Rochester WWTP/Water Reclamation Plant	Sand and Gravel Washing
RIVER CITY ASPHALT INC	Surface Water	0.037	9.8	Met Council - Empire	Sand and Gravel Washing
ROVERUD CONSTRUCTION INC	Surface Water	0.000	>10	Winona	Sand and Gravel Washing
ROVERUD CONSTRUCTION INC	Surface Water	0.000	>10	Winona	Sand and Gravel Washing
SHAMROCK ENTERPRISES	Ground Water	0.048	5.9	Rochester WWTP/Water Reclamation Plant	Sand and Gravel Washing
SOUTHERN MN CONSTRUCTION CO	Surface Water	0.275	10.0	Owatonna	Sand and Gravel Washing
STORLIE, JOHN	Surface Water	0.000	8.4	Met Council - Empire	Sand and Gravel Washing
TRI-COUNTY AGGREGATE, INC	Surface Water	0.019	4.4	Fairbault	Sand and Gravel Washing
NSP CO DBA XCEL ENERGY	Surface Water	42.659	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	2.104	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	1.0	Red Wing	STEAM POWER COOLING - ONCE THROUGH
ROCHESTER PUBLIC UTILITIES	Surface Water	26.622	3.0	Rochester WWTP/Water Reclamation Plant	STEAM POWER COOLING - ONCE THROUGH
ROCHESTER PUBLIC UTILITIES	Ground Water	0.212	3.0	Rochester WWTP/Water Reclamation Plant	STEAM POWER COOLING - WET TOWER
ROCHESTER PUBLIC UTILITIES	Ground Water	0.000	3.0	Rochester WWTP/Water Reclamation Plant	STEAM POWER COOLING - WET TOWER
ROCHESTER PUBLIC UTILITIES	Ground Water	0.193	3.0	Rochester WWTP/Water Reclamation Plant	STEAM POWER COOLING - WET TOWER

Count of Industries

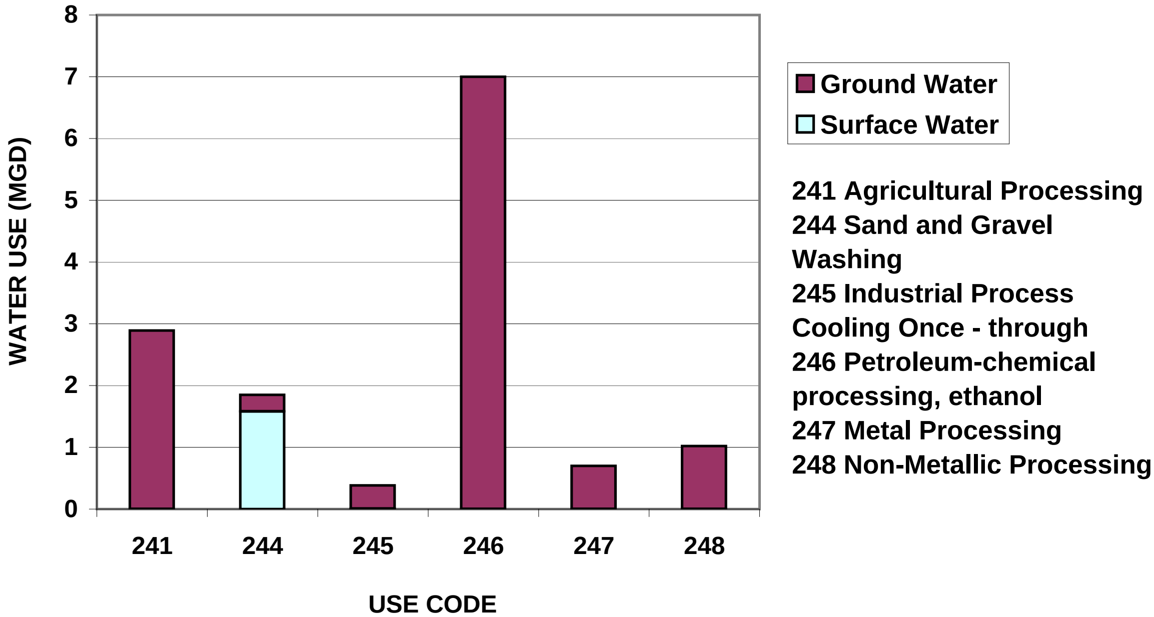


Figure 3.10a. Industrial Processing Water Use in the Lower Mississippi River Watershed, 2004

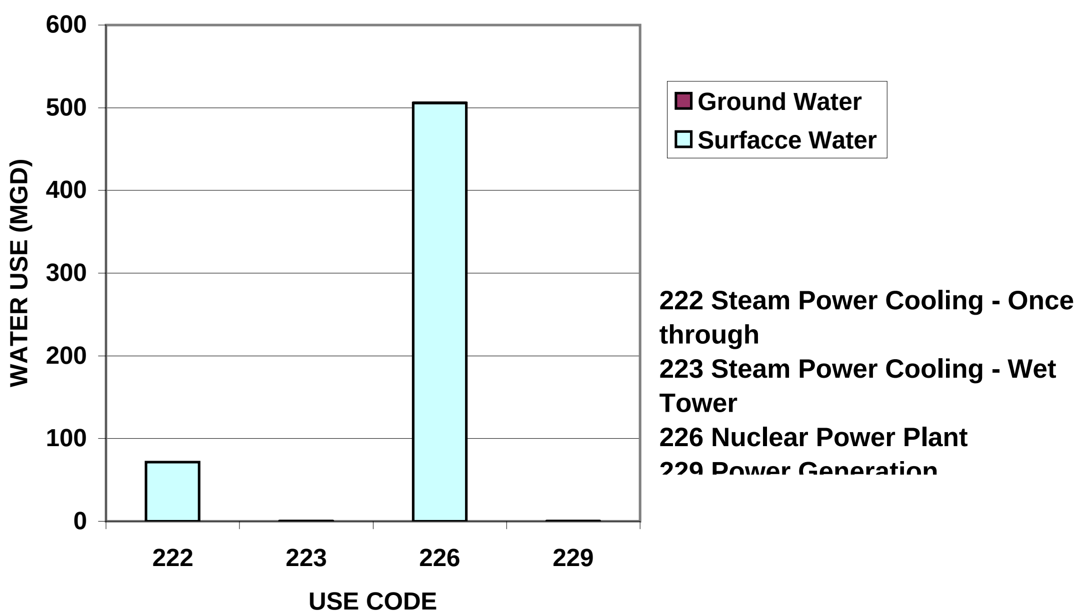


Figure 3.10b. Power Generation Water Use in the Lower Mississippi River Watershed, 2004

Table 3.11a. Industrial Water Use in the Minnesota River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	11.14	0.00	11.14
Industrial Process Cooling - Once Through	1.88	0.00	1.88
Industrial Processing	0.17	0.00	0.17
Metal Processing	1.31	0.00	1.31
Mine Processing	0.20	0.04	0.24
Non-Metallic Processing	0.43	0.00	0.43
Petroleum - Chemical Processing, ethanol	1.18	0.00	1.18
Pulp and Paper Processing	0.05	0.00	0.05
Sand and Gravel Washing	0.83	1.62	2.45
Steam Power Cooling - Once Through	0.11	326.00	326.11
Total	17.30	327.66	344.96

Table 3.11b. WWTPs in the Minnesota River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd	Flow as % of Design Capacity
		2005	2005
Fairmont WWTP	3.900	1.595	41%
Granite Falls WWTP	1.111	0.477	43%
Madelia WWTP	1.310	0.907	69%
Mankato WWTP	11.250	6.861	61%
Marshall WWTP	4.500	2.518	56%
Met Council - Blue Lake WWTP*	37.000	28.420	77%
Met Council - Seneca WWTP*	39.000	23.353	60%
Montevideo WWTP	3.000	1.083	36%
New Prague WWTP	1.378	0.662	48%
New Ulm WWTP	6.770	2.582	38%
St James WWTP	2.960	1.032	35%
St Peter WWTP	4.000	1.170	29%
Waseca WWTP	3.500	1.580	45%
Wells Easton Minnesota Lake WWTP	1.088	0.516	47%
Winnebago WWTP	1.700	0.592	35%
Total	122.467	73.348	60%

* Design capacity changed per MCES instructions.

Table 3.11d. Industries in the Minnesota River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ANDERSON CUSTOM PROCESSING	Ground Water	0.0318	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.1422	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0000	>5	Marshall	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0803	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0518	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0427	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0814	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.0197	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.5162	>5	New Ulm	Agricultural Processing
ARCHER DANIELS MIDLAND CO	Ground Water	0.2940	>5	New Ulm	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.0866	>5	Montevideo	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.1129	>5	Montevideo	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.0000	1.0	New Prague	Agricultural Processing
AUGUST SCHELL BREWERY	Ground Water	0.0000	1.5	New Ulm	Agricultural Processing
AUGUST SCHELL BREWERY	Ground Water	0.0000	1.5	New Ulm	Agricultural Processing
BONGARDS CREAMERIES	Ground Water	0.1362	>5	Met Council - Blue Lake	Agricultural Processing
BONGARDS CREAMERIES	Ground Water	0.1104	>5	Met Council - Blue Lake	Agricultural Processing
BONGARDS CREAMERIES	Ground Water	0.1384	>5	Met Council - Blue Lake	Agricultural Processing
BUTTERFIELD FOODS COMPANY	Ground Water	0.1386	>5	St James	Agricultural Processing
BUTTERFIELD FOODS COMPANY	Ground Water	0.0115	>5	St James	Agricultural Processing
BUTTERFIELD FOODS COMPANY	Ground Water	0.0353	>5	St James	Agricultural Processing
BUTTERFIELD FOODS COMPANY	Ground Water	0.0416	>5	St James	Agricultural Processing
CENEX HARVEST STATES COOPERATIVES	Ground Water	3.5781	2.0	Mankato	Agricultural Processing
CHRISTENSEN FAMILY FARMS	Ground Water	0.0060	>5	New Ulm	Agricultural Processing
COCA-COLA BOTTLING MW	Ground Water	0.0266	3.7	Met Council - Seneca	Agricultural Processing
COCA-COLA BOTTLING MW	Ground Water	0.6797	3.7	Met Council - Seneca	Agricultural Processing
DAIRY FARMERS OF AMERICA INC	Ground Water	0.0000	>5	New Ulm	Agricultural Processing
DARLING INTERNATIONAL INC	Ground Water	0.0625	>5	Winnebago	Agricultural Processing
DEL MONTE CORPORATION	Ground Water	0.0690	>5	New Ulm	Agricultural Processing
DEL MONTE CORPORATION	Ground Water	0.0710	>5	New Ulm	Agricultural Processing
FAIRMONT FOODS OF MINNESOTA	Ground Water	0.0000	1.2	Fairmont	Agricultural Processing
FAIRMONT FOODS OF MINNESOTA	Ground Water	0.0000	1.2	Fairmont	Agricultural Processing
FAIRMONT FOODS OF MINNESOTA	Ground Water	0.0321	1.4	Fairmont	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.0000	>5	Granite Falls	Agricultural Processing
FARMERS UNION MARKETING	Surface Water	0.0005	>5	Granite Falls	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.0068	>5	Granite Falls	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.0249	>5	Granite Falls	Agricultural Processing
GEDNEY COMPANY, M A	Ground Water	0.1666	>5	Met Council - Blue Lake	Agricultural Processing
GEDNEY COMPANY, M A	Ground Water	0.0000	>5	Met Council - Blue Lake	Agricultural Processing
NICOLLET FOOD PRODUCTS	Ground Water	0.0134	>5	New Ulm	Agricultural Processing
NICOLLET FOOD PRODUCTS	Ground Water	0.0000	>5	New Ulm	Agricultural Processing
PEPSI COLA BOTTLING CO	Ground Water	0.1548	2.9	Met Council - Seneca	Agricultural Processing
PEPSI COLA BOTTLING CO	Ground Water	0.1663	2.9	Met Council - Seneca	Agricultural Processing

Table 3.11d. Industries in the Minnesota River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
PROTEIN INGREDIENT TECHNOLOGIES INC	Ground Water	0.1249	>5	St James	Agricultural Processing
RAHR MALTING COMPANY	Ground Water	0.2033	>5	Met Council - Blue Lake	Agricultural Processing
RAHR MALTING COMPANY	Ground Water	0.0000	>5	Met Council - Blue Lake	Agricultural Processing
RAHR MALTING COMPANY	Ground Water	0.7937	>5	Met Council - Blue Lake	Agricultural Processing
RAHR MALTING COMPANY	Ground Water	1.0378	>5	Met Council - Blue Lake	Agricultural Processing
RAHR MALTING COMPANY	Ground Water	0.5066	>5	Met Council - Blue Lake	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.0441	>5	New Prague	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.2808	>5	New Prague	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.1932	>5	Winnebago	Agricultural Processing
SOUTHERN MINNESOTA SUGAR COOP	Ground Water	0.2581	>5	Granite Falls	Agricultural Processing
SOUTHERN MINNESOTA SUGAR COOP	Ground Water	0.0000	>5	Granite Falls	Agricultural Processing
SOUTHERN MINNESOTA SUGAR COOP	Ground Water	0.0000	>5	Granite Falls	Agricultural Processing
SOUTHERN MINNESOTA SUGAR COOP	Ground Water	0.1386	>5	Granite Falls	Agricultural Processing
SOUTHERN MINNESOTA SUGAR COOP	Ground Water	0.0537	>5	Granite Falls	Agricultural Processing
WIS-PAK OF MANKATO INC	Ground Water	0.0005	2.5	Mankato	Agricultural Processing
WIS-PAK OF MANKATO INC	Ground Water	0.3704	2.5	Mankato	Agricultural Processing
AG PROCESSING INC	Ground Water	0.7123	>5	Montevideo	Industrial Process Cooling - Once Through
AG PROCESSING INC	Ground Water	0.6288	>5	Montevideo	Industrial Process Cooling - Once Through
AG PROCESSING INC	Ground Water	0.0000	>5	Montevideo	Industrial Process Cooling - Once Through
ROSEMOUNT INC	Ground Water	0.0030	4.5	Met Council - Blue Lake	Industrial Process Cooling - Once Through
THERMOTECH	Ground Water	0.5263	>5	Met Council - Blue Lake	Industrial Process Cooling - Once Through
THERMOTECH	Ground Water	0.0058	>5	Met Council - Blue Lake	Industrial Process Cooling - Once Through
CARGILL INC	Ground Water	0.0016	>5	Winnebago	Industrial Processing
DUKE REALTY INVESTMENTS INC	Ground Water	0.1671	>5	Met Council - Blue Lake	Industrial Processing
PINGEL, RON	Ground Water	0.0000	>5	Met Council - Blue Lake	Industrial Processing
SURMODICS INC	Ground Water	0.0033	4.0	Met Council - Seneca	Industrial Processing
WATONWAN FARM SERVICE CO	Ground Water	0.0011	>5	Wells Easton Minnetonka Lake	Industrial Processing
CYPRESS SEMICONDUCTOR	Ground Water	0.8532	2.5	Met Council - Seneca	Metal Processing
CYPRESS SEMICONDUCTOR	Ground Water	0.0000	2.5	Met Council - Seneca	Metal Processing
CYPRESS SEMICONDUCTOR	Ground Water	0.0000	2.5	Met Council - Seneca	Metal Processing
EATON CORP	Ground Water	0.0488	5.0	Met Council - Blue Lake	Metal Processing
GOPHER RESOURCE CORP	Ground Water	0.1296	4.5	Met Council - Seneca	Metal Processing
HINIKER COMPANY	Ground Water	0.0005	5.0	Mankato	Metal Processing
HINIKER COMPANY	Ground Water	0.0005	5.0	Mankato	Metal Processing
HINIKER COMPANY	Ground Water	0.0060	5.0	Mankato	Metal Processing
HOLNAM INC	Ground Water	0.0003	4.8	Met Council - Seneca	Metal Processing
NORTHWEST AIRLINES INC	Ground Water	0.0956	4.2	Met Council - Seneca	Metal Processing
NORTHWEST AIRLINES INC	Ground Water	0.1668	4.2	Met Council - Seneca	Metal Processing
VALMONT COATINGS INC	Ground Water	0.0115	5.0	Met Council - Blue Lake	Metal Processing
NEW ULM QUARTZITE QUARRY	Surface Water	0.0416	1.3	New Ulm	Mine Processing
VETTER STONE CO	Ground Water	0.0000	5.0	St Peter	Mine Processing
VETTER STONE CO	Ground Water	0.0608	3.9	Mankato	Mine Processing
VETTER STONE CO	Ground Water	0.0611	3.9	Mankato	Mine Processing

Table 3.11d. Industries in the Minnesota River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
VETTER STONE CO	Ground Water	0.0778	3.9	Mankato	Mine Processing
VETTER STONE CO	Ground Water	0.0000	3.9	Mankato	Mine Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.0000	>5	New Prague	Non-Metallic Processing
ANCHOR GLASS CONTAINER CORP	Ground Water	0.0636	2.0	Met Council - Blue Lake	Non-Metallic Processing
ANCHOR GLASS CONTAINER CORP	Ground Water	0.0036	2.0	Met Council - Blue Lake	Non-Metallic Processing
AVR INC	Ground Water	0.0121	>5	Met Council - Seneca	Non-Metallic Processing
GREENMAN TECHNOLOGIES OF MN	Ground Water	0.0025	2.7	Met Council - Blue Lake	Non-Metallic Processing
MICRON MOLDING INC	Ground Water	0.0148	4.5	Met Council - Seneca	Non-Metallic Processing
MIDWEST ELECTRIC	Ground Water	0.0186	4.6	Mankato	Non-Metallic Processing
MIDWEST ELECTRIC	Ground Water	0.0003	4.6	Mankato	Non-Metallic Processing
PLASTECH CORP	Ground Water	0.0000	>5	New Prague	Non-Metallic Processing
POLARFAB LLC	Ground Water	0.0995	2.4	Met Council - Seneca	Non-Metallic Processing
POLARFAB LLC	Ground Water	0.1658	2.4	Met Council - Seneca	Non-Metallic Processing
STARBUCK CEMENT	Ground Water	0.0447	>5	Montevideo	Non-Metallic Processing
STARBUCK CEMENT	Ground Water	0.0016	>5	Montevideo	Non-Metallic Processing
WATONWAN FARM SERVICE CO	Ground Water	0.0005	>5	Wells Easton Minnetonka Lake	Non-Metallic Processing
CHIPPEWA VALLEY ETHANOL CO	Ground Water	0.1003	>5	Montevideo	Petroleum - Chemical Processing
CHIPPEWA VALLEY ETHANOL CO	Ground Water	0.1003	>5	Montevideo	Petroleum - Chemical Processing
CHIPPEWA VALLEY ETHANOL CO	Ground Water	0.1003	>5	Montevideo	Petroleum - Chemical Processing
CHIPPEWA VALLEY ETHANOL CO	Ground Water	0.1003	>5	Montevideo	Petroleum - Chemical Processing
CORN PLUS	Ground Water	0.1359	1.0	Winnebago	Petroleum - Chemical Processing
CORN PLUS	Ground Water	0.0000	1.0	Winnebago	Petroleum - Chemical Processing
CORN PLUS	Ground Water	0.0000	1.0	Winnebago	Petroleum - Chemical Processing
DIVERSIFIED ENERGY CO LLC	Ground Water	0.1107	>5	Montevideo	Petroleum - Chemical Processing
DIVERSIFIED ENERGY CO LLC	Ground Water	0.2570	>5	Montevideo	Petroleum - Chemical Processing
GRANITE FALLS ENERGY LLC	Ground Water	0.0000	>5	Granite Falls	Petroleum - Chemical Processing
HEARTLAND CORN PRODUCTS	Ground Water	0.2781	>5	St Peter	Petroleum - Chemical Processing
INLAND PAPERBOARD & PACKAGING INC	Ground Water	0.0279	2.0	Met Council - Blue Lake	Pulp and Paper Processing
INLAND PAPERBOARD & PACKAGING INC	Ground Water	0.0225	2.0	Met Council - Blue Lake	Pulp and Paper Processing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.0000	>5	Montevideo	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.0000	>5	Montevideo	Sand and Gravel Washing
ALEXANDRIA GRAVEL PRODUCTS	Ground Water	0.0211	>5	Montevideo	Sand and Gravel Washing
BRYAN ROCK PRODUCTS INC	Ground Water	0.0142	>5	Met Council - Blue Lake	Sand and Gravel Washing
BUFFALO BITUMINOUS	Surface Water	0.0000	>5	Met Council - Blue Lake	Sand and Gravel Washing
CENTRAL-ALLIED ENTERPRISES INC	Ground Water	0.0000	>5	Montevideo	Sand and Gravel Washing
DUININCK BROTHERS INC	Surface Water	0.0000	>5	Marshall	Sand and Gravel Washing
DUININCK BROTHERS INC	Surface Water	0.0000	>5	New Prague	Sand and Gravel Washing
DUININCK CONCRETE LLC	Surface Water	0.0329	>5	Granite Falls	Sand and Gravel Washing
EDWARD KRAEMER & SONS INC	Surface Water	0.4129	4.8	Met Council - Seneca	Sand and Gravel Washing
EDWARD KRAEMER & SONS INC	Ground Water	0.0003	4.8	Met Council - Seneca	Sand and Gravel Washing
HANCOCK CONCRETE PRODUCTS	Ground Water	0.0000	>5	Montevideo	Sand and Gravel Washing
HANCOCK CONCRETE PRODUCTS	Ground Water	0.1447	>5	Montevideo	Sand and Gravel Washing
HENRICH & SONS INC	Surface Water	0.0748	>5	Marshall	Sand and Gravel Washing

Table 3.11d. Industries in the Minnesota River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
JOHNSON, WAYNE F	Ground Water	0.1652	5.0	St Peter	Sand and Gravel Washing
JOHNSON, WAYNE F	Ground Water	0.1019	5.0	St Peter	Sand and Gravel Washing
L & S CONSTRUCTION CORP	Surface Water	0.0000	>5	Marshall	Sand and Gravel Washing
L & S CONSTRUCTION CORP	Surface Water	0.0000	>5	Marshall	Sand and Gravel Washing
L & S CONSTRUCTION CORP	Surface Water	0.0000	>5	Marshall	Sand and Gravel Washing
MARSHALL SAND & GRAVEL	Surface Water	0.0000	5.0	Marshall	Sand and Gravel Washing
MINNESOTA QUARRIES INC	Ground Water	0.1096	1.0	Mankato	Sand and Gravel Washing
MINNESOTA QUARRIES INC	Ground Water	0.0071	1.0	Mankato	Sand and Gravel Washing
MORRIS SAND & GRAVEL	Surface Water	0.1597	>5	Montevideo	Sand and Gravel Washing
MUELLER & SONS INC, WM	Ground Water	0.0414	>5	Met Council - Blue Lake	Sand and Gravel Washing
NORTHERN CON-AGG INC	Surface Water	0.0589	>5	Marshall	Sand and Gravel Washing
ORTONVILLE STONE CO	Surface Water	0.0000	>5	Montevideo	Sand and Gravel Washing
PRIOR LAKE AGGREGATES	Surface Water	0.3816	>5	Met Council - Blue Lake	Sand and Gravel Washing
SHAKOPEE GRAVEL INC	Ground Water	0.0011	2.5	Met Council - Blue Lake	Sand and Gravel Washing
SOUTHERN MINNESOTA CONSTRUCTION CO	Ground Water	0.1501	4.0	St Peter	Sand and Gravel Washing
SOUTHERN MN CONSTRUCTION CO	Surface Water	0.0000	4.5	Mankato	Sand and Gravel Washing
SOUTHERN MN CONSTRUCTION CO	Surface Water	0.4195	5.0	Mankato	Sand and Gravel Washing
UNIMIN MINNESOTA CORP	Surface Water	0.0000	2.5	St Peter	Sand and Gravel Washing
UNIMIN MINNESOTA CORP	Ground Water	0.0688	5.0	St Peter	Sand and Gravel Washing
WASECA SAND & GRAVEL	Surface Water	0.0789	4.4	Waseca	Sand and Gravel Washing
KOCH MATERIALS COMPANY	Ground Water	0.0000	>5	Met Council - Blue Lake	STEAM POWER - OTHER THAN COOLING
FAIRMONT, CITY OF	Surface Water	0.1030	1.0	Fairmont	STEAM POWER COOLING - ONCE THROUGH
FAIRMONT, CITY OF	Surface Water	0.0726	1.0	Fairmont	STEAM POWER COOLING - ONCE THROUGH
FAIRMONT, CITY OF	Surface Water	0.2334	1.0	Fairmont	STEAM POWER COOLING - ONCE THROUGH
INTERSTATE POWER & LIGHT CO	Surface Water	8.5427	>5	Fairmont	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	295.4600	2.5	Met Council - Seneca	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Ground Water	0.1123	2.5	Met Council - Seneca	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Ground Water	0.0000	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Ground Water	0.0000	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	4.0655	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	6.2948	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	11.1874	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0332	1.0	Mankato	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0082	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.0000	1.0	Granite Falls	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Ground Water	0.0000	1.0	Met Council - Blue Lake	STEAM POWER COOLING - WET TOWER

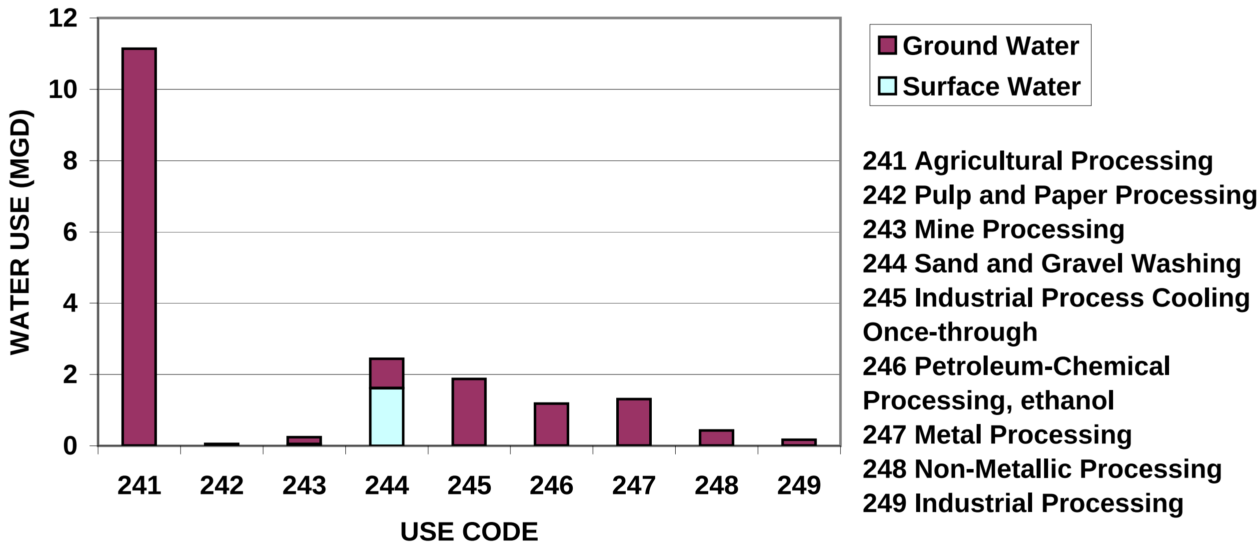


Figure 3.11a. Industrial Processing Water Use in the Minnesota River Watershed, 2004

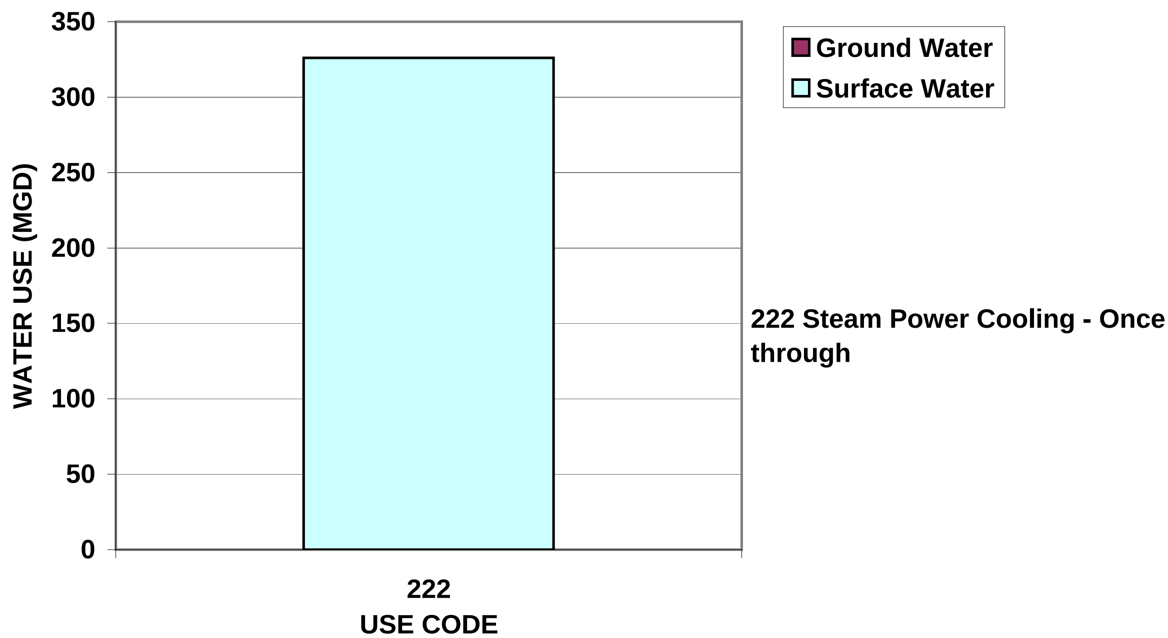


Figure 3.11b. Power Generation Water Use in the Minnesota River Watershed, 2004

Table 3.12a. Industrial Water Use in the Mississippi River Headwaters Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	6.49	0.00	6.49
Hydropower	0.00	0.12	0.12
Industrial Process Cooling - Once Through	3.58	0.51	4.09
Industrial Processing	0.87	0.00	0.87
Metal Processing	1.88	0.00	1.88
Mine Processing	0.24	0.00	0.24
Non-Metallic Processing	0.95	0.00	0.95
Nuclear Power Plant	0.05	346.60	346.65
Petroleum - Chemical Processing, ethanol	2.13	0.00	2.13
Power Generation	0.31	0.01	0.32
Pulp and Paper Processing	2.17	26.84	29.01
Sand and Gravel Washing	1.13	2.56	3.69
Steam Power Cooling - Once Through	0.19	544.49	544.68
Steam Power Cooling - Wet Tower	0.18	18.47	18.65
Steam Power Other than Cooling	1.36	0.00	1.36
Total	21.53	939.60	961.13

Table 3.12b. WWTPs in the Mississippi River Headwaters Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd			Flow as % of Design Capacity
		2003	2004	2005	2005
Alexandria Lake Area Sanitary District	3.750			2.906	77%
Bemidji WWTP	2.500			1.056	42%
Brainerd WWTP	3.130			2.438	78%
Buffalo WWTP	3.600			1.628	45%
Cambridge WWTP	1.920			0.847	44%
Camp Ripley WWTP	1.440			0.115	8%
Elk River WWTP	2.200			1.186	54%
Glencoe WWTP	2.600			0.69	27%
Grand Rapids WWTP	15.200			7.33	48%
Hutchinson WWTP	4.270			2.574	60%
Litchfield WWTP	1.900			1.513	80%
Little Falls WWTP	2.400			1.182	49%
Melrose WWTP	2.500			2.001	80%
Met Council - Eagles Point WWTP*	10.000			2.34	23%
Met Council - Hastings WWTP*	2.900			1.592	55%
Met Council - Metropolitan WWTP	251.000			187.018	75%
Monticello WWTP	2.360			1.189	50%
Otsego WWTP East	1.650			0.206	12%
Rogers WWTP	1.602			0.769	48%
St Cloud WWTP	13.000			10.358	80%
St Michael WWTP	2.445			0.834	34%
Willmar WWTP	5.040			3.81	76%
Total	337.407			233.582	69%

* Design capacity changed per MCES instructions.

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ADM MILLING CO	Ground Water	0.000	>5	Met Council - Metropolitan	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.024	1.00	Glencoe	Agricultural Processing
ASSOCIATED MILK PRODUCERS	Ground Water	0.013	>5	Litchfield	Agricultural Processing
BURN PHILP FOOD INGREDIENTS	Ground Water	0.000	1.00	Hutchinson	Agricultural Processing
BURN PHILP FOOD INGREDIENTS	Ground Water	0.412	1.00	Hutchinson	Agricultural Processing
BURN PHILP FOOD INGREDIENTS	Ground Water	0.076	1.00	Hutchinson	Agricultural Processing
BURN PHILP FOOD INGREDIENTS	Ground Water	0.429	1.00	Hutchinson	Agricultural Processing
CAPTAIN KENS FOODS INC	Ground Water	0.009	2.30	Met Council - Metropolitan	Agricultural Processing
DAIRI CONCEPTS LP	Ground Water	0.000	>5	Buffalo	Agricultural Processing
DAIRI CONCEPTS LP	Ground Water	0.000	>5	Buffalo	Agricultural Processing
DECHENE CORP	Ground Water	0.002	1.00	Monticello	Agricultural Processing
DECHENE CORP	Ground Water	0.002	1.00	Monticello	Agricultural Processing
DEEP ROCK WATER CO	Ground Water	0.019	>5	Met Council - Metropolitan	Agricultural Processing
DEEP ROCK WATER CO	Ground Water	0.019	>5	Met Council - Metropolitan	Agricultural Processing
EWING FARMS INC	Ground Water	0.004	1.50	Monticello	Agricultural Processing
FARIBAULT FOODS INC	Ground Water	0.022	>5	Buffalo	Agricultural Processing
FARIBAULT FOODS INC	Ground Water	0.226	>5	Buffalo	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.003	>5	St Cloud	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.094	>5	Little Falls	Agricultural Processing
FARMERS UNION MARKETING	Ground Water	0.000	>5	Little Falls	Agricultural Processing
FIRST DISTRICT ASSOC	Ground Water	0.105	1.00	Litchfield	Agricultural Processing
FIRST DISTRICT ASSOC	Ground Water	0.021	1.00	Litchfield	Agricultural Processing
GENERAL MILLS OPERATIONS INC	Ground Water	0.061	>5	Met Council - Metropolitan	Agricultural Processing
GENERAL MILLS OPERATIONS INC	Ground Water	0.025	>5	Met Council - Metropolitan	Agricultural Processing
GENERAL MILLS OPERATIONS INC	Ground Water	0.048	>5	Met Council - Metropolitan	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.144	>5	St Cloud	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.118	>5	St Cloud	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.089	>5	St Cloud	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.137	>5	St Cloud	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.285	>5	St Cloud	Agricultural Processing
GOLD N PLUMP POULTRY	Ground Water	0.000	>5	St Cloud	Agricultural Processing
ISANTI FOODS LLC	Ground Water	0.001	>5	Cambridge	Agricultural Processing
ISANTI FOODS LLC	Ground Water	0.076	>5	Cambridge	Agricultural Processing
LAKESIDE FOODS INC	Ground Water	0.131	>5	Melrose	Agricultural Processing
LAMB WESTON/RDO FROZEN	Ground Water	0.000	>5	Bemidji	Agricultural Processing
LAMB WESTON/RDO FROZEN	Ground Water	0.480	>5	Bemidji	Agricultural Processing
LAMB WESTON/RDO FROZEN	Ground Water	1.110	>5	Bemidji	Agricultural Processing
MEYER BROTHERS DAIRY	Ground Water	0.007	>5	Buffalo	Agricultural Processing
M-FOODS DAIRY LLC	Ground Water	0.605	>5	Met Council - Metropolitan	Agricultural Processing
MINNESOTA BEEF INDUSTRIES INC	Ground Water	0.076	>5	Glencoe	Agricultural Processing
MINNESOTA BEEF INDUSTRIES INC	Ground Water	0.000	>5	Glencoe	Agricultural Processing
NORTHERN FOOD & DAIRY INC	Ground Water	0.028	>5	Alexandria Lake Area Sanitary District	Agricultural Processing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
NORTHERN FOOD & DAIRY INC	Ground Water	0.000	1.50	Alexandria Lake Area Sanitary District	Agricultural Processing
NORTHERN FOOD & DAIRY INC	Ground Water	0.310	1.50	Alexandria Lake Area Sanitary District	Agricultural Processing
NORTHERN STAR COMPANY	Ground Water	0.324	>5	Met Council - Metropolitan	Agricultural Processing
OAK GROVE DAIRY	Ground Water	0.009	>5	Glencoe	Agricultural Processing
OLD DUTCH FOODS INC	Ground Water	0.068	>5	Met Council - Metropolitan	Agricultural Processing
OPTA FOOD INGREDIENTS INC	Ground Water	0.200	1.00	Cambridge	Agricultural Processing
PETRON, JOHN AND CHRISTINE	Ground Water	0.031	>5	Little Falls	Agricultural Processing
REFLO INC	Ground Water	0.070	>5	St Cloud	Agricultural Processing
REFLO INC	Ground Water	0.096	>5	St Cloud	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.183	1.00	Glencoe	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.084	1.00	Glencoe	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.028	1.00	Glencoe	Agricultural Processing
SENECA FOODS CORP	Ground Water	0.183	1.00	Glencoe	Agricultural Processing
SONSTEGARD FOODS	Ground Water	0.000	>5	Buffalo	Agricultural Processing
SONSTEGARD FOODS	Ground Water	0.003	>5	Buffalo	Agricultural Processing
U OF MN	Surface Water	0.122	>5	Met Council - Metropolitan	HYDRO POWER
3M COMPANY	Ground Water	0.135	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
3M COMPANY	Ground Water	0.290	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
3M COMPANY	Ground Water	0.184	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
3M COMPANY	Ground Water	0.525	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
3M COMPANY	Ground Water	0.981	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
3M COMPANY	Ground Water	0.673	2.00	Met Council - Eagles Point	Industrial Process Cooling Once Through
ATEK MANUFACTURING LLC	Ground Water	0.024	4.20	Brainerd	Industrial Process Cooling Once Through
ATEK MANUFACTURING LLC	Ground Water	0.000	4.20	Brainerd	Industrial Process Cooling Once Through
FORD MOTOR CO	Surface Water	0.512	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
GAF MATERIALS CORP	Ground Water	0.195	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
HONEYWELL INC	Ground Water	0.410	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
HONEYWELL INC	Ground Water	0.000	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
MED-TEK INC	Ground Water	0.000	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
PREMIER PRODUCTS INC	Ground Water	0.003	>5	Cambridge	Industrial Process Cooling Once Through
SPX CORPORATION	Ground Water	0.098	>5	St Cloud	Industrial Process Cooling Once Through
SPX CORPORATION	Ground Water	0.033	>5	St Cloud	Industrial Process Cooling Once Through
VEECO INSTRUMENTS INC	Ground Water	0.030	>5	Met Council - Metropolitan	Industrial Process Cooling Once Through
AMERICAN LINEN SUPPLY CO	Ground Water	0.248	>5	Met Council - Metropolitan	Industrial Processing
ANOKA RED-E-MIX INC	Ground Water	0.005	>5	Rogers	Industrial Processing
AVR INC	Ground Water	0.007	>5	Rogers	Industrial Processing
CEMSTONE PRODUCTS	Ground Water	0.004	3.60	Met Council - Metropolitan	Industrial Processing
DBL LABS INC	Ground Water	0.002	>5	St Cloud	Industrial Processing
DBL LABS INC	Ground Water	0.004	>5	St Cloud	Industrial Processing
ECOLAB INC	Ground Water	0.016	\	\	Industrial Processing
G & K SERVICES	Ground Water	0.104	>5	Met Council - Metropolitan	Industrial Processing
G & K SERVICES	Ground Water	0.061	>5	Met Council - Metropolitan	Industrial Processing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
HONEYWELL INC	Ground Water	0.210	>5	Met Council - Metropolitan	Industrial Processing
HONEYWELL INC	Ground Water	0.126	>5	Met Council - Metropolitan	Industrial Processing
JERRYS ICE SERVICE	Ground Water	0.008	2.50	Bemidji	Industrial Processing
LEEF BROTHERS INC	Ground Water	0.059	>5	Met Council - Metropolitan	Industrial Processing
PEARSON CANDY COMPANY	Ground Water	0.013	>5	Met Council - Metropolitan	Industrial Processing
SPRING PARK LAUNDRY	Ground Water	0.001	>5	Buffalo	Industrial Processing
STYLMARK INC	Ground Water	0.001	>5	Met Council - Metropolitan	Industrial Processing
AACRON INC	Ground Water	0.321	>5	Met Council - Metropolitan	Metal Processing
AACRON INC	Ground Water	0.224	>5	Met Council - Metropolitan	Metal Processing
ACME METAL SPINNING	Ground Water	0.001	>5	Met Council - Metropolitan	Metal Processing
ALEXANDRIA EXTRUSION CO	Ground Water	0.004	1.50	Alexandria Lake Area Sanitary District	Metal Processing
COOPERATIVE PLATING	Ground Water	0.053	>5	Met Council - Metropolitan	Metal Processing
FLAME METALS PROCESSING	Ground Water	0.000	>5	Met Council - Metropolitan	Metal Processing
HARD CHROME INC	Ground Water	0.054	>5	Met Council - Metropolitan	Metal Processing
HIAWATHA METALCRAFT INC	Ground Water	0.504	>5	Met Council - Metropolitan	Metal Processing
HIAWATHA METALCRAFT INC	Ground Water	0.047	>5	Met Council - Metropolitan	Metal Processing
KURT MANUFACTURING COMPANY	Ground Water	0.000	>5	Met Council - Metropolitan	Metal Processing
METAL-MATIC INC	Ground Water	0.224	>5	Met Council - Metropolitan	Metal Processing
METAL-MATIC INC	Ground Water	0.000	>5	Met Council - Metropolitan	Metal Processing
MINNESOTA METAL FINISHING INC	Ground Water	0.024	>5	Met Council - Metropolitan	Metal Processing
NORTH STAR STEEL MINNESOTA	Ground Water	0.000	2.50	Met Council - Metropolitan	Metal Processing
NORTH STAR STEEL MINNESOTA	Ground Water	0.059	2.50	Met Council - Metropolitan	Metal Processing
NORTH STAR STEEL MINNESOTA	Ground Water	0.082	2.50	Met Council - Metropolitan	Metal Processing
NORTH STAR STEEL ST PAUL	Ground Water	0.022	2.50	Met Council - Metropolitan	Metal Processing
NORTH STAR STEEL ST PAUL	Ground Water	0.013	2.50	Met Council - Metropolitan	Metal Processing
NORTHERN MALLEABLE IRON CO	Ground Water	0.038	3.00	Met Council - Metropolitan	Metal Processing
PIONEER METAL FINISHING CORP	Ground Water	0.133	>5	Met Council - Metropolitan	Metal Processing
PLATING INC	Ground Water	0.016	>5	Met Council - Metropolitan	Metal Processing
REO PLASTICS INC	Ground Water	0.000	>5	Rogers	Metal Processing
REO PLASTICS INC	Ground Water	0.003	>5	Rogers	Metal Processing
SPECTRO ALLOYS CORP	Ground Water	0.006	4.70	Met Council - Eagles Point	Metal Processing
SPECTRO ALLOYS CORP	Ground Water	0.000	4.70	Met Council - Eagles Point	Metal Processing
SUPERIOR PLATING INC	Ground Water	0.048	>5	Met Council - Metropolitan	Metal Processing
COLD SPRING GRANITE CO	Ground Water	0.005	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.021	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.045	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.001	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.009	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.009	>5	St Cloud	Mine Processing
COLD SPRING GRANITE CO	Ground Water	0.009	>5	St Cloud	Mine Processing
EDWARD KRAEMER & SONS INC	Ground Water	0.000	>5	Little Falls	Mine Processing
EDWARD KRAEMER & SONS INC	Ground Water	0.000	>5	Little Falls	Mine Processing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
UNITED STATES STEEL CORP	Ground Water	0.141	>5	Grand Rapids	Mine Processing
3M COMPANY	Ground Water	0.000	3.40	Met Council - Metropolitan	Non-Metallic Processing
3M COMPANY	Ground Water	0.000	3.40	Met Council - Metropolitan	Non-Metallic Processing
3M COMPANY	Ground Water	0.190	3.40	Met Council - Metropolitan	Non-Metallic Processing
3M COMPANY	Ground Water	0.132	3.40	Met Council - Metropolitan	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.016	>5	Rogers	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.009	>5	Met Council - Metropolitan	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.009	2.00	Rogers	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.001	4.50	Elk River	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.004	4.50	Elk River	Non-Metallic Processing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.002	>5	Rogers	Non-Metallic Processing
BAUERLY BROTHERS INC	Ground Water	0.004	>5	St Cloud	Non-Metallic Processing
BAUERLY BROTHERS INC	Ground Water	0.005	4.00	Cambridge	Non-Metallic Processing
BAUERLY BROTHERS INC	Ground Water	0.002	>5	St Cloud	Non-Metallic Processing
BAUERLY BROTHERS INC	Ground Water	0.004	1.50	Hutchinson	Non-Metallic Processing
BUFFALO BITUMINOUS	Ground Water	0.003	>5	Monticello	Non-Metallic Processing
C S MCCROSSAN CONSTRUCTION0	Ground Water	0.007	>5	Rogers	Non-Metallic Processing
CEMSTONE PRODUCTS	Ground Water	0.007	2.30	Met Council - Metropolitan	Non-Metallic Processing
CEMSTONE PRODUCTS	Ground Water	0.014	>5	Met Council - Metropolitan	Non-Metallic Processing
CEMSTONE PRODUCTS	Ground Water	0.008	>5	Met Council - Metropolitan	Non-Metallic Processing
CF INDUSTRIES INC	Ground Water	0.010	4.80	Met Council - Eagles Point	Non-Metallic Processing
CF INDUSTRIES INC	Ground Water	0.000	4.80	Met Council - Eagles Point	Non-Metallic Processing
D & D LAND LLC	Ground Water	0.000	3.30	Met Council - Metropolitan	Non-Metallic Processing
ELK RIVER RED-E-MIX INC	Ground Water	0.006	3.90	Elk River	Non-Metallic Processing
FEDERAL CARTRIDGE CO	Ground Water	0.003	>5	Rogers	Non-Metallic Processing
FEDERAL CARTRIDGE CO	Ground Water	0.000	>5	Rogers	Non-Metallic Processing
FEDERAL CARTRIDGE CO	Ground Water	0.131	>5	Rogers	Non-Metallic Processing
HANSON SPANCRETE MIDWEST INC	Ground Water	0.000	>5	Rogers	Non-Metallic Processing
HANSON SPANCRETE MIDWEST INC	Ground Water	0.021	>5	Rogers	Non-Metallic Processing
HONEYWELL INC	Ground Water	0.136	>5	Met Council - Metropolitan	Non-Metallic Processing
MARSHALL CONCRETE PRODUCTS INC	Ground Water	0.006	>5	Otesego East	Non-Metallic Processing
MARSHALL CONCRETE PRODUCTS INC	Ground Water	0.006	>5	Met Council - Metropolitan	Non-Metallic Processing
MCO LENS INC	Ground Water	0.011	>5	St Cloud	Non-Metallic Processing
PECHINEY PLASTIC PACKAGING INC	Ground Water	0.008	>5	Met Council - Metropolitan	Non-Metallic Processing
POTLATCH CORPORATION	Ground Water	0.012	>5	Bemidji	Non-Metallic Processing
POTLATCH CORPORATION	Ground Water	0.065	>5	Bemidji	Non-Metallic Processing
ROBINSON RUBBER	Ground Water	0.032	>5	Rogers	Non-Metallic Processing
TWO THOUSAND FAHRENHEIT INC	Ground Water	0.001	>5	Monticello	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.007	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.006	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.000	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.021	>5	Brainerd	Non-Metallic Processing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
WEYERHAEUSER COMPANY	Ground Water	0.009	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.022	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.005	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.005	>5	Brainerd	Non-Metallic Processing
WEYERHAEUSER COMPANY	Ground Water	0.006	>5	Brainerd	Non-Metallic Processing
XCEL OPTICAL COMPANY	Ground Water	0.005	3.00	St Cloud	Non-Metallic Processing
NSP CO DBA XCEL ENERGY	Surface Water	346.603	4.30	Monticello	NUCLEAR POWER PLANT
NSP CO DBA XCEL ENERGY	Ground Water	0.047	4.30	Monticello	NUCLEAR POWER PLANT
NSP CO DBA XCEL ENERGY	Ground Water	0.000	4.30	Monticello	NUCLEAR POWER PLANT
BUSHMILLS ETHANOL	Ground Water	0.000	>5	Willmar	Petroleum-chemical Processing, Ethanol
FLINT HILLS RESOURCES LP	Ground Water	0.000	5.00	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
GOPHER STATE ETHANOL LLC	Ground Water	0.181	4.00	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
GOPHER STATE ETHANOL LLC	Ground Water	0.000	4.00	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MARATHON ASHLAND PETROLEUM LLC	Ground Water	0.716	>5	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MARATHON ASHLAND PETROLEUM LLC	Ground Water	0.631	>5	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MARATHON ASHLAND PETROLEUM LLC	Ground Water	0.098	>5	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MARATHON ASHLAND PETROLEUM LLC	Ground Water	0.200	>5	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MARATHON ASHLAND PETROLEUM LLC	Ground Water	0.065	>5	Met Council - Metropolitan	Petroleum-chemical Processing, Ethanol
MINNESOTA ENERGY	Ground Water	0.000	>5	Glencoe	Petroleum-chemical Processing, Ethanol
MINNESOTA ENERGY	Ground Water	0.239	>5	Glencoe	Petroleum-chemical Processing, Ethanol
ELK RIVER, CITY OF	Surface Water	0.006	1.00	Elk River	POWER GENERATION
LSP-COTTAGE GROVE LP	Ground Water	0.000	2.00	Met Council - Eagles Point	POWER GENERATION
NSP CO DBA XCEL ENERGY	Ground Water	0.192	>5	Met Council - Metropolitan	POWER GENERATION
NSP CO DBA XCEL ENERGY	Ground Water	0.114	>5	Met Council - Metropolitan	POWER GENERATION
BLANDIN PAPER CO	Surface Water	16.680	1.50	Grand Rapids	Pulp and Paper Processing
INTERNATIONAL PAPER CO	Surface Water	9.801	>5	St Cloud	Pulp and Paper Processing
LIBERTY PAPER INC	Ground Water	0.354	>5	Monticello	Pulp and Paper Processing
LIBERTY PAPER INC	Ground Water	0.256	>5	Monticello	Pulp and Paper Processing
LIBERTY PAPER INC	Ground Water	0.000	>5	Monticello	Pulp and Paper Processing
NORBORD MINNESOTA	Ground Water	0.025	>5	Bemidji	Pulp and Paper Processing
NRG ENERGY CENTER INC	Ground Water	0.204	3.10	Met Council - Metropolitan	Pulp and Paper Processing
POTLATCH CORPORATION	Surface Water	0.007	3.50	Grand Rapids	Pulp and Paper Processing
POTLATCH CORPORATION	Ground Water	0.015	>5	Bemidji	Pulp and Paper Processing
POTLATCH CORPORATION	Ground Water	0.000	>5	Bemidji	Pulp and Paper Processing
WALDORF CORPORATION	Ground Water	0.009	>5	Met Council - Metropolitan	Pulp and Paper Processing
WALDORF CORPORATION	Ground Water	0.000	>5	Met Council - Metropolitan	Pulp and Paper Processing
WALDORF CORPORATION	Ground Water	0.000	>5	Met Council - Metropolitan	Pulp and Paper Processing
WALDORF CORPORATION	Ground Water	1.307	>5	Met Council - Metropolitan	Pulp and Paper Processing
WAUSAU PAPER OF MINNESOTA LLC	Surface Water	0.353	4.20	Brainerd	Pulp and Paper Processing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	1.092	4.50	Met Council - Metropolitan	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.028	4.50	Met Council - Metropolitan	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.000	>5	Rogers	Sand and Gravel Washing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.000	>5	Rogers	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.373	5.00	Elk River	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.434	4.50	Elk River	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.067	>5	Bemidji	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.000	>5	Brainerd	Sand and Gravel Washing
ALEXANDRIA CONCRETE	Ground Water	0.136	>5	Alexandria Lake Area Sanitary District	Sand and Gravel Washing
AMCON BLOCK & PRECAST	Surface Water	0.000	4.80	St Cloud	Sand and Gravel Washing
ANNANDALE ROCK PRODUCTS	Surface Water	0.132	>5	Litchfield	Sand and Gravel Washing
BARTON CONTRACTING CO	Surface Water	0.028	>5	Monticello	Sand and Gravel Washing
BARTON SAND & GRAVEL	Ground Water	0.089	3.50	Elk River	Sand and Gravel Washing
BARTON SAND & GRAVEL	Surface Water	0.093	>5	Rogers	Sand and Gravel Washing
BARTON SAND AND GRAVEL CO	Ground Water	0.000	2.90	Elk River	Sand and Gravel Washing
BAUERLY BROTHERS INC	Ground Water	0.017	>5	Brainerd	Sand and Gravel Washing
BAUERLY BROTHERS INC	Ground Water	0.000	>5	Litchfield	Sand and Gravel Washing
BAUERLY BROTHERS INC	Surface Water	0.000	>5	Litchfield	Sand and Gravel Washing
BAUERLY BROTHERS INC	Ground Water	0.108	>5	Litchfield	Sand and Gravel Washing
BAUERLY BROTHERS INC	Surface Water	0.002	>5	St Cloud	Sand and Gravel Washing
BAUERLY BROTHERS INC	Ground Water	0.000	>5	Cambridge	Sand and Gravel Washing
BAUERLY BROTHERS INC	Ground Water	0.006	>5	Brainerd	Sand and Gravel Washing
BREMIX/MILLE LACS AGGR & CONCRETE	Surface Water	0.012	>5	Cambridge	Sand and Gravel Washing
CENTRAL-ALLIED ENTERPRISES INC	Ground Water	0.132	>5	Melrose	Sand and Gravel Washing
CENTRAL-ALLIED ENTERPRISES INC	Surface Water	0.000	>5	Willmar	Sand and Gravel Washing
CENTRAL-ALLIED ENTERPRISES INC	Surface Water	0.137	>5	Willmar	Sand and Gravel Washing
CHAD MONSON EXCAVATING LLC	Surface Water	0.000	>5	Willmar	Sand and Gravel Washing
DUININCK BROTHERS INC	Surface Water	0.000	>5	Willmar	Sand and Gravel Washing
GERTKEN, RALPH	Ground Water	0.047	>5	Litchfield	Sand and Gravel Washing
GESELL CONCRETE PRODUCTS INC	Surface Water	0.049	>5	Bemidji	Sand and Gravel Washing
GESELL CONCRETE PRODUCTS INC	Ground Water	0.024	>5	Bemidji	Sand and Gravel Washing
GRANITE CITY CONCRETE INC	Surface Water	0.158	5.00	Little Falls	Sand and Gravel Washing
GRANITE CITY CONCRETE OF WATKINS	Surface Water	0.022	>5	St Cloud	Sand and Gravel Washing
GRANITE CITY READY MIX	Surface Water	0.259	2.50	St Cloud	Sand and Gravel Washing
GRANITE CITY READY MIX	Ground Water	0.068	>5	St Cloud	Sand and Gravel Washing
HASSAN SAND & GRAVEL INC	Surface Water	0.041	2.00	Rogers	Sand and Gravel Washing
HENGEL, ELMER JR	Ground Water	0.001	>5	Brainerd	Sand and Gravel Washing
HENGEL, ELMER JR	Ground Water	0.002	>5	Brainerd	Sand and Gravel Washing
HENGEL, ELMER JR	Ground Water	0.000	>5	Brainerd	Sand and Gravel Washing
HENGEL, ELMER JR	Ground Water	0.001	>5	Brainerd	Sand and Gravel Washing
KINGSWAY CONSTRUCTION	Surface Water	0.005	>5	Little Falls	Sand and Gravel Washing
KRAMER EXCAVATING, RANDY	Surface Water	0.029	>5	St Cloud	Sand and Gravel Washing
LEE, MARK	Ground Water	0.001	1.50	Alexandria Lake Area Sanitary District	Sand and Gravel Washing
MORICAL BROTHERS INC	Surface Water	0.044	>5	Alexandria Lake Area Sanitary District	Sand and Gravel Washing

Table 3.12c. Industries in the Mississippi River Headwaters Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
NORTHSTAR MATERIALS, INC	Surface Water	0.000	>5	Bemidji	Sand and Gravel Washing
SCHWARTZ REDI MIX INC	Surface Water	0.059	4.30	Grand Rapids	Sand and Gravel Washing
STOMMES CONSTRUCTION	Surface Water	0.000	>5	Monticello	Sand and Gravel Washing
FOSTER WHEELER TWIN CITIES INC	Surface Water	0.000	>5	Met Council - Metropolitan	STEAM POWER - OTHER THAN COOLING
GREAT RIVER ENERGY	Ground Water	0.054	1.00	Elk River	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.000	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.131	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.149	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.135	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.299	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.000	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.258	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.224	>5	Monticello	STEAM POWER - OTHER THAN COOLING
NSP CO DBA XCEL ENERGY	Ground Water	0.107	>5	Met Council - Metropolitan	STEAM POWER - OTHER THAN COOLING
OTTER TAIL POWER CO	Ground Water	0.004	>5	Bemidji	STEAM POWER - OTHER THAN COOLING
GREAT RIVER ENERGY	Surface Water	34.728	1.00	Elk River	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	38.494	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	38.410	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	38.574	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	38.250	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Ground Water	0.049	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Ground Water	0.000	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Ground Water	0.144	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.361	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.098	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	11.936	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.316	>5	Grand Rapids	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	126.474	>5	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	>5	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	>5	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	0.000	>5	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	84.215	>5	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	132.737	3.70	Met Council - Metropolitan	STEAM POWER COOLING - ONCE THROUGH
NSP CO DBA XCEL ENERGY	Surface Water	18.467	>5	Monticello	STEAM POWER COOLING - WET TOWER
OTTER TAIL POWER CO	Ground Water	0.002	>5	Bemidji	STEAM POWER COOLING - WET TOWER
POTLATCH CORPORATION	Ground Water	0.182	>5	Bemidji	STEAM POWER COOLING - WET TOWER

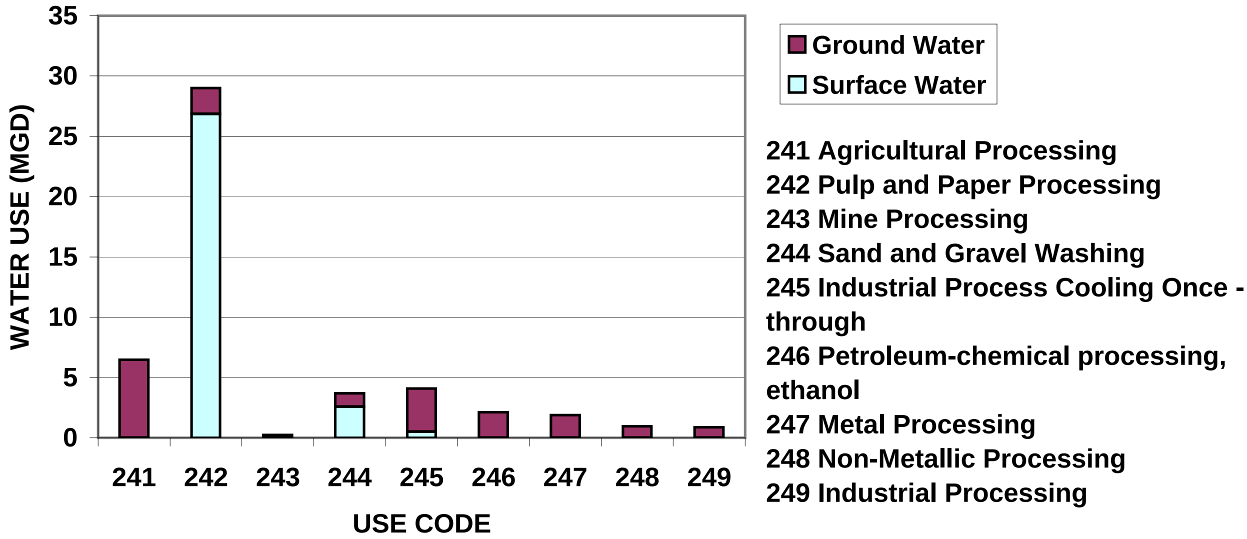


Figure 3.12a. Industrial Processing Water Use in the Mississippi River Headwaters Watershed, 2004

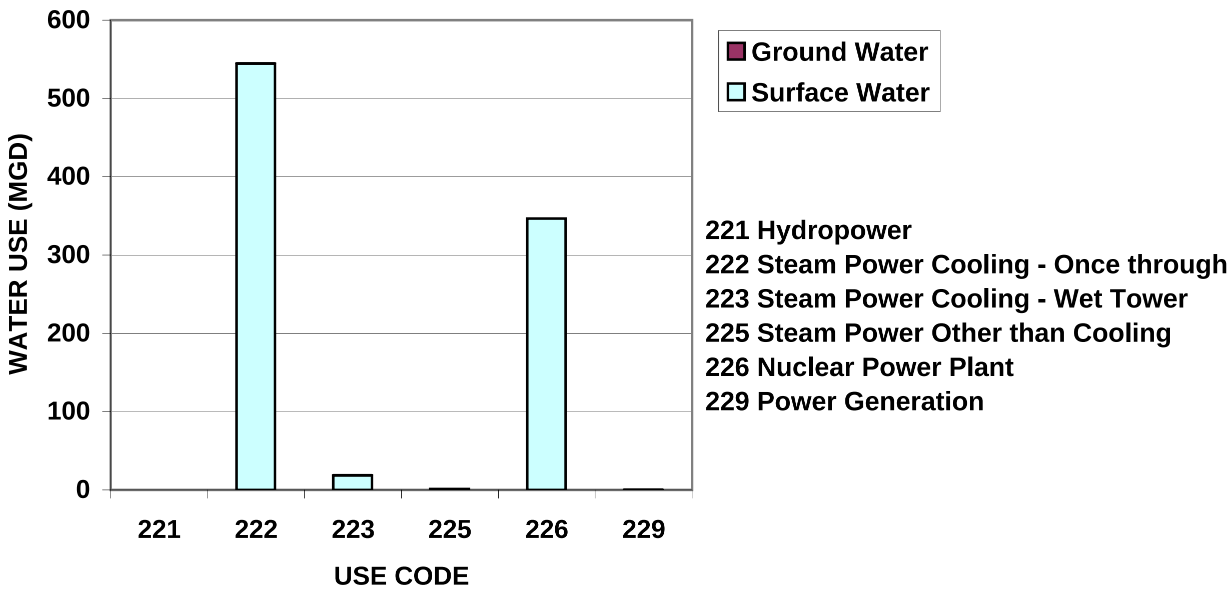


Figure 3.12b. Power Generation Water Use in the Mississippi River Headwaters Watershed, 2004

Table 3.13a. Industrial Water Use in the Missouri River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Sand and Gravel Washing	0.00	0.06	0.06
Total	0.00	0.06	0.06

Table 3.13b. WWTPs in the Missouri River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Luverne WWTP	1.500			0.865
Total	1.500			0.865

Table 3.13c. Industries in the Missouri River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
NORTHERN CON-AGG INC	Surface Water	0.000	5.0	Luverne	Sand and Gravel Washing
NORTHERN CON-AGG INC	Surface Water	0.061	2.5	Luverne	Sand and Gravel Washing

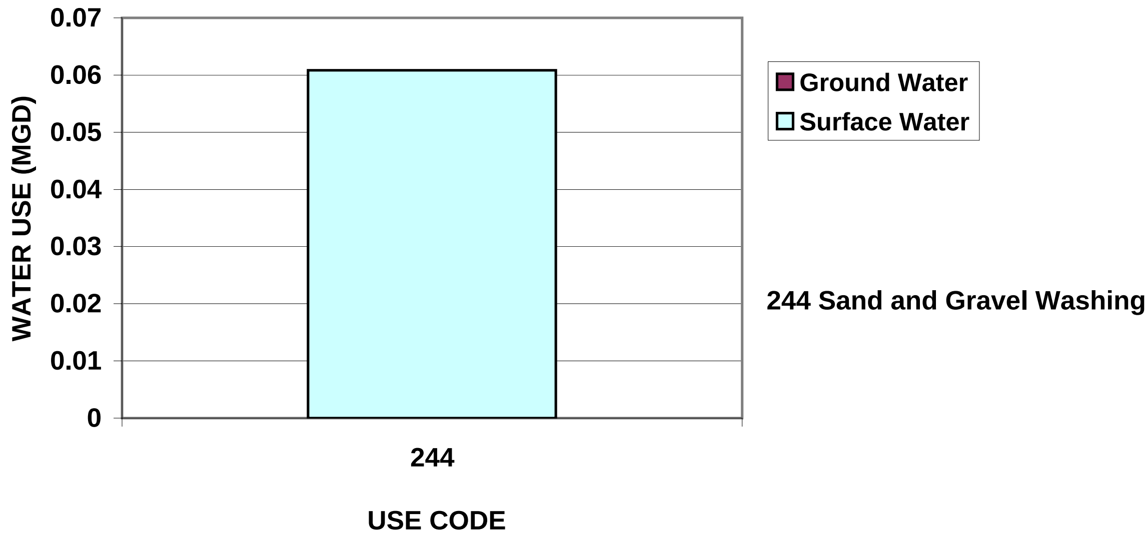


Figure 3.13a. Industrial Processing Water Use in the Missouri River Watershed, 2004

Table 3.14a. Industrial Water Use in the Rainy River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Mine Processing	0.00	0.01	0.01
Pulp and Paper Processing	0.07	46.70	46.77
Sand and Gravel Washing	0.00	0.14	0.14
Total	0.07	46.85	46.92

Table 3.14b. WWTPs in the Rainy River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
NKASD WWTP	2.300			1.264
Ely WWTP	1.500			0.688
Total	3.800			1.952

Table 3.14c. Industries in the Rainy River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
UNITED STATES STEEL CORP	Surface Water	0.010	>10	Ely	Mine Processing
BOISE WHITE PAPER LLC	Surface Water	26.133	2.3	NKASD	Pulp and Paper Processing
BOISE WHITE PAPER LLC	Surface Water	20.551	2.3	NKASD	Pulp and Paper Processing
KNAEBLE TIMBER INC	Surface Water	0.018	>10	NKASD	Pulp and Paper Processing
POTLATCH CORPORATION	Ground Water	0.067	>10	Ely	Pulp and Paper Processing
POTLATCH CORPORATION	Ground Water	0.000	>10	Ely	Pulp and Paper Processing
SEPPI BROS CONCRETE	Surface Water	0.005	>10	Ely	Sand and Gravel Washing
SEPPI BROS CONCRETE	Surface Water	0.131	>10	Ely	Sand and Gravel Washing

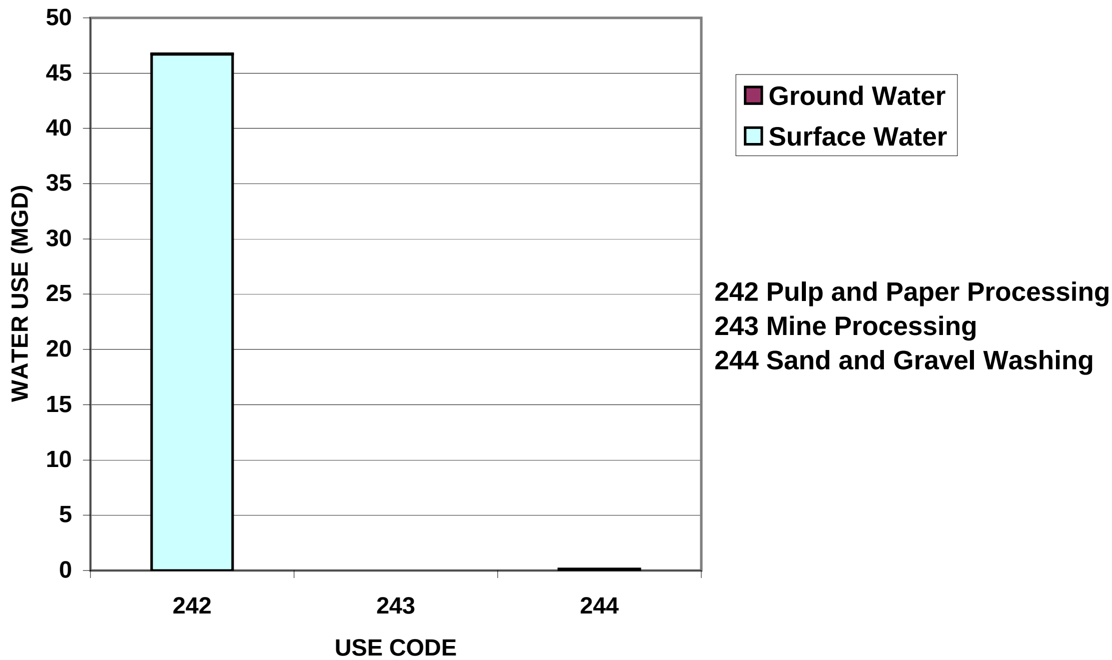


Figure 3.14. Industrial Processing Water Use in the Rainy River Watershed, 2004

Table 3.15a. Industrial Water Use in the Red River of the North Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Agricultural Processing	0.91	0.09	1.00
Power Generation	0.00	54.43	54.43
Sand & Gravel Washing	1.26	0.69	1.95
Total	2.17	55.21	57.38

Table 3.15b. WWTPs in the Red River of the North Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Crookston WWTP	1.400			1.117
Detroit Lakes WWTP	3.000			1.256
East Grand Forks WWTP	1.400			1.193
Fergus Falls WWTP	2.810			1.909
Moorhead WWTP	9.000			4.753
Thief River Falls WWTP	2.140			1.447
Total	19.750			11.675

Table 3.15c. Industries in the Red River of the North Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
AMERICAN CRYSTAL SUGAR CO	Surface Water	0.000	1	Moorhead WWTP	Agricultural Processing
AMERICAN CRYSTAL SUGAR CO	Surface Water	0.010	1.2	Crookston WWTP	Agricultural Processing
AMERICAN CRYSTAL SUGAR CO	Surface Water	0.000	2	East Grand Forks WWTP	Agricultural Processing
AMERICAN CRYSTAL SUGAR CO	Surface Water	0.077	>10	East Grand Forks WWTP	Agricultural Processing
BONGARDS CREAMERIES	Ground Water	0.122	>10	Detroit Lakes WWTP	Agricultural Processing
BONGARDS CREAMERIES	Ground Water	0.707	>10	Detroit Lakes WWTP	Agricultural Processing
NORTHERN FOOD & DAIRY INC	Ground Water	0.077	>10	Crookston WWTP	Agricultural Processing
NORTHERN PRIDE INC	Ground Water	0.000	2.6	Thief River Falls WWTF	Agricultural Processing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.096	>10	Moorhead WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.118	>10	Moorhead WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	>10	Moorhead WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	>10	Detroit Lakes WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.000	>10	Detroit Lakes WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.262	>10	Detroit Lakes WWTP	Sand and Gravel Washing
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.000	>10	Detroit Lakes WWTP	Sand and Gravel Washing
AMES SAND & GRAVEL	Surface Water	0.000	>10	Moorhead WWTP	Sand and Gravel Washing
AMES SAND & GRAVEL	Surface Water	0.195	>10	Moorhead WWTP	Sand and Gravel Washing
AMES SAND & GRAVEL	Surface Water	0.005	>10	Moorhead WWTP	Sand and Gravel Washing
BRADSHAW GRAVEL SUP	Surface Water	0.238	> 10	Crookston WWTP	Sand and Gravel Washing
CONTRACTORS LEASING	Surface Water	0.000	>10	Detroit Lakes WWTP	Sand and Gravel Washing
DUNHAM, DAVID	Surface Water	0.000	>10	Moorhead WWTP	Sand and Gravel Washing
MNDAK CONCRETE INC	Surface Water	0.034	7.5	Thief River Falls WWTF	Sand and Gravel Washing
MNDAK CONCRETE INC	Ground Water	0.025	7.5	Thief River Falls WWTF	Sand and Gravel Washing
NORTHSTAR MATERIALS INC	Ground Water	0.022	>10	Crookston WWTP	Sand and Gravel Washing
ROCK RIDGE RESOURCES	Surface Water	0.000	3	Detroit Lakes WWTP	Sand and Gravel Washing
ROCK RIDGE RESOURCES	Ground Water	0.515	3	Detroit Lakes WWTP	Sand and Gravel Washing
ROCK RIDGE RESOURCES	Ground Water	0.151	3	Detroit Lakes WWTP	Sand and Gravel Washing
STRATA CORPORATION	Ground Water	0.282	> 10	Thief River Falls WWTF	Sand and Gravel Washing
MOORHEAD PUBLIC SERVICE	Surface Water	0.000	1.5	Moorhead WWTP	STEAM POWER COOLING - ONCE THROUGH
MOORHEAD PUBLIC SERVICE	Surface Water	0.000	1.5	Moorhead WWTP	STEAM POWER COOLING - ONCE THROUGH
OTTER TAIL POWER CO	Surface Water	0.000	3.5	Fergus Falls WWTP	STEAM POWER COOLING - ONCE THROUGH
OTTER TAIL POWER CO	Surface Water	54.428	3.5	Fergus Falls WWTP	STEAM POWER COOLING - ONCE THROUGH
OTTER TAIL POWER CO	Ground Water	0.000	3.5	Fergus Falls WWTP	STEAM POWER COOLING - WET TOWER
OTTER TAIL POWER CO	Ground Water	0.000	3.5	Fergus Falls WWTP	STEAM POWER COOLING - WET TOWER

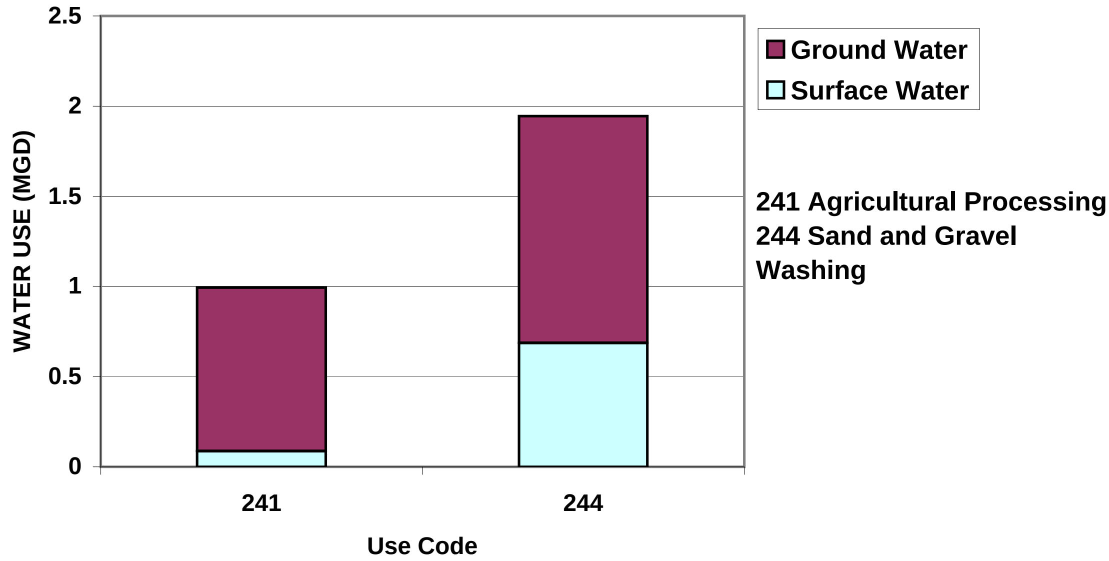


Figure 3.15a. Industrial Processing Water Use in the Red River of the North Watershed, 2004

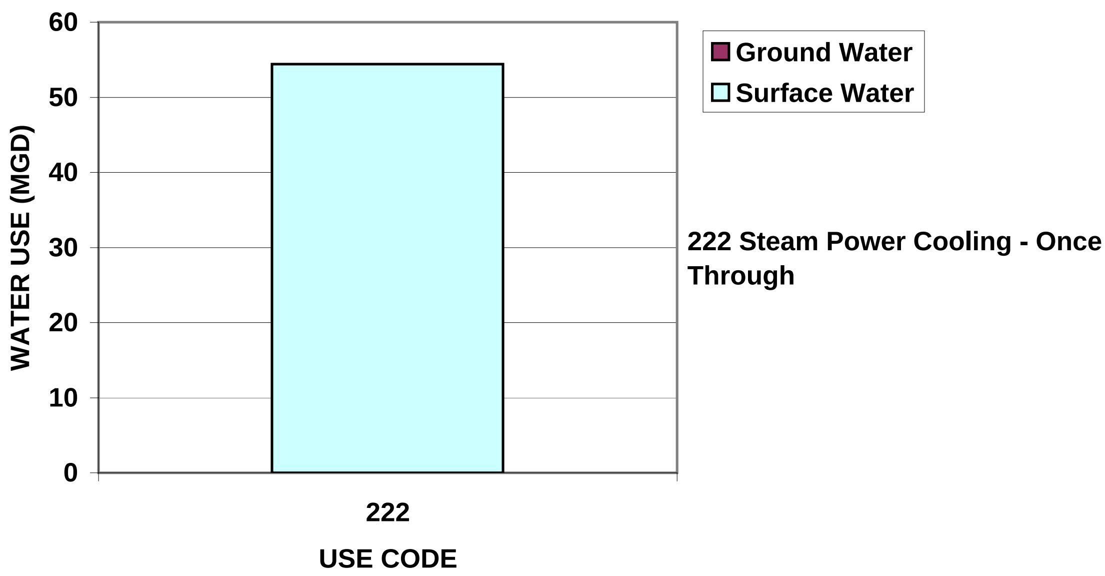


Figure 3.15b. Power Generation Water Use in the Red River of the North Watershed, 2004

Table 3.16a. Industrial Water Use in the St. Croix River Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Non-Metallic Processing	0.59	0.00	0.59
Sand & Gravel Washing	0.33	0.35	0.68
Steam Power Other than Cooling	0.00	325.35	325.35
Total	0.92	325.70	326.62

Table 3.16b. WWTPs in the St. Croix River Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Chisago Lakes Joint STC	1.26			0.756
Met Council - St Croix Valley WWTP*	4.50			3.126
Total	5.76			3.882

* Design capacity changed per MCES instructions.

Table 3.16c. Industries in the St. Croix River Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
ANDERSEN CORPORATION	Ground Water	0.303	4	MCES St. Croix Valley	NON-METALLIC PROCESSING
ANDERSEN CORPORATION	Ground Water	0.288	4	MCES St. Croix Valley	NON-METALLIC PROCESSING
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.135	5	MCES St. Croix Valley	SAND & GRAVEL WASHING
AGGREGATE INDUSTRIES-NCR INC	Surface Water	0.315	9	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
AGGREGATE INDUSTRIES-NCR INC	Ground Water	0.092	9	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BARTON SAND & GRAVEL	Ground Water	0.004	8	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BARTON SAND & GRAVEL	Ground Water	0.004	7	MCES St. Croix Valley	SAND & GRAVEL WASHING
BAUERLY BROTHERS INC	Surface Water	0.000	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BAUERLY BROTHERS INC	Ground Water	0.005	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
BLACK DIAMOND INC	Ground Water	0.079	8	MCES St. Croix Valley	SAND & GRAVEL WASHING
BRACHT BROS INC	Ground Water	0.001	>10	MCES St. Croix Valley	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	Ground Water	0.013	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	Ground Water	0.007	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
HOPKINS SAND & GRAVEL	Ground Water	0.002	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
STAFNE AND AND GRAVEL LLC	Surface Water	0.037	>10	Chisago Lakes Joint STC	SAND & GRAVEL WASHING
NSP CO DBA XCEL ENERGY	Surface Water	325.347	5	MCES St. Croix Valley	STEAM POWER - OTHER THAN COOLING

Figure 3.16a. Industrial Processing Water Use in the St. Croix Watershed, 2004

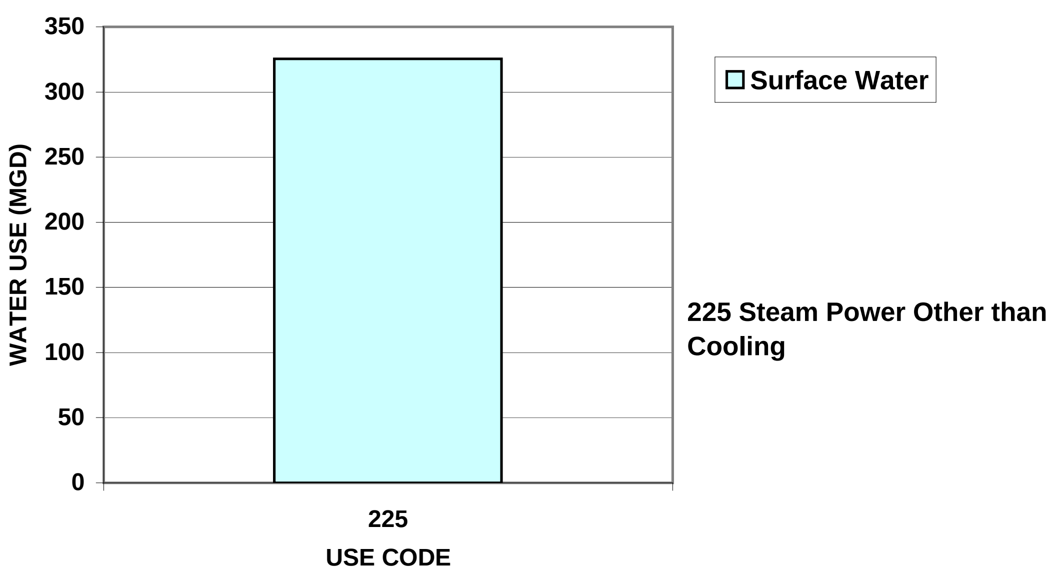


Figure 3.16b. Power Generation Water Use in the St. Croix Watershed, 2004

Table 3.17a. Industrial Water Use in the Western Lake Superior Watershed

Industry Category	2004 Water Use, mgd		
	Groundwater	Surface Water	Total
Mine Processing	0.01	296.51	296.52
Non-metallic Processing	0.01	0.00	0.01
Petroleum - Chemical Processing, ethanol	0.00	0.43	0.43
Pulp and Paper Processing	0.00	6.78	6.78
Sand and Gravel Washing	0.01	0.30	0.31
Steam Power Cooling - Once through	0.00	182.35	182.35
Steam Power Cooling - Wet Tower	0.12	0.00	0.12
Total	0.15	486.37	486.52

Table 3.17b. WWTPs in the Western Lake Superior Watershed

Facility Name	Design Capacity, mgd	Ann Avg Flow, mgd		
		2003	2004	2005
Eveleth WWTP	1.000			0.645
Hibbing WWTP North Plant	3.200			0.000
Hibbing WWTP South Plant	2.000			2.573
Two Harbors WWTP	1.600			0.701
Virginia WWTP	4.300			2.182
WLSSD WWTP	48.800			38.797
Total	60.900			44.898

Table 3.17c. Industries in the Western Lake Superior Watershed

Industry Name	Resource Name	2004 Water Use, mgd	Distance to WWTP, miles	Closest WWTP	Industry Category
DULUTH, MISSABE & IRON RANGE RAIL	Surface Water	0.002	1.5	WLSSD	Mine Processing
ISPAT INLAND MINING	Surface Water	0.000	3.5	Virginia	Mine Processing
MINNESOTA POWER & CLIFFS ERIE LLC	Surface Water	0.000	>10	Virginia	Mine Processing
MINNESOTA POWER & CLIFFS ERIE LLC	Surface Water	157.490	>10	Two harbors	Mine Processing
NORTHSHORE MINING COMPANY	Surface Water	128.764	>10	Two harbors	Mine Processing
NORTHSHORE MINING COMPANY	Surface Water	3.665	>10	Two harbors	Mine Processing
UNITED STATES STEEL CORP	Surface Water	0.000	4.0	Virginia	Mine Processing
UNITED STATES STEEL CORP	Surface Water	0.000	6.0	Virginia	Mine Processing
UNITED STATES STEEL CORP	Surface Water	0.010	7.5	Virginia	Mine Processing
UNITED TACONITE LLC	Surface Water	6.575	6.3	Eveleth	Mine Processing
UNITED TACONITE LLC	Ground Water	0.000	1.2	Eveleth	Mine Processing
UNITED TACONITE LLC	Ground Water	0.000	1.2	Eveleth	Mine Processing
UNITED TACONITE LLC	Ground Water	0.000	7.0	WLSSD	Mine Processing
UNITED TACONITE LLC	Ground Water	0.009	7.0	WLSSD	Mine Processing
UNITED TACONITE LLC	Ground Water	0.000	1.5	Virginia	Mine Processing
UNITED TACONITE LLC	Ground Water	0.000	1.5	Virginia	Mine Processing
ARROWHEAD CONCRETE WORKS	Ground Water	0.005	9.9	WLSSD	Non-Metallic Processing
ELK RIVER CONCRETE PRODUCTS	Ground Water	0.001	9.0	Virginia	Non-Metallic Processing
TATE & LYLE CITRIC ACID INC	Surface Water	0.429	5.0	WLSSD	Petroleum - Chemical Processing
DIAMOND BRANDS INC	Surface Water	0.106	>10	WLSSD	Pulp and Paper Processing
GEORGIA PACIFIC CORP	Surface Water	1.228	1.6	WLSSD	Pulp and Paper Processing
GEORGIA PACIFIC CORP	Surface Water	0.000	1.6	WLSSD	Pulp and Paper Processing
SAPPI CLOQUET LLC	Surface Water	3.905	>10	WLSSD	Pulp and Paper Processing
USG INTERIORS INC	Surface Water	1.375	>10	WLSSD	Pulp and Paper Processing
USG INTERIORS INC	Surface Water	0.161	>10	WLSSD	Pulp and Paper Processing
COONS AGGREGATE SUPPLY CO	Surface Water	0.098	>10	WLSSD	Sand and Gravel Washing
DULUTH READY MIX CONCRETE	Surface Water	0.082	>10	WLSSD	Sand and Gravel Washing
ISAK HANSON & SONS INC	Ground Water	0.000	>10	Two harbors	Sand and Gravel Washing
ISAK HANSON & SONS INC	Ground Water	0.007	>10	Two harbors	Sand and Gravel Washing
SEPPI BROS CONCRETE	Surface Water	0.115	2.5	Hibbing North Plant	Sand and Gravel Washing
MINNESOTA POWER	Surface Water	0.321	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	61.531	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	64.498	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.058	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.001	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	1.439	>10	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	43.716	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.537	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.013	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Surface Water	0.000	2.6	WLSSD	STEAM POWER COOLING - ONCE THROUGH
TWO HARBORS, CITY OF	Surface Water	0.002	1.0	Two harbors	STEAM POWER COOLING - ONCE THROUGH
VIRGINIA PUBLIC UTILITIES	Surface Water	7.915	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
VIRGINIA PUBLIC UTILITIES	Surface Water	2.038	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
VIRGINIA PUBLIC UTILITIES	Surface Water	0.276	2.5	Virginia	STEAM POWER COOLING - ONCE THROUGH
MINNESOTA POWER	Ground Water	0.000	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
MINNESOTA POWER	Ground Water	0.001	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
MINNESOTA POWER	Ground Water	0.014	9.0	WLSSD	STEAM POWER COOLING - WET TOWER
MINNESOTA POWER	Ground Water	0.102	3.5	WLSSD	STEAM POWER COOLING - WET TOWER

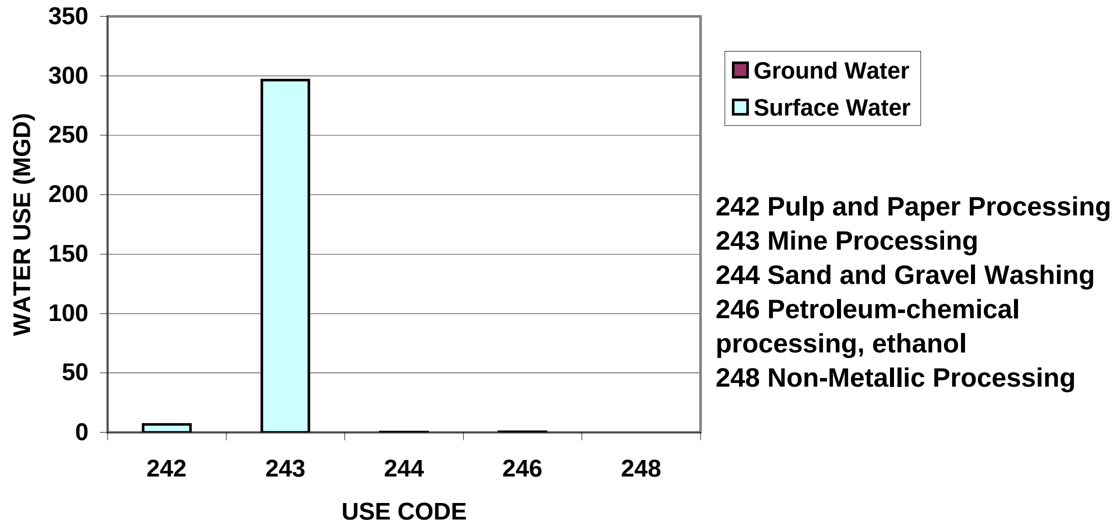


Figure 3.17a. Industrial Processing Water Use in the Western Lake Superior Watershed, 2004

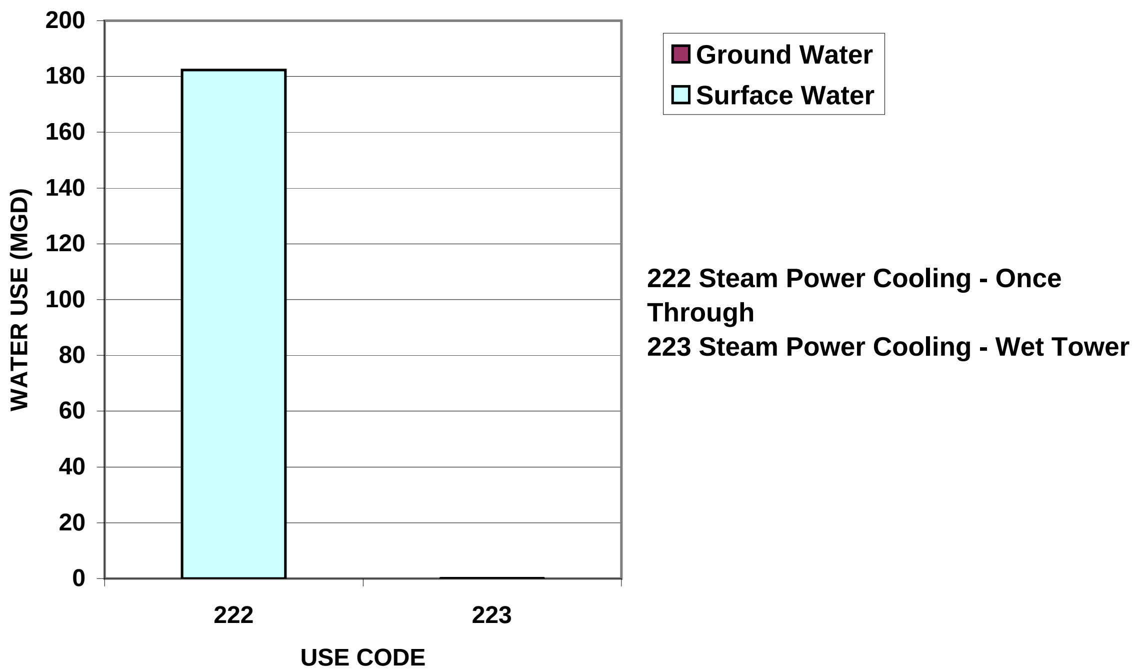


Figure 3.17b. Power Generation Water Use in the Western Lake Superior Watershed, 2004

Minnesota Municipal WWTP Capacity and 2003-2005 Flow

(Facilities with Permitted Capacity Greater Than 1 mgd)

Source: MPCA Discharge Monitoring Report Database Summary

MN Permit No	Facility	Permitted Capacity[1] mgd	2003 Average Flow mgd	2004 Average Flow mgd	2005 Average Flow mgd
MN0030627	Hibbing WWTP North Plant	3.20	0.60	0.50	0.00
MN0025721	Camp Ripley WWTP	1.44	0.16	0.11	0.12
MN0064190	Otsego WWTP East	1.65	0.14	0.19	0.21
MN0021211	Granite Falls WWTP	1.111	0.37	0.41	0.48
MN0024473	Perham WWTP	1.172	0.47	0.49	0.51
MNG580117	Wells Easton Minnesota Lake WWTP	1.088	0.49	0.52	0.52
MN0020681	Stewartville WWTP	1.11	0.62	0.75	0.53
MN0020664	Lake City WWTP	1.52	0.65	0.56	0.56
MN0025267	Winnebago WWTP	1.7	0.32	0.43	0.59
MN0023337	Eveleth WWTP	1	0.65	0.70	0.65
MN0020150	New Prague WWTP	1.378	0.57	0.59	0.66
MN0020508	Ely WWTP	1.5	0.57	0.73	0.69
MN0022233	Glencoe WWTP	2.6	0.69	0.69	0.69
MN0046868	Whitewater River Regional WWTP	1.12	0.70	0.89	0.70
MN0022250	Two Harbors WWTP	1.6	0.61	0.66	0.70
MN0055808	Chisago Lakes Joint STC	1.26	0.82	0.79	0.76
MN0029629	Rogers WWTP	1.602	0.69	0.74	0.77
MN0020222	St Michael WWTP	2.45	0.66	0.62	0.83
MN0020362	Cambridge WWTP	1.92	0.73	0.85	0.85
MN0020141	Luverne WWTP	1.5	0.76	0.83	0.86
MN0025488	Met Council - Rosemount WWTP[7]	1.40	0.76	0.82	0.90
MN0024040	Madelia WWTP	1.31	0.67	0.74	0.91
MN0024759	St James WWTP	2.96	0.94	0.85	1.03

Minnesota Municipal WWTP Capacity and 2003-2005 Flow

(Facilities with Permitted Capacity Greater Than 1 mgd)

Source: MPCA Discharge Monitoring Report Database Summary

MN Permit No	Facility	Permitted Capacity[1] mgd	2003 Average Flow mgd	2004 Average Flow mgd	2005 Average Flow mgd
MN0055361	Plainview-Elgin Sanitary District WWTP	1.421	0.73	0.92	1.05
MN0022462	Bemidji WWTP	2.5	1.09	1.05	1.06
MN0022217	Windom WWTP	1.83	0.98	0.98	1.07
MN0020133	Montevideo WWTP	3	0.88	0.96	1.08
MN0021423	Crookston WWTP	1.4	0.94	1.23	1.12
MN0022535	St Peter WWTP	4.00	0.93	1.40	1.17
MN0020761	Little Falls WWTP	2.4	1.33	1.05	1.18
MN0020788	Elk River WWTP	2.2	1.08	1.14	1.19
MN0020567	Monticello WWTP	2.36	1.08	1.11	1.19
MN0021814	East Grand Forks WWTP	1.4	1.12	1.19	1.19
MN0020192	Detroit Lakes WWTP	3	1.07	1.21	1.26
MN0020257	North Koochiching Area Sanitary District (NKASD) WWTP	2.3	0.84	1.16	1.26
MN0021431	Thief River Falls WWTP	2.14	1.24	1.40	1.45
MN0023973	Litchfield WWTP	1.9	1.40	1.47	1.51
MN0020796	Waseca WWTP	3.5	1.16	1.56	1.58
MN0029955	Met Council - Hastings WWTP[5]	2.69	1.62	1.61	1.59
MN0030112	Fairmont WWTP	3.9	1.10	1.36	1.60
MN0040649	Buffalo WWTP	3.6	1.39	1.40	1.63
MN0050628	Fergus Falls WWTP	2.81	1.73	1.82	1.91
MN0031186	Worthington WWTP	4	1.74	1.83	1.99
MN0020290	Melrose WWTP	2.5	2.10	2.01	2.00
MN0024571	Red Wing WWTP	4	2.51	2.49	2.06
MN0024368	Northfield WWTP	5.2	2.12	2.14	2.07

Minnesota Municipal WWTP Capacity and 2003-2005 Flow

(Facilities with Permitted Capacity Greater Than 1 mgd)

Source: MPCA Discharge Monitoring Report Database Summary

MN Permit No	Facility	Permitted Capacity[1] mgd	2003 Average Flow mgd	2004 Average Flow mgd	2005 Average Flow mgd
MN0030163	Virginia WWTP	4.3	1.90	2.14	2.18
MN0029904	Met Council - Eagles Point WWTP[3]	11.90	1.96	1.98	2.34
MN0049328	Brainerd WWTP	3.13	2.61	2.27	2.44
MN0022179	Marshall WWTP	4.5	2.12	2.29	2.52
MN0030643	Hibbing WWTP South Plant	2	1.41	2.05	2.57
MN0055832	Hutchinson WWTP	4.27	2.18	2.18	2.57
MN0030066	New Ulm WWTP	6.77	2.50	2.57	2.58
MN0040738	Alexandria Lake Area Sanitary District	3.75	2.69	2.72	2.91
MN0029998	Met Council - St Croix Valley WWTP[9]	5.80	3.27	3.13	3.13
MN0051284	Owatonna WWTP	5	3.19	3.54	3.53
MN0030121	Faribault WWTP	7	3.84	4.23	3.70
MN0025259	Willmar WWTP	5.04	3.69	3.63	3.81
MN0030147	Winona WWTP	6.5	3.44	3.79	3.95
MN0041092	Albert Lea WWTP	18.38	4.38	4.44	4.23
MN0049069	Moorhead WWTP	9	3.90	4.36	4.75
MN0022683	Austin WWTP	8.475	4.88	5.43	5.42
MN0030171	Mankato WWTP	11.25	5.42	6.64	6.86
MN0022080	Grand Rapids WWTP	15.2	7.61	6.71	7.33
MN0045845	Met Council - Empire WWTP[4]	28.61	8.57	8.39	8.46
MN0040878	St Cloud WWTP	13	9.59	9.62	10.36
MN0024619	Rochester Water Reclamation Plant	19.1	13.16	15.46	13.46
MN0030007	Met Council - Seneca WWTP[8]	38.00	23.67	23.46	23.35
MN0029882	Met Council - Blue Lake WWTP[2]	42.00	26.85	27.67	28.42

Minnesota Municipal WWTP Capacity and 2003-2005 Flow

(Facilities with Permitted Capacity Greater Than 1 mgd)

Source: MPCA Discharge Monitoring Report Database Summary

MN Permit No	Facility	Permitted Capacity[1] mgd	2003 Average Flow mgd	2004 Average Flow mgd	2005 Average Flow mgd
MN0049786	Western Lake Superior Sanitary District (WLSSD) WWTP	48.8	36.09	38.13	38.80
MN0029815	Met Council - Metropolitan WWTP[6]	251	195.09	188.16	187.02

[1] The plant capacity as reported in the MPCA database. The permitted capacity listed is typically the average wet weather flow identified in the National Pollutant Discharge Elimination System (NPDES) Permit. The basis of the capacity can be verified by review of individual NPDES Permits.

[2] The Metropolitan Council's established design capacity for this facility is 37 mgd.

[3] The Metropolitan Council's established design capacity for this facility is 10 mgd.

[4] The Metropolitan Council's established design capacity for this facility is 24 mgd.

[5] The Metropolitan Council's established design capacity for this facility is 2.9 mgd.

[6] The Metropolitan Council's established design capacity for this facility is 251 mgd.

[7] The Metropolitan Council's established design capacity for this facility is 1.3 mgd.

[8] The Metropolitan Council's established design capacity for this facility is 39 mgd.

[9] The Metropolitan Council's established design capacity for this facility is 4.5 mgd.

Source: Minnesota Pollution Control Agency (MPCA), 2005. Minnesota Discharge Monitoring Report Data Summary. Data summarized for dischargers in 2003-2005 were obtained from the MPCA in April 2006. This Technical Memorandum uses the annual discharge volume reported to MPCA, presented as the average annual water discharged in million gallons per day (mgd). The annual average flows listed are as reported in the MPCA database and have not been verified with individual facility records.

Appendix D
Reference Documents

Where Is Ground Water and Is It Available for Use?

Ground-water resources vary across the state.

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

Minnesota has six ground-water areas that combine the two general types of bedrock, sedimentary and fractured igneous and metamorphic, with two general types of overlying sediments, sandy and clayey. In the northeast and southeast, overlying sediment is thin or absent. The layers of sedimentary limestone and sandstone bedrock that form the bedrock aquifers in southeastern Minnesota are well known for their good aquifer qualities and are commonly used. Elsewhere in Minnesota, the fractured igneous and metamorphic bedrock has relatively poor aquifer qualities, generally supporting only limited use.

Much of Minnesota is covered by sediments deposited by glaciers or streams. Some of those sediments are sands and gravels that occur as surficial deposits or they may be buried within clayey glacial deposits. The sandy glacial deposits that cover much of central Minnesota include extensive sand and gravel aquifers at or near the land surface that have good aquifer qualities. South and west, the glacial sediments are more clayey, and aquifers within the sediments are less common and generally more limited in extent.

Many parts of Minnesota are underlain by sediment and rock that do not make good aquifers. Nonetheless, that sediment and rock is still important for limited ground-water storage. The water stored in those sediments and rocks is the source of slow replenishment for aquifers and surface waters.

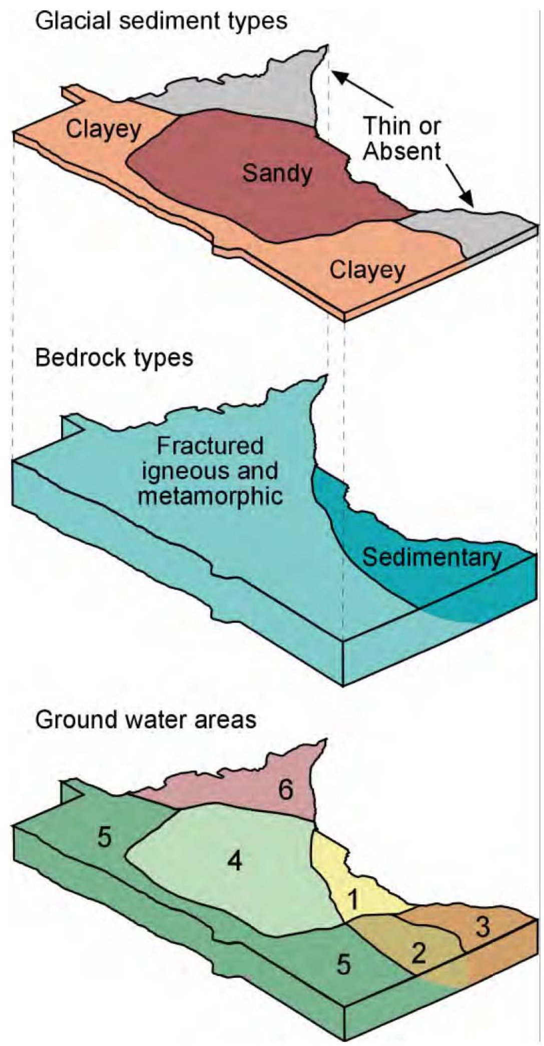


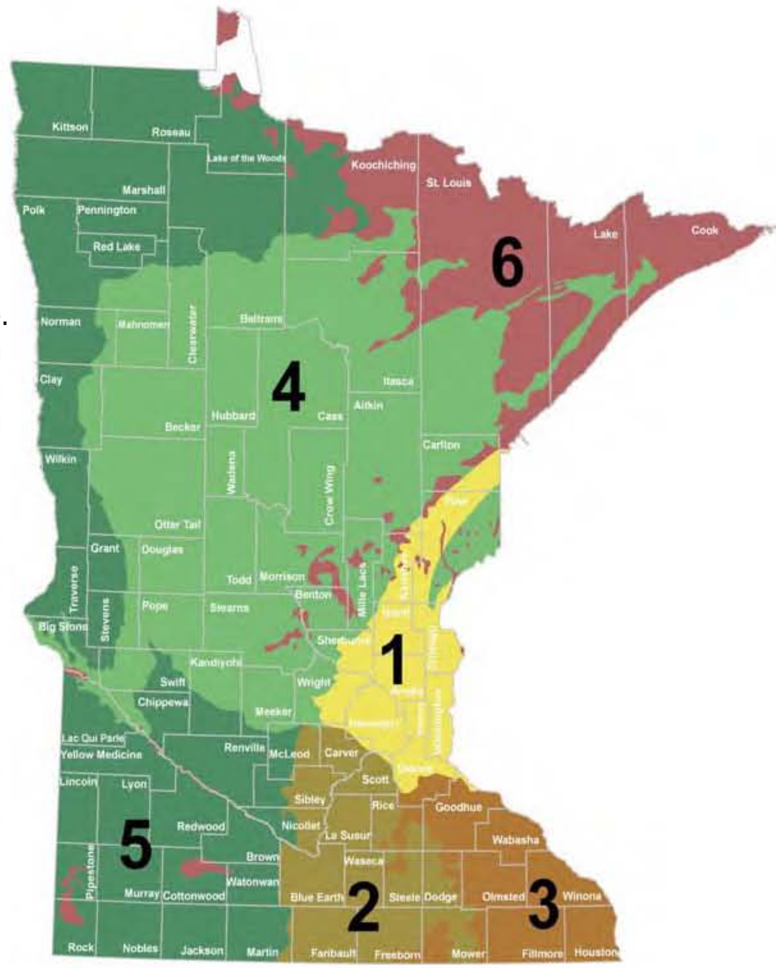
FIGURE 1. General availability of ground-water resources depends on the type of sediment and rock beneath the land surface.

General Ground-Water Availability in Minnesota

Minnesotans generally live where aquifers are present. With proper management, those aquifers can provide some or all of their water-supply needs. In some areas, such as the Twin Cities metropolitan area, where ground water and surface water are both available, those resources used together can provide a dependable long-term supply. In other areas, such as western Minnesota, ground-water resources in both glacial sediment and bedrock are limited. Careful management of water resources is needed in those areas to ensure adequate, long-term supply.

TABLE 1. Ground-water availability in the state.

	General Availability of Ground Water by Source		
Area	Surficial Sands	Buried Sands	Bedrock
1	Moderate	Moderate	Good
2	Limited	Moderate	Good
3	Limited	Limited	Good
4	Good	Moderate	Limited
5	Moderate	Limited	Limited
6	Limited	Limited	Limited



Long-Term Availability of Ground Water and Management Issues in Minnesota

Area 1—Ground water supports lakes, wetlands, and streams; includes core of Twin Cities metropolitan area and expanding northern edge. Expect continuing pressure on all ground-water resources as development continues.

Area 2—Limited buried sand aquifers can be easily depleted. The northern part of the area includes the southern Twin Cities metropolitan area that is expanding south.

Area 3—Karst common; springs and cold-water streams depend on ground-water discharge; overpumping ground water may deplete surface waters dependant on ground water.

Area 4—Ground water supports lakes, wetlands, and streams; overpumping ground water may deplete them.

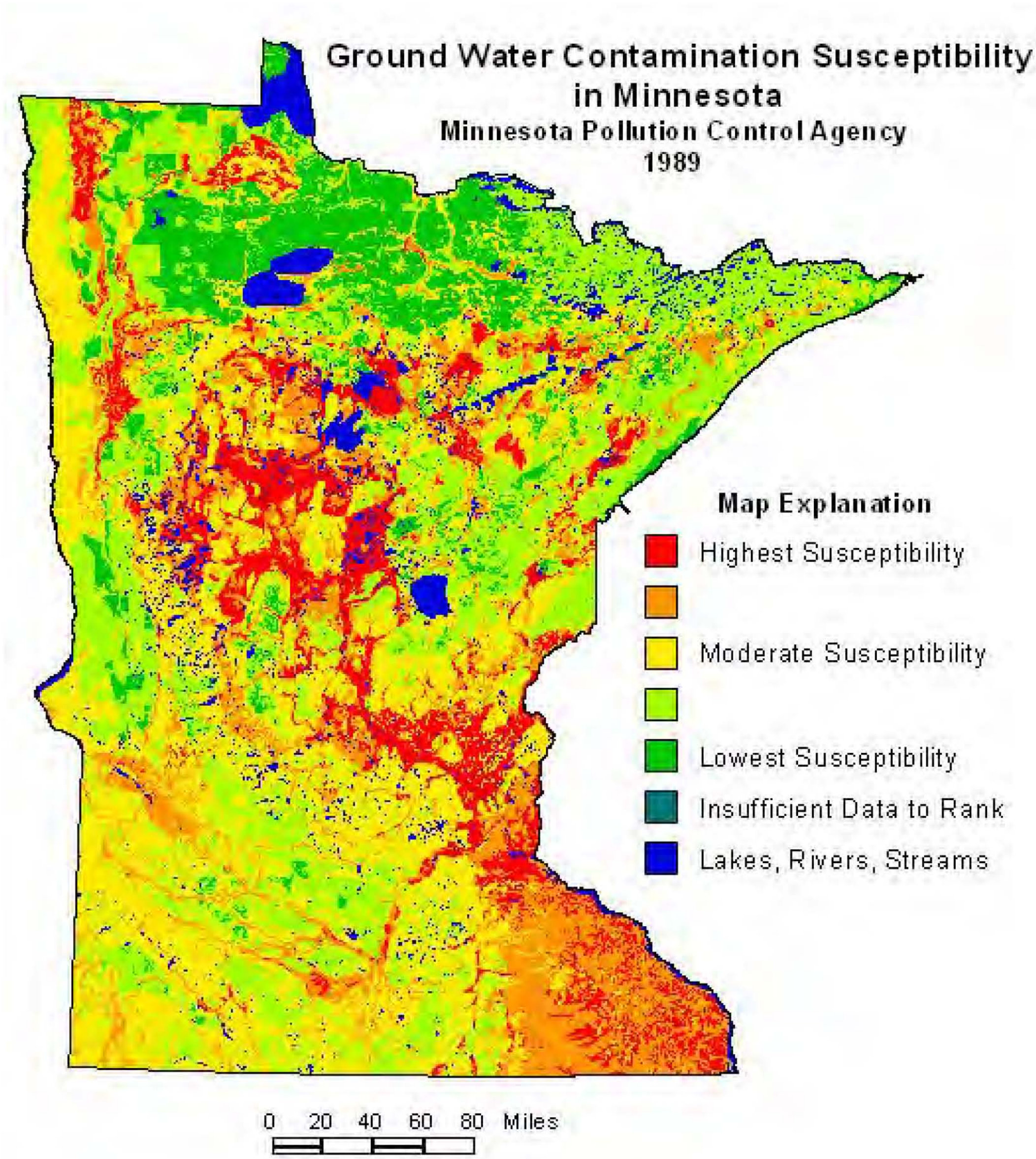
Area 5—Limited buried sand and gravel aquifers can be easily depleted; stream flow depletions from surficial aquifer use are likely; ground water from bedrock is generally very limited.

Area 6—Generally poor supply from both sediment and fractured rock requires careful water supply planning and management for dependable supplies. Surface water may be the only available resource.

Statewide contamination susceptibility

Ground water contamination susceptibility in Minnesota

In 1989, the Minnesota Pollution Control Agency published a statewide evaluation of ground water contamination susceptibility. The assessment used four parameters (aquifer materials, recharge potential, soil materials, and vadose zone materials) to delineate areas of relative susceptibility to ground water contamination. The assessment method used Geographic Information System (GIS) technology. The project was published in both poster and report format.



RELATED PAGES:

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Assessment Prog

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External links

The contamination susceptiblity map was made from digital files available at the time or were digitized from existing published maps. Useable map scale is approximately 1:500,000 or 1 inch = 8 miles. This map is best used as a regional-scale screening aid.

Digital data

The digital file of the map is included on the EPIC 2001 CD-ROM from the Land Management Information Center, which did the original GIS analysis for the project.

References

Minnesota Pollution Control Agency, 1989, Ground Water Contamination Susceptibility in Minnesota, St. Paul, MN, (poster). Out of print.

Porcher, Eric, 1989, Ground Water Contamination Susceptibility in Minnesota (revised edition), Minnesota Pollution Control Agency, St. Paul, MN, 29 p. Out of print.

EPPL7/ EPIC 2000 dataset CD-ROM available from the Land Management Information Center.

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Appendix E

Metropolitan Council Industrial Dischargers – Water Demand

Metropolitan Council Industrial Dischargers Water Demand, 2005
Sorted by Business Category and Organization Name

Permit No.	Organization	NAICS Code[1]	NAICS Description	MCES Business Category[2]	DNR Use Code[3]	Incoming Water Type	Incoming (Gal)	Sewered (Gal)	Incoming (mgd)
0333	Anchor Block Co	327331	Concrete Block and Brick Manufacturing	Building Materials	249	CITY	16,995,000	12,253,002	0.0466
0401	Andersen Corp	321911	Wood Window and Door Manufacturing	Building Materials	249	CITY,WELL	377,765,800	61,354,422	1.0350
0957	Bell Lumber & Pole Co (0957)	321114	Wood Preservation	Building Materials	249	OTHER	209,880	209,880	0.0006
0287	Certainteed Corp	324122	Asphalt Shingle and Coating Materials Manufacturing	Building Materials	249	CITY	320,600,000	271,630,000	0.8784
0415	GAF Materials Corp	324122	Asphalt Shingle and Coating Materials Manufacturing	Building Materials	249	CITY,WELL	230,267,232	18,882,273	0.6309
1238	Zenith Products	327331	Concrete Block and Brick Manufacturing	Building Materials	249	CITY,WELL	82,000	82,000	0.0002
0809	Determan Brownie Inc	23594	Wrecking and Demolition Contractors	Central Treatment	249	CITY,WELL,OTHER	7,314,452	7,119,168	0.0200
1302	Healthcare Waste Solutions	562211	Hazardous Waste Treatment and Disposal	Central Treatment	249	CITY	2,014,000	2,001,200	0.0055
0916	Stericycle Inc	562211	Hazardous Waste Treatment and Disposal	Central Treatment	249	CITY,OTHER	4,830,746	4,454,836	0.0132
1346	U of M - Animal Digester			Central Treatment	249	CITY	1,160,720	1,160,720	0.0032
1017	U of M - Animal Waste			Central Treatment	249	CITY	1,898,692	1,303,438	0.0052
1042	U of M - TCEM	562219	Other Nonhazardous Waste Treatment and Disposal	Central Treatment	249	CITY	1,116,927	1,086,927	0.0031
0719	U S Filter Recovery Services Inc	22132	Sewage Treatment Facilities	Central Treatment	249	CITY,OTHER	32,810,914	31,298,658	0.0899
0995	Alpha Ceramics Inc	327113	Porcelain Electrical Supply Manufacturing	Chemical Products	248	CITY	3,986,405	3,985,823	0.0109
1311	Apex International Mfg (1311)	32562	Toilet Preparation Manufacturing	Chemical Products	248	CITY	56,180,000	20,342,435	0.1539
0926	Aveda Corp	32562	Toilet Preparation Manufacturing	Chemical Products	248	CITY	30,534,780	24,608,676	0.0837
1175	Boomerang Laboratories Inc	32562	Toilet Preparation Manufacturing	Chemical Products	248	CITY,OTHER	14,452,400	6,512,042	0.0396
0801	Brenntag Great Lakes LLC	42269	Other Chemical and Allied Products Wholesalers	Chemical Products	248	CITY	334,678	160,588	0.0009
1066	C & H Chemical Inc	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	332,000	531,998	0.0009
0575	Chaska Chemical Co Inc	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	750,863	252,002	0.0021
0570	Conklin Co	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	57,427,080	6,297,000	0.1573
1294	Conwed Plastics	326199	All Other Plastics Product Manufacturing	Chemical Products	248	CITY	8,574,324	6,799,140	0.0235
0928	Cortec Corp	325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	Chemical Products	248	CITY	1,246,338	476,538	0.0034
0239	Davis-Frost Inc	311223	Other Oilseed Processing	Chemical Products	248	CITY	4,986,660	3,490,664	0.0137
0964	Degussa Building Systems (0964)	32552	Adhesive Manufacturing	Chemical Products	248	CITY	6,176,698	1,512,186	0.0169
0088	Diamond Products Co	32562	Toilet Preparation Manufacturing	Chemical Products	248	CITY,OTHER	156,428,996	54,188,072	0.4286
1055	Diversified Mfg Corp	325611	Soap and Other Detergent Manufacturing	Chemical Products	248	CITY	4,949,700	1,671,207	0.0136
0006	Ecolab Inc	325613	Surface Active Agent Manufacturing	Chemical Products	248	CITY	*12,775,000*	*60,531,054*	*0.0350* *
1044	Electrochemicals Inc	325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	Chemical Products	248	CITY	6,100,890	3,996,300	0.0167
0429	FilmTec Corp (0429)	32613	Laminated Plastics Plate, Sheet, and Shape Manufacturing	Chemical Products	248	CITY,WELL	262,314,624	262,314,768	0.7187
1085	Fox Packaging Inc	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	40,351,608	679,728	0.1106
0268	Fremont Industries Inc	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	WELL	11,628,000	4,851,468	0.0319
0949	GreenMan Technologies of MN Inc	56292	Materials Recovery Facilities	Chemical Products	248	CITY,WELL	1,301,980	1,301,980	0.0036
1097	Greenway Research Lab	32562	Toilet Preparation Manufacturing	Chemical Products	248	CITY	5,040,000	2,804,979	0.0138
0937	H B Fuller Co #0937	32552	Adhesive Manufacturing	Chemical Products	248	CITY	6,401,700	4,779,302	0.0175
1021	H B Fuller Co #1021	32552	Adhesive Manufacturing	Chemical Products	248	CITY,WELL	73,776,000	3,920,076	0.2021
1049	H B Fuller Co #1049	32551	Paint and Coating Manufacturing	Chemical Products	248	CITY	1,137,330	1,039,140	0.0031
0450	Hawkins Chemical Inc	325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	Chemical Products	248	CITY	26,171,376	22,168,080	0.0717
1250	Hawkins Chemical Inc	325181	Alkalies and Chlorine Manufacturing	Chemical Products	248	CITY	44,480,568	4,753,782	0.1219
1002	Hawkins Chemical Inc-Terminal I	325181	Alkalies and Chlorine Manufacturing	Chemical Products	248	CITY	36,940,728	12,064,020	0.1012
1171	Hoffman Enclosure (SCO)	326199	All Other Plastics Product Manufacturing	Chemical Products	248	CITY	6,248,096	5,516,226	0.0171

Metropolitan Council Industrial Dischargers Water Demand, 2005
Sorted by Business Category and Organization Name

Permit No.	Organization	NAICS Code[1]	NAICS Description	MCES Business Category[2]	DNR Use Code[3]	Incoming Water Type	Incoming (Gal)	Sewered (Gal)	Incoming (mgd)
1228	Illbruck Foamtec Inc	32615	Urethane and Other Foam Product (except Polystyrene) Manufacturing	Chemical Products	248	CITY	954,448	890,448	0.0026
1192	Intek Plastics Inc			Chemical Products	248	CITY	1,724,400	858,716	0.0047
1125	Intek Plastics Inc	326199	All Other Plastics Product Manufacturing	Chemical Products	248	CITY	7,120,800	4,870,446	0.0195
0244	Interplastic Corp	325211	Plastics Material and Resin Manufacturing	Chemical Products	248	CITY,OTHER	33,551,088	25,832,283	0.0919
1328	IonBond Inc			Chemical Products	248	CITY	12,297,120	12,174,148	0.0337
0816	KIK Minnesota	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	31,038,000	1,257,040	0.0850
0969	Kohl & Madden Printing Ink Corp	32591	Printing Ink Manufacturing	Chemical Products	248	CITY	13,119,266	13,119,266	0.0359
1331	LSI Corp of America			Chemical Products	248	CITY	5,330,000	4,784,000	0.0146
0792	McLaughlin Gormley King Co	32532	Pesticide and Other Agricultural Chemical Manufacturing	Chemical Products	248	CITY	4,300,140	540,160	0.0118
1353	Minnesota Petroleum Service			Chemical Products	248	CITY,OTHER	149,684	149,684	0.0004
0354	Minntech Corp	325412	Pharmaceutical Preparation Manufacturing	Chemical Products	248	CITY	102,546,840	26,791,324	0.2810
0906	Multi-Clean Inc	325612	Polish and Other Sanitation Good Manufacturing	Chemical Products	248	CITY	2,852,000	857,224	0.0078
1026	NatureWorks LLC	325211	Plastics Material and Resin Manufacturing	Chemical Products	248	CITY	25,400	25,400	0.0001
1288	Norwesco Inc	326199	All Other Plastics Product Manufacturing	Chemical Products	248	CITY	3,313,206	2,302,743	0.0091
1344	Novus Inc			Chemical Products	248	CITY	1,064,820	1,013,979	0.0029
1282	Nu Coat Inc	32551	Paint and Coating Manufacturing	Chemical Products	248	CITY	1,675,200	878,642	0.0046
1227	Par Aide Products Co (1227)	33992	Sporting and Athletic Goods Manufacturing	Chemical Products	248	CITY	167,000	166,600	0.0005
1314	Porous Media	339999	All Other Miscellaneous Manufacturing	Chemical Products	248	CITY	23,109,000	19,191,000	0.0633
1322	Powder Coating Technologies Inc			Chemical Products	248	CITY	487,632	487,632	0.0013
0953	Pump & Meter Services Inc	562211	Hazardous Waste Treatment and Disposal	Chemical Products	248	CITY,OTHER	227,934	225,434	0.0006
1124	Quality Mfg Inc			Chemical Products	248	WELL	204,550	204,232	0.0006
0371	Release Coatings of Minneapolis Inc	81131	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repa	Chemical Products	248	CITY	1,607,000	1,607,000	0.0044
1292	Ritrama Inc	322222	Coated and Laminated Paper Manufacturing	Chemical Products	248	CITY	6,217,791	6,188,226	0.0170
0198	Rubber Industries Inc	326291	Rubber Product Manufacturing for Mechanical Use	Chemical Products	248	CITY	550,000	466,230	0.0015
0558	Sierra Corp	32551	Paint and Coating Manufacturing	Chemical Products	248	CITY	2,871,570	1,990,158	0.0079
0992	Silver Pockets Inc	42193	Recyclable Material Wholesalers	Chemical Products	248	CITY,OTHER	2,212	2,212	0.0000
1325	Sunburst Chemicals Inc			Chemical Products	248	CITY	6,855,000	5,065,926	0.0188
0110	Univar USA Inc	42269	Other Chemical and Allied Products Wholesalers	Chemical Products	248	CITY	1,313,200	521,400	0.0036
1183	Uponor Wirsbo	325211	Plastics Material and Resin Manufacturing	Chemical Products	248	CITY	13,682,760	13,202,760	0.0375
1122	Vision-Ease Lens	339115	Ophthalmic Goods Manufacturing	Chemical Products	248	CITY	74,440,134	45,598,569	0.2039
1146	XSYS Print Solutions Inks, LLC			Chemical Products	248	CITY	712,000	712,000	0.0020
0830	XSYS Print Solutions Inks, LLC	32591	Printing Ink Manufacturing	Chemical Products	248	CITY	1,540,000	1,510,557	0.0042
1129	Zomax Optical Media			Chemical Products	248	CITY	7,007,960	3,199,760	0.0192
1218	Owens Corning (1218)	324122	Asphalt Shingle and Coating Materials Manufacturing	Contaminated Groundwater	249	CITY	78,946,992	69,511,806	0.2163
0056	AaCron Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL,OTHER	107,231,242	61,461,344	0.2938
0024	AbelConn LLC	335931	Current-Carrying Wiring Device Manufacturing	Electronic Products	247	CITY	9,786,120	9,778,780	0.0268
1102	ABW Plating Service Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,OTHER	1,285,510	1,231,510	0.0035
0806	Added Value Technology	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY	1,669,500	1,669,500	0.0046
1299	APA Enterprises Inc	333314	Optical Instrument and Lens Manufacturing	Electronic Products	247	CITY	1,285,126	891,816	0.0035
0748	Arrow Cryogenics Inc #748	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	10,672,254	10,672,254	0.0292
0583	Aztec Electronics Inc	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	1,514,081	1,514,081	0.0041

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1306	BOC Edwards Inc	333295	Semiconductor Machinery Manufacturing	Electronic Products	247	CITY	2,721,680	2,721,680	0.0075
0134	Co-Operative Plating	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL	40,107,760	36,068,414	0.1099
0814	Cypress Semi-Conductor (MN) Inc	334413	Semiconductor and Related Device Manufacturing	Electronic Products	247	CITY,WELL	729,422,000	68,120,000	1.9984
0139	Douglas Corp, Plating Div	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	72,130,440	71,137,380	0.1976
1242	Eaglemaster Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	1,066,573	1,030,141	0.0029
0007	Electronic Industries Inc	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	2,684,686	2,619,536	0.0074
1107	FSI International Inc (1107)	333295	Semiconductor Machinery Manufacturing	Electronic Products	247	CITY	75,887,460	66,769,614	0.2079
0221	General Dynamics Advanced Information Systems	334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument M	Electronic Products	247	CITY	13,679,400	6,644,000	0.0375
1206	Gustafson Finishing Corp	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	172,400	172,400	0.0005
0089	Hard Chrome Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL,OTHER	22,625,473	22,194,241	0.0620
0248	Hiawatha Metalcraft Inc (Plant #1)	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL	44,630,086	25,988,452	0.1223
0210	Holaday Circuits Inc	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY,OTHER	37,134,797	28,484,336	0.1017
0066	Honeywell Inc (0066)	334413	Semiconductor and Related Device Manufacturing	Electronic Products	247	CITY,WELL	77,875,193	48,084,000	0.2134
1202	Innovex Inc	334413	Semiconductor and Related Device Manufacturing	Electronic Products	247	CITY	17,150,322	15,799,060	0.0470
1169	IntraSpec Solutions	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,OTHER	9,590,500	9,524,095	0.0263
0663	Kangas Enameling Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	154,180	154,180	0.0004
0320	Ken's Metal Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,OTHER	478,328	454,788	0.0013
0176	Leaf Industries Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	2,667,000	1,834,000	0.0073
0787	Linfor Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	5,448,000	5,448,000	0.0149
1180	M & D Metal Finishing Inc (1180)	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	1,639,196	1,472,596	0.0045
0129	Micom Corp	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	68,202,270	50,090,340	0.1869
1194	Micro Control Co	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	207,317	207,317	0.0006
0736	Micro Finish Co	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	63,378	63,378	0.0002
1196	Midwest Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	11,818,800	11,316,760	0.0324
1111	Minco Products Inc	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY	19,194,200	19,194,200	0.0526
0163	Minco Products Inc	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY	35,662,000	35,662,000	0.0977
1347	Minnesota Metal Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	8,310,216	8,151,456	0.0228
0206	Nor-Ell Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL	11,600,736	11,136,706	0.0318
1093	NVE Corp	334413	Semiconductor and Related Device Manufacturing	Electronic Products	247	CITY	319,812	319,812	0.0009
0112	Pioneer Metal Finishing	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL,OTHER	164,627,572	121,380,400	0.4510
0229	Polar Semiconductor Inc	335931	Current-Carrying Wiring Device Manufacturing	Electronic Products	247	CITY,WELL	*98,550,000*	*404,042,460*	*0.2700* *
0253	Printed Circuits Inc	334419	Other Electronic Component Manufacturing	Electronic Products	247	CITY	17,401,410	17,364,330	0.0477
1295	Production Technologies Inc			Electronic Products	247	CITY	370,000	369,600	0.0010
1221	Pro-Tech Interconnect Solutions, LLC	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY	13,237,000	13,237,000	0.0363
0962	RMS Co	334417	Electronic Connector Manufacturing	Electronic Products	247	CITY	18,815,600	16,738,108	0.0515
1257	Ron-Vik Inc	332618	Other Fabricated Wire Product Manufacturing	Electronic Products	247	CITY	2,012,000	1,988,000	0.0055
0108	Rosemount Aerospace Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	4,701,800	2,887,916	0.0129
0109	Rosemount Aerospace Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY,WELL	98,041,800	41,704,464	0.2686
0107	Rosemount Inc #0107	334513	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling In	Electronic Products	247	CITY,WELL	221,213,640	154,606,044	0.6061
0878	Rosemount Inc #0878	334513	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling In	Electronic Products	247	CITY	45,078,000	30,068,040	0.1235
1204	Seagate Technology LLC	334112	Computer Storage Device Manufacturing	Electronic Products	247	CITY,OTHER	58,838,028	14,665,797	0.1612

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0205	Seagate Technology LLC	334112	Computer Storage Device Manufacturing	Electronic Products	247	CITY	*123,483,720*	*244,058,696*	*0.3383* *
0702	TRC Circuits Inc	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	3,118,268	2,970,030	0.0085
1095	Twin Star Electronics Inc	334412	Bare Printed Circuit Board Manufacturing	Electronic Products	247	CITY	455,860	455,860	0.0012
0714	Universal Circuits Inc	334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing	Electronic Products	247	CITY	49,392,000	47,758,228	0.1353
0138	Wolkerstorfer Co Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Electronic Products	247	CITY	17,353,460	16,977,540	0.0475
1003	ADM Milling	311211	Flour Milling	Food Products	241	CITY	7,977,645	2,804,238	0.0219
1224	American Fish & Seafood	42242	Packaged Frozen Food Wholesalers	Food Products	241	CITY	868,344	631,000	0.0024
0273	Anamax Corp (0273)	311613	Rendering and Meat Byproduct Processing	Food Products	241	CITY,OTHER	192,136,941	189,253,431	0.5264
0637	Arden International Kitchens LLC	311412	Frozen Specialty Food Manufacturing	Food Products	241	CITY	26,429,640	21,873,108	0.0724
0590	Best Brands Inc	311211	Flour Milling	Food Products	241	CITY	30,932,400	24,186,920	0.0847
1297	Bix Produce Co	44523	Fruit and Vegetable Markets	Food Products	241	CITY	40,398,144	36,846,144	0.1107
1178	Buddy's Kitchen Inc	72231	Food Service Contractors	Food Products	241	CITY	5,307,000	5,307,000	0.0145
1336	Calco Sprouts Inc			Food Products	241	CITY,WELL	5,564,072	1,406,444	0.0152
0448	Captain Ken's Foods Inc	311991	Perishable Prepared Food Manufacturing	Food Products	241	WELL	7,171,200	5,399,097	0.0196
1208	Cargill Inc-Process Development Facility	54171	Research and Development in the Physical, Engineering, and Life Sciences	Food Products	241	CITY	833,770	833,770	0.0023
0363	Central Livestock Association	42252	Livestock Wholesalers	Food Products	241	CITY,OTHER	51,837,900	47,149,400	0.1420
0923	Chef Solutions	311812	Commercial Bakeries	Food Products	241	CITY	12,702,500	6,405,643	0.0348
0810	Conagra Foods-Snack Food Group	311919	Other Snack Food Manufacturing	Food Products	241	CITY	2,538,537	1,613,049	0.0070
1334	Cre 8 It Inc			Food Products	241	CITY	837,000	837,000	0.0023
1333	Cre 8 It Inc			Food Products	241	CITY	8,084,613	8,084,613	0.0221
0428	Dakota Growers Pasta Co - MN Div	311823	Dry Pasta Manufacturing	Food Products	241	CITY	21,278,000	3,706,000	0.0583
0312	Dakota Premium Foods LLC	311611	Animal (except Poultry) Slaughtering	Food Products	241	CITY	206,366,000	200,212,800	0.5654
0296	Dean Foods Woodbury	311511	Fluid Milk Manufacturing	Food Products	241	CITY	67,671,000	61,235,952	0.1854
0884	Domino's National Commissary Corp	311822	Flour Mixes and Dough Manufacturing from Purchased Flour	Food Products	241	CITY	7,377,000	4,871,379	0.0202
0076	E A Sween Co dba Deli Express	311991	Perishable Prepared Food Manufacturing	Food Products	241	CITY	12,540,474	11,094,183	0.0344
0625	Earthgrains / Metz Baking Co	311812	Commercial Bakeries	Food Products	241	CITY	53,250,000	38,553,070	0.1459
0323	Everfresh Food Corp	311823	Dry Pasta Manufacturing	Food Products	241	CITY,OTHER	899,876	727,892	0.0025
0782	Fischer's United Supply Inc	311421	Fruit and Vegetable Canning	Food Products	241	CITY	652,500	467,037	0.0018
0849	General Mills Inc - Bakeries & Foodservice	311812	Commercial Bakeries	Food Products	241	CITY	214,401,474	115,621,602	0.5874
0034	General Mills Inc - Purity Oats	311211	Flour Milling	Food Products	241	CITY,OTHER	4,644,132	938,134	0.0127
0002	General Mills Inc (JFBTC)	311211	Flour Milling	Food Products	241	CITY,WELL	56,043,000	41,150,700	0.1535
0848	General Mills Operations Inc	311211	Flour Milling	Food Products	241	CITY	19,028,250	8,440,911	0.0521
0362	General Mills Technology Center E	54171	Research and Development in the Physical, Engineering, and Life Sciences	Food Products	241	CITY	15,461,016	8,849,074	0.0424
0326	Glenwood-Inglewood Co	312112	Bottled Water Manufacturing	Food Products	241	CITY,WELL,OTHER	20,523,736	10,324,142	0.0562
1104	Haagen-Dazs R & D	31152	Ice Cream and Frozen Dessert Manufacturing	Food Products	241	CITY	2,142,660	2,132,760	0.0059
1084	Happy's Potato Chip Co	311919	Other Snack Food Manufacturing	Food Products	241	CITY	36,656,900	34,959,356	0.1004
0058	Hastings Coop Creamery	311511	Fluid Milk Manufacturing	Food Products	241	CITY	10,829,000	8,867,000	0.0297
1298	Johnson Brothers Liquor Co	42282	Wine and Distilled Alcoholic Beverage Wholesalers	Food Products	241	CITY	4,393,752	1,620,896	0.0120
0064	Kemps LLC	311511	Fluid Milk Manufacturing	Food Products	241	CITY,WELL	93,467,000	63,191,200	0.2561
0589	King's Deluxe Foods (0589)	42242	Packaged Frozen Food Wholesalers	Food Products	241	CITY	19,557,750	10,857,750	0.0536
0480	Land O'Lakes Inc	311511	Fluid Milk Manufacturing	Food Products	241	CITY	19,692,800	15,215,000	0.0540

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1283	Leeann Chin Inc	72231	Food Service Contractors	Food Products	241	CITY	3,198,500	2,822,460	0.0088
1358	Lettieri's Inc			Food Products	241	CITY	6,557,700	6,323,700	0.0180
0793	Lloyd's Barbeque Co	311613	Rendering and Meat Byproduct Processing	Food Products	241	CITY	92,279,000	57,723,125	0.2528
0942	Loft House Bakery Products Inc	311812	Commercial Bakeries	Food Products	241	CITY	57,975,900	33,059,535	0.1588
0820	LSG/Sky Chef	72232	Frozen Specialty Food Manufacturing	Food Products	241	CITY,OTHER	188,147,112	172,559,160	0.5155
1348	Lunds Mitchell Road LLC			Food Products	241	CITY	33,816,300	18,461,727	0.0926
0014	M - Foods Dairy LLC	311511	Fluid Milk Manufacturing	Food Products	241	CITY,WELL	679,061,886	143,923,464	1.8604
0630	Marcom Services Inc			Food Products	241	CITY	2,137,000	2,137,000	0.0059
0264	Marigold Foods Inc - Mpls Plant	311511	Fluid Milk Manufacturing	Food Products	241	CITY	296,410,352	289,063,656	0.8121
0272	Midwest Coca Cola Bottling Inc (0272)	312111	Soft Drink Manufacturing	Food Products	241	CITY,WELL	245,280,000	161,733,376	0.6720 *
1134	Mission Foods	31183	Tortilla Manufacturing	Food Products	241	CITY	11,366,000	7,734,324	0.0311
0059	Northern Star Co	311411	Frozen Fruit, Juice, and Vegetable Manufacturing	Food Products	241	CITY,WELL	289,044,104	280,372,298	0.7919
0873	Novartis Nutrition Corp	311999	All Other Miscellaneous Food Manufacturing	Food Products	241	CITY	13,992,310	6,317,830	0.0383
0634	Novartis Nutrition Corp			Food Products	241	CITY	559,697,385	419,159,635	1.5334
0116	Old Dutch Foods Inc	311919	Other Snack Food Manufacturing	Food Products	241	CITY,WELL	59,345,600	58,649,200	0.1626
0322	Old Home Foods Inc	311511	Fluid Milk Manufacturing	Food Products	241	CITY,OTHER	19,129,352	15,690,178	0.0524
1166	Olsen Fish Co			Food Products	241	CITY	874,997	788,213	0.0024
0298	Pearson Candy Co	31133	Confectionery Manufacturing from Purchased Chocolate	Food Products	241	CITY,WELL	21,237,213	14,099,208	0.0582
0366	Pepsi Bottling Group LLC	312111	Soft Drink Manufacturing	Food Products	241	CITY,WELL	703,974,000	181,752,420	1.9287
0817	Quali-Tech Inc	311999	All Other Miscellaneous Food Manufacturing	Food Products	241	CITY	1,849,000	1,386,750	0.0051
1293	Quality Ingredients Corp	311514	Dry, Condensed, and Evaporated Dairy Product Manufacturing	Food Products	241	CITY	17,876,000	13,474,788	0.0490
0036	Rahr Malting Co	311213	Malt Manufacturing	Food Products	241	CITY,WELL	359,151,462	359,152,382	0.9840
0413	Ry-Krisp Plant, Ralston Foods	311821	Cookie and Cracker Manufacturing	Food Products	241	CITY	1,066,094	692,871	0.0029
0300	Schroeder Milk Co Inc	311511	Fluid Milk Manufacturing	Food Products	241	CITY	328,940,000	279,263,404	0.9012
0373	Schumacher Wholesale Meats Inc	311612	Meat Processed from Carcasses	Food Products	241	CITY	7,925,100	7,925,100	0.0217
1182	Siyeza Creative Foods LLC	311412	Frozen Specialty Food Manufacturing	Food Products	241	CITY	21,228,836	19,698,992	0.0582
1051	Stock Yards Meat Packing Co	42247	Meat and Meat Product Wholesalers	Food Products	241	CITY	1,290,000	1,290,000	0.0035
1161	Summit Brewing Co			Food Products	241	CITY	19,412,096	12,643,804	0.0532
0844	SuperMom's LLC	311812	Commercial Bakeries	Food Products	241	CITY	11,207,400	7,369,166	0.0307
1029	Swanson Meats Inc	42242	Packaged Frozen Food Wholesalers	Food Products	241	CITY	1,084,500	925,140	0.0030
1327	The New French Bakery Inc	311812	Commercial Bakeries	Food Products	241	CITY	5,453,284	4,086,064	0.0149
0114	United Sugars Corp	311313	Beet Sugar Manufacturing	Food Products	241	WELL	29,606,600	3,373,290	0.0811
1281	Upscale Foods	311412	Frozen Specialty Food Manufacturing	Food Products	241	CITY	1,080,000	1,056,000	0.0030
0826	VICOM (0826)	311813	Frozen Cakes, Pies, and Other Pastries Manufacturing	Food Products	241	CITY,OTHER	16,327,800	13,137,116	0.0447
0999	Waymouth Farms Inc	311511	Fluid Milk Manufacturing	Food Products	241	CITY	3,001,100	3,001,100	0.0082
0960	Anchor Glass Container Corp	327213	Glass Container Manufacturing	Glass Products	248	CITY,WELL	21,138,600	4,157,998	0.0579
1074	Twin City Optical	339115	Ophthalmic Goods Manufacturing	Glass Products	248	CITY	3,332,000	3,327,000	0.0091
0501	Abbott Northwestern Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY,WELL	150,813,450	137,791,318	0.4132
0517	Children's Hospitals/Clinics - Mpls	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	109,828,500	109,366,500	0.3009
0840	Fairview Ridges Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	15,943,000	13,670,000	0.0437
0509	Fairview Southdale Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY,WELL	148,723,269	120,309,441	0.4075

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0535	Fairview University Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY,WELL	98,481,900	89,726,550	0.2698
0507	Fairview University Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	143,342,106	128,535,374	0.3927
0511	Hennepin County Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	81,663,648	81,663,648	0.2237
0023	Lakeview Memorial Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	32,013,000	22,782,504	0.0877
0513	Mercy Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	30,689,000	22,828,847	0.0841
0514	Methodist Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY,WELL	60,682,000	52,724,400	0.1663
0520	North Memorial Health Care	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	197,314,424	158,060,872	0.5406
0522	Regina Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	29,010,000	24,129,884	0.0795
0526	Regions Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	102,180,870	84,680,504	0.2799
0533	Ridgeview Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	16,145,000	15,264,452	0.0442
1114	St Francis Regional Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	17,085,720	12,813,472	0.0468
0829	St John's Hospital NE	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	20,582,790	14,688,806	0.0564
0524	St Joseph's Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	29,914,764	27,834,016	0.0820
0530	United Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	141,926,268	136,368,768	0.3888
0531	Unity Hospital	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	31,926,180	25,133,305	0.0875
0532	V A Medical Center	62211	General Medical and Surgical Hospitals	Health Care	213	CITY,WELL	867,189,000	156,372,000	2.3759
1231	Woodwinds Health Campus	62211	General Medical and Surgical Hospitals	Health Care	213	CITY	10,756,330	8,031,980	0.0295
1214	Biovest International Inc	54171	Research and Development in the Physical, Engineering, and Life Sciences	Laboratory	213	CITY	1,849,500	1,849,500	0.0051
0402	Birchwood Laboratories Inc			Laboratory	213	CITY,WELL	1,219,804	745,120	0.0033
1246	Boos Dental Laboratory			Laboratory	213	CITY	813,491	813,491	0.0022
0835	R & D Systems Inc (0835)	325413	In-Vitro Diagnostic Substance Manufacturing	Laboratory	213	CITY	9,793,000	6,673,786	0.0268
0041	Ameripride Services (0041)	812332	Industrial Launderers	Laundry	213	CITY,WELL	63,921,750	43,427,268	0.1751
1136	Aramark Uniform Services Inc	812332	Industrial Launderers	Laundry	213	CITY	106,660,000	95,994,000	0.2922
0656	Cintas Corp - Eagan	812332	Industrial Launderers	Laundry	213	CITY	30,720,000	28,569,600	0.0842
1199	Cintas Corp - Maple Grove	812332	Industrial Launderers	Laundry	213	CITY	65,097,000	60,312,150	0.1783
1207	G & K Services	812332	Industrial Launderers	Laundry	213	CITY	7,108,992	6,540,089	0.0195
0341	G & K Services	812332	Industrial Launderers	Laundry	213	CITY,WELL	23,262,026	21,701,076	0.0637
0443	G & K Services	812332	Industrial Launderers	Laundry	213	CITY,WELL	38,990,026	38,990,026	0.1068
1341	Health Systems Cooperative Laundries	81232	Drycleaning and Laundry Services (except Coin-Operated)	Laundry	213	CITY	212,120,832	173,677,628	0.5812
1094	Huebsch Laundry Co	812332	Industrial Launderers	Laundry	213	CITY	2,428,000	2,384,196	0.0067
0259	Leef Brothers Inc	812332	Industrial Launderers	Laundry	213	CITY,WELL	52,757,708	45,566,268	0.1445
1254	Mid City Industrial Laundry	812332	Industrial Launderers	Laundry	213	CITY	1,106,500	1,029,045	0.0030
1148	Spruce Co	812332	Industrial Launderers	Laundry	213	CITY	3,972,000	3,696,450	0.0109
1309	Tek Products	812332	Industrial Launderers	Laundry	213	CITY	6,695,200	6,356,440	0.0183
0048	Twin City Hide Inc (0048)	42259	Other Farm Product Raw Material Wholesalers	Leather Products	248	CITY	20,393,344	18,801,110	0.0559
0784	Twin City Tanning Co (0784)	31611	Leather and Hide Tanning and Finishing	Leather Products	248	CITY	304,869,000	249,551,235	0.8353
1267	Accellent Inc	339112	Surgical and Medical Instrument Manufacturing	Medical Products	248	CITY	2,378,090	2,216,880	0.0065
1141	American Medical Systems			Medical Products	248	CITY	7,196,090	3,521,540	0.0197
1273	ATS Medical Inc	339113	Surgical Appliance and Supplies Manufacturing	Medical Products	248	CITY	1,934,400	1,934,400	0.0053
0291	Beckman Coulter Inc	325412	Pharmaceutical Preparation Manufacturing	Medical Products	248	CITY	14,078,322	11,280,588	0.0386
0843	Boston Scientific Corporation (0843)	339112	Surgical and Medical Instrument Manufacturing	Medical Products	248	CITY,OTHER	260,943,900	146,066,055	0.7149

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1223	Boston Scientific Corporation (1223)	339112	Surgical and Medical Instrument Manufacturing	Medical Products	248	CITY	165,848,000	111,874,772	0.4544
1260	Cima Labs Inc	325412	Pharmaceutical Preparation Manufacturing	Medical Products	248	CITY	9,480,000	9,417,000	0.0260
0397	DiaSorin Inc			Medical Products	248	CITY	8,906,000	7,152,520	0.0244
0412	Guidant	334510	Electromedical and Electrotherapeutic Apparatus Manufacturing	Medical Products	248	CITY	26,128,654	12,994,084	0.0716
0915	Lifecore Biomedical (0915)	339113	Surgical Appliance and Supplies Manufacturing	Medical Products	248	CITY	10,082,200	8,237,008	0.0276
1154	Medtronic Perfusion Systems			Medical Products	248	CITY,OTHER	10,781,100	7,313,160	0.0295
1010	Mentor Corp Minnesota	339113	Surgical Appliance and Supplies Manufacturing	Medical Products	248	CITY	23,316,285	23,316,285	0.0639
1256	Micro-Matics LLC	332721	Precision Turned Product Manufacturing	Medical Products	248	CITY	186,000	156,400	0.0005
1290	ProtaTek International Inc	325414	Biological Product (except Diagnostic) Manufacturing	Medical Products	248	CITY	1,535,000	1,535,000	0.0042
1195	Protein Design Labs Inc	325412	Pharmaceutical Preparation Manufacturing	Medical Products	248	CITY	8,411,600	8,411,600	0.0230
0973	St Jude Medical Inc	339113	Surgical Appliance and Supplies Manufacturing	Medical Products	248	CITY	9,832,000	9,720,082	0.0269
1137	Upsher-Smith Laboratories Inc (1137)			Medical Products	248	CITY	2,550,910	1,723,336	0.0070
1313	Upsher-Smith Laboratories Inc (1313)			Medical Products	248	CITY	2,712,000	2,712,000	0.0074
1269	ViroGen Inc	325414	Biological Product (except Diagnostic) Manufacturing	Medical Products	248	CITY	366,350	366,350	0.0010
0924	3M Co			Metal Products	247	CITY	4,517,436	2,799,800	0.0124
1268	A & E Metal Finishing Inc			Metal Products	247	CITY	303,600	272,860	0.0008
1251	A W Beadblasting Co			Metal Products	247	CITY	147,356	134,506	0.0004
1138	ADC Telecommunications Inc	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	*32,120,000*	*445,173,300*	*0.0880* *
1153	ADDCO Inc	33429	Other Communications Equipment Manufacturing	Metal Products	247	CITY	3,964,400	2,824,224	0.0109
1258	Advance Corp #1258	33995	Sign Manufacturing	Metal Products	247	CITY	3,995,000	1,861,000	0.0109
1275	Aljon Tool Inc	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	309,000	309,000	0.0008
1198	Alliance Steel Service Co	42193	Recyclable Material Wholesalers	Metal Products	247	CITY,OTHER	355,966	355,966	0.0010
1081	Alumiplate Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	1,086,346	1,084,346	0.0030
1310	AmeriStar Laser Cutting Inc	33271	Machine Shops	Metal Products	247	CITY	1,381,500	1,311,500	0.0038
0951	Anotech Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	4,408,244	4,082,484	0.0121
0996	APG Cash Drawer	332439	Other Metal Container Manufacturing	Metal Products	247	CITY	8,583,600	8,366,700	0.0235
1211	Aspen Equipment Co	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	2,463,000	2,265,600	0.0067
0169	Avtec Finishing Systems	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	25,471,200	24,754,516	0.0698
0081	BAE Systems Land and Armaments (0081)	332995	Other Ordnance and Accessories Manufacturing	Metal Products	247	CITY	131,896,000	76,731,720	0.3614
0187	Bauer Welding & Metal Fabricators Inc	332996	Fabricated Pipe and Pipe Fitting Manufacturing	Metal Products	247	CITY	10,666,400	5,162,264	0.0292
0374	Bepex International LLC	333298	All Other Industrial Machinery Manufacturing	Metal Products	247	CITY	1,329,280	1,329,280	0.0036
0990	Bermo Inc #0990	332116	Metal Stamping	Metal Products	247	CITY	8,060,736	5,894,652	0.0221
1263	Better Parts Co	33271	Machine Shops	Metal Products	247	CITY	326,000	323,600	0.0009
0178	Bo-Decor Metal Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	2,498,000	2,178,000	0.0068
0912	Bodycote Thermal Processing Co	332811	Metal Heat Treating	Metal Products	247	CITY	3,915,000	3,014,749	0.0107
1060	Boker's Inc #1060	332116	Metal Stamping	Metal Products	247	CITY	135,020	135,020	0.0004
1233	Boker's Inc #1233	332116	Metal Stamping	Metal Products	247	CITY	1,414,984	1,414,984	0.0039
1070	Brady Worldwide Inc	333293	Printing Machinery and Equipment Manufacturing	Metal Products	247	CITY	1,125,000	370,984	0.0031
0919	BSM/CORAM North America, Inc.	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	279,670	176,609	0.0008
0633	Buhler Inc	33242	Metal Tank (Heavy Gauge) Manufacturing	Metal Products	247	CITY	1,878,660	1,878,660	0.0051
0827	Burr Technology Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	378,000	378,000	0.0010

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1181	Cannon Equipment	333922	Conveyor and Conveying Equipment Manufacturing	Metal Products	247	CITY	3,479,679	870,879	0.0095
1279	Carley Foundry Inc			Metal Products	247	CITY	3,262,598	2,918,500	0.0089
1167	Carter Day International Inc	333111	Farm Machinery and Equipment Manufacturing	Metal Products	247	CITY	397,000	397,000	0.0011
0029	Caterpillar Paving Products Inc	333924	Industrial Truck, Tractor, Trailer, and Stacker Machinery Manufacturing	Metal Products	247	CITY	13,921,500	11,238,300	0.0381
0755	Certified Painting Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	922,530	922,530	0.0025
0136	Circuit Science Inc			Metal Products	247	CITY	26,923,000	26,923,000	0.0738
1342	Consolidated Container Company	81131	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repa	Metal Products	247	CITY	1,484,132	1,484,132	0.0041
0460	Continental Machines	333911	Pump and Pumping Equipment Manufacturing	Metal Products	247	CITY	1,611,438	1,611,438	0.0044
0536	Continental Machines	333512	Machine Tool (Metal Cutting Types) Manufacturing	Metal Products	247	CITY	3,030,100	3,030,100	0.0083
1105	Dayton Rogers Mfg Co	332116	Metal Stamping	Metal Products	247	CITY	4,808,854	1,886,388	0.0132
0572	Deburring Inc	33271	Machine Shops	Metal Products	247	CITY	815,000	815,000	0.0022
0557	Detector Electronics Corp	334419	Other Electronic Component Manufacturing	Metal Products	247	CITY	2,450,000	1,277,543	0.0067
0750	Donaldson Co Inc			Metal Products	247	CITY	18,462,000	13,074,000	0.0506
0694	Douglas Corp	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	10,288,000	10,264,000	0.0282
0145	Dugas Bowers Plating Co	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	13,729,400	12,341,640	0.0376
0666	E/M Corp	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	7,360,000	7,360,000	0.0202
0743	Eaton MDH Inc, Eden Prairie Plant	333999	All Other Miscellaneous General Purpose Machinery Manufacturing	Metal Products	247	WELL	96,809,628	42,235,152	0.2652
1034	ECO Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	33,783,000	30,299,764	0.0926
0151	Edco Products Inc	332320		Metal Products	247	CITY	16,259,160	9,178,044	0.0445
1200	Electro Static Corp	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	2,268,684	1,898,325	0.0062
1280	Electro-Mechanical Industries Inc	335313	Switchgear and Switchboard Apparatus Manufacturing	Metal Products	247	CITY,OTHER	345,920	345,920	0.0009
0693	ELO Engineering	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	1,720,060	1,720,060	0.0047
1345	Engineered Finishing Corp	33271	Machine Shops	Metal Products	247	CITY	591,614	369,040	0.0016
0670	Excel Metal Finishing	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	373,000	373,000	0.0010
1261	Fed Tech			Metal Products	247	CITY	2,874,000	1,598,880	0.0079
0211	Federal Cartridge Co - ATK	332992	Small Arms Ammunition Manufacturing	Metal Products	247	CITY,WELL	*56,940,000*	*218,337,808*	*0.1560* *
0384	Flame Metals Processing Corp	332811	Metal Heat Treating	Metal Products	247	CITY,WELL	502,000	487,700	0.0014
1139	FMS Corp	332117	Powder Metallurgy Part Manufacturing	Metal Products	247	CITY	3,940,000	3,940,000	0.0108
0142	Ford Motor Co	336112	Light Truck and Utility Vehicle Manufacturing	Metal Products	247	CITY,OTHER	747,922,308	207,205,533	2.0491
0399	GE Osmonics Inc	333319	Other Commercial and Service Industry Machinery Manufacturing	Metal Products	247	CITY	63,039,000	36,933,000	0.1727
1106	Gerdau Ameristeel US Inc - St Paul Mill			Metal Products	247	CITY,WELL	219,247,191	66,444,633	0.6007
1340	Gopher Motor Rebuilding Inc			Metal Products	247	CITY	1,396,000	744,000	0.0038
0626	Gopher Resource Corp	331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum	Metal Products	247	CITY,WELL,OTHER	169,854,336	122,535,993	0.4654
0358	Graco Inc	333911	Pump and Pumping Equipment Manufacturing	Metal Products	247	CITY	4,808,668	4,703,275	0.0132
0360	Graco Inc	333911	Pump and Pumping Equipment Manufacturing	Metal Products	247	CITY	5,957,813	1,434,933	0.0163
1179	Great Lakes Engineering Inc			Metal Products	247	CITY	1,321,260	1,246,425	0.0036
0181	Gross-Given Mfg Co	333311	Automatic Vending Machine Manufacturing	Metal Products	247	CITY	7,099,930	7,099,930	0.0195
0012	H D Hudson Mfg Co	333111	Farm Machinery and Equipment Manufacturing	Metal Products	247	CITY	3,965,400	3,925,746	0.0109
0740	H&B Elevators Inc.	333921	Elevator and Moving Stairway Manufacturing	Metal Products	247	CITY	336,472	388,236	0.0009
1128	Hard Anodize Inc			Metal Products	247	CITY,OTHER	508,701	410,381	0.0014
0370	Hardcoat Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	222,850	219,850	0.0006

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0039	Hiawatha Metalcraft Inc (Plant #3)	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	181,006,641	30,297,357	0.4959
0364	Hitchcock Industries Inc	331521	Aluminum Die-Casting Foundries	Metal Products	247	CITY	16,327,400	14,830,872	0.0447
1210	Hoffman Enclosures	332322	Sheet Metal Work Manufacturing	Metal Products	247	CITY	79,255,275	50,699,463	0.2171
0130	Honeywell Inc (0130)	334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument M	Metal Products	247	CITY,WELL	133,083,164	26,438,060	0.3646
0189	Honeywell Inc (0189)	334512	Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance U	Metal Products	247	CITY,WELL	*175,200,000*	*182,299,520*	*0.4800* *
1152	Huot Mfg Co #1152			Metal Products	247	CITY	658,240	658,240	0.0018
1119	Hutchinson Technology Inc	33271	Machine Shops	Metal Products	247	CITY	30,095,200	19,997,722	0.0825
0061	Intermet Co			Metal Products	247	CITY	26,484,400	20,388,844	0.0726
1131	Inthermo Inc			Metal Products	247	CITY	447,000	263,725	0.0012
0735	Invest-Cast Inc	331512	Steel Investment Foundries	Metal Products	247	CITY	1,244,240	1,099,752	0.0034
1043	J & E Mfg	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	1,826,000	1,826,000	0.0050
1220	J & L Wire Cloth Co Inc	332618	Other Fabricated Wire Product Manufacturing	Metal Products	247	CITY	2,381,440	1,581,480	0.0065
1087	J I T Powder Coating	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	5,050,000	4,924,400	0.0138
1277	J L Industries	337215	Showcase, Partition, Shelving, and Locker Manufacturing	Metal Products	247	CITY	1,470,000	1,460,000	0.0040
1132	J R Williams Co Inc	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	154,832	143,942	0.0004
0303	Johnson Screens (0303)	333319	Other Commercial and Service Industry Machinery Manufacturing	Metal Products	247	CITY	35,040,000	35,040,000	0.0960
0117	Joyner's Silver & Electroplating	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	WELL	13,342,920	13,048,920	0.0366
1337	Kirchbaum-Krupp Metal Co			Metal Products	247	CITY,OTHER	403,671	403,671	0.0011
1323	Kurt Mfg Co			Metal Products	247	CITY	15,312,880	15,310,080	0.0420
0746	Kurt Mfg Co	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	41,662,800	41,662,800	0.1141
0909	Kurt Mfg Co - Die Cast Div	331521	Aluminum Die-Casting Foundries	Metal Products	247	CITY	2,037,900	1,039,090	0.0056
0790	Kurt Mfg Co (0790)	333515	Cutting Tool and Machine Tool Accessory Manufacturing	Metal Products	247	CITY	3,593,392	3,247,020	0.0098
0742	Kwik-File Inc	337214	Office Furniture (except Wood) Manufacturing	Metal Products	247	CITY	3,845,740	3,845,740	0.0105
1286	L & S Electric, Inc	811412	Appliance Repair and Maintenance	Metal Products	247	CITY	975,000	975,000	0.0027
1239	LAI Midwest Inc	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	9,284,000	7,427,200	0.0254
0406	Lake Air Metal Stampings LLC	33637	Motor Vehicle Metal Stamping	Metal Products	247	CITY	416,000	416,000	0.0011
1005	Lake Engineering Inc	33271	Machine Shops	Metal Products	247	CITY	1,973,370	1,934,457	0.0054
1110	LeJeune Bolt Co	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	142,890	142,890	0.0004
0988	Life Fitness Consumer Div	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	23,188,500	16,305,327	0.0635
0177	Lowell Inc	332721	Precision Turned Product Manufacturing	Metal Products	247	CITY	3,498,000	1,188,000	0.0096
0661	Maguire & Strickland Refining Inc			Metal Products	247	CITY	166,000	142,948	0.0005
1249	Mate Precision Tooling	333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	Metal Products	247	CITY	4,346,182	4,346,182	0.0119
1054	McLean Midwest	333415	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeratio	Metal Products	247	CITY	14,257,220	27,842,000	0.0391
0438	Med Tek Inc	332811	Metal Heat Treating	Metal Products	247	CITY	2,134,700	1,067,350	0.0058
0607	Medtronic Inc	334510	Electromedical and Electrotherapeutic Apparatus Manufacturing	Metal Products	247	CITY	8,161,380	1,350,720	0.0224
0598	Medtronic Inc	334510	Electromedical and Electrotherapeutic Apparatus Manufacturing	Metal Products	247	CITY	17,011,000	5,297,437	0.0466
0608	Medtronic Inc	54171	Research and Development in the Physical, Engineering, and Life Sciences	Metal Products	247	CITY	24,361,280	19,112,600	0.0667
1164	Metal Treaters Inc			Metal Products	247	CITY	2,108,858	1,772,258	0.0058
0032	Metal-Matic Inc	33121	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	Metal Products	247	CITY,WELL	163,309,270	11,547,790	0.4474
0643	Metal-Tronics Inc	337214	Office Furniture (except Wood) Manufacturing	Metal Products	247	CITY	284,000	228,565	0.0008
0126	Micro Parts Inc	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	6,748,000	6,748,000	0.0185

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1203	Mid Minnesota Wire & Mfg Inc			Metal Products	247	CITY	748,000	346,600	0.0020
0563	Mid-Continent Engineering	332439	Other Metal Container Manufacturing	Metal Products	247	CITY	80,178,750	77,429,850	0.2197
1289	Midwest Powdercoating & Screen Printing	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	1,363,880	1,083,880	0.0037
0258	Minnesota Metal Finishing Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	24,676,520	24,464,840	0.0676
0998	Modern Tool	332116	Metal Stamping	Metal Products	247	CITY	5,622,400	4,628,840	0.0154
0127	Molex Inc Copper Flex Products			Metal Products	247	CITY	38,861,592	38,609,724	0.1065
0691	Morrissey Inc			Metal Products	247	CITY	1,468,000	1,352,800	0.0040
0218	NiCo Products Inc #3	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	89,522,136	77,300,568	0.2453
0941	Nilfisk - Advance Inc	42183	Industrial Machinery and Equipment Wholesalers	Metal Products	247	CITY	15,260,700	12,632,772	0.0418
0571	Nor-Ell Inc, Powder Coating Div	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	5,341,170	5,122,027	0.0146
0765	Northern Screw Machine Co	332721	Precision Turned Product Manufacturing	Metal Products	247	CITY	300,726	300,726	0.0008
0328	Northland Aluminum Products Inc	332214	Kitchen Utensil, Pot, and Pan Manufacturing	Metal Products	247	CITY,OTHER	18,112,446	16,375,854	0.0496
0759	Northwest Swiss-Matic Inc	332721	Precision Turned Product Manufacturing	Metal Products	247	CITY	1,784,728	1,752,488	0.0049
1329	Nystrom Inc			Metal Products	247	CITY	4,980,000	3,510,000	0.0136
1173	Oildyne Inc (1173)	333995	Fluid Power Cylinder and Actuator Manufacturing	Metal Products	247	CITY	3,163,560	3,088,560	0.0087
0318	Onan - Main Plant	335312	Motor and Generator Manufacturing	Metal Products	247	CITY	69,249,400	40,954,820	0.1897
0319	Onan - Technical Center	335312	Motor and Generator Manufacturing	Metal Products	247	CITY,OTHER	3,278,380	2,842,680	0.0090
1059	Performance Industrial Coatings Inc			Metal Products	247	CITY	3,437,000	3,437,000	0.0094
1032	Phillips & Temro Industries Inc	336322	Other Motor Vehicle Electrical and Electronic Equipment Manufacturing	Metal Products	247	CITY	1,106,000	399,000	0.0030
1174	Phillips & Temro Industries Inc	33271	Machine Shops	Metal Products	247	CITY,OTHER	1,699,227	520,764	0.0047
0128	Plating Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	24,643,131	24,643,131	0.0675
1252	Powder Specialties	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	39,420	38,143	0.0001
1209	Power Coat			Metal Products	247	CITY	846,792	762,114	0.0023
1213	Precise Products Corp			Metal Products	247	CITY	1,118,264	622,214	0.0031
1319	Precision Associates Inc			Metal Products	247	CITY	4,874,000	3,933,000	0.0134
1190	Production Engineering Corp	33271	Machine Shops	Metal Products	247	CITY	786,305	499,073	0.0022
0642	Professional Plating Inc (0642)	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	10,995,390	10,138,908	0.0301
0800	Progress Casting Group (0800)	331521	Aluminum Die-Casting Foundries	Metal Products	247	CITY	19,537,980	12,210,891	0.0535
0274	Prospect Foundry Inc	331511	Iron Foundries	Metal Products	247	CITY	25,097,368	17,594,956	0.0688
0703	Quality Metals Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	3,846,692	3,846,692	0.0105
0188	Quality Painting & Metal Finishing	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	2,160,000	2,097,420	0.0059
1326	RAO Mfg			Metal Products	247	CITY	1,774,000	1,064,000	0.0049
1205	Remmele Engineering Inc	333514	Special Die and Tool, Die Set, Jig, and Fixture Manufacturing	Metal Products	247	CITY	2,879,600	1,117,114	0.0079
0028	Rexam Beverage Can	332431	Metal Can Manufacturing	Metal Products	247	CITY	82,393,836	82,395,036	0.2257
0707	Richald Metal Finishing Inc	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	254,440	254,440	0.0007
0918	Sifco Custom Machining Co	336412	Aircraft Engine and Engine Parts Manufacturing	Metal Products	247	CITY,OTHER	6,361,960	5,918,154	0.0174
0407	Silgan Containers Mfg Corp	332431	Metal Can Manufacturing	Metal Products	247	CITY	3,251,068	2,620,666	0.0089
1177	Skyline Exhibits	33995	Sign Manufacturing	Metal Products	247	CITY,OTHER	1,785,500	1,357,250	0.0049
1117	Spec Plating Corp	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	60,430,920	46,718,312	0.1656
1230	Springs Inc	332722	Bolt, Nut, Screw, Rivet, and Washer Manufacturing	Metal Products	247	CITY	420,000	420,000	0.0012
0331	St Paul Metalcraft Inc (0331)	331528	Other Nonferrous Foundries (except Die-Casting)	Metal Products	247	CITY,OTHER	5,763,400	2,481,080	0.0158

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0044	States Electric Mfg Co	335313	Switchgear and Switchboard Apparatus Manufacturing	Metal Products	247	CITY	305,000	305,000	0.0008
0068	Stylmark	337215	Showcase, Partition, Shelving, and Locker Manufacturing	Metal Products	247	CITY,WELL	27,734,550	23,808,550	0.0760
1321	Super Radiator Coils #1321			Metal Products	247	CITY	4,686,000	4,217,400	0.0128
0135	Superior Plating Inc (0135)	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY,WELL	152,009,910	152,009,910	0.4165
0788	TCR Engineered Components LLC	332722	Bolt, Nut, Screw, Rivet, and Washer Manufacturing	Metal Products	247	CITY,OTHER	9,435,152	9,435,152	0.0258
0879	Technical Plating Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	18,668,000	16,759,900	0.0511
1142	Tempco Mfg Co Inc			Metal Products	247	CITY	1,755,032	1,238,700	0.0048
0283	Tennant Co	333319	Other Commercial and Service Industry Machinery Manufacturing	Metal Products	247	CITY,WELL	1,926,200	1,374,320	0.0053
0185	Tennant Co	333319	Other Commercial and Service Industry Machinery Manufacturing	Metal Products	247	CITY	18,658,400	18,317,244	0.0511
0156	Thermo King Corp	333415	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration	Metal Products	247	CITY	17,861,400	10,095,420	0.0489
0255	Thomas Engineering Co	332116	Metal Stamping	Metal Products	247	CITY	1,100,000	1,097,452	0.0030
0466	Timmerman Finishing	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	740,000	479,648	0.0020
0430	Toro Co	333112	Lawn and Garden Tractor and Home Lawn and Garden Equipment Manufacturing	Metal Products	247	CITY	9,806,700	7,038,000	0.0269
1274	Twin City Metalseal	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	149,230	149,230	0.0004
0190	Twin City Plating Co	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	1,867,500	739,704	0.0051
0220	Universal Plating Co Inc	332813	Electroplating, Plating, Polishing, Anodizing, and Coloring	Metal Products	247	CITY	17,226,924	16,986,924	0.0472
1045	UPI Mech Plating & Galvanizing	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	86,778	86,778	0.0002
0191	Valmont / Applied Coating Technology #0191	332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacture	Metal Products	247	CITY	16,619,690	14,366,242	0.0455
1022	Valmont/Lexington	332323	Ornamental and Architectural Metal Work Manufacturing	Metal Products	247	CITY	1,438,000	420,300	0.0039
1068	Versa Die Cast Inc	331521	Aluminum Die-Casting Foundries	Metal Products	247	CITY	2,537,462	980,016	0.0070
0753	Versa Iron & Machine	331511	Iron Foundries	Metal Products	247	CITY,WELL	47,140,671	2,451,312	0.1292
1067	Viking Drill & Tool Inc	333515	Cutting Tool and Machine Tool Accessory Manufacturing	Metal Products	247	CITY	4,928,288	2,036,698	0.0135
1189	Waltek	331512	Steel Investment Foundries	Metal Products	247	CITY	467,166	467,166	0.0013
0421	Waterous Co	333911	Pump and Pumping Equipment Manufacturing	Metal Products	247	CITY	4,900,000	3,400,000	0.0134
1100	Weather Rite Inc	333412	Industrial and Commercial Fan and Blower Manufacturing	Metal Products	247	CITY	1,720,052	1,720,052	0.0047
0891	Wipaire Inc	48819	Other Support Activities for Air Transportation	Metal Products	247	CITY	530,880	506,280	0.0015
0219	World Aerospace Corp	332999	All Other Miscellaneous Fabricated Metal Product Manufacturing	Metal Products	247	CITY	6,510,000	5,211,000	0.0178
1126	Wrico Stamping Co of MN			Metal Products	247	CITY	2,904,000	2,129,776	0.0080
0369	Ziegler Inc	42181	Construction and Mining (except Oil Well) Machinery and Equipment Wholesalers	Metal Products	247	CITY	4,601,900	4,078,200	0.0126
0104	Culligan Soft Water Service Co	56199	All Other Support Services	Other	213	CITY	27,320,000	27,320,000	0.0748
1186	Culligan Water Conditioning #1186	333319	Other Commercial and Service Industry Machinery Manufacturing	Other	213	CITY	6,793,440	6,793,440	0.0186
0487	Ecowater Corp	333319	Other Commercial and Service Industry Machinery Manufacturing	Other	213	CITY	25,002,400	20,649,600	0.0685
0855	Smith Engineering Inc	333319	Other Commercial and Service Industry Machinery Manufacturing	Other	213	CITY	4,100,680	4,100,680	0.0112
1215	Sterling Water Inc dba Culligan	56199	All Other Support Services	Other	213	CITY	1,046,000	968,000	0.0029
1351	Wigen Water Technologies			Other	213	CITY	196,648	196,648	0.0005
0105	Americraft Carton Inc	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	1,800,000	1,800,000	0.0049
1248	B.F. Nelson Corporation	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	2,192,000	1,924,961	0.0060
1229	Central Container Corp	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	2,060,000	2,060,000	0.0056
1212	Creative Carton Corp	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	4,160,000	3,242,000	0.0114
1024	Green Bay Packaging Inc-Twintown	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	16,423,910	8,331,624	0.0450
0392	Greif Bros Corp	322224	Uncoated Paper and Multiwall Bag Manufacturing	Paper/Packaging	249	CITY	13,821,003	13,275,003	0.0379

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0266	Heinrich Envelope Corp	322232	Envelope Manufacturing	Paper/Packaging	249	CITY	12,490,400	12,490,400	0.0342
0271	International Paper Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	18,718,200	9,020,685	0.0513
1019	Liberty Carton Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	10,884,200	8,686,646	0.0298
0974	Longview Fibre Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	55,315,000	30,913,945	0.1515
0113	Menasha Corp	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	4,180,000	1,869,000	0.0115
0925	Menasha Packaging Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	1,190,000	1,138,000	0.0033
0950	Northwest Packaging Inc	323110	Setup Paperboard Box Manufacturing	Paper/Packaging	249	CITY	2,963,160	2,038,272	0.0081
0073	Packaging Corp of America	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	2,129,830	1,311,964	0.0058
0022	Packaging Corp of America	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	3,763,994	1,873,312	0.0103
0409	Smurfit-Stone Container Enterprises Inc	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	9,107,904	4,510,377	0.0250
0388	Stone Container Corp #0388	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	17,809,698	13,811,832	0.0488
0260	Temple-Inland	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	WELL	33,627,400	4,036,578	0.0921
0591	Waldorf Corporation (dba Rock-Tenn Co)	32213	Paperboard Mills	Paper/Packaging	249	CITY,WELL,OTHER	*580,350,000*	*1,202,584,765*	*1.5900* *
0889	Weyerhaeuser Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	13,531,320	8,366,490	0.0371
0038	Weyerhaeuser Co	322211	Corrugated and Solid Fiber Box Manufacturing	Paper/Packaging	249	CITY	15,920,190	10,963,800	0.0436
0556	Colorhouse / Mail-Well	323122	Prepress Services	Photofinishing	249	CITY	3,972,000	2,831,520	0.0109
1184	DIGIgraphics/Photos Inc	812921	Photofinishing Laboratories (except One-Hour)	Photofinishing	249	CITY	1,795,651	1,223,872	0.0049
1355	FilmTec Corp (1355)			Photofinishing	249	CITY,WELL	10,103,582	10,103,582	0.0277
1144	Fuji Color Processing			Photofinishing	249	CITY,OTHER	7,945,232	7,945,232	0.0218
1305	Lennon, Bausman & Fitzgerald Inc	541922	Commercial Photography	Photofinishing	249	CITY	336,000	336,000	0.0009
0055	Lifetouch Inc (NSS Division)	541921	Photography Studios, Portrait	Photofinishing	249	CITY	13,864,600	9,714,450	0.0380
0539	Acme Tag and Label Co	323112	Commercial Flexographic Printing	Printed Products	249	CITY	200,478	200,478	0.0005
1143	Ad Graphics			Printed Products	249	CITY	7,952,000	5,233,068	0.0218
0773	American Spirit Graphics	323110	Commercial Lithographic Printing	Printed Products	249	CITY	3,307,400	3,307,400	0.0091
0943	Banta Book Group - Eden Prairie	323110	Commercial Lithographic Printing	Printed Products	249	CITY	2,817,040	1,886,416	0.0077
0944	Banta Catalog Group - Mpls	323110	Commercial Lithographic Printing	Printed Products	249	CITY	77,160,000	42,767,800	0.2114
1082	Bureau of Engraving-Printing Div	323110	Commercial Lithographic Printing	Printed Products	249	CITY	4,019,446	1,724,544	0.0110
0845	Clariant Corp - Master Batches Div			Printed Products	249	CITY	4,794,652	3,542,256	0.0131
0868	Container Graphics	323122	Prepress Services	Printed Products	249	CITY	2,141,734	774,630	0.0059
0895	Custom Business Forms	323116	Manifold Business Forms Printing	Printed Products	249	CITY	426,644	421,644	0.0012
1191	Gannett Offset - Minneapolis	323110	Commercial Lithographic Printing	Printed Products	249	CITY	8,700,000	7,328,000	0.0238
0797	GML Inc			Printed Products	249	CITY	1,024,468	503,100	0.0028
1350	Immedia Inc			Printed Products	249	CITY	797,431	796,917	0.0022
0955	Impressions Inc	323110	Commercial Lithographic Printing	Printed Products	249	CITY	2,169,200	1,626,070	0.0059
1255	Inno-Flex Corp	323112	Commercial Flexographic Printing	Printed Products	249	CITY	2,228,000	2,228,000	0.0061
0854	IWCO Direct	323110	Commercial Lithographic Printing	Printed Products	249	CITY	18,375,000	11,599,158	0.0503
1133	Japs-Olson Co	323110	Commercial Lithographic Printing	Printed Products	249	CITY	13,290,000	13,290,000	0.0364
1264	Liberty Carton Co	32213	Paperboard Mills	Printed Products	249	CITY	3,735,000	3,735,000	0.0102
0562	Litho Technical Service	323110	Commercial Lithographic Printing	Printed Products	249	CITY	486,000	420,000	0.0013
0063	MacKay Envelope Co			Printed Products	249	CITY	4,218,750	2,933,750	0.0116
1216	Maximum Graphics Inc	323121	Tradebinding and Related Work	Printed Products	249	CITY	5,932,815	5,098,896	0.0163

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0993	Meyers Printing Co	323110	Commercial Lithographic Printing	Printed Products	249	CITY	26,952,600	18,423,900	0.0738
1276	Modernistic Inc			Printed Products	249	CITY	1,376,320	1,376,320	0.0038
0934	Northstar Financial Forms	323116	Manifold Business Forms Printing	Printed Products	249	CITY	4,156,640	3,794,960	0.0114
0968	Phoenix Packaging	322215	Nonfolding Sanitary Food Container Manufacturing	Printed Products	249	CITY	4,732,000	3,616,000	0.0130
1284	Process Displays Company	323110	Commercial Lithographic Printing	Printed Products	249	CITY	3,983,800	1,669,800	0.0109
1076	Random Specialties	323110	Commercial Lithographic Printing	Printed Products	249	CITY,WELL	2,542,200	1,290,300	0.0070
0917	Rayven Inc	326113	Unsupported Plastics Film and Sheet (except Packaging) Manufacturing	Printed Products	249	CITY	794,376	531,876	0.0022
0819	Schawk Minneapolis	323115	Digital Printing	Printed Products	249	CITY	1,098,255	1,076,255	0.0030
1318	Sefar Printing Solutions Inc.	334419	Other Electronic Component Manufacturing	Printed Products	249	OTHER	201,498	199,978	0.0006
0858	Sexton Printing Inc	323116	Manifold Business Forms Printing	Printed Products	249	CITY	912,621	860,200	0.0025
0760	Shakopee Valley Printing	323110	Commercial Lithographic Printing	Printed Products	249	CITY	5,033,000	2,621,766	0.0138
0445	Smead Mfg Co	323116	Manifold Business Forms Printing	Printed Products	249	CITY	5,186,000	4,452,000	0.0142
0042	Smyth Companies Inc	323110	Commercial Lithographic Printing	Printed Products	249	CITY	8,740,380	8,135,895	0.0239
0644	St Paul Pioneer Press Dispatch	51111	Newspaper Publishers	Printed Products	249	CITY	9,344,016	2,775,954	0.0256
0493	St Paul Pioneer Press Dispatch	51111	Newspaper Publishers	Printed Products	249	CITY,WELL	200,750,000	3,956,920	0.5500 *
0803	Star Tribune	51111	Newspaper Publishers	Printed Products	249	CITY	6,515,250	4,348,500	0.0179
0091	Thomson West - Eagan Production Facility	51113	Book Publishers	Printed Products	249	CITY,OTHER	33,893,200	22,527,464	0.0929
1226	Travel Tags	323112	Commercial Flexographic Printing	Printed Products	249	CITY	10,632,000	5,821,440	0.0291
0597	Minnesota Correctional Facility	92214	Correctional Institutions	Public Facilities	211	CITY,WELL	357,361,500	357,061,500	0.9791
1315	US Air Force Reserve - 934th Airlift Wing			Public Facilities	211	CITY	21,573,072	21,573,072	0.0591
0348	3M Co - 3M Center	54171	Research and Development in the Physical, Engineering, and Life Sciences	Research & Developement	213	CITY	319,081,945	223,527,155	0.8742 *
0379	Cargill Research Center (0379)	54171	Research and Development in the Physical, Engineering, and Life Sciences	Research & Developement	213	CITY,WELL	4,095,000	3,395,000	0.0112
1187	Dyneon, Subsidiary of 3M Co	54171	Research and Development in the Physical, Engineering, and Life Sciences	Research & Developement	213	CITY	3,314,000	3,314,000	0.0091
1354	Ecolab Schuman Campus			Research & Developement	213	CITY	39,335,007	39,335,007	0.1078
1162	Imation Corp	54171	Research and Development in the Physical, Engineering, and Life Sciences	Research & Developement	213	CITY	13,786,561	6,169,181	0.0378
0874	NatureWorks LLC	54171	Research and Development in the Physical, Engineering, and Life Sciences	Research & Developement	213	CITY	861,900	861,900	0.0024
0606	Computype Inc	561499	All Other Business Support Services	Service	213	CITY	3,246,000	3,246,000	0.0089
1349	E-Z Recycling, Inc.			Service	213	CITY,OTHER	522,404	522,404	0.0014
1237	Lason Inc	51421	Data Processing Services	Service	213	CITY	559,800	559,800	0.0015
1339	M J Ingber Co Inc/RBR Co			Service	213	CITY,OTHER	613,432	613,432	0.0017
1343	Mosaic Crop Nutrition LLC			Service	213	WELL	145,863	145,863	0.0004
0355	Minnesota Knitting Mills	315191	Outerwear Knitting Mills	Textiles	248	CITY	6,722,276	5,200,471	0.0184
1232	Buesing Bulk Transport Inc	811192	Car Washes	Transportation	247	CITY	2,785,200	2,785,200	0.0076
0434	Canadian Pacific Railway	482111	Line-Haul Railroads	Transportation	247	CITY,OTHER	12,826,984	12,826,984	0.0351
0776	Cleanco Truck Wash	811192	Car Washes	Transportation	247	CITY	2,692,000	2,422,800	0.0074
1121	Interstate Detroit Diesel	48849	Other Support Activities for Road Transportation	Transportation	247	CITY	2,390,100	1,581,183	0.0065
1304	Jefferson Partners L P	48849	Other Support Activities for Road Transportation	Transportation	247	CITY	1,697,667	1,625,667	0.0047
1262	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	2,339,617	1,872,865	0.0064
0614	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	4,209,744	3,879,128	0.0115
0613	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	4,753,353	4,364,393	0.0130
0611	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	5,764,799	5,756,219	0.0158

Metropolitan Council Industrial Dischargers Water Demand, 2005
Sorted by Business Category and Organization Name

Permit No.	Organization	NAICS Code[1]	NAICS Description	MCES Business Category[2]	DNR Use Code[3]	Incoming Water Type	Incoming (Gal)	Sewered (Gal)	Incoming (mgd)
0615	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	6,902,120	6,124,200	0.0189
0616	Metro Transit	485113	Bus and Other Motor Vehicle Transit Systems	Transportation	247	CITY	9,273,928	8,654,023	0.0254
1000	Metropolitan Airports Commission	48819	Other Support Activities for Air Transportation	Transportation	247			13,487,344	0.0000
0200	Northwest Airlines Inc (MB) 200	48819	Other Support Activities for Air Transportation	Transportation	247	WELL	216,470,888	286,339,144	0.5931
0050	Northwest Airlines Inc (OB)	334412	Bare Printed Circuit Board Manufacturing	Transportation	247	CITY	109,024,592	89,277,556	0.2987
1062	Penske Truck Leasing Co	53212	Truck, Utility Trailer, and RV (Recreational Vehicle) Rental and Leasing	Transportation	247	CITY	804,000	804,000	0.0022
0975	Servisair & Shell Fuel Services	48819	Other Support Activities for Air Transportation	Transportation	247	CITY,OTHER	2,460,688	2,460,688	0.0067
1316	South St Paul Truck Wash	562998	All Other Miscellaneous Waste Management Services	Transportation	247	CITY	7,050,000	7,050,000	0.0193
0003	The BNSF Railway Co	482111	Line-Haul Railroads	Transportation	247	CITY,OTHER	24,321,000	9,684,900	0.0666
0979	Upper River Services Inc	483211	Inland Water Freight Transportation	Transportation	247	WELL,OTHER	1,261,300	1,199,650	0.0035
0015	Upper River Services Inc	483211	Inland Water Freight Transportation	Transportation	247	OTHER	4,483,509	4,178,130	0.0123
1320	Wayne Transports Inc			Transportation	247	CITY,WELL	10,751,662	10,751,662	0.0295
0887	City of Apple Valley (0887)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	4,679,914,000	4,786,600	12.8217
1222	City of Champlin (1222)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	4,738,640,000	11,650,800	12.9826
0985	City of Eagan (0985)	22131	Water Supply and Irrigation Systems	Utilities	211	CITY	18,951,018,000	63,936,000	51.9206
0984	City of Edina (0984)	22131	Water Supply and Irrigation Systems	Utilities	211	CITY	3,342,954,000	11,691,600	9.1588
0852	City of Fridley (0852)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	1,204,423,000	12,664,975	3.2998
0959	City of New Brighton (0959)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	10,491,344,000	53,768,000	28.7434
1006	City of Orono (1006)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	280,296,000	2,241,600	0.7679
0709	City of St Louis Park (0709)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	2,229,384,000	2,403,000	6.1079
1016	City of St Louis Park (1016)	22131	Water Supply and Irrigation Systems	Utilities	211	WELL	114,877,340	348,000	0.3147
1172	Foster Wheeler Twin Cities Inc	61131	Colleges, Universities, and Professional Schools	Utilities	211	CITY	50,976,000	26,502,000	0.1397
0922	Minneapolis Water Works	22131	Water Supply and Irrigation Systems	Utilities	211	OTHER	22,618,000,000	1,639,500	61.9671
0018	Robbinsdale	22131	Water Supply and Irrigation Systems	Utilities	211	CITY	4,510,000	4,510,000	0.0124
0576	NSP, dba Xcel Energy (0576)	221112	Fossil Fuel Electric Power Generation	Utilities-Power	229	CITY,WELL	322,278,339	73,429,761	0.8830
0824	NSP, dba Xcel Energy (0824)	221112	Fossil Fuel Electric Power Generation	Utilities-Power	229	CITY	1,098,149	456,420	0.0030
1324	St Paul Cogeneration LLC			Utilities-Power	229	CITY,WELL	265,064,032	92,240,086	0.7262
0770	Covanta Hennepin Energy Resource Co LP	562213	Solid Waste Combustors and Incinerators	Utilities-Steam&AirCond	230	CITY	1,220,870,232	16,816,812	3.3448
0474	District Energy St Paul Inc	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	99,472,496	13,422,776	0.2725
1057	Foster Wheeler Twin Cities Inc	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	19,138,000	13,126,000	0.0524
1236	Hennepin County Energy Center	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	44,004,029	10,327,341	0.1206
1241	NRG Energy Center Minneapolis LLC	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	8,387,806	1,591,125	0.0230
0900	NRG Energy Center Minneapolis LLC	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	16,460,068	2,136,750	0.0451
1240	NRG Energy Center Minneapolis LLC	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY	20,381,591	4,708,391	0.0558
0603	NRG Energy Center Minneapolis LLC	22133	Steam and Air-Conditioning Supply	Utilities-Steam&AirCond	230	CITY,WELL	150,910,825	39,227,540	0.4135

[1] North American Industry Classification System (NAICS) code system category for each industrial discharger

[2] Business or industry categories established by Metropolit Council Environmental Services

[3] Water use code established by Minnesota DNR and assigned to MCES Industrial Discharge permittees to view both databases under one classification system

*Incoming water (gallons) reported to MCES with permit information was different than reported in the Industry Water Use Survey conducted for the Recycling Treated Municipal Wastewater for Industrial Water Use project.
This table lists the value reported in the survey, which in some cases is not consistent with the value recorded for "Sewered". Further use of the information should be verified with the industry and MCES.

Metropolitan Council
Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR05-07d

MCES Project Number 070186

TECHNICAL MEMORANDUM 2

Sampling Plan and Results

June 30, 2007

Craddock Consulting Engineers
In Association with
CDM and James Crook

Technical Memorandum 2
Sampling Plan and Results

1.0 Introduction

This technical memorandum is the second in a series of memoranda developed under a Metropolitan Council (Council) project titled "Recycling Treated Municipal Wastewater for Industrial Water Use." Funding for this project was recommended by the Legislative Commission on Minnesota Resources (LCMR) from the Minnesota Environment and Natural Resources Trust Fund. The Council is providing additional funding for the project through in-kind contributions of staff time. Other state agencies are participating via stakeholder meetings and technical review and input.

The project proposal to LCMR included the provision for the sampling of Council WWTPs if early project tasks determined that additional information was needed. Following completion of Task 1 of the project in June 2006, it was decided that the project would benefit from a better characterization of water quality constituents of concern applicable to a range of industries. This memorandum documents the sampling plan and the results.

1.1 Objectives

The goal of the sampling program was to define the concentrations of constituents of concern for industrial water use practices that are the more dominant uses of water in the state of Minnesota and for which use of reclaimed water is more likely. The sampling program targeted constituents that are not typically monitored in WWTP effluent.

1.2 Constituents of Concern

The historic water quality record of WWTP effluent is extensive for constituents of concern to the receiving waters. These constituents include carbonaceous or total biochemical oxygen demand (CBOD, TBOD, or BOD), total suspended solids (TSS), ammonia (NH3), total phosphorus (TP), and fecal coliform. These parameters are also important in characterizing the effluent quality and applicability for industrial use. However, there are many other constituents of concern for industrial applications and the majority of these are not commonly characterized in municipal WWTP effluent. Additional sampling is needed to accurately define the concentrations of these constituents in the WWTP effluent.

The industrial demand analysis of Technical Memorandum 1 of this project, titled "Implementation Issues and Customer Inventory", identified the major uses of water by industries in Minnesota and in more detail for the Minneapolis/St. Paul metropolitan area (metro area). One significant use of water in Minnesota is for cooling at power generation facilities and for other industrial processes. Use of reclaimed water for cooling water is common in states with established wastewater reuse practices. The use of the Mankato WWTP treated effluent for cooling water use at the new Mankato Energy Center facility demonstrates that this practice has strong potential in Minnesota.

In addition to constituents of concern for cooling water, other constituents will be analyzed for boiler feed water use, and other industrial categories, such as pulp & paper (indicative of requirements for paper and print production, a significant water use in the metro area), general chemical processing, and materials production (cement). Table 1 lists cooling water and industrial process water quality requirements for several industries.

1.3 Study Boundaries

The work program contained in the Agreement between the LCMR and Met Council limited the sampling program to Council facilities. With eight facilities of varying sizes, ground and surface community water supplies, a range of industrial dischargers, and different treatment processes, the sampling results will provide a range of values that can generally be applied across the state.

The effluent quality of a municipal WWTP is affected by many factors, including: the source water used by the community; industrial, commercial and domestic discharges to the WWTP; and the wastewater treatment processes (and recycles) of the WWTP. The range of concentrations for the constituents listed in Table 1 is expected to vary significantly over the state or even for WWTPs of communities using the same water supply. It is critical that a specific WWTP effluent be analyzed for the constituents of concern for each industry considering use of that reclaimed water supply.

While the sampling results of one facility can not be assumed directly for another facility, a potential range of concentrations can be assumed. A better understanding of variability in WWTP effluent quality for different plants will assist in determining the applicability of reclaimed water for a specific industry at a specific plant. The results can also help to identify where more sampling is required and can streamline additional sampling efforts.

2.0 Sampling Plan

2.1 Constituents of Concern

The constituents selected for the sampling program include those identified as a concern for general water uses or industry categories, as listed in Table 1, plus constituents that are anticipated to be regulated through a permit. The state of Minnesota uses the California Water Recycling Criteria for its regulatory review of water reuse practices, which includes limits for pathogens, organics, and solids. Total coliforms are the only regulated constituent for industrial water uses in the California Water Recycling Criteria. Table 2 lists all the constituents included for this sampling program.

Table 1. Generalized Water Quality Criteria for Select Industrial Uses

	Cooling Water	Boiler Feed Water			Pulp & Paper			Chemical	Petrochem & Coal	Textiles		Cement
Constituent (in mg/L)	(Makeup for Recirculating Systems)*	Low Pressure (<150 psig)	Medium Pressure (150-700 psig)	High Pressure (>700 psig)	Mechanical Piping	Chemical, Unbleached	Pulp & Paper, Bleached			Sizing Suspension	Scouring, Bleach & Dye	
Alkalinity (as CaCO3)	20-350	350	100	40	--	--	--	125	--	--	--	400
Aluminum (Al)	0.1	5	0.1	0.01	--	--	--	--	--	--	--	--
Calcium (Ca)	50	--	0.4	0.01	--	20	20	70	75	--	--	--
Chemical Oxygen Demand (COD)	45	5	5	1	--	--	--	--	--	--	--	--
Chloride (Cl)	100-500	--	--	--	1,000	200	200	500	300	--	--	250
Color (units)	--				30	30	10	20	25	5	5	--
Copper (Cu)	--	0.5	0.05	0.05	--	--	--	--	0.05	0.01	--	--
Dissolved Oxygen (DO)	--	2.5	0.007	0.007	--	--	--	--	--	--	--	--
Iron (Fe)	0.5	1	0.3	0.05	0.3	1	0.1	0.1	1	0.3	0.1	2.5
Hardness (as $CaCO_3$)	130-650	350	1	0.07	--	100	100	250	350	25	25	--
Bicarbonate (HCO_3)	25-200	170	120	48	--	--	--	130	450	--	--	--
Magnesium (Mg)	--	--	0.25	0.01	--	12	12	20	30	--	--	--
Manganese (Mn)	0.5	0.3	0.1	0.01	0.1	0.5	0.05	0.1	--	0.05	0.01	0.5
Ammonia (NH3)	24	0.1	0.1	0.1	--	--	--	--	40	--	--	--
Nitrate (NO_3)	--	--	--	--	--	--	--	5	10	--	--	--
Phosphorus (total: TP)	1	--	--	--	--	--	--	--	--	--	--	--
pH (units)	--	--	--	--	6 – 10	6 – 10	6 – 10	5.5-9.0	6 – 9	--	--	6.5 – 8.5
Silicondioxide (SiO_2)	50	30	10	0.7	--	50	50	50	60	--	--	35
Sulfate (SO_4)	200	--	--	--	--	--	--	100	600	--	--	250
Total Dissolved Solids (TDS)	500	700	500	200	--	--	--	1,000	1,000	100	100	600
Total Suspended Solids (TSS)	100	10	5	0.5	--	10	10	5	10	5	5	500
Zinc (Zn)	--	--	0.01	0.01	--	--	--	--	--	--	--	--

*Maximum of value range refers to concentration in final cooling stream discharge.

Source: Adapted from Water Pollution Control Federation, 1989; Goldstein et al, 1970; Metcalf & Eddy, 2007.

As shown in Table 2, there are several constituents that are routinely analyzed by Council, typically as part of their NPDES Permit requirements. The sampling program funded under this project included only those constituents not routinely sampled at each WWTP, listed in Table 3.

Table 2. Constituents to Characterize in Sampling Program

Constituent	Unit	Routinely Sampled (x=yes)
Alkalinity (as CaCO3)	mg/L	
Aluminum (Al)	mg/L	
Calcium (Ca)	mg/L	
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	X
Chemical Oxygen Demand (COD)	mg/L	X
Chloride (Cl)	mg/L	
Color	units	
Dissolved Oxygen (DO)	mg/L	X
E. Coli	-	
Fecal Coliform	No./100 ml	X
Iron (Fe)	mg/L	
Hardness (as $CaCO_3$)	mg/L	
Bicarbonate (HCO_3)	mg/L	
Magnesium (Mg)	mg/L	
Manganese (Mn)	mg/L	
Ammonia (NH3)	mg/L	X
Nitrate (NO_3)	mg/L	X
Orthophosphate (PO_4)	mg/L	X
Phosphorus (total: TP)	mg/L	X
pH	units	X
Silicon Dioxide (SiO_2)	mg/L	
Sulfate (SO_4)	mg/L	
Total Coliform	No./100 ml	
Total Dissolved Solids (TDS)	mg/L	
Total Organic Carbon (TOC)	mg/L	
Total Suspended Solids (TSS)	mg/L	X
Turbidity	NTU	

Table 3. Sampling Program Constituents

Alkalinity (as CaCO3)
Aluminum (Al)
Bicarbonate (HCO3)
Calcium (Ca)
Chloride (Cl)
Color
E. Coli
Iron (Fe)
Hardness (as CaCO3)
Magnesium (Mg)
Manganese (Mn)
Silicondioxide (SiO2)
Sulfate (SO4)
Total Coliform
Total Dissolved Solids (TDS)
Total Organic Carbon (TOC)
Turbidity

2.2 Sample Type, Collection, and Location

The Council handled all sampling and laboratory analyses. Samples were collected at the same location used to characterize the final effluent for permit monitoring. The routinely collected daily sample at the Metro Plant was used for this project's sampling program. An additional sampler was required at the other three plants because there is an insufficient sample volume routinely collected at those facilities for the additional analyses required by this sampling program. The samplers collected flow-weighted 24-hour composite samples, except at the Empire WWTP, which provided a time-weighted composite sample. The Council's Industrial Waste department staff setup and managed the sampler operation. Operators at each plant collected this program's samples at the same time as they collected the routine effluent samples.

The first sampling period included 8-15 samples collected over a three week period in late October to early November. Samples were collected on weekdays and weekends whenever routine samples were collected. After review of the Fall 2006 results it was determined that additional sampling would strengthen confidence in understanding constituent variability. A spring sampling schedule was performed: during the first three weeks of April, 8-12 samples were analyzed for the constituents listed in Table 3. All available data for the routine monitoring program were obtained for the similar time periods. The sample count varied with each plant based on the NPDES permit requirements.

Samples were collected at four Council WWTPs:

- Blue Lake
- Empire
- Metropolitan
- Seneca

3.0 Sampling Results

The sampling program developed for this project provided an initial base of information that was used for various tasks in the project, including:

- general characterizations of effluent water quality for Minnesota WWTPs

- plant-specific information to compare the effluent quality of the Council's four largest WWTPs

This technical memorandum serves to document the data and provide summary information on the effluent quality of the four Council WWTPs evaluated.

3.1 General Summary

The constituents analyzed in this project's sampling program, indicate that hardness and salt concentrations occur at concentration thresholds of concern for a range of industrial water uses. Similar to the results of Technical Memorandum 5, *Wastewater Treatment Plant Effluent Quality*, which reviewed general water quality parameters for all of Minnesota's WWTPs, the NPDES permitted constituents for the four WWTPs were well below required limits and had low variability in the samples measured.

Table 4 provides the mean and standard deviation of the samples collected for the Fall 2006 and Spring 2007 sampling periods. The recommended limits for each constituent as it relates to cooling water uses, is provided in the third column. Exhibit A provides additional statistics for this table, such as minimum and maximum values, and the number of samples the statistics are based upon. It also contains recommended limits for various industrial water uses in a format similar to Table 4. Exhibits B-D provide data for each WWTP.

The Fall 2006 sampling data were evaluated with time series plots to look for any outliers and see if any trends existed. Given that this is a small data set (8-28 samples), this effort was used more to screen and identify any gross trends. Additional data will need to be reviewed over a longer period of time to define any trends.

Table 4. Wastewater Recycling Sampling Program Summary Results[1]

			Blue Lake		Empire		Metro		Seneca	
Constituent	Unit	Limit[2]	Mean	St Dev[3]	Mean	St Dev	Mean	St Dev	Mean	St Dev
Alkalinity (as CaCO3)	mg/L	20-350	293	10	246	20	157	15	184	14
Aluminum (Al)	mg/L	0.1	0.022	0.008	0.023	0.006	0.030	0.004	0.024	0.002
Ammonia (NH3)	mg/L	24	0.182	0.068	0.2	0.3	0.216	0.34	0.117	0.110
Bicarbonate (HCO_3)	mg/L as $CaCO_3$	25-200	300	8	256	31	157	20	182	6
Calcium (Ca)	mg/L	50	93.2	3.8	82.2	4.5	72.2	4.4	62.9	5.3
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	<20	3.0	0.0	3.2	0.9	3.2	0.5	3.3	1.4
Chemical Oxygen Demand (COD)	mg/L	*	34.1	5.1	37.4	5.0	32.2	3.4	34.1	4.4
Chloride (Cl)	mg/L	50-500	387	34	387	28	239	11	285	27
Color	units	*	51	7	58	7	45	8	61	13
Copper (Cu)	mg/L	*	-	-	-	-	5.06	0.45	-	-
Dissolved Oxygen (DO)	mg/L	*	8.63	0.43	8.6	0.5	5.8	0.9	8.88	0.55
E. Coli	No./100ml	*	731	572	7	5	283	349	57	120
Fecal Coliform	No./100ml	*	75	66	15	17	68	80	33	55
Hardness (as $CaCO_3$)	mg/L as $CaCO_3$	130-650	351	17	293	16	258	15	243	14
Iron (Fe)	mg/L	0.5	0.076	0.015	0.105	0.023	0.068	0.018	0.133	0.043
Magnesium (Mg)	mg/L	*	35.9	1.8	27.6	1.3	24.0	0.6	25.4	1.2
Manganese (Mn)	mg/L	0.5	0.015	0.004	0.038	0.023	0.016	0.003	0.035	0.024
Nitrate (NO_3)	mg/L	*	10.97	0.83	15.8	2.5	16.4	1.8	15.9	1.4
Orthophosphate (PO_4)	mg/L	*	0.406	0.289	0.057	0.125	0.259	0.197	0.968	0.801
Phosphorus (total: TP)	mg/L	1	0.485	0.164	0.340	0.109	0.457	0.246	1.500	0.855
pH		*	7.3	0.2	7.0	0.1	7.0	0.1	7.1	0.1
Silicondioxide (SiO_2) or Silica	mg/L	50	22	2	19	1	17	0	18	2
Sulfate (SO_4)	mg/L	200	51.12	9.17	39.81	4.51	74.73	6.67	374.30	200.30
Total Coliform	No./100 ml	<23	3,496	1,150	499	721	3,798	2,655	2,491	2,175
Total Dissolved Solids (TDS)	mg/L	500	1,097	80	1,130	166	805	37	1,326	299
Total Organic Carbon (TOC)	mg/L	*	8.1	0.7	9.4	1.0	8.0	0.6	8.4	0.7
Total Suspended Solids (TSS)	mg/L	20-100	1.7	1.0	3	2	2.4	0.8	3.1	1.2
Turbidity	NTU	*	2	0	4	1	2	0	3	1

[1]Based on Fall 2006 and Spring 2007 sampling periods; see Exhibits for daily data and additional statistics

[2] Cooling Water (USEPA, 2004); variable range related to amount of recycling and materials of construction; high range is typically maximum in blowdown/final water

[3] St Dev = one standard deviation

3.2 Specific Constituents of Concern

Constituents exceeding the recommended limits for cooling water use or higher water quality uses were evaluated in more detail. The mean and standard deviation for the following constituents are summarized in Figures 1-8 at the end of the memorandum:

- Alkalinity
- Bicarbonate
- Calcium
- Chloride
- Hardness
- Silica
- Sulfate
- TDS

Lower hardness, alkalinity, calcium and bicarbonate concentrations would be expected for softer source water areas. A large percentage of the Metropolitan WWTP's service area is provided lime softened water by Minneapolis and St. Paul. The City of Bloomington has a lime softened water supply and contributes to a significant portion of the Seneca WWTP's influent. The Seneca WWTP also had lower average values for constituents characterizing hardness, as shown in Figures 1-4.

High WWTP effluent chloride concentrations often occur in areas with hard source water because of the increased loadings to the WWTP from the brine discharges of domestic water softeners or the concentrate streams from commercial or industrial softening systems. Figure 5 indicates this inference applies to the Council facilities evaluated. The Metro WWTP chloride concentration averaged 240 mg/L and never exceeded 265 mg/L. The Seneca WWTP had chloride concentrations averaging around 300 mg/L. The Empire and Blue Lake WWTP chloride concentrations averaged nearly 400 mg/L and had a wider range of variability.

All four WWTPs exceed chloride concentrations required for cooling water with systems recycling water more than 2 times. At concentrations greater than 500 mg/L there is concern with corrosion. This threshold will vary with materials of construction, and is referenced for 316 stainless steel condenser tubes (personal communication with D. Taylor, Great River Energy).

Chloride concentration in WWTP effluent has also been linked to the influence of infiltration and inflow (I&I) and chlorides imparted from road salt. The City of Oconomowoc, Wisconsin has monitored chlorides for ten years and found evidence of significant chloride contributions from chloride in soil below roadbeds that accumulated from road salting (personal communications with Tom Steinbach, City of Oconomowoc). The longer-term monitoring indicated that the highly variable loadings of chlorides can be inaccurately characterized with limited sampling (e.g. one sample each quarter).

Total dissolved solids (TDS) concentrations, which often follow chloride concentrations, did not have as extreme a difference between the WWTPs, as shown in Figure 6. The Metro WWTP was the lowest and had fairly low variability, averaging 800 mg/L of TDS. The Seneca WWTP had the highest average concentration with a high variability (no outliers were removed), averaging over 1,300 mg/L. The Blue Lake and Empire WWTPs averaged around 1,100 mg/L and the Metro WWTP was the lowest at 800 mg/L. All the facilities exceed recommended limits for a variety of industrial water uses. TDS concentrations over 1,000 mg/L are also not recommended for some irrigation practices, which includes landscape irrigation by an industry. If multiple-use options are considered and urban or agricultural irrigation is integrated with an industrial reuse system, a more detailed analysis of the dissolved solids would be required.

Silica concentrations averaged about 20 mg/L for all the facilities. These were acceptable levels for cooling water uses, but other uses, as for boiler feed water, would require silica removal to meet levels below 1 mg/L. Sulfate was not a concern at any of the plants except Seneca. The sulfate concentrations were highly variable, averaging 375 mg/L with a standard deviation of 200 mg/L. The implications of high sulfates would depend on the application for cooling water and could affect the treatment process selection. It is also a constituent that could be controlled at the WWTP or through source control if there is a known industrial contributor.

3.3 Results Summary and Next Steps

The sampling program initiated by this study provides a basis for the Council to consider a more routine sampling program for constituents that are poorly characterized in their WWTP effluent. It also provides information to other facilities that are considering wastewater recycling applications, particularly the parameters they should target.

The sampling results demonstrated how the Metropolitan WWTP's larger size dampens the variability. The standard deviations for most constituents were the lowest at the Metropolitan Plant. The concentrations of the constituents documented in Section 3.2 were also the lowest at the Metropolitan WWTP. This was likely a function of the source water (softened) and also the ability to dampen any industry or other specific discharges with more consistent quality sources.

It is recommended that additional data review and coordination with specific industries be conducted to establish a shorter list of parameters and identify those needing more samples to characterize variability. Incorporation of constituents of concern for potential treatment technologies should also be included in future sampling programs. For example, membrane modeling and pilot studies rely on specific ions as limiting factors to measure membrane performance. These dissolved ions may not be considered a concern for the industry, but are important in assessing treatment options.

The variability in the approximately 25 samples analyzed for each plant in this study indicates that additional sampling is warranted. At a minimum, chloride and TDS should be monitored, with a frequency of twice a week or more. These constituents have a higher variability at each plant than most constituents and are important parameters in assessing the application for a variety of water uses, as well as membrane system sizing. The WWTP effluent sampling program can add other parameters once more defined goals are in place on the potential uses of reclaimed water and the treatment technologies under consideration.

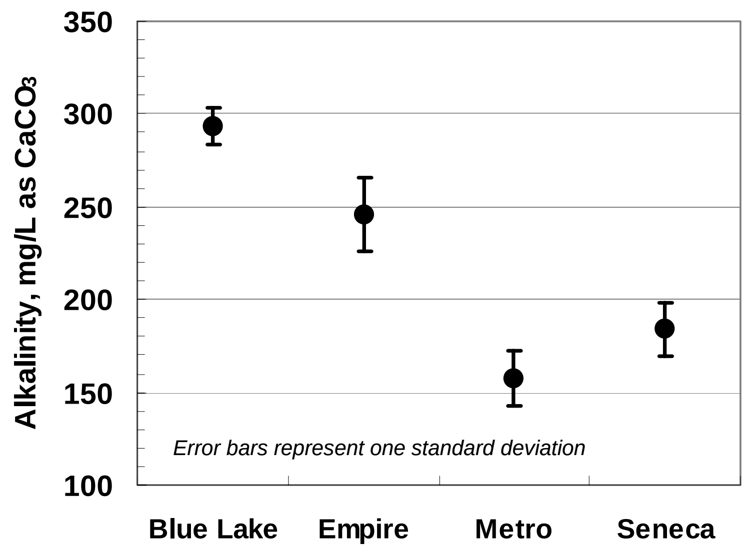

Figure 1. Average Alkalinity Concentration

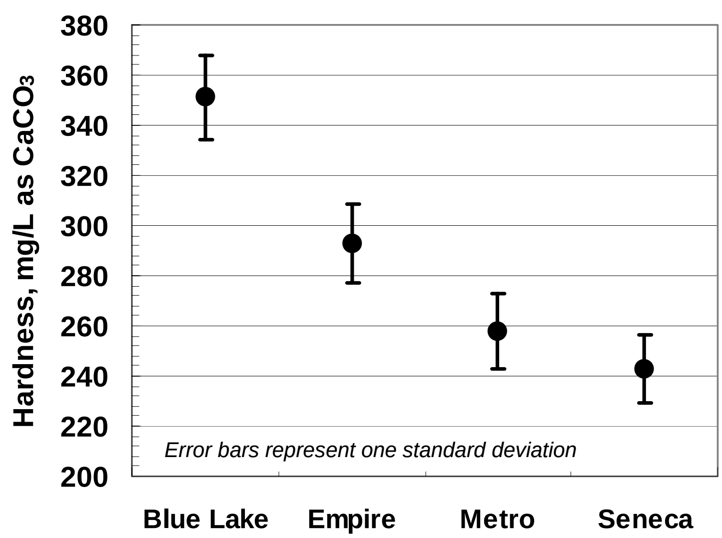

Figure 2. Average Hardness Concentration

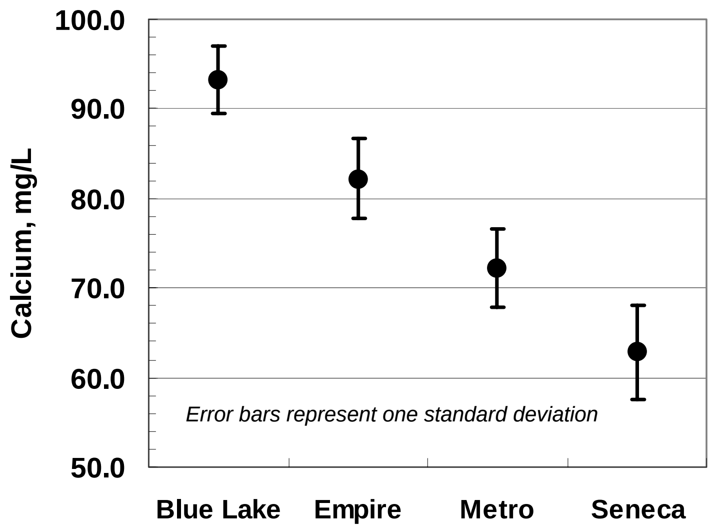

Figure 3. Average Calcium Concentration

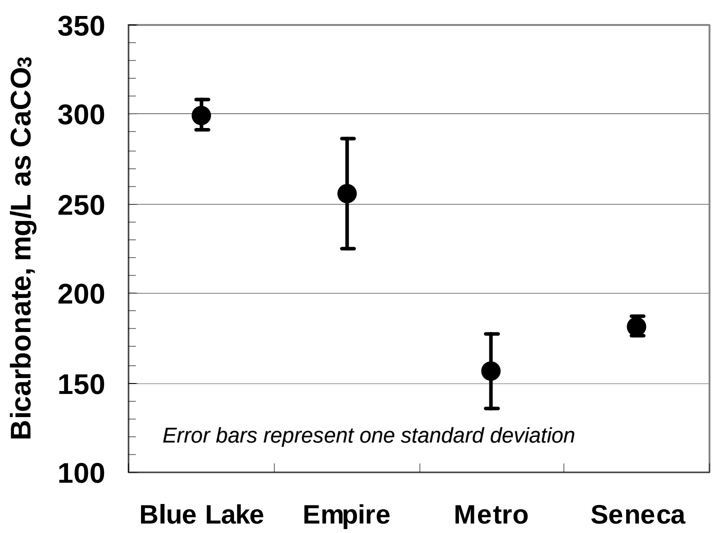

Figure 4. Average Bicarbonate Concentration

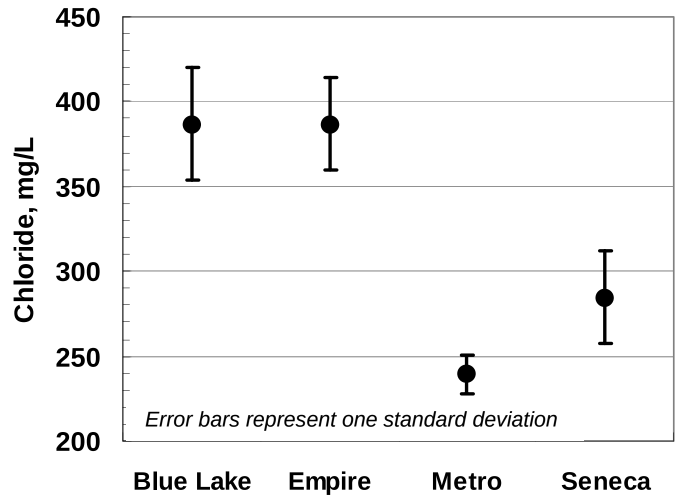

Figure 5. Average Chloride Concentration

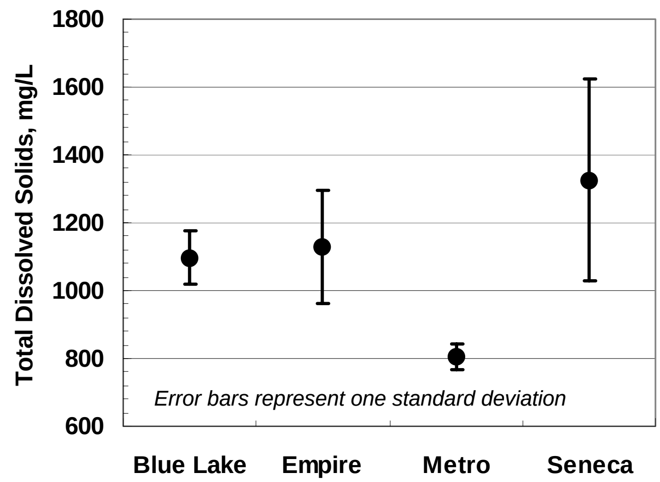

Figure 6. Average Total Dissolved Solids Concentration

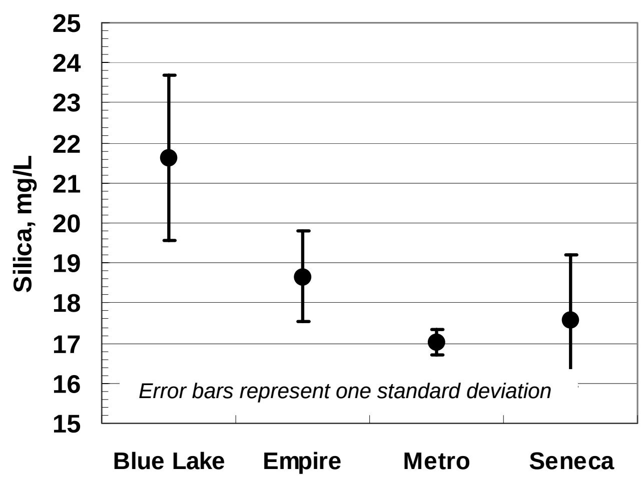

Figure 7. Average Silica Concentration

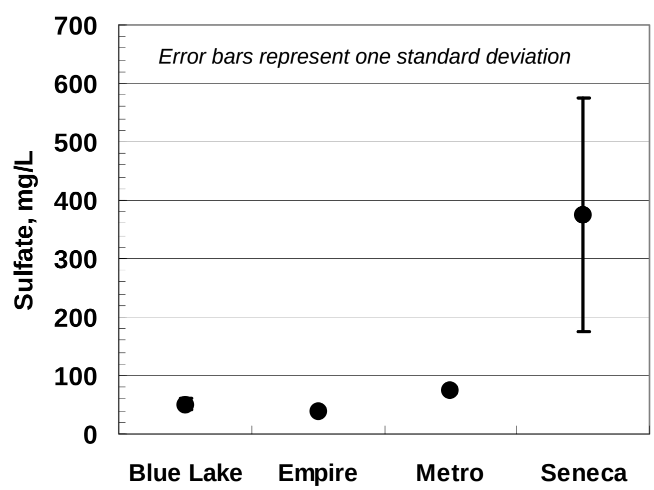

Figure 8. Average Sulfate Concentration

Exhibit A
Summary Results

Recommended Limits for Various Industrial Water Uses

Constituent	Unit	Limit[1]	Limit[2]	Limit[3]	Limit[4]	Limit[5]	Limit[6]	Limit[7]	Limit[8]	Limit[9]	Limit[10]	Limit[11]	Limit[12]	Limit[13]
Alkalinity (as CaCO3)	mg/L	20-350	350	100	40	*	*	*	125	*	*	*	400	20
Aluminum (Al)	mg/L	0.1	5	0.1	0.01	*	*	*	*	*	*	*	*	0.5
Ammonia (NH3)	mg/L	24	0.1	0.1	0.1	*	*	*	*	*	*	*	*	*
Bicarbonate ($HCO_{3)}$)	mg/L	25-200	170	120	48	*	*	*	128	*	*	*	*	*
Calcium (Ca)	mg/L	50	*	0.4	0.01	*	20	20	68	75	*	*	*	*
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	*	*	*	*	*	*	*	*	*	*	*	*	*
Chemical Oxygen Demand (COD)	mg/L	*	5	5	1	*	*	*	*	*	*	*	*	*
Chloride (Cl)	mg/L	500	*	*	*	1000	200	200	500	300	*	*	250	2
Color		*	*	*	*	30	30	10	20	*	5	5	*	*
Copper (Cu)	mg/L	*	*	*	*	*	*	*	*	0.05	0.01	*	*	*
Dissolved Oxygen (DO)	mg/L	*	2.5	0.007	0.007	*	*	*	*	*	*	*	*	*
E. Coli		*	*	*	*	*	*	*	*	*	*	*	*	*
Fecal Coliform		*	*	*	*	*	*	*	*	*	*	*	*	*
Hardness (as $CaCO_3$)	mg/L	130-650	350	1	0.07	*	100	100	250	350	25	25	*	20
Iron (Fe)	mg/L	0.5	1	0.3	0.05	0.3	1	0.1	0.1	1	0.3	0.1	2.5	0.05
Magnesium (Mg)	mg/L	*	*	0.25	0.01	*	12	12	19	30	*	*	*	*
Manganese (Mn)	mg/L	0.5	0.3	0.1	0.01	0.1	0.5	0.05	0.1	*	0.05	0.01	0.5	0.01
Nitrate ($NO_{3)}$)	mg/L	*	*	*	*	*	*	*	5	*	*	*	*	*
Orthophosphate (PO_4)	mg/L	*	*	*	*	*	*	*	*	*	*	*	*	*
Phosphorus (total: TP)	mg/L	1	*	*	*	*	*	*	*	*	*	*	*	1
pH		*	*	*	*	6-10	6-10	6-10	6.2-8.3	6-9	*	*	6.5-8.5	6.5-8.5
Silicondioxide ($SiO_{2)}$) or Silica	mg/L	50	30	10	0.7	*	50	50	50	*	*	*	35	*
Sulfate ($SO_{4)}$)	mg/L	200	*	*	*	*	*	*	100	*	*	*	250	3
Total Coliform		*	*	*	*	*	*	*	*	*	*	*	*	*
Total Dissolved Solids (TDS)	mg/L	500	700	500	200	*	*	*	1000	1000	100	100	600	*
Total Organic Carbon (TOC)	mg/L	*	*	*	*	*	*	*	*	*	*	*	*	6
Total Suspended Solids (TSS)	mg/L	100	10	5	0.5	*	10	10	5	10	5	5	500	0.5
Turbidity		*	*	*	*	*	*	*	*	*	*	*	*	*
Zinc (Zn)	mg/L	*	*	0.01	0.01	*	*	*	*	*	*	*	*	*

[2] Cooling Water (USEPA, 2004); variable range related to amount of recycling and materials of construction; high range is typically maximum in blowdown/final water

[2] Industrial Boiler Feed Water (low pressure) (Table 2-8, Technical Memorandum "Recycling Treated Wastewater for Industrial Water Use in Minneosta: Implementation Issues and Customer Inventory)

[3] Industrial Boiler Feed Water (medium pressure) (Table 2-8, Technical Memorandum "Recycling Treated Wastewater for Industrial Water Use in Minneosta: Implementation Issues and Customer Invento

[4] Industrial Boiler Feed Water (high pressure) (Table 2-8, Technical Memorandum "Recycling Treated Wastewater for Industrial Water Use in Minneosta: Implementation Issues and Customer Inventory)

[5] Pulp & Paper (Mechanical Pulping) (USEPA, 2004)

[6] Pulp & Paper (Chemical, Unbleached)(USEPA, 2004)

[7] Pulp & Paper (bleached) (USEPA, 2004)

[8] Chemical Processing (USEPA, 2004)

[9] Petrochem & Coal (USEPA, 2004)

[10] Textile (Sizing Suspension) (USEPA, 2004)

[11] Textile (Scouring, Bleach & Dye) (USEPA, 2004)

[12] Cement (USEPA, 2004)

[13] Ethanol process water (personal communications with undisclosed ethanol plant developers)

Wastewater Recycling Sampling Program Summary Results[1]

				Blue Lake					Empire					Metro					Seneca				
Constituent	Unit	Limit[2]	Limit[3]	Mean	St Dev[4]	Min	Max	Number	Mean	St Dev	Min	Max	Number	Mean	St Dev	Min	Max	Number	Mean	St Dev	Min	Max	Number
Alkalinity (as CaCO3)	mg/L	20-350	40	293	10	274	311	24	246	20	179	274	27	157	15	141	202	29	184	14	169	242	25
Aluminum (Al)	mg/L	0.1	0.01	0.022	0.008	0.012	0.051	24	0.023	0.006	0.013	0.034	27	0.030	0.004	0.020	0.037	29	0.024	0.002	0.018	0.028	25
Ammonia (NH3)	mg/L	24	0.1	0.182	0.068	0.060	0.330	37	0.2	0.3	0.1	2.0	43	0.216	0.338	0.020	2.320	61	0.117	0.110	0.030	0.620	40
Bicarbonate (HCO_3)	mg/L as $CaCO_3$	25-200	48	300	8	272	309	19	256	31	214	367	19	157	20	84	185	19	182	6	174	193	19
Calcium (Ca)	mg/L	50	0.01	93.2	3.8	87.3	101.0	24	82.2	4.5	65.4	88.0	27	72.2	4.4	67.2	80.2	29	62.9	5.3	58.5	86.6	25
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	*	*	3.0	0.0	3.0	3.0	30	3.2	0.9	3.0	8.0	35	3.2	0.5	3.0	5.0	61	3.3	1.4	3.0	11.0	33
Chemical Oxygen Demand (COD)	mg/L	*	1	34.1	5.1	21.0	48.0	37	37.4	5.0	24.0	52.0	39	32.2	3.4	22.0	39.0	61	34.1	4.4	28.0	48.0	40
Chloride (Cl)	mg/L	500	*	387	34	280	426	24	387	28	295	419	24	239	11	208	262	29	285	27	261	402	24
Color		*	*	51	7	36	61	12	58	7	47	77	12	45	8	33	62	12	61	13	41	78	12
Copper (Cu)	mg/L	*	*	-	-	-	-	-	-	-	-	-	-	5.06	0.45	4.5	5.7	5	-	-	-	-	-
Dissolved Oxygen (DO)	mg/L	*	0.007	8.63	0.43	7.50	10.40	50	8.6	0.5	7.5	10.1	54	5.8	0.9	3.0	8.5	61	8.88	0.55	8.01	10.02	54
E. Coli	No./100ml	*	*	731	572	96	2092	26	7	5	3	22	14	283	349	1	3973	22	57	120	4	548	22
Fecal Coliform	No./100ml	*	*	75	66	7	260	36	15	17	2	54	29	68	80	2	500	54	33	55	2	290	38
Hardness (as $CaCO_3$)	mg/L as $CaCO_3$	130-650	0.07	351	17	324	384	24	293	16	240	312	27	258	15	242	290	29	243	14	228	302	25
Iron (Fe)	mg/L	0.5	0.05	0.076	0.015	0.048	0.100	24	0.105	0.023	0.074	0.192	27	0.068	0.018	0.049	0.150	29	0.133	0.043	0.084	0.256	25
Magnesium (Mg)	mg/L	*	0.01	35.9	1.8	30.1	39.3	24	27.6	1.3	24.8	29.4	27	24.0	0.6	22.7	25.0	29	25.4	1.2	23.5	29.8	25
Manganese (Mn)	mg/L	0.5	0.01	0.015	0.004	0.009	0.027	24	0.038	0.023	0.008	0.097	27	0.016	0.003	0.010	0.023	29	0.035	0.024	0.011	0.094	25
Nitrate (NO_3)	mg/L	*	*	10.97	0.83	8.99	12.6	37	15.8	2.5	11.5	20.3	24	16.4	1.8	11.9	19.0	45	15.9	1.4	14.1	19.2	40
Orthophosphate (PO_4)	mg/L	*	*	0.406	0.289	0.167	1.370	24	0.057	0.125	0.006	0.614	27	0.259	0.197	0.093	0.810	29	0.968	0.801	0.019	3.050	25
Phosphorus (total: TP)	mg/L	1	*	0.485	0.164	0.290	0.860	37	0.340	0.109	0.190	0.710	28	0.457	0.246	0.200	1.500	61	1.500	0.855	0.560	3.700	40
pH		*	*	7.3	0.2	7.0	7.8	50	7.0	0.1	6.6	7.4	54	7.0	0.1	6.7	7.3	59	7.1	0.1	6.5	7.3	54
Silicondioxide (SiO_2) or Silica	mg/L	50	0.7	22	2	13	23	24	19	1	16	20	27	17	0	16	18	29	18	2	16	22	25
Sulfate (SO_4)	mg/L	200	*	51.1	9.2	39.7	83.1	24	39.8	4.5	23.8	47.1	26	74.7	6.7	63.4	93.8	29	374.3	200.3	39.7	724.2	25
Total Coliform		*	*	3,496	1,150	2,450	4,920	22	499	721	104	2,450	10	3,798	2,655	1,300	10,000	17	2,491	2,175	106	8,812	18
Total Dissolved Solids (TDS)	mg/L	500	200	1,097	80	875	1,260	24	1,130	166	961	1,920	27	805	37	716	907	29	1,326	299	900	1,960	25
Total Organic Carbon (TOC)	mg/L	*	*	8.1	0.7	7.0	10.0	23	9.4	1.0	7.6	11.8	27	8.0	0.6	7.0	9.2	29	8.4	0.7	7.3	9.6	25
Total Suspended Solids (TSS)	mg/L	100	0.5	1.7	1.0	1.0	6.0	37	3	2	1	15	43	2.4	0.8	1.0	4.0	61	3.1	1.2	1.0	7.0	40
Turbidity		*	*	2	0	1	3	24	4	1	1	5	27	2	0	1	3	29	3	1	2	5	25

[1] Based on Fall 2006 and Spring 2007 sampling periods; see other Exhibits for daily data

[2] Cooling Water (USEPA, 2004); variable range related to amount of recycling and materials of construction; high range is typically maximum in blowdown/final water

[3] Industrial Boiler Feed Water (high pressure) (Table 2-8, Technical Memorandum "Recycling Treated Wastewater for Industrial Water Use in Minnesota: Implementation Issues and Customer Inventory)

[4] St Dev = one standard deviation

Exhibit B
Blue Lake WWTP Sampling Results

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L
10/8/06	Sunday	25.92	288	0.019	0.26	306	92.9	3
10/9/06	Monday	26.78	286	0.018	0.26	303	90.6	<3
10/10/06	Tuesday	26.41	284	0.018	0.22	295	89.4	<3
10/11/06	Wednesday	26.82	288	0.051	0.24	297	90.9	<3
10/12/06	Thursday	26.22	302	0.019	0.19	306	92.5	
10/13/06	Friday	26.31						
10/14/06	Saturday	26						
10/15/06	Sunday	25.84	301	0.018	0.17	309	91.6	<3
10/16/06	Monday	26.93	289	0.018	0.18	299	89.3	<3
10/17/06	Tuesday	26.14	281	0.012	0.19	294	88.8	<3
10/18/06	Wednesday	26.1	281	0.033	0.18	291	89.4	3
10/19/06	Thursday	25.98	297	0.027	0.18	304	92.2	
10/20/06	Friday	25.25						
10/21/06	Saturday	25.16						
10/22/06	Sunday	25.75	301	0.027	0.16	305	93.1	3
10/23/06	Monday	26.58	293	0.024	0.13	303	92.1	<3
10/24/06	Tuesday	25.99	286	0.017	0.15	299	89.7	<3
10/25/06	Wednesday	25.95	278	0.016	0.14	301	91.3	<3
10/26/06	Thursday	25.94	289	0.018	0.16	307	93.4	
10/27/06	Friday	26.19						
4/1/07	Sunday	40.54			0.14			<3
4/2/07	Monday	34.3	274	0.025	0.06	272	87.3	<3
4/3/07	Tuesday	32.15			0.09			<3
4/4/07	Wednesday	31.26	308	0.016	0.23		97.6	<3
4/5/07	Thursday	30.54	311	0.017	0.08	304	99.1	
4/6/07	Friday	30.12						
4/7/07	Saturday	29.98						
4/8/07	Sunday	29.22	305	0.015	0.09		96.2	<3
4/9/07	Monday	29.83	291	0.017	0.09	302	96.4	<3
4/10/07	Tuesday	29			0.13			<3
4/11/07	Wednesday	30.03	301	0.027	0.16	295	98.1	<3
4/12/07	Thursday	29.85			0.18			
4/13/07	Friday	30.15						
4/14/07	Saturday	30.03						
4/15/07	Sunday	29.52	303	0.021	0.33		98.2	<3
4/16/07	Monday	29.8	298	0.022	0.29		96.7	3
4/17/07	Tuesday	28.55			0.26			3
4/18/07	Wednesday	28.59			0.32			3
4/19/07	Thursday	28.67	297	0.024	0.29		101	
4/20/07	Friday	28.22						
4/21/07	Saturday	27.79						
4/22/07	Sunday	28.53			0.19			<3
4/23/07	Monday	32.17			0.15			<3
4/24/07	Tuesday	29.76			0.22			3
4/25/07	Wednesday	29.22			0.23			3
4/26/07	Thursday	28.82			0.16			
4/27/07	Friday	28.58						

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L
4/28/07	Saturday	28.22						
4/29/07	Sunday	27.98			0.12			3
4/30/07	Monday	28.63			0.12			<3
Mean		28.45	293.00	0.02	0.18	299.58	93.24	3.00
Standard Deviation		2.70	9.92	0.01	0.07	8.30	3.77	0.00
Min		25.16	274	0.012	0.06	272	87.3	3
Max		40.54	311	0.051	0.33	309	101	3
No. of Samples		50	24	24	37	19	24	30
* Not included in statistics								

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	COD	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli	Hardness
		mg/L	mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100ml	mg/L CaCO3
10/8/06	Sunday	34	415			8.2			360
10/9/06	Monday	29	410			8.6		38	344
10/10/06	Tuesday	32	407			8.7		38	334
10/11/06	Wednesday	31	419			8.33		66	356
10/12/06	Thursday	38	426			8.4	1373	92	346
10/13/06	Friday					8.8	2092	150	
10/14/06	Saturday					9			
10/15/06	Sunday	25	411	54		7.5			342
10/16/06	Monday	31	400	50		8.05	411	48	334
10/17/06	Tuesday	33	397	50		7.96	96	64	332
10/18/06	Wednesday	36	407	61		8.17		35	338
10/19/06	Thursday	33	405	57		8.3	822	57	346
10/20/06	Friday					8.2	250	30	
10/21/06	Saturday					8.2			
10/22/06	Sunday	34	401	56		8.6			342
10/23/06	Monday	40	393	53		8.5	122	24	338
10/24/06	Tuesday	26	387			8.7	144	39	324
10/25/06	Wednesday	21	410			8.48	106	33	340
10/26/06	Thursday	26	409	49		8.5	120	32	346
10/27/06	Friday					8.5	311	35	
4/1/07	Sunday	33				8			
4/2/07	Monday	32	280	36		8.67		230	336
4/3/07	Tuesday	32				8.53	361	50	
4/4/07	Wednesday	34	332			9.03	816	130	368
4/5/07	Thursday	35	350	52		9.1	185	46	384
4/6/07	Friday					9.1	921	160	
4/7/07	Saturday					8.7			
4/8/07	Sunday	32	353			8.6			378
4/9/07	Monday	48	351	37		8.97	461	77	366
4/10/07	Tuesday	37				9.2	613	150	
4/11/07	Wednesday	36	381	52		9.37	1986	240	366
4/12/07	Thursday	40				10.4	1553	260	
4/13/07	Friday					9.2	921	150	
4/14/07	Saturday					9			
4/15/07	Sunday	38	375			8.8			372
4/16/07	Monday	34	369			8.71	903	48	358
4/17/07	Tuesday	33				8.73	816	69	
4/18/07	Wednesday	36				8.74	727	47	
4/19/07	Thursday	33	400			8.83	770	43	377
4/20/07	Friday					8.6	1516	42	
4/21/07	Saturday					8.66			
4/22/07	Sunday	36				8.43			
4/23/07	Monday	30				8.42	613	57	
4/24/07	Tuesday	44				8.69		22	
4/25/07	Wednesday	37				8.7		29	
4/26/07	Thursday	36				8.58		37	
4/27/07	Friday					8.61		8	

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	COD	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli	Hardness
		mg/L	mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100ml	mg/L CaCO3
4/28/07	Saturday					8.55			
4/29/07	Sunday	40				8.43			
4/30/07	Monday	36				8.54		7	
Mean		34.08	387.00	50.58		8.63	731	75	351.13
Standard Deviation		5.10	33.65	7.39		0.43	572	66	16.77
Min		21	280	36		7.5	96	7	324
Max		48	426	61		10.4	2092	260	384
No. of Samples		37	24	12		50	26	36	24
* Not included in statistics									

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Iron	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
10/8/06	Sunday	0.096	37.3	0.018	12.6		0.64	0.83	7.4	23
10/9/06	Monday	0.08	36.7	0.016	12		1.12	0.86	7.3	18
10/10/06	Tuesday	0.078	36	0.014	11.9		0.59	0.8	7.2	22
10/11/06	Wednesday	0.079	36.5	0.015	11.2		0.49	0.62	7.5	23
10/12/06	Thursday	0.08	36.5	0.016	11.4		0.365	0.56	7.5	23
10/13/06	Friday								7.5	
10/14/06	Saturday								7.4	
10/15/06	Sunday	0.08	36.6	0.014	11		0.27	0.43	7.4	22
10/16/06	Monday	0.076	35.2	0.014	11.6		0.322	0.45	7.3	22
10/17/06	Tuesday	0.078	35.2	0.014	12		0.347	0.52	7.3	22
10/18/06	Wednesday	0.1	34.8	0.02	11		1.37	0.43	7.4	22
10/19/06	Thursday	0.093	36.1	0.023	10.8		0.275	0.42	7.4	22
10/20/06	Friday								7.4	
10/21/06	Saturday								7.4	
10/22/06	Sunday	0.083	36.9	0.013	10.4		0.294	0.35	7.4	13
10/23/06	Monday	0.093	34.7	0.027	11.2		0.25	0.42	7.7	22
10/24/06	Tuesday	0.076	33.8	0.014	12		0.271	0.4	7.8	22
10/25/06	Wednesday	0.071	34.2	0.011	11.4		0.3	0.38	7.3	22
10/26/06	Thursday	0.085	35	0.012	11.1		0.255	0.37	7.4	22
10/27/06	Friday								7.4	
4/1/07	Sunday				8.99	0.07		0.29	7.3	
4/2/07	Monday	0.051	30.1	0.0085	9.25	<0.03	0.183	0.38	7.2	22
4/3/07	Tuesday				9.14	<0.03		0.8	7.1	
4/4/07	Wednesday	0.048	34.8	0.012	9.56	<0.03	0.456	0.62	7.1	22
4/5/07	Thursday	0.05	36.7	0.013	9.59	<0.03	0.229	0.45	7.2	23
4/6/07	Friday								7.2	
4/7/07	Saturday								7.2	
4/8/07	Sunday	0.054	36.8	0.01	10.6	0.05	0.167	0.33	7.1	22
4/9/07	Monday	0.054	37.2	0.009	10.9	0.05	0.271	0.45	7.2	22
4/10/07	Tuesday				11.6	0.11		0.84	7	
4/11/07	Wednesday	0.068	38.3	0.014	11.2	0.16	0.54	0.74	7	22
4/12/07	Thursday				10.8	0.18		0.48	7.5	
4/13/07	Friday								7.2	
4/14/07	Saturday								7.2	
4/15/07	Sunday	0.09	37.2	0.016	10.3	0.23	0.227	0.41	7.1	22
4/16/07	Monday	0.079	36.6	0.013	11.1	0.22	0.225	0.39	7.1	22
4/17/07	Tuesday				11.3	0.2		0.43	7.1	
4/18/07	Wednesday				10.6	0.23		0.45	7.1	
4/19/07	Thursday	0.088	39.3	0.018	10.2	0.22	0.29	0.54	7	22
4/20/07	Friday								7.2	
4/21/07	Saturday								7.2	
4/22/07	Sunday				11.5	0.12		0.43	7.1	
4/23/07	Monday				11.4	0.11		0.31	7.2	
4/24/07	Tuesday				11	0.14		0.33	7.1	
4/25/07	Wednesday				11	0.13		0.36	7	
4/26/07	Thursday				11.4	0.09		0.36	7.1	
4/27/07	Friday								7.2	

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Iron	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
4/28/07	Saturday								7.1	
4/29/07	Sunday				11.4	0.05		0.37	7.1	
4/30/07	Monday				11.4	0.05		0.36	7	
Mean		0.08	35.94	0.01	10.97	0.12	0.41	0.49	7.25	21.63
Standard Deviation		0.02	1.79	0.00	0.83	0.07	0.29	0.16	0.18	2.06
Min		0.048	30.1	0.0085	8.99	0.03	0.167	0.29	7	13
Max		0.1	39.3	0.027	12.6	0.23	1.37	0.86	7.8	23
No. of Samples		24	24	24	37	22	24	37	50	24
* Not included in statistics										

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Sulfate	Temp (Inf)	Total Coliform	TKN	TDS	TOC	TSS	Turbidity
		mg/L	Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
10/8/06	Sunday	47.11				1190	8.5	~2	2
10/9/06	Monday	43.98				1260	7.7	~2	2
10/10/06	Tuesday	53.76				1140	7.6	~2	2
10/11/06	Wednesday	58.93				1150	7.9	~1	2
10/12/06	Thursday	55.86		>4840		1160	8.4	~1	2
10/13/06	Friday			>4838					
10/14/06	Saturday								
10/15/06	Sunday	45.67				1130	8.6	~1	1
10/16/06	Monday	39.65		>4839		1110	7.1	<1	1
10/17/06	Tuesday	51.14		>4839		1090	7.5	<1	2
10/18/06	Wednesday	43				1120	8	~1	1
10/19/06	Thursday	43.48		3431		1100	8.8	~2	2
10/20/06	Friday			>4839					
10/21/06	Saturday								
10/22/06	Sunday	52.9				1130	8.5	~1	2
10/23/06	Monday	55.26		3466		1110	7.7	6	2
10/24/06	Tuesday	42.47		4920		1090	7.4	~1	2
10/25/06	Wednesday	57.49		4839		1150	7.8	<1	3
10/26/06	Thursday	48.6		3973		1170	8.7	~1	2
10/27/06	Friday			4839					
4/1/07	Sunday		9		3.8			~2	
4/2/07	Monday	43.9	10.5		3	875	7.3	~1	2
4/3/07	Tuesday		10.5		3.6			~2	
4/4/07	Wednesday	49	10.5		3.5	993	7.8	~2	2
4/5/07	Thursday	53.5	10		3.9	1030	8.5	~1	1
4/6/07	Friday		10	>2420					
4/7/07	Saturday		9						
4/8/07	Sunday	50.7	9		4.1	1050	8.7	~2	1
4/9/07	Monday	64.8	10.5	>2420	4.3	1030	7	~2	2
4/10/07	Tuesday		10.5	>2420	4.9			~2	
4/11/07	Wednesday	83.1	11	>2420	4.9	1080	8.4	~2	2
4/12/07	Thursday		10	>2420	4.6			~2	
4/13/07	Friday		10	>2420					
4/14/07	Saturday		10						
4/15/07	Sunday	47.9	10		4.4	968	10	~1	2
4/16/07	Monday	43	11	>2420	3.6	1060	9	~1	2
4/17/07	Tuesday		11.5	>2420	4.1			~2	
4/18/07	Wednesday		11	>2420	4			~1	
4/19/07	Thursday	51.7	11	>2420	5.4	1140		~2	2
4/20/07	Friday		11.5						
4/21/07	Saturday		11.5						
4/22/07	Sunday		11		4.5			~1	
4/23/07	Monday		11.5	>2420	3.6			~2	
4/24/07	Tuesday		11.5		4.1			~2	
4/25/07	Wednesday		11.5		4			~2	
4/26/07	Thursday		11.5		4.3			~1	
4/27/07	Friday		12						

MCES Blue Lake Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Sulfate	Temp (Inf)	Total Coliform	TKN	TDS	TOC	TSS	Turbidity
		mg/L	Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
4/28/07	Saturday		12						
4/29/07	Sunday		11.5		4.7			4	
4/30/07	Monday		11.5		4.5			~2	
Mean		51.12	10.73	3496	4.17	1096.92	8.13	1.70	1.83
Standard Deviation		9.17	0.86	1150	0.55	79.83	0.71	0.97	0.48
Min		39.65	9	2450	3	875	7	1	1
Max		83.1	12	4920	5.4	1260	10	6	3
No. of Samples		24	30	22	22	24	23	37	24
* Not included in statistics									

Exhibit C
Empire WWTP Sampling Results

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow mgd	Alkalinity mg/L CaCO3	Aluminum mg/L	Ammonia mg/L	Bicarbonate mg/L CaCO3	Calcium mg/L	CBOD mg/L	COD mg/L
10/24/06	Tuesday	8.01	230	0.027	0.31	244	84.5	3	36
10/25/06	Wednesday	7.96			0.53			4	31
10/26/06	Thursday	7.87	264	0.025	0.08	276	81.4		24
10/27/06	Friday	7.86							
10/28/06	Saturday	8.48							
10/29/06	Sunday	8.94	246	0.027	0.42	367	79.2	4	34
10/30/06	Monday	8.13	237	0.034	0.54	245	80	4	42
10/31/06	Tuesday	7.78	243	0.027	0.7	243	86	3	40
11/1/06	Wednesday	8.3	274	0.028	0.06	275	86.6	<3	32
11/2/06	Thursday	8.3	268	0.027	0.25	269	84.3		34
11/3/06	Friday	8.13							
11/4/06	Saturday	8.76							
11/5/06	Sunday	9.13	238	0.024	0.22	250	78.3	<3	33
11/6/06	Monday	8.57	232	0.023	0.25	237	76.8	<3	38
11/7/06	Tuesday	8.26	243	0.022	~0.06	242	81.3	<3	33
11/8/06	Wednesday	8.21			0.28			<3	34
11/9/06	Thursday	8.27	253	0.023	0.11	253	85.6	<3	
11/10/06	Friday	8.36			0.07			<3	
11/11/06	Saturday	8.94	255	0.029		254	80.6		
11/12/06	Sunday	9.21			0.93			3	35
11/13/06	Monday	8.47	227	0.023	1.96	231	80.1	<3	35
11/14/06	Tuesday	8.16			0.06			3	38
11/15/06	Wednesday	8.25	261	0.026	0.08	261	88	<3	32
11/16/06	Thursday	8.27	252	0.026	~0.05	257	85.9		32
4/1/07	Sunday	10.99			0.08			<3	40
4/2/07	Monday	9.29	213	0.019	~0.05	214	76.8	<3	36
4/3/07	Tuesday	8.96			0.08			<3	36
4/4/07	Wednesday	8.8	257	0.016	0.08		85	<3	36
4/5/07	Thursday	8.96	270	0.013	0.08	260	84.1		38
4/6/07	Friday	9.18							
4/7/07	Saturday	9.56							
4/8/07	Sunday	9.47	271	0.016	0.07		82.7	<3	36
4/9/07	Monday	9.11	239	0.018	0.1	238	82.9	<3	37
4/10/07	Tuesday	8.9			0.1			<3	40
4/11/07	Wednesday	8.89	255	0.022	0.09	252	84.2	<3	34
4/12/07	Thursday	8.94			0.09				35
4/13/07	Friday	9.02			0.12			<3	
4/14/07	Saturday	9.56			0.1				
4/15/07	Sunday	9.73	251	0.02	0.11		85.8	3	44
4/16/07	Monday	9.06	243	0.02	0.15		83	3	46
4/17/07	Tuesday	8.69			0.15			3	38
4/18/07	Wednesday	8.72			0.14			8	52
4/19/07	Thursday	8.7	179	0.033	0.11		65.4		42
4/20/07	Friday	8.68	249	0.014			84		
4/21/07	Saturday	9.02	249	0.014			84		
4/22/07	Sunday	9.5	236	0.015	0.49		83.7	<3	40
4/23/07	Monday	8.8			0.14			<3	37
4/24/07	Tuesday	8.52			0.13			3	45
4/25/07	Wednesday	8.53			0.1			<3	41

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD	COD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L	mg/L
4/26/07	Thursday	8.4			0.09				40
4/27/07	Friday	8.64							
4/28/07	Saturday	9.13							
4/29/07	Sunday	9.41			0.09			<3	44
4/30/07	Monday	8.9			0.1			<3	40
Mean		8.75	245.74	0.02	0.23	256.21	82.23	3.23	37.44
Standard Deviation		0.57	19.75	0.01	0.33	30.79	4.47	0.88	5.00
Min		7.78	179	0.013	0.05	214	65.4	3	24
Max		10.99	274	0.034	1.96	367	88	8	52
No. of Samples		54	27	27	43	19	27	35	39
* Not included in statistics									

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli.	Hardness	Iron
		mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100 mL	mg/L CaCO3	mg/L
10/24/06	Tuesday	406	77		9.2		42	302	0.094
10/25/06	Wednesday				7.5		48		
10/26/06	Thursday	348	64		8.2		54	278	0.099
10/27/06	Friday				8.3		45		
10/28/06	Saturday				8.1				
10/29/06	Sunday	371			8.1			282	0.122
10/30/06	Monday	383			8.3		50	288	0.128
10/31/06	Tuesday	418			8		36	304	0.106
11/1/06	Wednesday	402			8.1			304	0.096
11/2/06	Thursday	392			8			306	0.101
11/3/06	Friday				8.2				
11/4/06	Saturday				8.3				
11/5/06	Sunday	400			8.3			292	0.104
11/6/06	Monday	386			8			276	0.102
11/7/06	Tuesday	419	52		8			290	0.094
11/8/06	Wednesday				8				
11/9/06	Thursday	410	54		8.1	59*		298	0.115
11/10/06	Friday				8.2				
11/11/06	Saturday	399	60		8.5			274	0.127
11/12/06	Sunday				9.1				
11/13/06	Monday	406	56		8.6			270	0.096
11/14/06	Tuesday				8.2				
11/15/06	Wednesday	404	59		8			292	0.11
11/16/06	Thursday	406	59		8			294	0.13
4/1/07	Sunday				8.8				
4/2/07	Monday	339	56		8.5		6	282	0.116
4/3/07	Tuesday				8.9	9	4		
4/4/07	Wednesday	374			8.8	11	6	312	0.084
4/5/07	Thursday	379	47		10.09	7	8	310	0.076
4/6/07	Friday				9.1	4	3		
4/7/07	Saturday				9.1				
4/8/07	Sunday	379			9			304	0.087
4/9/07	Monday	384	54		9.4		5	298	0.074
4/10/07	Tuesday				9.8	3	4		
4/11/07	Wednesday	393	55		8.85		5	302	0.082
4/12/07	Thursday				9	4	7		
4/13/07	Friday				9.1	5	6		
4/14/07	Saturday				9.1		4		
4/15/07	Sunday	394			8.9		37	298	0.105
4/16/07	Monday	398			8.1	22	10	294	0.089
4/17/07	Tuesday				8.3	9	4		
4/18/07	Wednesday				8.5	9	8		
4/19/07	Thursday	295			8.6	5	5	240	0.192
4/20/07	Friday				9.2	5	3	306	0.106
4/21/07	Saturday				8.8			300	0.093
4/22/07	Sunday				9.1			308	0.106
4/23/07	Monday				8.79	3	7		
4/24/07	Tuesday				8.69		4		
4/25/07	Wednesday				8.78	3	5		

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli.	Hardness	Iron
		mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100 mL	mg/L CaCO3	mg/L
4/26/07	Thursday				9		7		
4/27/07	Friday				8.9		2		
4/28/07	Saturday				8.8				
4/29/07	Sunday				8.3				
4/30/07	Monday				8.74		3		
Mean		386.88	57.75		8.60	7	15	292.74	0.10
Standard Deviation		27.60	7.44		0.51	5	17	15.63	0.02
Min		295	47		7.5	3	2	240	0.074
Max		419	77		10.09	22	54	312	0.192
No. of Samples		24	12		54	14	29	27	27
* Not included in statistics									

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	Ortho P mg/L	TP mg/L	pH	Silica mg/L	Sulfate mg/L
10/24/06	Tuesday	25.9	0.025	18		0.295	0.71	7	19	41.07
10/25/06	Wednesday							7		
10/26/06	Thursday	24.8	0.035	11.8		0.016	0.39	7	19	45.86
10/27/06	Friday							6.8		
10/28/06	Saturday							6.9		
10/29/06	Sunday	26.9	0.044	11.8		0.056	0.32	7	20	40.02
10/30/06	Monday	27.2	0.03			0.017		6.8	19	42.77
10/31/06	Tuesday	28.2	0.041	18.7		0.015	0.32	7	20	45.93
11/1/06	Wednesday	28	0.041			0.017		7	20	43.54
11/2/06	Thursday	28.2	0.05	11.5		0.014	0.54	7.2	19	41.64
11/3/06	Friday							6.9		
11/4/06	Saturday							6.9		
11/5/06	Sunday	27.1	0.014	16.2		0.015	0.29	6.9	20	39.31
11/6/06	Monday	27.1	0.008			0.018		7.1	19	37.54
11/7/06	Tuesday	28	0.01	19.1		0.019	0.35	7.3	19	36.62
11/8/06	Wednesday			18.2			0.32	7		
11/9/06	Thursday	28	0.097			0.021	0.33	7.1	20	37.61
11/10/06	Friday						0.3	7		
11/11/06	Saturday	26.3	0.047			0.027		7	20	34.55
11/12/06	Sunday			17.7			0.38	6.9		
11/13/06	Monday	24.9	0.015			0.011		7	20	37.43
11/14/06	Tuesday			17			0.36	7		
11/15/06	Wednesday	28.3	0.058			0.019		7.1	19	40.59
11/16/06	Thursday	28.3	0.082	17.1		0.038	0.53	7.1	20	38.88
4/1/07	Sunday			17.1	0.07		0.32	6.9		
4/2/07	Monday	24.9	0.068			0.017		6.6	17	43.1
4/3/07	Tuesday			15.2	0.03		0.27	7.1		
4/4/07	Wednesday	28	0.052			0.011		6.9	18	43.8
4/5/07	Thursday	27.5	0.054	12.1	<0.03	~0.006	0.4	7	18	47.1
4/6/07	Friday							7.1		
4/7/07	Saturday							7.1		
4/8/07	Sunday	28	0.039	13.5	0.03	0.012	0.21	7	18	39.8
4/9/07	Monday	28.6	0.032			0.023		7.1	18	23.8
4/10/07	Tuesday			17.1	0.03		0.19	7		
4/11/07	Wednesday	28.9	0.036			0.015		7	18	41.5
4/12/07	Thursday			15	<0.03		0.28	7.2		
4/13/07	Friday						0.36	7.1		
4/14/07	Saturday						0.41	7		
4/15/07	Sunday	28.8	0.021	15.4	0.04	0.039	0.27	7.1	18	39.1
4/16/07	Monday	28.8	0.018			0.014		7	18	38.7
4/17/07	Tuesday			20.3	0.07		~0.24	7.1		
4/18/07	Wednesday							7		
4/19/07	Thursday	26.1	0.061	14.7	0.04	0.614	0.31	7.1	16	860
4/20/07	Friday	29.1	0.021			~0.007		7	17	38.7
4/21/07	Saturday	29.2	0.01			0.097		7.1	17	39
4/22/07	Sunday	29.4	0.009	14.9	0.04	0.097	0.33	7.1	18	37
4/23/07	Monday							6.9		
4/24/07	Tuesday			17.6	0.05		0.3	6.8		
4/25/07	Wednesday							6.8		

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica	Sulfate
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
4/26/07	Thursday			12.6	<0.03		0.28	7		
4/27/07	Friday							7.1		
4/28/07	Saturday							7.1		
4/29/07	Sunday			15.6	0.03		0.2	6.8		
4/30/07	Monday							7.4		
Mean		27.57	0.04	15.76	0.04	0.06	0.34	7.01	18.67	39.81
Standard Deviation		1.34	0.02	2.52	0.01	0.12	0.11	0.13	1.14	4.51
Min		24.8	0.008	11.5	0.03	0.006	0.19	6.6	16	23.8
Max		29.4	0.097	20.3	0.07	0.614	0.71	7.4	20	47.1
No. of Samples		27	27	24	13	27	28	54	27	26
* Not included in statistics										

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Temp (Inf)	Total coliform	TKN	TDS	TOC	TSS	Turbidity
		Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
10/24/06	Tuesday				1120	8.7	5	5
10/25/06	Wednesday						6	
10/26/06	Thursday				1040	10.2	3	4
10/27/06	Friday							
10/28/06	Saturday							
10/29/06	Sunday				1060	10.2	3	5
10/30/06	Monday				1070	9.2	7	5
10/31/06	Tuesday				1150	9.8	4	5
11/1/06	Wednesday				1140	9.4	3	4
11/2/06	Thursday				1110	8.9	3	4
11/3/06	Friday							
11/4/06	Saturday							
11/5/06	Sunday				1120	10.6	~1	4
11/6/06	Monday				1090	9.7	~2	4
11/7/06	Tuesday				1140	10.4	~2	4
11/8/06	Wednesday						~2	
11/9/06	Thursday		>9678*		1150	10.4	8	4
11/10/06	Friday						~2	
11/11/06	Saturday				1110	11.8		4
11/12/06	Sunday						3	
11/13/06	Monday				1130	11.1	~2	4
11/14/06	Tuesday						3	
11/15/06	Wednesday				1120	9.8	3	4
11/16/06	Thursday				1160	9.4	3	4
4/1/07	Sunday	13.5		3.8			4	
4/2/07	Monday	13.5			961	8.9	~1	5
4/3/07	Tuesday	13.5		4.7			3	
4/4/07	Wednesday	12.5			1050	7.6	3	3
4/5/07	Thursday	12.5		3.2	1050	7.7	7	1
4/6/07	Friday	12.5						
4/7/07	Saturday	12						
4/8/07	Sunday	12		4	1050	8.1	~2	2
4/9/07	Monday	13.5			1070	8.2	~2	2
4/10/07	Tuesday	12.5	179	4.4			~2	
4/11/07	Wednesday	13.5	172		1080	8.6	~2	3
4/12/07	Thursday	13.5	104	3.7			3	
4/13/07	Friday	13.5	772	4.1			3	
4/14/07	Saturday	13.5		4.4			~2	
4/15/07	Sunday	13.5		3.6	1220	9.9	~2	3
4/16/07	Monday	13.2	150		1090	9.3	~2	3
4/17/07	Tuesday	13	173	4.3			4	
4/18/07	Wednesday	13.5	>2420				15	
4/19/07	Thursday	13	613	4.6	1920	9.4	~2	4
4/20/07	Friday	13.5			1080	8.3		2
4/21/07	Saturday	13.5			1110	8.7		3
4/22/07	Sunday	12.5		6.1	1110	8.2	~2	2
4/23/07	Monday	14.5	196				3	
4/24/07	Tuesday	13.7		4.4			4	
4/25/07	Wednesday	13.4	179				~2	

MCES Empire Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Temp (Inf)	Total coliform	TKN	TDS	TOC	TSS	Turbidity
		Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
4/26/07	Thursday	13.5		4.3			~2	
4/27/07	Friday	13.5						
4/28/07	Saturday	13.5						
4/29/07	Sunday	13.5		4.5			~2	
4/30/07	Monday	14.5					~2	
Mean		13.26	499	4.27	1129.67	9.35	3.28	3.59
Standard Deviation		0.60	721	0.65	165.50	1.04	2.39	1.08
Min		12	104	3.2	961	7.6	1	1
Max		14.5	2450	6.1	1920	11.8	15	5
No. of Samples		30	10	15	27	27	43	27
* Not included in statistics								

Exhibit D
Metropolitan (Metro) WWTP
Sampling Results

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow mgd	Alkalinity mg/L CaCO3	Aluminum mg/L	Ammonia mg/L	Bicarbonate mg/L CaCO3	Calcium mg/L	CBOD mg/L
10/8/06	Sunday	174.01	152	0.036	0.09	163	70.3	4
10/9/06	Monday	183.52			0.1			3
10/10/06	Tuesday	179.59			0.08			<3
10/11/06	Wednesday	182.8			0.09			3
10/12/06	Thursday	179.64			0.06			3
10/13/06	Friday	178.68			0.07			4
10/14/06	Saturday	173.21			0.07			4
10/15/06	Sunday	172.27			0.07			3
10/16/06	Monday	184.17	152	0.03	0.07	158	68.5	3
10/17/06	Tuesday	178.89	149	0.032	0.18	157	71.5	<3
10/18/06	Wednesday	178.61	144	0.034	0.07	153	70	<3
10/19/06	Thursday	175.89	141	0.035	0.09	150	69.4	<3
10/20/06	Friday	176.28			0.07			3
10/21/06	Saturday	169.28			0.08			4
10/22/06	Sunday	169.52	143	0.028	0.08	155	70.3	3
10/23/06	Monday	178.66	149	0.028	0.07	160	68.8	<3
10/24/06	Tuesday	175.13	143	0.03	0.07	159	70.6	<3
10/25/06	Wednesday	175.09	148	0.03	0.06	155	71.4	3
10/26/06	Thursday	176.14	152	0.034	0.05	154	70.3	<3
10/27/06	Friday	176.06	150	0.028	0.06	153	67.6	3
10/28/06	Saturday	171.4	152	0.032	0.06	153	69.7	4
10/29/06	Sunday	171.1	153	0.029	0.05	155	69.3	3
10/30/06	Monday	178.78	155	0.028	0.02	159	68.8	<3
10/31/06	Tuesday	172.52	154	0.031	0.14	157	69.5	<3
11/1/06	Wednesday	171.93	152	0.032	0.54		69.4	<3
11/2/06	Thursday	174.81			0.17			<3
11/3/06	Friday	174.45	148	0.031	0.1		69.4	<3
11/4/06	Saturday	168.99			0.07			<3
11/5/06	Sunday	169.06	151	0.034	0.05		67.7	<3
11/6/06	Monday	174.46	154	0.035	0.05		67.2	<3
11/7/06	Tuesday	172.74	149	0.037	0.2		68.9	<3
4/1/07	Sunday	227.99			0.19			<3
4/2/07	Monday	210.21	178	0.024	0.1	180	78.4	3
4/3/07	Tuesday	202.83			0.21			4
4/4/07	Wednesday	197.78	180	0.021	0.23		77.3	4
4/5/07	Thursday	193.53	184	0.024	0.33	185	80.2	3
4/6/07	Friday	195.56			0.28			3
4/7/07	Saturday	187.99			0.24			<3
4/8/07	Sunday	185.25	202	0.02	0.11		78.9	3
4/9/07	Monday	190.71	178	0.024	0.44	184	77.6	3
4/10/07	Tuesday	187.27			0.56			3
4/11/07	Wednesday	197.24	169	0.028	0.42	84	79.2	<3
4/12/07	Thursday	191.91			1.35			3
4/13/07	Friday	187.45			0.28			4
4/14/07	Saturday	188.48			0.1			<3
4/15/07	Sunday	190.93	168	0.032	0.06		78.8	3
4/16/07	Monday	203.71	163	0.03	0.15		78.5	3
4/17/07	Tuesday	201.44			0.27			3
4/18/07	Wednesday	200.32			0.39			3

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L
4/19/07	Thursday	200.19	152	0.029	0.26		77.1	3
4/20/07	Friday	202.49			0.26			3
4/21/07	Saturday	197.82			0.11			4
4/22/07	Sunday	206.28			0.14			3
4/23/07	Monday	215.74			0.32			<3
4/24/07	Tuesday	206.33			0.17			3
4/25/07	Wednesday	206.01			0.09			4
4/26/2007	Thursday	206.43			0.07			3
4/27/2007	Friday	207.93			0.38			5
4/28/2007	Saturday	201.53			0.25			3
4/29/2007	Sunday	200.11			0.07			3
4/30/2007	Monday	211.26			2.32			4
Mean		187.55	157.41	0.03	0.22	156.53	72.23	3.21
Stan Dev		14.41	14.52	0.00	0.34	20.47	4.38	0.45
Min		168.99	141	0.02	0.02	84	67.2	3
Max		227.99	202	0.037	2.32	185	80.2	5
No. Samples		61	29	29	61	19	29	61
* Not included in statistics								

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	COD	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli.	Hardness
		mg/L	mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100ml	mg/L CaCO3
10/8/06	Sunday	27	238			5.81		86	258
10/9/06	Monday	29				6.12		54	
10/10/06	Tuesday	35				6.07		90	
10/11/06	Wednesday	30				6.11		72	
10/12/06	Thursday	32				8.17		130	
10/13/06	Friday	29				8.49		120	
10/14/06	Saturday	32				6.12		35	
10/15/06	Sunday	26				6.04		110	
10/16/06	Monday	33	236	49		5.98		41	244
10/17/06	Tuesday	33	246	52		5.73		68	254
10/18/06	Wednesday	34	248	56		6.22		61	252
10/19/06	Thursday	32	243	46		5.85		35	244
10/20/06	Friday	32				5.83		36	
10/21/06	Saturday	34				5.93		44	
10/22/06	Sunday	27	240	43		6.08		44	252
10/23/06	Monday	31	223	62		6.12	170	48	242
10/24/06	Tuesday	27	244			6.32		160	248
10/25/06	Wednesday	22	249	42		5.93	551	68	246
10/26/06	Thursday	30	247	45		6.12	798	100	248
10/27/06	Friday	29	242			6.32	413	93	246
10/28/06	Saturday	29	245			6.08		95	248
10/29/06	Sunday	30	233			6.15		100	250
10/30/06	Monday	32	231			6.04	952	110	242
10/31/06	Tuesday	34	239			6.32	3973*	400*	256
11/1/06	Wednesday	33	254			5.96			254
11/2/06	Thursday	33				6.05			
11/3/06	Friday	33	247			5.71			248
11/4/06	Saturday	34				6.37			
11/5/06	Sunday	33	233			6.29			246
11/6/06	Monday	32	224			6.49			242
11/7/06	Tuesday	29	242			6.29			252
4/1/07	Sunday	29			4.5	4.63		28	
4/2/07	Monday	28	208	33		5.76	57	22	282
4/3/07	Tuesday	36				5.53	411	50	
4/4/07	Wednesday	31	239			4.77	28	9	290
4/5/07	Thursday	37	244	38		4.98	1	2	288
4/6/07	Friday	31				4.78	98	10	
4/7/07	Saturday	37				5.06		10	
4/8/07	Sunday	30	235		4.8	4.34		27	278
4/9/07	Monday	32	223	38		5.64	150	34	274
4/10/07	Tuesday	38				2.99	6	4	
4/11/07	Wednesday	34	262	41		3.84	11	7	276
4/12/07	Thursday	30				3.9	93	27	
4/13/07	Friday	31				3.67		10	
4/14/07	Saturday	30				4.41		24	
4/15/07	Sunday	31	236		5.1	6		320	276
4/16/07	Monday	28	231			5.81	118	56	272
4/17/07	Tuesday	33				6.09	93	20	
4/18/07	Wednesday	34				5.81	291	68	

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	COD	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli.	Hardness
		mg/L	mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100ml	mg/L CaCO3
4/19/07	Thursday	34	255			6.52	86	20	272
4/20/07	Friday	36				5.84	130	40	
4/21/07	Saturday	37				5.96		32	
4/22/07	Sunday	31			5.7	6.8		61	
4/23/07	Monday	33				6.06	1300	500	
4/24/07	Tuesday	34				5.45		20	
4/25/07	Wednesday	38				5.37	196	38	
4/26/2007	Thursday	37				5.66		120	
4/27/2007	Friday	38				4.54		94	
4/28/2007	Saturday	38				5.76		52	
4/29/2007	Sunday	36			5.2	6.31		66	
4/30/2007	Monday	39				5.81		42	
Mean		32.25	239.21	45.42	5.06	5.76	283	68	257.93
Stan Dev		3.45	11.05	8.23	0.45	0.90	349	80	15.11
Min		22	208	33	4.5	2.99	1	2	242
Max		39	262	62	5.7	8.49	1300	500	290
No. Samples		61	29	12	5	61	21	53	29
* Not included in statistics									

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Iron	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
10/8/06	Sunday	0.15	24.1	0.019	17.68		0.224	0.4	7	17
10/9/06	Monday				17.37			0.4	6.9	
10/10/06	Tuesday				18.24			0.5	7.2	
10/11/06	Wednesday				18.57			0.4	7.1	
10/12/06	Thursday				18.73			0.4	7.1	
10/13/06	Friday							0.4	7.2	
10/14/06	Saturday							0.4	7.1	
10/15/06	Sunday				17.29			0.4	7.1	
10/16/06	Monday	0.063	23.5	0.016	16.99		0.223	0.4	6.9	17
10/17/06	Tuesday	0.066	24.4	0.019	18.99		0.273	0.5	7	17
10/18/06	Wednesday	0.066	24.6	0.021	18.88		0.227	0.4	7	17
10/19/06	Thursday	0.07	23.6	0.022	18.17		0.333	0.6	6.9	17
10/20/06	Friday							0.7	7	
10/21/06	Saturday							1	7	
10/22/06	Sunday	0.055	24.4	0.018	17.52		0.765	1	7.1	18
10/23/06	Monday	0.056	23.9	0.017	17.17		0.81	1.3	7	18
10/24/06	Tuesday	0.063	22.9	0.018	18.55		0.59	1.5	7	17
10/25/06	Wednesday	0.064	23.3	0.014	18.08		0.56	0.7	6.9	17
10/26/06	Thursday	0.07	22.7	0.016	17.33		0.43	0.7	7	17
10/27/06	Friday	0.07	23.2	0.014			0.402	0.6	7	17
10/28/06	Saturday	0.072	24.1	0.016			0.33	0.5	7	17
10/29/06	Sunday	0.062	24.1	0.013	16.79		0.202	0.4	7	17
10/30/06	Monday	0.059	23.9	0.01	16.4		0.162	0.4	7	17
10/31/06	Tuesday	0.072	24.1	0.013	17.45		0.159	0.3	7	17
11/1/06	Wednesday	0.073	23.4	0.015	17.75		0.153	0.3	6.94	17
11/2/06	Thursday				18.06			0.5	6.9	
11/3/06	Friday	0.071	23.6	0.012			0.141	0.5	6.8	17
11/4/06	Saturday							0.4	7	
11/5/06	Sunday	0.068	24.3	0.013	16.23		0.184	0.4	7	17
11/6/06	Monday	0.07	24	0.012	15.9		0.178	0.4	7	17
11/7/06	Tuesday	0.09	24.7	0.014	17.69		0.193	0.4	7	17
4/1/07	Sunday				11.86	0.07		0.3		
4/2/07	Monday	0.056	23.2	0.013	13.22	0.06	0.102	0.2	7.1	17
4/3/07	Tuesday				13.82	0.17		0.3	6.9	
4/4/07	Wednesday	0.049	23.8	0.017	14.89	0.26	0.093	0.3	6.9	17
4/5/07	Thursday	0.057	24.8	0.023	13.45	0.73	0.114	0.3	7	17
4/6/07	Friday							0.3	6.7	
4/7/07	Saturday							0.3		
4/8/07	Sunday	0.058	24.9	0.014	13.29	0.13	0.133	0.4	7.3	17
4/9/07	Monday	0.059	24.3	0.019	13.92	0.43	0.12	0.5	6.8	17
4/10/07	Tuesday				15.59	0.3		0.9	7.2	
4/11/07	Wednesday	0.064	24.9	0.02	15.62	0.35	0.113	0.4	7.1	17
4/12/07	Thursday				17.59	0.5		0.3	7.2	
4/13/07	Friday							0.3	7.1	
4/14/07	Saturday							0.3	7.2	
4/15/07	Sunday	0.078	25	0.015	14.65	<0.03	0.105	0.3	7	17
4/16/07	Monday	0.07	24.9	0.016	15.03	0.14	0.098	0.4	7	17
4/17/07	Tuesday				16.79	0.17		0.7	7	
4/18/07	Wednesday				17.14	0.27		0.3	7.1	

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Iron	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
4/19/07	Thursday	0.06	24.8	0.018	17.61	0.21	0.107	0.3	7	16
4/20/07	Friday							0.3	7.3	
4/21/07	Saturday							0.3	7	
4/22/07	Sunday				15.21	0.07		0.2	7	
4/23/07	Monday				14.5	0.16		0.3	7	
4/24/07	Tuesday				16.72	0.13		0.3	7.2	
4/25/07	Wednesday				16.81	0.06		0.4	6.9	
4/26/2007	Thursday				16.36	0.13		0.3	7	
4/27/2007	Friday							0.3	6.9	
4/28/2007	Saturday							0.3	7.2	
4/29/2007	Sunday				15.2	<0.03		0.3	7	
4/30/2007	Monday				13.74	0.57		0.6	7.1	
Mean		0.07	24.05	0.02	16.42	0.23	0.26	0.46	7.02	17.03
Stan Dev		0.02	0.65	0.00	1.78	0.19	0.20	0.25	0.12	0.33
Min		0.049	22.7	0.01	11.86	0.03	0.093	0.2	6.7	16
Max		0.15	25	0.023	18.99	0.73	0.81	1.5	7.3	18
No. Samples		29	29	29	45	22	29	61	59	29
* Not included in statistics										

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Sulfate	Temp (Inf)	Total Coliform	TKN	TDS	TOC	TSS	Turbidity
		mg/L	Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
10/8/06	Sunday	66.24				800	7.4	2	2
10/9/06	Monday							2	
10/10/06	Tuesday							1	
10/11/06	Wednesday							3	
10/12/06	Thursday							3	
10/13/06	Friday							1	
10/14/06	Saturday							4	
10/15/06	Sunday							2	
10/16/06	Monday	72.44				760	8.2	3	2
10/17/06	Tuesday	81.22				821	8.7	2	2
10/18/06	Wednesday	82.81				833	8.1	2	2
10/19/06	Thursday	83.12				831	7.7	3	2
10/20/06	Friday							2	
10/21/06	Saturday							2	
10/22/06	Sunday	76.69				797	7.3	3	2
10/23/06	Monday	73.83		>4839		768	7.8	2	2
10/24/06	Tuesday	72.24				821	8	3	3
10/25/06	Wednesday	74.74		>4839		826	7.9	2	2
10/26/06	Thursday	74.73		>9678		838	8.1	2	2
10/27/06	Friday	76.9		>4839		791	8.1	1	2
10/28/06	Saturday	77.68				808	7.9	2	2
10/29/06	Sunday	72.24				780	7.5	2	2
10/30/06	Monday	64.28		>9678		753	7.5	3	2
10/31/06	Tuesday	74.04		>9678*		797	8.2	2	2
11/1/06	Wednesday	80.68				840	8.3	2	3
11/2/06	Thursday							3	
11/3/06	Friday	78.72				824	8.7	2	2
11/4/06	Saturday							3	
11/5/06	Sunday	71.58				790	7.9	3	2
11/6/06	Monday	65.96				774	8.3	4	2
11/7/06	Tuesday	76.98				824	8.6	3	2
4/1/07	Sunday		13		3.1			2	
4/2/07	Monday	63.4	13		3.1	716	7	3	2
4/3/07	Tuesday		13		3.4			2	
4/4/07	Wednesday	78.4	13		3.3	812	7.5	2	2
4/5/07	Thursday	76.9	13		3.7	820	7.4	2	2
4/6/07	Friday		13	>2420	4.2			2	
4/7/07	Saturday		13		4			3	
4/8/07	Sunday	70.2			3.8	783	7	2	1
4/9/07	Monday	67.4	13	>2420	4.1	764	7.3	2	2
4/10/07	Tuesday		13	1300	4			2	
4/11/07	Wednesday	93.8	13	2420	4.3	856	8	3	3
4/12/07	Thursday		13	>2420	5.4			2	
4/13/07	Friday		14		3.8			2	
4/14/07	Saturday		13		3.6			2	
4/15/07	Sunday	70.4	14		3.4	907	9.2	4	2
4/16/07	Monday	67.6	14	>2420	3	780	8.9	2	2
4/17/07	Tuesday		14	>2420	3.9			3	
4/18/07	Wednesday		14	>2420	3.6			3	

MCES Metropolitan Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Sulfate	Temp (Inf)	Total Coliform	TKN	TDS	TOC	TSS	Turbidity
		mg/L	Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
4/19/07	Thursday	82	14	>2420	4	824	8.6	2	2
4/20/07	Friday		15		3.7			3	
4/21/07	Saturday		14		4.1			3	
4/22/07	Sunday				4			1	
4/23/07	Monday		14	>2420	3.5			4	
4/24/07	Tuesday		15		3.5			2	
4/25/07	Wednesday		15	>2420	3.3			4	
4/26/2007	Thursday		15		3.9			2	
4/27/2007	Friday		15		3.8			2	
4/28/2007	Saturday		15		3.7			2	
4/29/2007	Sunday		15		4.2			1	
4/30/2007	Monday		15		6.3			3	
Mean		74.73	13.86	3798	3.86	804.76	7.97	2.39	2.07
Stan Dev		6.67	0.85	2655	0.65	36.87	0.56	0.76	0.37
Min		63.4	13	1300	3	716	7	1	1
Max		93.8	15	10000	6.3	907	9.2	4	3
No. Samples		29	28	17	30	29	29	61	29
* Not included in statistics									

Exhibit E
Seneca WWTP Sampling Results

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD	COD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L	mg/L
10/8/06	Sunday	23.03	173	0.023	0.09	177	60.5	<3	28
10/9/06	Monday	23.48	180	0.023	0.1	181	58.5	<3	30
10/10/06	Tuesday	23.16	178	0.025	0.07	185	61.2	<3	32
10/11/06	Wednesday	22.7	173	0.027	0.1	181	61.5	<3	32
10/12/06	Thursday	22.73	180	0.025	0.07	178	58.8		33
10/13/06	Friday	22.72							
10/14/06	Saturday	22.88							
10/15/06	Sunday	22.88	184	0.024	0.08	182	60.6	<3	29
10/16/06	Monday	22.77	181	0.024	0.08	185	60.1	<3	34
10/17/06	Tuesday	22.4	183	0.018	0.09	191	62.1	<3	36
10/18/06	Wednesday	22.56	183	0.026	0.07	176	62	<3	36
10/19/06	Thursday	22.5	186	0.024	0.12	179	62.5		36
10/20/06	Friday	22.48							
10/21/06	Saturday	22.95							
10/22/06	Sunday	23.47	191	0.023	0.49	183	61.3	<3	36
10/23/06	Monday	23.81	186	0.022	0.18	185	62.2	<3	38
10/24/06	Tuesday	22.86	188	0.024	~0.03	193	64.3	<3	31
10/25/06	Wednesday	23.14	196	0.023	~0.06	190	64.4	<3	29
10/26/06	Thursday	22.91	194	0.024	0.08	188	63.8		28
10/27/06	Friday	22.84							
10/28/06	Saturday	23.03							
10/29/06	Sunday	23.17			0.08			3	28
10/30/06	Monday	23.27			~0.05			5	35
10/31/06	Tuesday	22.28			~0.03			3	36
4/1/07	Sunday	24.81			0.12			<3	34
4/2/07	Monday	23.44	170	0.022	~0.05	175	60.4	<3	31
4/3/07	Tuesday	22.95			0.09			<3	32
4/4/07	Wednesday	22.99	192	0.023	0.25		63.5	3	33
4/5/07	Thursday	23.07	183	0.023	0.08	178	63.8		36
4/6/07	Friday	23.54							
4/7/07	Saturday	23.67							
4/8/07	Sunday	22.57	192	0.019	0.07		62.1	11	30
4/9/07	Monday	23.26	170	0.021	0.08	174	59	3	29
4/10/07	Tuesday	23.06			0.09			<3	48
4/11/07	Wednesday	23.55	178	0.026	0.08	174	61.3	3	34
4/12/07	Thursday	23.5			0.13				38
4/13/07	Friday	23.56							
4/14/07	Saturday	23.94							
4/15/07	Sunday	23.73	174	0.028	0.12		64.1	<3	30
4/16/07	Monday	23.19	176	0.028	0.08		62.3	<3	33
4/17/07	Tuesday	22.61			0.08			<3	32
4/18/07	Wednesday	22.98			0.11			<3	34
4/19/07	Thursday	23.13	242	0.024	0.13		86.6		38
4/20/07	Friday	22.95							
4/21/07	Saturday	23.1							
4/22/07	Sunday	23.5			0.17			<3	40
4/23/07	Monday	23.43	169	0.025	0.09		64.7	<3	30
4/24/07	Tuesday	22.85			0.08			3	36

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Flow	Alkalinity	Aluminum	Ammonia	Bicarbonate	Calcium	CBOD	COD
		mgd	mg/L CaCO3	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L	mg/L
4/25/07	Wednesday	23.46			0.11			3	38
4/26/07	Thursday	22.72			0.62				44
4/27/07	Friday	22.88							
4/28/07	Saturday	23.2							
4/29/07	Sunday	22.86			0.11			<3	40
4/30/07	Monday	23.04			0.07			<3	38
Mean		23.10	184.08	0.02	0.12	181.84	62.86	3.30	34.13
Standard Deviation		0.44	14.36	0.00	0.11	5.82	5.25	1.42	4.42
Min		22.28	169	0.018	0.03	174	58.5	3	28
Max		24.81	242	0.028	0.62	193	86.6	11	48
No. of Samples		54	25	25	40	19	25	33	40
* Not included in statistics									

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli	Hardness	Iron
		mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100 mL	mg/L CaCO3	mg/L
10/8/06	Sunday	294			8.32			236	0.123
10/9/06	Monday	280			8.6		10	234	0.096
10/10/06	Tuesday	297			8.66		20	242	0.095
10/11/06	Wednesday	278			8.41		20	246	0.118
10/12/06	Thursday	269			8.44	26	20	232	0.111
10/13/06	Friday				8.3	38	22		
10/14/06	Saturday				8.45				
10/15/06	Sunday	268	61		8.42			240	0.116
10/16/06	Monday	273	59		8.17	32	31	236	0.087
10/17/06	Tuesday	279	75		8.06	14	20	238	0.103
10/18/06	Wednesday	279	78		8.28		40	242	0.129
10/19/06	Thursday	283	70		8.25		30	248	0.119
10/20/06	Friday				8.2		33		
10/21/06	Saturday				8.42				
10/22/06	Sunday	286	76		8.24			228	0.127
10/23/06	Monday	274	67		8.5		20	236	0.084
10/24/06	Tuesday	289			8.78		20	248	0.121
10/25/06	Wednesday	299			8.01	52	27	252	0.14
10/26/06	Thursday	297	61		8.81		44	246	0.13
10/27/06	Friday				8.2	29	21		
10/28/06	Saturday				8.33				
10/29/06	Sunday				8.3				
10/30/06	Monday				8.28		8		
10/31/06	Tuesday				8.36	14	7		
4/1/07	Sunday				9.19				
4/2/07	Monday	261	44		10.02		2	242	0.105
4/3/07	Tuesday				9.83	13	10		
4/4/07	Wednesday	275			9.51	33	20	246	0.133
4/5/07	Thursday	272	54		10	18	10	248	0.182
4/6/07	Friday				9.82	548	290		
4/7/07	Saturday				9.74				
4/8/07	Sunday	266			9.52			240	0.189
4/9/07	Monday	268	41		9.62	4	4	238	0.123
4/10/07	Tuesday				9.32	47	28		
4/11/07	Wednesday	282	48		9.01	15	10	238	0.143
4/12/07	Thursday				9.2	238	160		
4/13/07	Friday				9.27	18	20		
4/14/07	Saturday				9.04				
4/15/07	Sunday	285			9.04			238	0.226
4/16/07	Monday	274			9.11	6	20	232	0.183
4/17/07	Tuesday				9.26	5	9		
4/18/07	Wednesday				9.44	6	10		
4/19/07	Thursday	402			9.49	71	47	302	0.095
4/20/07	Friday				9.17	23	20		
4/21/07	Saturday				8.98				
4/22/07	Sunday				8.99				
4/23/07	Monday				8.98		170	246	0.256
4/24/07	Tuesday				9.1		10		

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Chloride ion	Color	Copper	DO	E. coli	Fecal Coli	Hardness	Iron
		mg/L	units	mg/L	mg/L	mpn/100ml	mpn/100 mL	mg/L CaCO3	mg/L
4/25/07	Wednesday				9.13	5	5		
4/26/07	Thursday				9.49		3		
4/27/07	Friday				8.68		10		
4/28/07	Saturday				8.59				
4/29/07	Sunday				9.32				
4/30/07	Monday				8.76		2		
Mean		284.58	61.17		8.88	57	33	242.96	0.13
Standard Deviation		27.07	12.57		0.55	120	55	13.68	0.04
Min		261	41		8.01	4	2	228	0.084
Max		402	78		10.02	548	290	302	0.256
No. of Samples		24	12		54	22	38	25	25
* Not included in statistics									

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	Ortho P mg/L	TP mg/L	pH	Silica mg/L	Sulfate mg/L
10/8/06	Sunday	25.5	0.018	18.3		1.6	2.4	7.1	18	447.82
10/9/06	Monday	25.5	0.012	16.9		0.55	1.5	7.2	22	286.15
10/10/06	Tuesday	26.1	0.012	17.2		0.44	0.78	7.2	18	380.42
10/11/06	Wednesday	25.9	0.011	18.7		0.32	0.59	7.1	18	417.92
10/12/06	Thursday	24.9	0.013	19.2		0.195	0.56	7.1	18	195.87
10/13/06	Friday							7.1		
10/14/06	Saturday							7		
10/15/06	Sunday	26.1	0.039	17.8		0.328	0.58	7.1	18	103.04
10/16/06	Monday	26.2	0.012	16.6		0.461	0.8	7.1	18	85.9
10/17/06	Tuesday	26.9	0.014	17.7		0.388	0.76	7.2	18	94.23
10/18/06	Wednesday	25.8	0.017	18.1		0.371	1.8	7.1	18	287.04
10/19/06	Thursday	25.7	0.025	17.7		1.9	2.6	7.1	18	518.02
10/20/06	Friday							7.2		
10/21/06	Saturday							7.1		
10/22/06	Sunday	25.3	0.036	16		1.99	2.8	6.9	22	387.76
10/23/06	Monday	25.2	0.016	15.4		2.02	2.5	7.1	17	238.86
10/24/06	Tuesday	25.5	0.016	15.5		2.05	2.7	7.1	18	531.07
10/25/06	Wednesday	25.3	0.018	16.2		2.31	3	7.2	18	663.65
10/26/06	Thursday	25	0.022	16.4		3.05	3.7	7.2	19	724.17
10/27/06	Friday							7.1		
10/28/06	Saturday							7.2		
10/29/06	Sunday			17.3			3	7.1		
10/30/06	Monday			15.9			2.2	7.2		
10/31/06	Tuesday			16.8			3.3	7.3		
4/1/07	Sunday			14.3	0.11		1.4	7		
4/2/07	Monday	23.5	0.063	14.4	<0.03	0.72	1.1	7	16	279
4/3/07	Tuesday			14.2	<0.03		1.1	6.5		
4/4/07	Wednesday	24.2	0.066	15.4	<0.03	0.89	1.3	7	16	678
4/5/07	Thursday	24.6	0.094	15	0.06	0.81	1.1	7.1	16	679
4/6/07	Friday							7.1		
4/7/07	Saturday							7		
4/8/07	Sunday	24.5	0.066	14.1	<0.03	0.65	1	6.9	16	282
4/9/07	Monday	24	0.051	14.4	<0.03	1.01	1.4	7.1	16	206
4/10/07	Tuesday			14.4	<0.03		1.4	7		
4/11/07	Wednesday	24.6	0.059	15.5	0.05	0.54	0.93	7.2	16	558
4/12/07	Thursday			15.1	0.08		1.1	7.1		
4/13/07	Friday							7		
4/14/07	Saturday							7.1		
4/15/07	Sunday	24.6	0.063	15.2	0.07	0.49	1	7	16	442
4/16/07	Monday	25	0.053	14.4	<0.03	0.55	0.86	7	16	320
4/17/07	Tuesday			15	<0.03		0.88	7.1		
4/18/07	Wednesday			15.4	0.03		1.1	7.2		
4/19/07	Thursday	29.8	0.028	15.4	0.04	0.019	1.1	7.2	17	39.7
4/20/07	Friday							7.1		
4/21/07	Saturday							7.2		
4/22/07	Sunday			14.8	0.04		0.89	7.1		
4/23/07	Monday	25.4	0.053	14.9	0.04	0.56	0.82	7.1	16	512
4/24/07	Tuesday			15.3	<0.03		0.67	7.1		

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Magnesium	Manganese	Nitrate	Nitrite	Ortho P	TP	pH	Silica	Sulfate
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
4/25/07	Wednesday			16.1	0.03		0.85	7.1		
4/26/07	Thursday			14.2	0.08		0.91	7.1		
4/27/07	Friday							7.2		
4/28/07	Saturday							7.1		
4/29/07	Sunday			15.3	<0.03		1.9	7.1		
4/30/07	Monday			15	<0.03		1.6	7		
Mean		25.40	0.04	15.89	0.04	0.97	1.50	7.09	17.56	374.30
Standard Deviation		1.19	0.02	1.38	0.02	0.80	0.86	0.12	1.66	200.30
Min		23.5	0.011	14.1	0.03	0.019	0.56	6.5	16	39.7
Max		29.8	0.094	19.2	0.11	3.05	3.7	7.3	22	724.17
No. of Samples		25	25	40	22	25	40	54	25	25
* Not included in statistics										

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Temp (Inf)	Total coliform	TKN	TDS	TOC	TSS	Turbidity
		Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
10/8/06	Sunday				1460	8.6	~2	3
10/9/06	Monday				1150	7.5	~2	2
10/10/06	Tuesday				1400	8.2	~2	3
10/11/06	Wednesday				1310	8	~1	3
10/12/06	Thursday		3973		1070	7.4	~2	3
10/13/06	Friday		1670					
10/14/06	Saturday							
10/15/06	Sunday				917	8.5	3	3
10/16/06	Monday		3466		900	8.5	3	2
10/17/06	Tuesday		3973		910	9	~2	3
10/18/06	Wednesday				1070	8.6	~2	3
10/19/06	Thursday				1560	9.2	3	3
10/20/06	Friday							
10/21/06	Saturday							
10/22/06	Sunday				1400	9.3	4	3
10/23/06	Monday				1120	7.9	3	3
10/24/06	Tuesday				1570	9.2	~2	3
10/25/06	Wednesday		>4839		1840	8.9	~3	3
10/26/06	Thursday				1960	9.4	~2	2
10/27/06	Friday		3719					
10/28/06	Saturday							
10/29/06	Sunday						3	
10/30/06	Monday						6	
10/31/06	Tuesday		8812				~2	
4/1/07	Sunday	16		3.6			5	
4/2/07	Monday	18		3.4	1130	7.3	~3	2
4/3/07	Tuesday	17		4			3	
4/4/07	Wednesday	16		4.1	1720	7.8	3	2
4/5/07	Thursday	16		3.5	1740	7.7	4	2
4/6/07	Friday	15.5	>2420					
4/7/07	Saturday	15.5						
4/8/07	Sunday	15.7		3.9	1140	7.6	4	2
4/9/07	Monday	16	106	3.7	1090	7.4	3	2
4/10/07	Tuesday	15.8	1986	4.1			~2	
4/11/07	Wednesday	18	649	4.8	1580	8.2	~3	3
4/12/07	Thursday	16	>2420	3.8			4	
4/13/07	Friday	16.5	2420					
4/14/07	Saturday	16.8						
4/15/07	Sunday	16.9		3.9	1270	9.3	3	2
4/16/07	Monday	17	313	4.2	1250	9	~2	3
4/17/07	Tuesday	17.4	261	4.2			~2	
4/18/07	Wednesday	17.2	866	4.3			3	
4/19/07	Thursday	17.4	>2420	4.5	1090	9.6	3	3
4/20/07	Friday	17						
4/21/07	Saturday	17						
4/22/07	Sunday	16.9		4.4			5	
4/23/07	Monday	17		4.4	1500	7.8	4	5
4/24/07	Tuesday	17		4.2			3	

MCES Seneca Plant Final Effluent Sampling Results
Recycling Treated Municipal Wastewater for Industrial Water Use

Date	Day of Wk	Temp (Inf)	Total coliform	TKN	TDS	TOC	TSS	Turbidity
		Deg C	mpn/100ml	mg/L	mg/L	mg/L	mg/L	NTU
4/25/07	Wednesday	17	272	4.5			3	
4/26/07	Thursday	17		6			3	
4/27/07	Friday	16.8						
4/28/07	Saturday	16.5						
4/29/07	Sunday	17		4.9			5	
4/30/07	Monday	18		3.8			7	
Mean		16.73	2491	4.19	1325.88	8.40	3.10	2.72
Standard Deviation		0.70	2175	0.56	299.35	0.73	1.22	0.68
Min		15.5	106	3.4	900	7.3	1	2
Max		18	8812	6	1960	9.6	7	5
No. of Samples		30	18	22	25	25	40	25
* Not included in statistics								

Metropolitan Council

Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR05-07d

MCES Project Number 070186

TECHNICAL MEMORANDUM 3

Recycled Wastewater System Components and Costs

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In Association with

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Technical Memorandum 3
Recycled Wastewater System Components and Costs

1.0 Introduction

This technical memorandum is the third in a series of memoranda developed under a Metropolitan Council (Council) project titled "Recycling Treated Municipal Wastewater for Industrial Water Use." Funding for this project was recommended by the Legislative Commission on Minnesota Resources (LCMR) from the Minnesota Environment and Natural Resources Trust Fund. The Met Council is providing additional funding for the project through in-kind contributions of staff time. Other state agencies are participating via stakeholder meetings and technical review and input.

The terms "recycled wastewater", "water reuse", and "reclaimed water" are synonymous and used interchangeably in this document and related project documents.

1.1 Objectives

There are three main objectives of this memorandum:

- Provide an overview of water reuse system components and the various technologies to treat wastewater effluent for a range of industrial water uses.

- Define water reuse system components and technologies as the basis for the estimation of the cost of service to supply reclaimed water to Minnesota industries.

- Estimate the water reuse system costs to provide a base level of water quality and alternative quality water supplies to industries.

1.2 Memorandum Contents

The memorandum is structured to provide overview information as a context for assumptions made to define water reuse systems serving Minnesota industries and the associated costs. A "base" level water quality is established, which in turn defines the treatment processes required, and with other system component assumptions form a "base water reuse system" (base system). Costs are developed for the base system and alternatives to meet a range of water quality goals. The memorandum is organized by the following subsections:

- Water Reuse System Components

    - Identifies the basic equipment and structures in a water reuse system.
    - Establishes a conceptual model that this study uses as a basis for the costs estimated for a water reuse system.

- Treatment
  - Defines the water quality requirements for industrial water uses and to meet regulatory requirements.
  - Provides an overview of treatment technologies to meet reclaimed water quality requirements.
  - Establishes the wastewater treatment plant (WWTP) processes for a "base" level of treatment.
  - Identifies treatment technologies for specific industrial uses, with a focus on those with optimum application in Minnesota.
- Storage and Transmission
  - Provides an overview of considerations for storage, pumping, and transmission piping in a water reuse system.
  - Defines the assumptions used to establish storage and transmission costs.
- Costs
  - Defines the financial criteria, other cost assumptions, and describes the cost model developed for this study.
  - Presents the cost of service for a "base system" and alternative reclaimed water quality supplies.
  - Summarizes the cost information and relevance to implementation of water reuse systems with industries in Minnesota.

2.0 Water Reuse System Components

2.1 Overview

Water reuse systems are generally categorized as a centralized system, satellite system or decentralized system. In a centralized water reuse system, all wastewater flow is collected and treated at a central WWTP and distributed to customers from this facility. In a satellite system, a portion of the raw wastewater is diverted to a separate facility for treatment and distribution of reclaimed water. The sludge and waste streams from the satellite treatment facility may be directed back to the collection system for treatment at the main WWTP. Satellite systems are typically located in the upper reaches of the service area where there is a concentrated demand for reclaimed water. Satellite systems provide the reclaimed supply in close proximity to the customer and avoid the longer transmission mains required to supply water from the central WWTP, plus free up capacity in the collection system and central WWTP. Decentralized systems consist of the collection, treatment, and reuse of wastewater from individual homes, isolated communities, industries, institutional facilities, or portions of existing communities near the point of wastewater generation. Treatment of the wastewater and management of sludge and waste streams is all onsite and is separate from a central collection and treatment system (Metcalf & Eddy, 2007). These three configurations are illustrated in Figure 1.

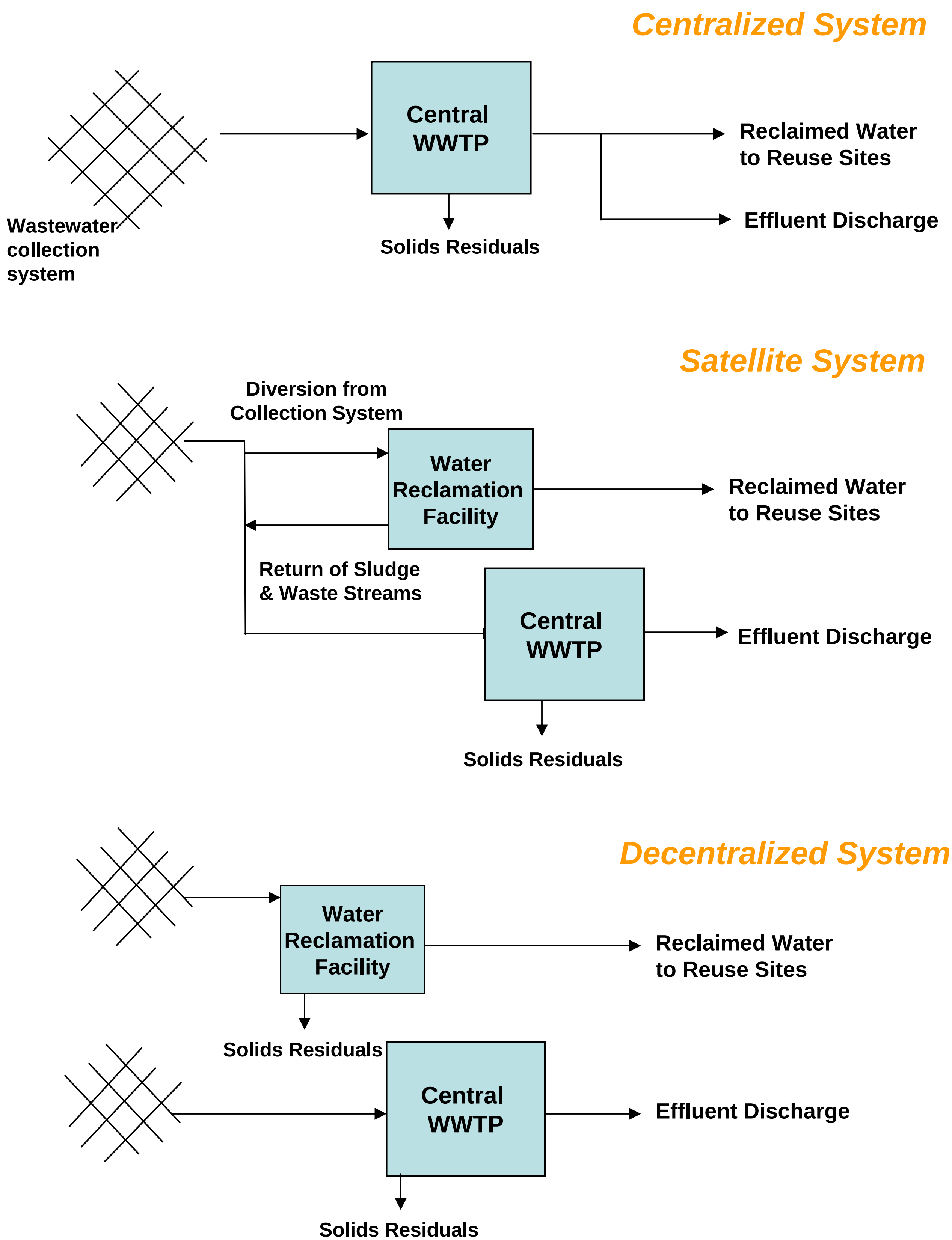

Figure 1. Water Reuse System Configurations

There are four main components of a typical water reuse system, regardless of the system configuration: treatment, pumping, storage, and transmission pipelines.

Storage needs depend heavily on the demand patterns of the customer. Some systems may not require separate reclaimed water storage facilities because the wastewater treatment facility has a base wastewater flow greater than the reuse demand or internal process storage to meet the demand. Storage at or near the point of use can be used to reduce the size of pumping and transmission facilities (associated with capital costs) by avoiding the need to pump at peak demand flow rates.

For centralized treatment, an existing WWTP may or may not need additional treatment facilities, depending on the water quality requirements of the reclaimed water user(s). For a new WWTP, the quality requirements for reclaimed water can be incorporated into the design, and also into the siting of the facility to account for the transmission costs of the reclaimed water. New treatment facilities will be required for satellite and decentralized systems.

All system types will require pumping and transmission piping, with centralized systems typically requiring longer transmission pipelines.

2.2 Basis for this Study

The technologies used to treat and convey water are similar for the centralized, satellite, and decentralized systems. The system model used in this study to estimate reclaimed system costs typifies the centralized system configuration. The reuse system starts with the final effluent of an existing municipal WWTP and the end point is an industry with a specific water supply quantity and quality requirement. Transmission distances of 1 to 10 miles are evaluated. Satellite systems will have similar facilities, but the longer transmission distances are not as likely to be applicable. Decentralized systems will require considerations for solids residual handling, which is assumed to be processed at the WWTP for centralized and satellite systems.

It is important to note that many industries already reuse water from their onsite industrial wastewater treatment systems. In most instances, onsite treatment is the cost-effective alternative for those with sufficient space for new facilities and qualified staff to operate the treatment systems. In addition, many industries also treat their water supply prior to specific uses, such as for boiler feed water. The technologies presented in this memorandum are also generally applicable to treatment of an industrial wastewater and/or water supply.

2.3 Conceptual Model

A basic model of a water reuse or reclaimed water system includes facilities, as depicted in Figure 2, and noted by the component number (1-7) on the schematic:

- Treatment of WWTP Effluent (1)
  - New processes in addition to existing WWTP unit processes, if needed. These processes can be sized for the portion of the plant flow serving water reuse customers.
  - New WWTP processes to replace existing processes during a plant upgrade, such as membrane filtration which replaces clarification.
- Additional Disinfection (2)
  - A residual disinfectant is often used in the transmission system to minimize bacterial growth. Chlorine is assumed for this study.
  - Additional disinfection is required for year-round disinfection and more stringent pathogen limits. The existing facilities may be able to achieve this, but it is assumed new equipment is required.
- Non-Seasonal Storage (3)
  - In some instances, storage will be required to balance the diurnal or other WWTP flow variations, with the requirements of a specific industrial demand for different peak hour, weekly or other dominant demand patterns.
  - Storage will likely be required for WWTPs that reclaim over 50 percent of their flow. Smaller facilities, with less equalization capacity, are more likely to need storage.
  - This model assumes no seasonal storage requirements.
- Pump Station (4)
  - A pump station located onsite at the WWTP.
  - Assumes delivery of supply to industry at 40 psi and same elevation as the WWTP.
- Reclaimed Water Transmission System (5)
  - Transmission main and branch transmission lines supplying water to industrial users of reclaimed water.
  - Variable flows and distances.
- Booster Pumps (6)
  - Some industries may require booster pumps depending on their location and delivery pressure requirements.
  - Industries A-D shown on the schematic represent potential configurations for pumping and treatment facilities not located on the WWTP site (either at the industry or in the conveyance system).
- Industrial Site Treatment (7)
  - Some industries already treat their existing supply (ground or surface water withdrawals or a potable supply) to meet specific water quality requirements. These same processes or modifications may be required with a reclaimed supply.
  - Some industries may require new treatment processes with a reclaimed supply. This may be the most cost-effective approach if there are multiple users in a system with different water quality requirements.

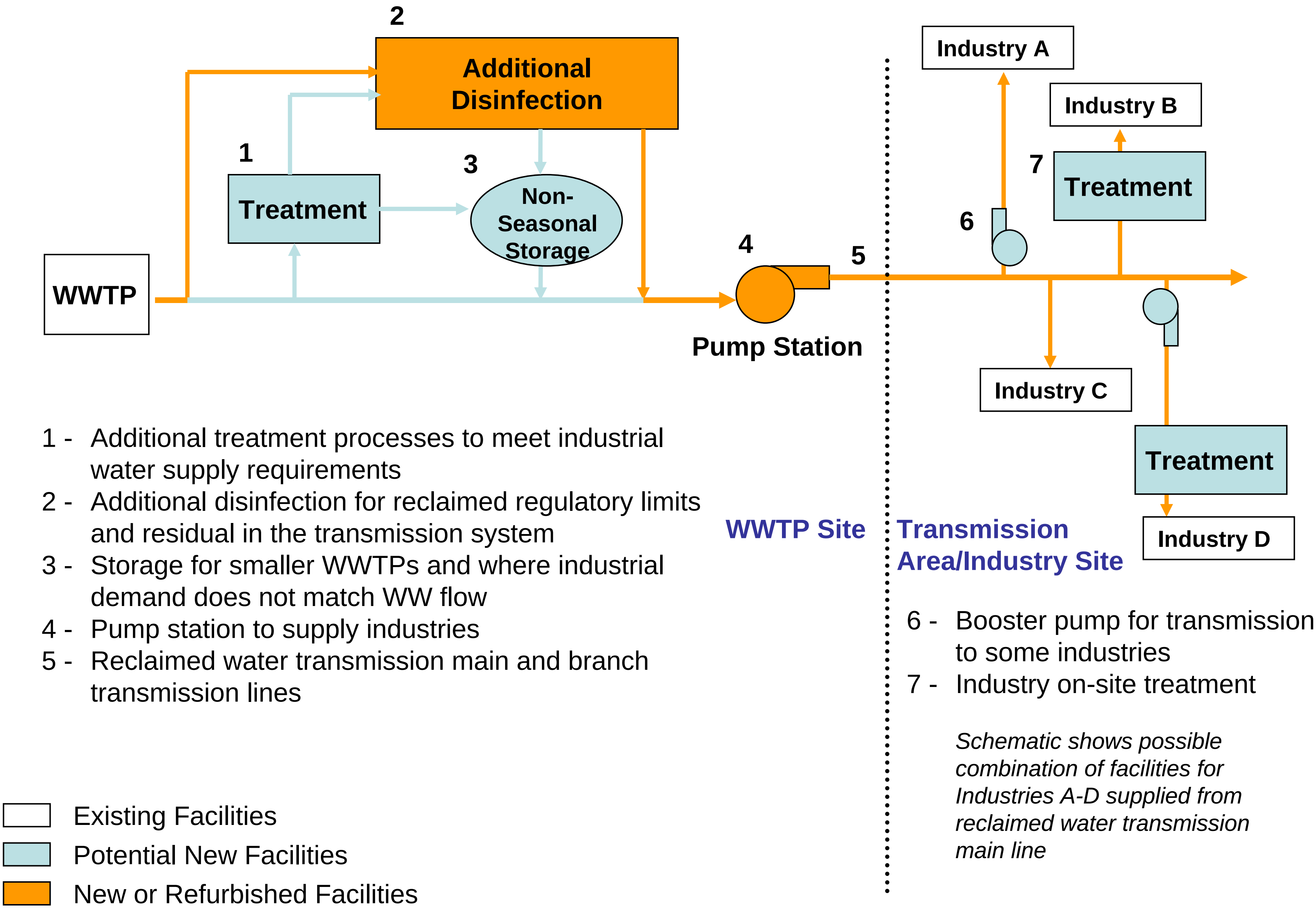

Figure 2. Water Reuse System Conceptual Model

3.0 Treatment

3.1 Industrial Water Quality Requirements

There are two water quality drivers that affect the treatment requirements for reclaimed water:

- The regulatory requirements which are typically for the protection of public health and the environment and focus on microbiological parameters.
- The user-specific requirements for the water supply, which in the case of industries is a very specific set of water quality criteria for a given facility.

3.1.1 Regulatory Requirements

Reclaimed water for industrial use in Minnesota is currently required to meet regulatory limits based on the California Water Recycling Criteria, Title 22 California Code of Regulations (Title 22). The complete list of criteria is included in Appendix A, Exhibit 1. The criteria specific to industrial applications (excluding any irrigation uses) are listed in Table 1. The Minnesota Pollution Control Agency (MPCA) handles permitting recycled wastewater as part of the National Pollutant Discharge Elimination System (NPDES) permit process. The MPCA establishes recycled wastewater water quality criteria on a case-by-case basis and bases its assessment on the Title 22 criteria. Therefore, the Title 22 criteria will serve as the basis for selection of treatment technologies to meet regulatory requirements in this study.

Table 1. California Water Recycling Criteria (Industrial Uses)

Type of Use	Total Coliform Limits	Treatment Required
▪ Cooling water where no mist created ▪ Process water where no worker contact ▪ Boiler feed ▪ Mixing concrete	▪ ≤ 23/100 ml[1] ▪ ≤ 240/100 ml (max in any 30-day period)	▪ Secondary ▪ Disinfection
▪ Cooling water where mist created[2] ▪ Process water where worker contact likely	▪ ≤ 2.2/100 ml[1] ▪ ≤ 23/100 ml (max in any 30-day period)	▪ Secondary ▪ Coagulation[3] ▪ Filtration ▪ Disinfection

Source: Adapted from State of California [2000a].
[1] Based on running 7-day median; daily sampling is required.
[2] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.
[3] Not required under certain conditions.

In addition to the specific constituent limits established by the Title 22 criteria, which are only for total coliform, there are also best practices that must be employed for specific uses. Title 22 defines the water quality/treatment technology criteria applied to reclaimed water for industrial uses under two general categories:

- Disinfected secondary-23 recycled water (secondary-23 recycled water)
- Disinfected tertiary recycled water (tertiary recycled water)

Secondary-23 recycled water is wastewater processed through a secondary treatment system that is disinfected to meet a total coliform limit of 23/100 ml, based on a running 7-day median, and does not exceed 240/100 ml total coliforms in any 30-day period. There are no specific treatment requirements following secondary treatment or for disinfection practices. Any technologies employed must be on the Title 22 approved list or demonstrated to be effective as defined in the regulations. Appendix A, Exhibit 2 contains the list of approved technologies.

Tertiary recycled water must meet a total coliform limit of 2.2/100 ml, based on a running 7-day median, and cannot exceed 23/100 ml total coliforms in any 30-day period. The secondary treatment system effluent must be filtered using any Title 22 approved filtration technology. Disinfection by chlorination requires a 90-minute contact time, based on peak dry weather design flow, with a dose that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 mg-min/l at all times. Other disinfection processes, when combined with the filtration process, must demonstrate inactivation and/or removal of 99.999 percent of the plaque-forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration. In addition, if the tertiary recycled water is used as cooling water in a process with cooling towers or other equipment that produces a mist, a drift eliminator and use of chlorine or a biocide to control *Legionella* and other microorganisms are required.

3.1.2 User-Specific Requirements

The total coliform limits imposed by the Title 22 regulations are the regulatory criteria assumed for all Minnesota industrial reclaimed water uses. The other water quality criteria that will drive the treatment process selection will vary with the specific use of the water. These use-specific criteria do not need to meet a regulatory permit limit, but would likely be listed as site-specific water quality standards in a user agreement. Generalized water quality limits for various industrial uses are provided in Table 2. While this is a limited list, it is the mid-range of quality expected for use by each industry group listed. Industries such as sand and gravel washing operations would have less stringent criteria, while electronics production typically requires much more stringent criteria.

3.2 Water Reuse Treatment Technologies

3.2.1 Overview

Treatment requirements for specific industrial reuse applications are based on multiple factors including: the quality of the source water used by a community, chemicals discharged to the WWTP, the WWTP's existing process train, water reuse regulations, the intended use of the water by the industry, and the quantity of water reclaimed at an individual facility. The treatment technology selected will depend in part on whether treatment is incorporated at the centralized WWTP, onsite at the industry, or at a satellite facility along the distribution line. If storage is required, additional treatment may be required for algae growth and by-products and for residual disinfection. With all these variables, the treatment process and transmission system selected is a site and case-specific one.

Treatment process requirements for reclaimed water beyond standard secondary treatment processes can be categorized by the target parameter (adapted from Metcalf & Eddy, 2007):

- Enhanced suspended and dissolved solids removal (chemical addition/softening)
- Residual suspended solids removal (filtration)
- Residual colloidal solids removal (membrane filtration)
- Residual dissolved solids removal (demineralization/softening)
- Residual and specific trace constituent removal (multiple processes)
- Disinfection (microorganim removal/inactivation)

The relationship of various treatment technologies that can be used to achieve a desired reclaimed water quality is depicted in Figure 3. The treatment process schematic assumes a WWTP secondary effluent as the beginning point of the treatment train. The schematic shows the **potential use** of one or more of the processes targeting a specific parameter. A treatment train would consist of several of the processes shown, but would not include all processes shown.

The effluent quality of various treatment trains is compared in Table 3 to provide a perspective on the additional removals obtained with different levels of treatment. Secondary effluent from an activated sludge facility with and without nutrient removal are listed in the first two columns of the table and represent a quality for non-contact industrial activities without concern for hardness and dissolved solids. An example industrial water use application for secondary treatment water is sand and gravel washing operations or site dust control. Advanced secondary treatment water, which has reduced levels of phosphorus and ammonia, could be used for cooling water purposes if the hardness and dissolved salt concentrations are not too high or an industry provides their own additional onsite treatment. For these process trains (referring to Figure 3) the only processes required would be the disinfection process to meet regulatory standards (for health effects) for micororgansims.

Table 3. Typical Wastewater Treatment Plant Effluent Quality[1]

	Effluent Constituent Concentration by Treatment Level					
Constituent	**Secondary Treatment**	**Advanced Secondary Treatment[2] (Base WWTP)**	**AST with Filtration[3]**	**AST with Chemical Addition & Filtration[4]**	**Membrane Bioreactor[5]**	**Advanced Tertiary Processes[6]**
BOD, mg/L	5-20	5-10	≤5	≤5	<1-5	≤1
TSS, mg/L	5-20	5-10	≤3	≤3	≤2	≤1
TOC, mg/L	8-30	8-20	1-5	*1-5*	0.5-5	0.1-1
Total Phosphorus, mg/L	3-10	≤1	≤0.8	≤0.4	0.5-2	≤0.5
Ammonia, mg/L	10-40	≤3	≤2	≤2	<1-5	≤0.1
Nitrate, mg/L	trace	10-30	10-30	*10-30*	<10	≤1
Total Nitrogen, mg/L	15-45	15-35	15-35	*15-35*	<10	≤1
Turbidity, NTU	2-15	2-8	0.3-2	*0.3-2*	≤1	0.01-1
TDS, mg/L	500-1500	500-1500	500-1500	<100-500	500-1500	≤5-40
Fecal Coliform[7]	$>10^4$/< 200	$>10^4$/< 200	$>10^4$/< 200	---	---	Approx. 0
Total Coliform[7]	$>10^4$/< 23	$>10^4$/< 23	$>10^4$/< 2.2	$>10^4$/< 2.2	<100/<2.2	Approx. 0

[1] Adapted in part from Metcalf & Eddy, 2007.
[2] Conventional activated sludge treatment with nutrient removal based on meeting a discharge permit ammonia limit of 3 mg/L and total phosphorus limit of 1 mg/L. It does not include total nitrogen removal (denitrification).
[3] Filtered advanced secondary treatment effluent using depth filtration, surface filtration, or dissolved air flotation.
[4] Same as filtered advanced secondary treatment effluent, but it includes a chemical addition/coagulation/flocculation/sedimentation process typically using ferric chloride (or alum) and lime for softening (additional unit processes required for softening)
[5] Secondary treatment comprised of aeration with membranes configured as external pressure-driven, integrated submerged, or external submerged rotating bioreactors with biological nutrient removal (for total nitrogen).
[6] Treatment processes to remove residual dissolved solids and specific trace constituents, including chemical/physical and ion exchange softening. These processes follow or include a filtration process.
[7] Values are presented as most probable number /100 ml for estimated fecal and total coliform concentrations without disinfection and with disinfection (without/with). The second concentration is also the reclaimed water quality standard hat the disinfection process is designed to meet.

If advanced secondary treatment effluent is to be used directly for cooling water, additional hardness and dissolved salts may need to be removed. For existing WWTPs, one option is chemical addition/ coagulation/flocculation/ sedimentation. This process system could be incorporated with chemical phosphorus removal to meet both water reuse requirements and NPDES permit limits, either as a polishing step or the principal point of chemical application. Lime softening will be required to remove excessive hardness, however, it does not remove a significant level of

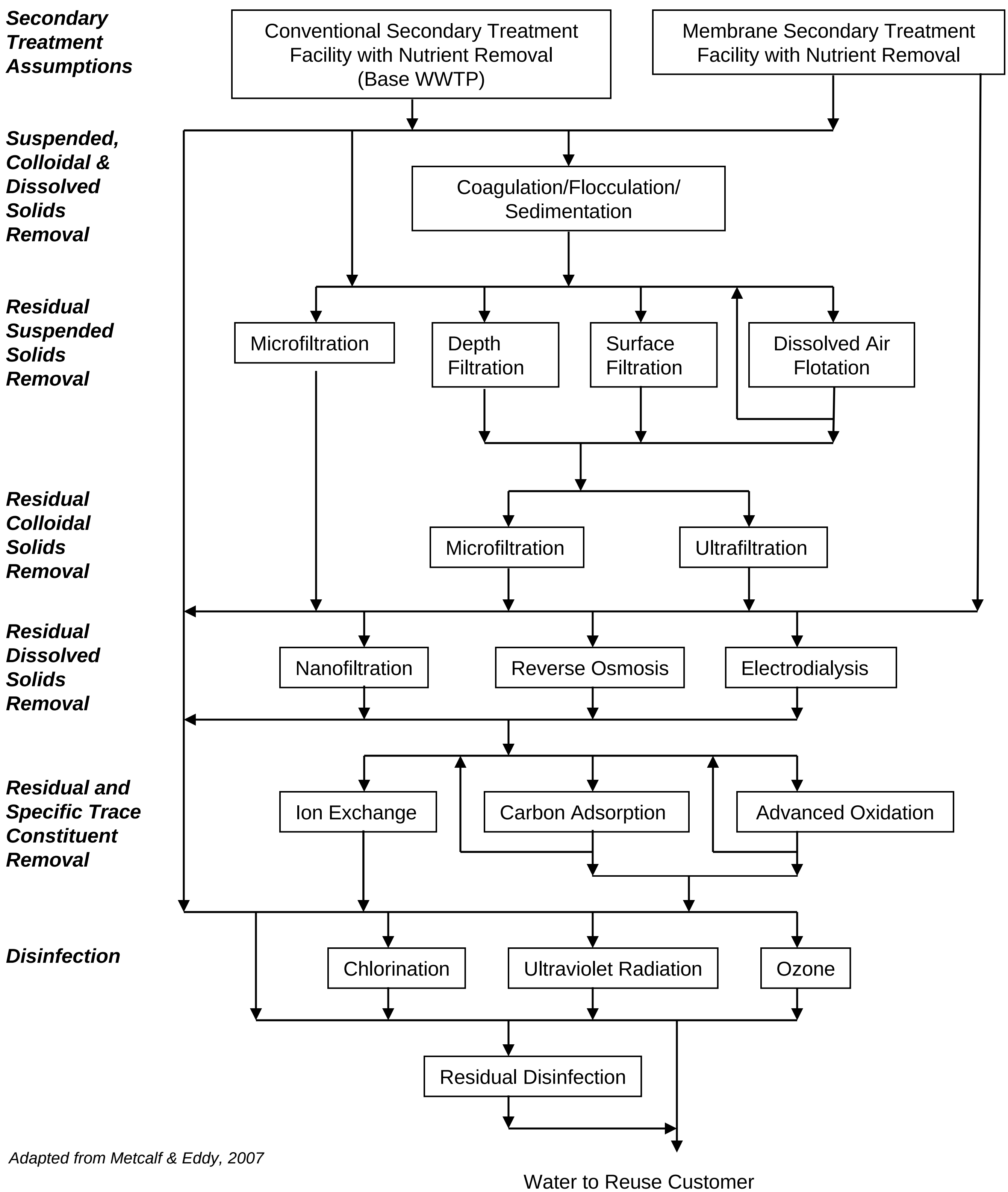

Figure 3. Schematic of Available Treatment Technologies for Water Reuse

dissolved salts. The sedimentation process would be followed by filtration and disinfection. Another alternative is a microfiltration process followed by membrane softening, which could also serve industries that need nearly complete removal of dissolved salts, as with boiler feed water. Removal of dissolved salts can also be handled with an ion exchange unit process after a softening/filtration process.

A secondary membrane WWTP (membrane bioreactor) would be an option for a new or expanding WWTP that expects a significant reclaimed water use. Disinfection requirements would be less and the majority of other constituents are markedly lower than with conventional secondary treatment. Trace constituent removal can also be achieved with carbon adsoprtion and advanced oxidation processes, as discussed in subsequent sections.

If Minnesota continues to adhere to the Title 22 California Water Recycling Criteria and the reuse application requires a recycled tertiary water (for potential human contact uses such as recycle water in cooling towers), most existing WWTPs would need to add a filtration process to supply reclaimed water. The requirement for a chemical addition/flocculation/ sedimentation process will be site-specific and in some cases will depend on the types and size of particles in the secondary effluent and effectiveness of the disinfection process. Some facilities may include the chemical addition process system to meet phosphorus removal goals for both the NPDES permit and specific reclaimed water requirements for the industry served. The treatment technologies approved to meet the Title 22 criteria are listed in Appendix A, Exhibit 2.

The following subsections provide an introduction to unit processes to remove specific categorical constituents. The technologies presented are principally for applications onsite at WWTPs. However, the processes could be used alone or in combination with treatment facilities on the industrial site, particularly where a single user has a unique water quality. Package systems (multiple process units) supplied by manufacturers, applicable to industries with smaller demands and/or to target specific constituents, are not identified in this study. Some proprietary processes are identified for specific unit processes to present the variety of technologies available.

3.2.2 Enhanced Suspended and Dissolved Solids Removal (Chemical Addition/Softening)

With hard, high salt waters common in Minnesota, treatment may be required to lower hardness and dissolved solids in the reclaimed supply to an industry. Traditional chemical addition/coagulation/flocculation/sedimentation processes can be used to reduce dissolved solids, as well as remove suspended solids in the effluent. In addition, a coagulation process may be required to meet the Title 22 regulations for process requirements.

If the industrial water demand uses the majority of the municipal effluent generated, it may be cost-effective to locate the treatment process at the WWTP. Additional benefits can also be realized by the municipality if the planning for a reclaimed supply coincides with expansion and/or improvements planning to meet new discharge limits, notably for phosphorus. The WWTP can incorporate a unit process that optimizes chemical addition for phosphorus removal and achieves some other dissolved solids removal. While lime softening is what is needed for hardness removal; metal salts, the chemical of choice for phosphorus removal, can achieve some reduction in dissolved solids. In addition it provides a polishing step to ensure that phosphorus concentrations in the reclaimed supply are consistently below 1 mg/L.

The facilities for chemical addition through sedimentation can be package or proprietary systems or designed systems, typically with in-ground tanks. The proprietary systems are typically more compact and well suited for a reduced footprint. Two process systems commonly used for coagulation, flocculation and sedimentation are the Kruger Actiflo and Infilco Densadeg. For larger flows, it is likely that specifically designed facilities would be used. The sedimentation process would be followed by a filtration process, as described in Section 3.2.3.

3.2.3 Residual Suspended and Colloidal Solids Removal (Filtration)

The removal of suspended solids from WWTP secondary effluent is a physical process typically performed by one of the following technologies: depth filtration, surface filtration, membrane filtration, and dissolved air flotation (DAF). Membrane filtration is also used for colloidal solids removal.

Depth Filtration

Depth filtration is used in water reuse applications for a variety of purposes including: additional removal of particles for more effective disinfection; as part of the process train following lime softening or chemical precipitation of phosphorus; and as a pretreatment step for additional treatment processes such as membrane filtration, carbon adsorption or advanced oxidation.

Depth filtration has a long history of use in the treatment of potable water. The same principles and design features are used in the treatment of wastewater effluent. Particulate material is removed by passing the water through a filter bed of granular or compressible filter media. There are a variety of depth filters used for reclaimed water applications (Metcalf & Eddy, 2007; as adapted from Tchobanoglous et al, 2003) and include:

- Conventional downflow – consists of a single, dual or multimedia filter material (sand and anthracite are most common)
- Deep-bed downflow – a deeper bed filter than conventional downflow filters; allows for extended run lengths
- Pressure filters – operate as conventional gravity filters, but in a closed vessel under pressurized conditions achieved by pumping; achieve longer filter runs and are typically used for smaller systems
- Proprietary Filters
  - Deep-bed upflow continuous backwash
  - Pulsed-bed
  - Traveling bridge

- Synthetic medium
- Two-stage

Surface Filtration

Surface filtration has been used for the same purposes as depth filtration, with more specific application in the removal of algae and other suspended solids from stabilization pond effluents. In surface filtration, particulate matter is removed by passing water through a filter material, in a mechanical sieving process. Cloth fabrics, woven metal fabrics, and various synthetic materials have been used as the filter material. This subsection focuses on the cloth media filters. Membranes and cartridge filters are also surface filters and are discussed in subsequent subsections.

The cloth media surface filters used are known under the names of Cloth-Media Filter (CMF), Discfilter (DF), and the diamond cloth-media filter (DCMF). The CMF, by Aqua-Aerobic Systems under the trademark name AquaDisk, uses either a needle felt cloth of polyester or a synthetic pile fabric cloth. The cloth covers several disks mounted vertically in a tank. Water flows by gravity from the exterior of the disks through the filter media to an internal collection system. The DF, by Veolia Water Systems under the trademark name Hydrotech, brings water through the central feed tube and the effluent exits on the exterior of the disks. The cloth screen material is either polyester or Type 304 or 316 stainless steel. A more recent product on the market is the DCMF. The cloth filter elements, which have a diamond shaped cross pattern, are cleaned by a vacuum sweep moving along the length of the filter.

Membrane Filtration

Membrane filtration is a fast-growing sector of the filtration market for potable water treatment, wastewater treatment, and water reuse applications. The number of potable water systems in the upper Midwest has increased dramatically over the past decade. Full-scale membrane bioreactor (MBR) WWTPs are also in operation and are an integral part of the facility planning for new and expanding WWTPs in Minnesota. Factors influencing the use of membranes at WWTPs include: a smaller footprint is required, a reduction (or elimination) of chemicals or energy use for disinfection, and use of secondary effluent for water reuse applications.

Membrane filtration is a general term that encompasses a wide range of filtration types. The common feature is the use of a thin membrane for the purpose of removing constituents from water. Membrane processes include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), and electrodialysis (ED). This subsection focuses on MF and UF as unit processes in place of depth and surface filtration for removal of suspended particulates. NF, RO, and ED are processes that also remove dissolved solids, as depicted in Figure 4, and discussed in subsequent sections.

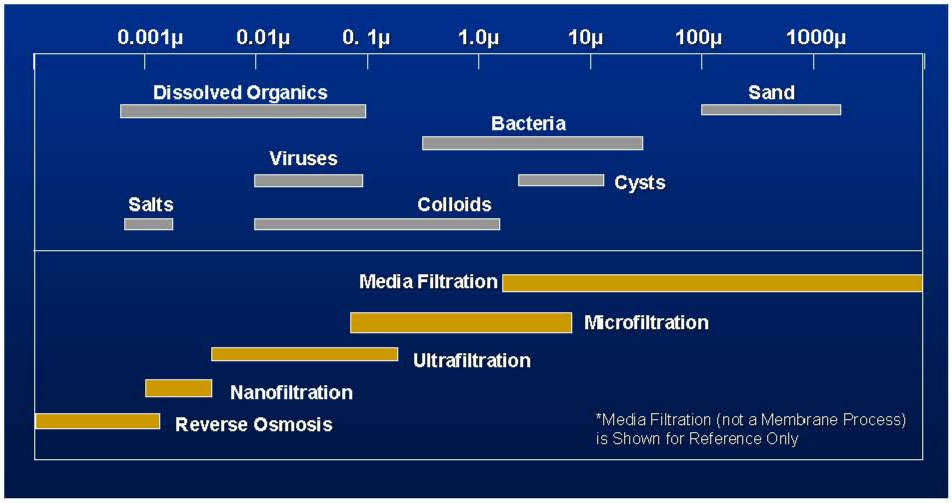

Figure 4. Constituent Rejection by Membranes

Membranes (MF or UF) are used at WWTPs for two primary purposes:

- As a replacement for the sedimentation process (MBR)
- As a filtration process in place of depth or surface filters following secondary treatment

While this section specifically addresses the use of MF and UF for filtration following secondary treatment, similar effluent quality can be obtained from MBRs, depending on the operation of the secondary system.

A significant advantage of MF/UF for production of reclaimed water is the additional barrier protection from microorganisms. As presented earlier in Table 3, total coliform counts following membrane filtration (without any disinfection) are typically below 100/100ml. Following conventional filtration, total coliform counts can be above 10,000/100ml. In addition, MF/UF removes protozoan, cysts, oocysts, and helminths ova. There are also disadvantages to MF/UF, as summarized in Table 4.

Dissolved Air Flotation

Dissolved air flotation (DAF) has traditionally been used in the wastewater treatment industry for removal of oil and grease, to thicken waste-activated sludge, and remove algae from pond water. High-rate DAF technology has made its way into the water treatment industry, where it is used to remove low density floc particles, difficult to remove in a gravity sedimentation process. DAF technology for water reuse systems had been used in place of a coagulation/flocculation/sedimentation process followed by filtration. In some of these applications, it was further treated for dissolved constituents and required a microfiltration followed by a RO process. It is also used to treat algae in systems with seasonal storage ponds and reservoirs.

Table 4. Comparison of Microfiltration/Ultrafiltration to Depth/Surface Filtration[1]

Advantages
Better microorganism removal: removes protozoans, cysts, oocysts, and helminthes; partial removal of bacteria and viruses; could result in lower costs for disinfection.
Smaller footprint for equipment; typically 50-80 percent less.
As an MBR, can be cost-competitive to conventional secondary treatment processes.
Disadvantages
Higher O&M costs associated with: º Energy º Membrane replacement (approximately every 5 yrs) º Monitoring for performance (membrane integrity testing) º Residuals handling and disposal of concentrate (for some facilities)
Pretreatment may be required to prevent fouling, adding to footprint and overall costs.
Scale formation can lead to problems.
Less flow variation capability.

[1]Adapted from Metcalf & Eddy, 2007

The DAF process relies on the formation of microbubbles released after air dissolved under pressure in the water is brought to standard conditions. The bubbles surround slow-settling particles and float them to the surface. The float layer accumulates solids and thickens and is removed by mechanical skimming systems. Clarified water is removed from below the surface.

3.2.4 Residual Dissolved Solids Removal (Demineralization/ Softening)

Reclaimed supplies from areas with traditionally hard source waters and high dissolved salts may require some type of softening or demineralization process to meet the requirements of certain industrial water uses. Most of Minnesota's water supplies are of medium to high hardness and are higher in dissolved salts. However, some waters may have an adequate balance of anions and cations and depending on the use of the water, could be of adequate quality without the need for additional treatment. A complete analysis of the secondary effluent is required to assess the additional treatment needs. The applicable technologies addressed in this study are limited to membrane processes and VRTX, a hydrodynamic cavitation process, since lime softening was summarized in Section 3.2.2. Reuse applications include recycled cooling water uses and electronics production.

There are two basic membrane separation processes: pressure driven and electrically driven. Nanofiltration (NF) and reverse osmosis (RO) are pressure driven processes and require hydrostatic pressure to overcome the osmotic pressure of the feed stream. Reverse osmosis provides the most complete removal of constituents of concern for industrial water use applications, such as TDS, hardness, nitrate, and dissolved organic compounds. The removal rate of these constituents is between 90-98 percent for osmosis and half that for nanofiltration (Wong, 2003). Electrodialysis has removal rates of 50-95 percent for multivalent ions and does not remove smaller organic compounds. Microorganism removal (bacteria, protozoa, viruses) is considered to be 4-7 log removal for RO and 3-6 log removal for NF. No log removal credit is given for

ED. Table 5 summarizes removal rates for the three membrane technologies, as well as other factors related to the process and application uses pertinent to reuse.

Table 5. Factors and Applications for Dissolved Solids Removal Membrane Processes[1]

Factor/Application	Nanofiltration	Reverse Osmosis	Electrodialysis
Factors			
Typical constituents removed	• small molecules • color • some hardness • bacteria, viruses • proteins	• very small molecules • color • hardness • sulfates • nitrate, sodium • other ions • bacteria, viruses	• charged ionic solutes
Molecular weight cutoff	300-1000	<300	na
Energy consumption[2]	0.6-1.2 kWh/m^3	1.5-2.5 kWh/m^3	1.1-2.6 kWh/m^3
Constituent Removal TDS TOC Hardness Nitrate Bacteria	 40-60% 90-98% 80-85% 10-30% 3-6 log removal	 90-98% 90-98% 90-98% 84-98% 4-7 log removal	 50-94% 20-40%[3] ? 55-95%[3] No log credits
Product Recovery	70-90%	50-85%	80-90%
Applications			
Desalination	Not common	Remove dissolved constituents from brackish and sea water	Remove dissolved constituents from brackish water
Water Softening	Partial reduction of multivalent ion concentrations	Most complete removal of multivalent ions	Higher level of multivalent ion reduction than NF
Water Reuse	• TDS and hardness reduction for various applications • for groundwater injection (following MF or UF)	• same as NF, but where lower concentrations are required • with two-stage RO, used for high pressure boiler feed water	• TDS and hardness reduction for various applications • only for ionized compounds; dissolved organic compounds and microorganisms are not captured

[1]Adapted from Tchobanoglous et al, 2003; Stephenson et al, 2000, Wong, 2003; and Metcalf & Eddy, 2007.
[2] Based on treating reclaimed water with a TDS concentration in the range form 1000-2500 mg/L.
[3]Reahl, Eugene, 2006.

All three membrane processes require pretreatment of secondary effluent. In all cases, particulate matter must be removed to levels typical of the filtration technologies discussed previously. Cartridge filters, pressure-driven filters, are commonly installed ahead of RO membranes. Other pretreatment requirements depend on the secondary effluent quality and type of membrane selected. Pretreatment processes can be required for iron and manganese removal (to avoid scaling on the membranes), disinfection to avoid biofouling (some membranes are sensitive to chlorine), pH adjustment to avoid scale formation, and antiscalants. ED membranes have the least pretreatment requirements, with cartridge filtration recommended.

In addition to pretreatment considerations, there is the management and disposal of the waste streams. The amount of product water resulting from the treatment of the incoming water, also called recovery, can range from 50-85 percent for RO, 70-90 percent for NF facilities, and 80-90 percent for ED. Disposal options for the concentrated waste streams vary from energy intensive thermal evaporation processes to ocean discharge. As concern for trace constituents grows, surface water discharges may be less likely. Concentrate disposal and flexibility of options should be incorporated in the planning stages to assure it is the optimum choice for a specific site and application.

VRTX Technologies has a product that prevents scale and biofouling in cooling water systems without the use of chemicals. It relies on localized effects of hydrodynamic cavitation to create high temperatures and pressures that break the bonds between the dissolved mineral and water. Minerals (including calcium) are precipitated out of the water stream as solids for disposal. Most microbiological cells are also destroyed at these extreme temperatures and pressures and dissolved gases leading to corrosion are stripped away. This technology may be an appropriate application for reclaimed waters where hardness is an issue; but may not apply to high dissolved salt waters.

This unit process will likely be located on the industry site. A major benefit of the technology is the reduction in chemical use. If it is at the WWTP site, then disinfectant may need to be added for transmission to the industry, which may not be cost-effective or meet other industry goals.

3.2.5 Residual and Specific Trace Constituent Removal (Multiple Processes)

Residual amount of organic and inorganic constituents can still remain after reverse osmosis and may need to be removed for specific industrial applications. Other constituents occur in trace amount in conventionally treated secondary effluent. These trace constituents are of concern because of known or suspected toxicity. Of heightened interest, is the environmental impact of several emerging contaminants of concern, such as:

- pharmaceutically active chemicals (PhACs)
- endocrine disrupting compounds (EDCs)
- disinfection by products (DBPs) such as N-nitrosodimethylamine (NDMA)
- a host of groundwater supply contaminants such as 1,4-dioxane and methyl tertiary-butyl ether (MTBE)
- new and reemerging pathogenic microorganisms such as *Legionella pneumophila, Cryptosporidium,* and *Giardia*

These emerging contaminants of concern have been an issue for aquifer recharge and reuse applications that affect potable water supplies. They are likely not an issue for industrial water reuse except for applications with potential for human or animal consumption. They are mentioned because it is a concern for potable water treatment and water reuse in general and could affect future regulations and the direction for best management practices that would impact the entire water reuse industry.

While NF and RO are able to remove or reduce most of these emerging contaminant compounds, there are some processes and groups of processes that may be more effective and/or economical. The treatment processes with the widest range of application include:

- Adsorption
- Ion Exchange
- Advanced Oxidation – hydrogen peroxide, ultraviolet radiation (UV), and ozone

Other processes used to destroy or remove trace constituents include: distillation, chemical oxidation, photolysis and advanced biological treatment.

Adsorption

Activated carbon is the most commonly used adsorbent in water reuse treatment systems and will serve as the general reference for adsorption technologies. Adsorption is used in water reuse treatment systems for either the continuous removal of compounds or as a barrier to protect against breakthrough from other unit processes. Organic compounds are the most commonly removed constituent with adsorption processes, but adsorption has been used to remove nitrogen, sulfides, heavy metals, and odor compounds.

A fixed-bed downflow reactor configuration is the most typical for activated carbon adsorption. This configuration is assumed for the cost information presented in Section 4.

Ion Exchange

Ion exchange involves the replacement of an ion in the aqueous phase for an ion in the solid phase. In the case of water reuse systems, the goal is to remove specific ions from the treated wastewater effluent to the solid material in the ion exchange column. The applications expected for water reuse systems supplying industries include:

- **Softening:** Industrial water uses such as recycled cooling water require removal of calcium and magnesium ions. Ion exchange units with a cationic exchange resin, exchange sodium for calcium and magnesium ions in the water. Several industries surveyed for this project used softening ion exchange units for various uses including cooling water.
- **Nitrogen Control:** Typically synthetic resins are used to remove ammonium and nitrate.

- **Heavy Metals Removal:** Industrial processes have historically used ion exchange to recover heavy metals. A variety of natural an synthetic resins are available with selectivity for specific metals.
- **Total Dissolved Solids Removal:** Anionic and cationic exchange units used in a series can be used to remove TDS or demineralize the water.
- **Reduction of Organics:** Ion exchange can be used to remove the highly ionized organics in the water. Specifically prepared resins have been used to reduce TOC levels by 50 percent.

Advanced Oxidation Processes (AOPs)

Advanced oxidation processes destroy trace constituents that are not completely oxidized by conventional oxidation processes. There are a host of processes and groupings of processes that have been used, principally in the drinking water industry and research stages, to handle specific contaminants and the emerging contaminants of concern. These processes are all applicable to treatment of water for reuse.

The primary AOPs that have application to water reuse systems include:

- Hydrogen Peroxide/Ultraviolet Light (H_2O_2/UV)
- Hydrogen Peroxide/Ozone (H_2O_2/Ozone)
- Ozone/Ultraviolet Light (Ozone/UV)

The UV processes are the most promising for Minnesota application, where UV radiation is becoming amore common form of disinfection. UV facilities could be retrofitted or planned for new construction to handle any specific removal of trace constituents.

The use of AOPs will be a very site-specific application or is a consideration for future management of trace constituents. The technology is identified in this study to emphasize that applications do exist and research is ongoing to prepare for handling the treatment of these constituents.

3.2.6 Disinfection (Microorganism Removal/Inactivation)

Most Minnesota WWTPs disinfect with chlorine or UV. The main compounds used for chlorination are gaseous chlorine (Cl_2) and liquid sodium hypochlorite (NaOCl). Because of safety concerns and regulatory requirements, many WWTPs have moved from chlorine gas to sodium hypochlorite. Other disinfectants (not emphasized in this study) include ozone, chlorine dioxide, and calcium hypochlorite (for smaller WWTPs). Membranes also provide a barrier to microorganisms and reduce or can potentially remove the need for chemical or UV disinfection.

Given the elevated potential for human contact, disinfection is an essential part of the process train in treating water for reuse. Disinfection requirements for reuse under the Title 22 criteria are greater than for discharge to the receiving stream under most Minnesota NPDES permits. Specific needs for Minnesota's wastewater treatment facilities to achieve microbial limits to protect public health are discussed under Section 3.3.

3.3 Municipal WWTP Processes and Water Quality

3.3.1 Overview

Assumptions were made to define a starting point for treatment requirements to meet regulatory and industrial specific uses of a reclaimed water supply. For this project, it is assumed that the WWTP is supplying an effluent from a secondary treatment system. The secondary system is an activated sludge system with nitrification and phosphorus removal, defined for this project as 'advanced secondary treatment'. While some Minnesota municipal facilities may have total nitrogen removal or the capability, the majority do not. Hence, in this study only ammonia nitrogen removal is assumed under the term 'advanced secondary treatment' or when the term nutrient removal is used.

The majority of Minnesota's larger WWTPs have an advanced secondary treatment process or will have this capability as Total Maximum Daily Loads (TMDLs) are developed across the state. New facilities and major expansions permitted in the state are anticipated to have nutrient limits that would dictate this assumed process train. In addition, because one of the largest and most likely industrial uses of reclaimed water is for cooling water, which requires minimal levels of phosphorus and ammonia – use of an advanced secondary treatment system effluent is an optimum starting point. This assumption does not exclude consideration of other types of wastewater treatment facilities for water reclamation, such as fixed film systems (trickling filters and rotating biological contactors), stabilization ponds, chemical/physical package systems, or natural systems (wetland treatment). However, it is likely that additional processes would need to be added to meet the water quality requirements of a specific industry and the regulatory requirements.

3.3.2 Base WWTP Definition and Effluent Quality

A "base level" water quality produced by a "base WWTP" was assumed for purposes of estimating costs of service for a municipality to supply an industry with reclaimed water. The base level reclaimed water quality is defined for this study as a hard water that meets regulatory standards for non-contact industrial water uses. The base level water quality is assumed to have the constituent concentrations listed in Table 6, as typical of an advanced secondary wastewater facility effluent. This list includes constituents in most Minnesota NPDES permits (for discharge to a receiving water), those required by the California Title 22 regulations, and others that relate to specific industrial water uses, such as total dissolved solids (TDS).

If a facility has advanced secondary treatment, the first seven constituents listed in Table 6 (through fecal coliform) are expected to be included in the facility's NPDES permit, with the exception of nitrate. The concentrations listed for these seven parameters are considered "typical" effluent concentrations, based on a review of Minnesota WWTP discharge reports and typical operations of similar secondary WWTPs across the U.S. The BOD and TSS concentrations listed are typically less than the concentration limits in the existing NPDES permit, which are commonly 20 mg/L and 30 mg/L, respectively.

The total coliform limit is based on the Title 22 criteria for a secondary-23 recycled water and assumes a use of the water that does not contact humans. The remainder of the constituents listed are those used in treatment technology selection and sizing of equipment/processes for removal of residual colloidal/dissolved solids and trace constituents. The concentrations listed reflect the variability in the source waters in Minnesota. In general, Minnesota has hard water with high salt concentrations. These concentrations increase with domestic practices, particularly home softening units. Average (Source A) and Hard (Source B) water quality types are assumed for cost analyses.

Table 6. Assumed Base WWTP Effluent Quality

Constituent	Effluent Concentration[1]
BOD, mg/L	<10
TSS, mg/L	<10
Total Phosphorus, mg/L	≤1
Ammonia, mg/L	≤3
Nitrate, mg/L	<30
pH	6-9
Fecal Coliform[2] , No./100 ml	< 200
Total Coliform[3] , No./100 ml	< 23
TOC, mg/L	10
Turbidity, NTU	3
Silica, mg/L	20
TDS, mg/L	750/1500
Chloride, mg/L	250/500
Hardness, mg/L as CaCO3	250/400
Alkalinity, mg/L as CaCO3	150/300

1 Average or maximum effluent concentration of constituent. When two concentrations are given, these represent the average concentration for two different supplies: Source A (Average), Source B (Hard, High Salt).

2 Calendar month geometric mean.

3 Median concentration for seven day period, where the number does not exceed 240/100 ml in more than one sample in any 30 day period.

3.3.3 Base WWTP Unit Processes

Existing Facilities

The base WWTP is comprised of preliminary treatment, primary treatment, and a secondary treatment activated sludge system with nitrification and phosphorus removal, followed by a disinfection process. Activated sludge systems are typically comprised of an aeration and sedimentation process. The use of membrane bioreactors is emerging in the U.S. and is being evaluated by some municipalities in Minnesota looking at expansions and upgrades. In general, membrane bioreactors reduce space by replacing the sedimentation process, while producing a higher quality effluent. Membrane bioreactors are included in Figure 3, recognizing it as a future technology for Minnesota.

The type of phosphorus removal is not identified in the Base WWTP. A facility could use chemical or biological phosphorus removal to achieve a 1 mg/L total phosphorus limit. Certain technologies could be selected because of benefits to the phosphorus removal mechanism. For example, if a facility uses chemical phosphorus removal, the use of a chemical softening process with coagulation, flocculation, and sedimentation could provide a more optimum use of chemicals for phosphorus removal, provide flexibility in chemical addition points, and reduce suspended solids and hardness. For example, the City of Mankato considered these benefits in the selection of their processes to produce reclaimed water for the cooling towers of the Mankato Energy Center.

Additional Disinfection Requirements

The base WWTP assumes the facility has disinfection equipment and structures to meet Minnesota's seasonal fecal coliform limits. The majority of Minnesota's WWTPS are permitted to disinfect from April through October and is the assumed period of disinfection for this study. There are three disinfection system improvements required to produce a reclaimed supply from WWTPs in Minnesota for a non-contact industrial water use:

- Year-round disinfection
- Higher levels of disinfection to meet reclaimed water pathogen limits
- Transmission system residual disinfection

In Minnesota, disinfection for pathogens in WWTP effluent is required only from April through October. For a reclaimed supply, disinfection must occur year-round or any time during which reclaimed water is delivered to users. While the existing facilities will be adequate to disinfect the WWTP effluent year-round to the levels required by the NPDES permit limit (typically a fecal coliform limit of 200/100 ml) there will be additional O&M costs associated with the extra five months of disinfection a year.

The California Water Recycling Criteria include a total coliform limit of 23/100 ml for the base system reclaimed supply. Most Minnesota WWTPs use chlorination or UV radiation for disinfection. In the case of chlorination systems, higher levels of disinfection can be achieved by increasing the concentration of chlorine in the effluent while using the same contact tanks. With UV radiation, the need to upgrade or add equipment will depend on the peaking factor criteria used to design the system and other flexibilities designed in the system.

The other disinfection requirement is the presence of a residual disinfectant in the transmission system. The most common practice is the use of sodium hypochlorite which is the practice assumed for this study. While some systems may have adequate capacity to add a residual with their existing chlorination system, those with UV radiation processes will need new facilities and equipment.

Sodium hypochlorite feed systems provide a unit process that can meet the three disinfection system improvement requirements: to meet a year-round disinfectant, provide a higher level of disinfection, and maintain a residual in the transmission system. A conservative assumption is made that all WWTPs will require new equipment for application of sodium hypochlorite. It is assumed that the chlorine dose can be elevated sufficiently to meet the disinfection requirements without the need for additional detention time (new contact tanks).

Chlorine doses were assumed as follows for the two annual operating practices and residual disinfection:

- April-October months with disinfection practiced by Minnesota WWTPs, where chlorination provides incremental disinfection from the NPDES pathogen limit to the reclaimed water pathogen limit.
- November-March months with no disinfection practiced by Minnesota WWTPs to provide disinfection to the reclaimed water pathogen limit.
- A chlorine dose of 2.5 mg/L was selected to achieve adequate residual through the transmission system. This is a dose commonly used by reclaimed systems across the country.

Chlorination practices at MCES facilities and facilities with reuse systems were reviewed to identify chlorine doses for existing systems to meet NPDES permit limits and to meet a variety of state reclaimed water criteria. For MCES facilities, average chlorine doses to meet NPDES discharge limits range from 2-4 mg/L with peak demands requiring 6 mg/L of chlorine. A reclaimed system in Cary, North Carolina reported the use of an 8 mg/L dose to meet pathogen kill and residual disinfection requirements. Use of the Refined Collins-Selleck Model to estimate chlorine dosages for disinfection of a nitrified secondary effluent (White, 1999) to meet a 23/100 ml total coliform limit indicates that for a contact time of 15 minutes (the contact tank design criteria typically used in Minnesota), a dose of 4-15 mg/L is required depending on the nitrification process (ammonia at concentrations from 0.5 – 2 mg/L).

For this study, it is assumed that a chlorine dose of 6.5 mg/L applied to an advanced secondary treatment system effluent is required to meet a total coliform limit of 23/100 ml. For the disinfection season months of April through October it is assumed that WWTPs have a disinfection process equivalent to a chlorination system with an average dose of 3 mg/L. Therefore, an additional 3.5 mg/L chlorine is required to meet the more stringent reclaimed water pathogen limit from April to October. When the 2.5 mg/L chlorine dose for disinfection residual is included, the chlorine doses are as follows:

- April-October (7 months): 3.5 mg/L + 2.5 mg/L = 6 mg/L
- November-March (5 months): 6.5 mg/L + 3.5 mg/L = 9 mg/L
- Average Annual (based on weighted average, rounded) = 7 mg/L

3.4 Selection of Water Reuse Treatment Technologies for Specific Industrial Water Uses

3.4.1 Factors to Consider

There are a host of factors to consider in selecting a treatment process train for water reuse applications. The main factors have been discussed in this document and were used to define the base level water quality and base WWTP processes, including:

- Water reuse quality goals
- Effluent wastewater characteristics
- Type of water reuse application (purpose of water supply)

The other factors to consider for specific applications are those typical of any planning study:

- Integration with existing facility processes, hydraulics, and site conditions
- Future facility or other service area expansions and proximity and treatment requirements for water reuse applications
- Process flexibility (for new and existing processes)
- Environmental issues
- Operation and maintenance (O&M) requirements including energy, chemicals, labor, automation, laboratory, and general maintenance.

3.4.2 Technologies by Target Constituents

Section 3.2.1 presented the treatment processes typically used to produce different levels of quality for water reuse applications. Table 7 lists these processes and identifies the specific categories of constituents they remove. The base WWTP defined for this study removes suspended solids, dissolved organic matter, ammonia-nitrogen, phosphorus, and pathogens (advanced secondary treatment). This supply may be adequate for some industries without additional treatment.

The next level of treatment is usually filtration for consistent disinfection practices and/or additional particulate removal. Filtration is required by Title 22 for water used in cooling towers, or other applications with the potential for human contact.

Particulate matter includes: suspended solids, colloidal, and/or organic matter and the related phosphorus (cell content). Filtration reduces particulates, including pathogens (bacteria, protozoan cysts, and oocysts), and also improves the disinfection process by removing particles that shield pathogens from the disinfectant (chlorine, UV, ozone).

The next level of treatment will typically require some degree of dissolved constituent removal or additional nutrient removal. Hardness, related salts, metals, silica, and color were some of the constituents identified in Table 2 that required limited concentrations for various industrial uses. The treatment technology selected will depend on the exact constituents and amount to be removed, as well as the other processes used for the main WWTP and reclamation-specific processes.

Table 7. Treatment Technologies/Processes for Removal of Constituents in Wastewater for Water Reuse Applications

Unit Operation or Process	Suspended Solids	Colloidal Solids	Particulate Organic Matter	Dissolved Organic Matter	Nitrogen	Phosphorus	Trace Constituents	Total Dissolved Solids	Pathogens
Coventional Secondary Treatment	x			x					
Advanced Secondary Treatment	x			x	x	x			
Coagulation/Flocculation/Sedimentation	x	x	x	x		x		x	
Depth Filtration	x								x
Surface Filtration	x		x						x
Microfiltration	x	x	x						x
Ultrafiltration	x	x	x						x
Dissolved Air Flotation	x	x	x						x
Nanofiltration			x	x			x	x	x
Reverse Osmosis				x	x	x	x	x	x
Electrodialysis		x						x	
Carbon Adsorption				x			x		
Ion Exchange					x		x	x	
Advanced Oxidation			x	x			x		x
Disinfection				x					x

Source: Adapted from Metcalf & Eddy, 2007.

Specific industrial applications may require the removal of trace constituents in the wastewater. The technology selected will vary with the constituent and specific application.

3.4.3 Treatment Technologies for Minnesota Industry Reuse Applications

Approach

One of the objectives of this technical memorandum is to define water reuse system requirements and costs for Minnesota's industries. Given the diversity of source water quality characteristics and varying requirements of the industries in Minnesota, a technology-based approach is used. Industry-specific water quality requirements are compared to a set of reclaimed water system supplies, with defined water quality constituents and concentrations. The different reclaimed supplies are defined by specific treatment technologies, which provide the basis for estimating costs. A range of treatment requirements and costs can then be applied to industry categories.

Five types of reclaimed water, listed in Table 8, are used to categorize the reclaimed water quality options available for specific industrial water supply requirements. The classification is based on a train of treatment technologies to meet a set of water quality goals. This classification system is based on treatment of the base WWTP effluent, which is a secondary activated sludge system with nitrification and phosphorus removal. New facilities or major expansions could incorporate membrane bioreactors, which are not considered in this classification system. For comparison purposes, the effluent quality of membrane bioreactors would be similar to Tertiary 2-Membrane Filtration. Table 9 identifies the typical water quality constituent concentrations for the five classes of reclaimed water.

Industry Treatment Requirements

Water use for a significant portion of Minnesota's industries is tracked through the Minnesota Department of Natural Resources' (MDNR) Water Appropriations Permit program. The water demand analysis of Minnesota's industries, documented in Technical Memorandum 1 (June 2006) of this project, used the industry categories established for the permit program's database. These same categories are used to document the treatment requirements and costs for Minnesota's industries.

Many industries have multiple uses for their total water supply. The quality requirements can vary with the type of use and many industries currently use different water supplies to meet their various needs. One of the most significant industrial uses of water is for cooling. Water can also be used in the industry's manufacturing or washing processes, as boiler feed water, for landscape irrigation, or typical potable uses for employees. Table 10 lists the dominant water uses and the reclaimed water quality (based on the classification systems defined in Tables 8 and 9) required for Minnesota industries. Table 11 provides the subcategories for major industry categories that have a wide range of industry types.

Table 8. Reclaimed Water Classifications

Classification	Characteristics
Advanced Secondary	• For non-contact industrial uses with low concern for hardness and dissolved solids • Base WWTP process train • Meets secondary-23 recycled water criteria
Tertiary 1 Conventional	• For industrial uses with human contact potential and/or industries that require partial hardness and dissolved salt removal • Requires a coagulation/flocculation/sedimentation process with filtration • Removes some hardness and dissolved salts; provides some soluble organic removal and color removal • Meets tertiary recycled water criteria
Tertiary 2 Membrane Filtration	• For industrial uses with human contact potential and/or industries that can use hard/high salt water • Provides soluble organic removal and color removal • Provides pathogen removal and reduces disinfection requirements • Meets tertiary recycled water criteria
Tertiary 3 Membrane Softening	• For industries requiring low dissolved salts • Requires Tertiary 2 water followed by softening with RO or ED depending on the target constituents • Meets tertiary recycled water criteria
Tertiary 4 Advanced	• For industries requiring low dissolved salts and removal of trace constituents • Requires Tertiary 3 water with RO and either ion exchange, carbon adsorption or advanced oxidation processes, depending on the target constituent. • Meets tertiary recycled water criteria

As shown in Table 10, a significant portion of industries use their water supply as cooling water. For most industries that require water as a cooling source for various equipment and processes, cooling water accounts for 30-95% of the water use. Existing facilities still use once-through cooling and some of these facilities could use the base quality supply, depending on the hardness and salt concentrations. As industrial facilities upgrade, once-through systems are being replaced by recirculating systems that use less water. Most new facilities with a ground water supply source use recirculating systems, in keeping with Minnesota water appropriations permit guidelines.

Recirculating systems have limits on the concentration of dissolved salts in the cooling water, where excessive concentrations result in scaling and corrosion problems. There are different unit processes and groupings of processes that can remove salts and provide a softened supply for cooling water uses. Both Tertiary 1 and 3 could provide an adequate supply for cooling water, depending on the source water quality and the cycles of concentration required for the cooling water system. It is also possible that the base reclaimed supply with or without filtration could meet cooling water requirements if the industry uses chemicals to keep the water in the right ionic balance to prevent scaling. Potable supplies with medium to high hardness are often treated with scalants for use as cooling water. The generally high hardness and high salt concentrations in Minnesota waters and wastewater make it plausible that Tertiary 1 and 3 level water may be required for recirculating cooling water use in Minnesota.

Table 9. Water Quality for the Reclaimed Water Classifications[1]

	Reclaimed Water Concentration[2]				
Constituent	**Advanced Secondary**	**Tertiary 1 Conven-tional**	**Tertiary 2 Membrane Filtration**	**Tertiary 3 Membrane Softening**	**Tertiary 4 Advanced**
BOD, mg/L	5-10	≤5	<1-5	≤1	≤1
TSS, mg/L	5-10	≤3	≤2	≤1	≤1
Total Phosphorus, mg/L	≤1	≤0.4	≤1	≤0.5	≤0.5
Ammonia, mg/L	≤3	≤2	≤3	≤0.1	≤0.1
Nitrate, mg/L	10-30	10-30	10-30	≤1	≤1
Total Coliform[3], No./100 ml	< 23	<2.2	<2.2	Approx. 0	Approx. 0
TOC, mg/L	8-20	1-5	0.5-5	0.1-1	Approx. 0
Turbidity, NTU	3	0.3-2	≤1	0.01-1	0.01-1
TDS, mg/L	750/1500	<500/800	750/1500	≤5-40	≤5-30
Hardness, mg/L as CaCO3	250/400	100/200	250/400	<30	<20
Trace Constituents	Variable	Variable	Variable	Variable	Approx. 0

Source: Multiple sources including Metcalf & Eddy, 2007; HDR Engineering, Inc, 2001; Minnesota Discharge Monitoring Reports, 2004; and vendor literature.

[1] Classifications are described in Table 6 of this document.

[2] Average or maximum effluent concentration of constituent. When two concentrations are given, these represent the average concentration for two different supplies: Source A (Average), Source B (Hard, High Salt).

[3] Median concentration for seven day period, where the number does not exceed 240/100 ml for advanced secondary treatment and 23/100ml for tertiary treatment in more than one sample in any 30 day period.

Another common industrial water use is for boiler feed water. Most industries use RO and ion exchange units to treat the water they use in their boilers. Given that this is typically a smaller percentage of the water use for most industries, it may not be a practical treatment process to employ at a WWTP, unless there is a concentrated set of customers requiring this high level of water quality. Likely, on-site systems will continue to be used for boiler feed water, unless there are large facilities and other customers in the vicinity requiring a high quality water like the Tertiary 4 reclaimed water.

Table 10. Water Quality and Treatment Requirements by Industry Category

Industry Category	Type of Water Use	Reclaimed Water Quality Classification Required				
		Base	Tertiary 1	Tertiary 2	Tertiary 3	Tertiary 4
		Advanced Secondary	Conven-tional	Membrane Filtration	Membrane Softening	Advanced Processes
Agricultural	Cooling, Boiler Feed		x		x	x
Pulp & Paper	Process, Boiler Feed		x	x	x	x
Mining	Process, Boiler Feed	x	x		x	x
Sand & Gravel Washing	Process	x				
Industrial Cooling-Once-Through	Cooling	x	x		x	
Petroleum, Chemical & Ethanol	Cooling, Process, Boiler Feed		x		x	x
Metals	Process, Cooling, Boiler Feed		x		x	x
Non-Metals	Process, Cooling, Boiler Feed	x	x	x	x	x
Other	Process	x	x	x	x	x
Power Cooling-Once Through/Other	Cooling, Boiler Feed	x	x	x	x	x
Power Cooling-Recirculating	Cooling, Boiler Feed		x	x	x	x

Table 11. Select Industry Subcategories

Agricultural	Pulp and Paper
Food Production	Mills
Beverage Production	Paper and Packaging
Non-Metals	Printed Products
Building Materials	**Metals**
Glass Products	Foundries
Leather Products	Metal Product Fabrication
Plastics	Machine and Tool Shops
Rubber Products	Electronic and Computer Products
Miscellaneous Non-Metal Products	Electroplating
Other	
Other Industries (not defined above)	

Process water quality requirements can dictate a range of treatment requirements. For the industry categories represented in Table 10, the base supply is sufficient for sand and gravel washing. It could also be an acceptable source for use in other processes that are not concerned with hardness and dissolved salts, as in the Non-Metals and Other industry categories. Process water is not listed for agricultural processing because most of these products are for human consumption and similar to some state's practices, is expected to be lower on the list of practices for approval. If reclaimed water is used in food products, Tertiary 4 water with final UV would likely be required.

Reclaimed water with tertiary treatment is expected to be required for water supplies used by the pulp and paper, mining, petroleum, chemical, ethanol, and metals industries. It is possible that a base supply could be used in the iron mining industry, but the separation processes for iron ore include use of chemicals and excessive dissolved constituents may cause problems. Likewise, some processes in pulp and paper production could use a base reclaimed water supply, but typically dissolved constituents are not desired because of potential effects on attributes such as color quality. These industries, along with petroleum, chemical, ethanol, and metals industries typically require process water with low dissolved solids and the absence of trace constituents. Tertiary processes such as reverse osmosis followed by GAC, ion exchange or other technologies may be required.

4.0 Storage and Transmission

4.1 Overview

An integral part of the planning, operation, and maintenance of water reuse systems is for the transmission of the reclaimed water to the customer. Transmission costs, both capital and O&M, are often the largest cost component of projects for centralized systems. Transmission systems include on-site storage, pump station(s), piping, off-site storage, diversion structures to off-site storage ponds, service connections, and metering. Most states with regulations and guidelines include standards for the design, installation, operation, and maintenance of the transmission systems. There are very specific guidelines for prevention of cross-connections to other systems, including use of backflow preventions devices and other plumbing features.

4.2 Storage

This study assumes only storage for diurnal, daily or weekly industrial demand patterns that the WWTP cannot meet with their continuous supply. The conceptual water reuse system presented in Figure 1 provides for storage facilities on the WWTP to meet a range of storage volumes. The base water reuse system assumes that no storage is required. This assumption is valid for a larger WWTP serving smaller industrial demands.

Storage requirements for industrial applications can vary widely. Some industries may have adequate storage to meet peak hour requirements, but most would not have storage to handle significant volumes. The need for storage is most likely with smaller WWTPs where the diurnal flows could drop below the required demand of an industry or group of industries. Weekly demand patterns of industry could also change and should be accounted for when establishing storage requirements.

This study does not consider any seasonal storage requirements for a reclaimed supply. Seasonal storage would be required for WWTPs that incorporate reuse practices to reduce their discharges to waterways and supply seasonal customers. These facilities would need to store effluent during periods when the seasonal reuse customers do not use water. These are cases where the WWTP's NPDES permit limits are more stringent in the warmer months and rather than upgrade treatment facilities to meet the lower seasonal mass limits, a portion of the plant effluent is reused and not discharged to the receiving stream. Seasonal storage may also be required to meet a seasonal water demand, where peak demands cannot be consistently matched by the WWTP flow. The majority of Minnesota's industries have year-round water demands, with the exclusion of agricultural processing industries that may depend on seasonal crops, industries that use reclaimed water for landscape irrigation, and some cooling water applications. Seasonal storage facilities are more commonly used in water reuse systems for irrigation practices.

Reclaimed water storage can also provide system reliability with a short-term supply if there is a process disruption, as well as additional contact time for chlorine disinfection.

4.3 Pumping

The model for this study assumes a pump station is located on the WWTP site and is owned by the municipality. The pump station will include redundancy and reliability features consistent with state water supply requirements. The pump station is sized for peak flow and a residual pressure at the end of the pipe line of 40 psi, assuming delivery at the same elevation as the WWTP.

4.4 Transmission Pipelines

The majority of reclaimed transmission piping is polyvinyl chloride pipe (PVC) or ductile iron pipe (DIP) meeting specific industry standards. For this study, the transmission system is assumed to be all forcemain: pipe with a diameter of 24 inches or less is PVC, DR 18, Class 150. Greater than 24 inch diameter pipe is assumed to be DIP, Class 51 with push-on joints. Pipelines are sized to carry the peak hour demand (peaking factor of 3) of a given industry at a target velocity of 5 to 7 fps.

5.0 Costs

5.1 Overview

This section presents the estimated cost of service for a municipal water reuse system to serve a "base level" water quality and "alternative" water quality supplies to industries. The base level quality is defined as a hard water that meets regulatory standards for non-contact industrial water uses. The processes needed to produce the base level water quality define a "base WWTP" for water reuse to which other processes and their associated costs can be added to meet the specific needs of an industry. The "base water reuse system" includes treatment processes and the transmission system for delivery from the WWTP to the industry. "Alternative water reuse systems" differ from the base system in the treatment processes used to produce a prescribed set of water quality goals.

Costs are presented as the cost of service in $ /1000 gallons. The cost of service is the annualized capital cost over 20-years plus the annual O&M cost. Cost curves are used to provide the cost of service to supply a given demand for a 10-mile range from the WWTP. The base water reuse system costs are presented followed by systems providing alternative water quality supplies and storage facilities.

5.2 Cost Basis and Assumptions

The estimated capital and O&M costs and the cost of service ($/1000 gallons supplied) are based on cost information obtained from equipment manufacturers, constructed projects, peer-reviewed publications, as well as the financial analysis guidance set by Council. Redundancy and reliability criteria follow the Council's recommendations for WWTPs (which incorporates MPCA guidelines), standard potable water system practices, and documented reuse system practices. The major criteria and assumptions are listed in Table 12.

Table 12. Cost Criteria and Assumptions

Description	Value
Rates & Planning Information	
Discount Rate	5.0%
Planning Period	20 years
Present Year	Sep 2006 (ENR=7763)
Debt Financing Issuance Costs	1% capital cost
Useful Lives	
Force mains	40 years
Process Piping	30 years
Equipment	20 years
Redundancy & Reliability	
Equipment	1 unit out of service at peak hour flow
Piping	Single force main
Capital Cost Assumptions	
Undeveloped Design Details	50% of Construction Cost
Engineering, Admin & Legal	20% of Construction Cost
Operations & Maintenance Assumptions	
Electricity	$0.045/kwh
Sodium Hypochlorite, 12.5%	$0.70/gallon
Pump System Equipment	1% capital cost/yr
Treatment System Equipment	5% capital cost/yr
Transmission System	$5,500/mile/yr

5.3 Cost Model

A cost estimating tool was developed to evaluate the costs for a range of reclaimed water systems to serve industries a water supply. The cost tool is based on the conceptual system model shown in Figure 1, for those facilities on or originating on the WWTP site. There are four major facility components to the cost model:

- Treatment (includes residual disinfection)
- Storage
- Pump Station
- Piping (transmission)

Each of these facility components is addressed in a separate module within the spreadsheet-based cost tool. Different system configurations can be evaluated to provide the estimated costs for a given supply water quality, quantity supplied, and distance of the industry from the WWTP. The model provides the transmission system costs for a specified flow and distance from the WWTP to the point of delivery.

The cost model is predicated on treatment being provided on the WWTP site and water delivered with the prescribed water quality at a delivery pressure of 40 psi. The water quality delivered will depend on the treatment processes used. The base system will deliver quality with the characteristics listed previously in Table 6. The model does not include costs for treatment facilities at the industry site or booster pumps to meet industry specific requirements. An industry with more stringent water quality or pressure requirements would likely have existing facilities on their site to treat the reclaimed water supply.

The cost model was used to develop cost curves for a range of industrial water demands and transmission distances. Capital costs are annualized based on a 20-year debt service and presented as a cost of service, in $/1000 gallons, in conjunction with all major O&M costs. The cost of service provides a unit of measure that can be compared to existing water supply costs.

An example of the cost model summary spreadsheet, shown in Table 13, provides the assumptions used for the base system and presents estimated costs for a reclaimed supply of 1.0 mgd (annual average) delivered 1.0 mile. As with other transmission cost information, this assumes a peaking factor of 3, or maximum flow of 3 mgd. The average annual flow/demand and length of transmission piping are the main input parameters.

Other spreadsheets in the cost tool determine the capital costs for treatment, storage, pump station, and piping and annual pumping power costs based on the flow and pipe length input. Assumptions for unit costs of O&M items not presented in Table 12 are shown in Table 13. These include equipment maintenance, laboratory sampling and analysis, and general administrative costs.

Table 13
WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$1,412,830
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Annual Avg Flow/Demand (MGD)	**1.0**
Length of Distribution System (mi)	**1.0**

Summary of Capital Cost Estimates

Description	Total Cost
Treatment Facilities	$180,000
Storage Facilities	$0
Pump Station	$485,630
Piping	$747,200
TOTAL CAPITAL	**$1,412,830**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		*Maintenance*	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2007)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$109,050	Fixed	**$0.30**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$4,856	Combination	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$14,736	Variable	$0.04
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$0	Variable	$0.00
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$9,000	Combination	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$5,500	Combination	$0.02
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$15,000	Combination	$0.04
	Finance and Accounting	0.15 FTE	$12,000	Combination	$0.03
	Legal	0.05 FTE	$7,500	Combination	$0.02
	Customer Service	0.05 FTE	$4,000	Combination	$0.01
	TOTAL OF ALL COST COMPONENTS FOR SYSTEM:				**$0.62**

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

In addition to the reclaimed water costs, customers will incur internal costs for installation, operation, and maintenance of point-of-use treatment systems needed to use the reclaimed water for the facilities specific needs.

5.4 Base Water Reuse System Costs

5.4.1 Treatment

Section 3.3.3 defined the base water reuse system to be an advanced secondary WWTP with disinfection facilities. It was assumed the facility had all the required facilities to meet the base level water quality established except for additional disinfection system equipment to disinfect year-round and provide a residual disinfectant for transmission. The base system disinfects to a total coliform limit of 23/100 ml and provides a 2.5 mg/L chlorine dose for residual. Newdisinfection equipment and the associated O&M costs are the only additional treatment system requirements identified for the base water reuse treatment system.

The chlorine doses and disinfection assumptions identified in Section 3.3.3 are applied to all WWTPs regardless of the disinfection process. The cost model reflects having the facilities sized to meet the highest dose requirement (with a peaking factor considered for feed rate ranges). As shown in Table 14, the capital cost for disinfection is estimated as a base system cost plus a cost per gallon/day (gpd) to account for the incremental costs of metering pumps, tank storage, and building footprint.

Table 14. Base System: Sodium Hypochlorite Capital Costs

Capacity, mgd	Construction Cost	
	Base, $	**($/gpd)**
≤ 0.5	$100,000	$0.10
0.5 - 5	$150,000	$0.03
>5	$250,000	$0.02

The O&M costs for the sodium hypochlorite system in the cost model include the chemical cost at $0.70/gallon of 12.5% sodium hypochlorite and equipment maintenance. The electrical costs are considered negligible.

5.4.2 Storage

Storage is not considered in the base water reuse system.

5.4.3 Pump Station

The cost model uses a flow-based cost equation, as shown in Table 15, to determine the pump station costs. The pump station cost equations reflect some economy of scale and are based on Camp Dresser & McKee (CDM) estimates prepared for other projects (CDM, 2006 & 2003). These cost equations were checked with data compiled by MCES in review of lift station costs (MCES, 2006a & 2006b) and were found to be representative and on the conservative side. The capacity shown is for the annual average flow and assumes a peaking factor of 3 for the maximum flow pumped.

Table 15. Pump Station Unit Costs

Capacity, mgd	Capital Cost, $/gpd
≤ 0.5	0.61
0.5 to 7.5	0.49
≥ 7.5	0.40

Source: CDM, 2006 & 2003

5.4.4 Transmission Piping

Transmission piping is a significant cost of the base system. For this study, the cost model was developed to account for a range of transmission main sizes and lengths, providing a family of cost curves. These cost curves, based on flow and pipe length, allow one to estimate the cost of transmission piping from a WWTP to an industry.

Capital Costs

The transmission system is a force main from the WWTP to an industry or a group of industries. Pipe materials for reclaimed water mains are typically polyvinyl chloride pipe (PVC) , DR 18, Class 150, AWWA Specifications C-900 and C-905 with push-on joints, or ductile iron pipe (DIP), Class 51, with push-on joints and cement lining on the inside and a bituminous coating (16 mils DFT) on the outside. For this cost model, it is assumed that all mains will be PVC, DR 18, Class 150 for pipe 24 inch or less in diameter and DIP Class 51 for pipe larger then 24-inch.

The unit cost for materials and labor to install reclaimed water piping are summarized in Table 16. Construction and project costs are provided. The unit costs were developed from a transmission cost tool documented in Appendix B. These compare to force main interceptor costs (MCES, 2006a & 2006b) and water distribution system costs (Gumerman et al, 1992).

The reclaimed water transmission piping is sized to convey the peak hour demand and to maintain a target velocity at the peak hour demand of 5 to 7 feet per second (fps). A peaking factor of 3.0 (peak hour/annual average) is assumed for this study. It is recognized that peak hour requirements can be much higher for some industries, particularly with batch or shift related process activity. A peaking factor of 3.0 assumes that there is a main pipeline with laterals to multiple facilities and peak flows of the various industries do not all coincide.

An overall minimum target pressure of 40 pound per square inch (psi) was assumed at the delivery point. This is a pressure that is suitable for most cooling water systems (one of the largest potential uses of reclaimed water for Minnesota’s industries).

The annual average day reclaimed water demand evaluated with this cost model ranges from 0.1 to 30 mgd. Regression analysis was performed to find the best fit line to estimate pipeline capital costs for a given flow at given pipe lengths. Appendix B provides the details of these analyses.

Table 16. Unit Construction and Project Costs for Force Mains[1]

Diameter (inches)	Unit Construction Cost , $/lf		Unit Project Cost[2], $/lf	
	Urban Area	Rural Area	Urban Area	Rural Area
4	54	44	97	79
6	59	48	106	86
8	64	53	115	95
10	71	60	128	108
12	78	66	140	119
14	87	76	157	137
16	105	93	189	167
18	117	105	211	189
20	131	119	236	214
24	158	146	284	263
30	196	180	353	324
36	241	224	434	403
42	295	277	531	499
48	373	353	671	635
54	434	413	781	743
60	495	470	891	846

[1]Based on the following:
- -Sept. 2006 dollars, ENR CCI = 7763
- -Mean Indices, 2006 and Cost Tool with detailed unit costs (App. B, Exhibit 1)
- -Average depth of installation for force mains assumed to be 8 ft.
- -4 to 24" pipe is PVC; >24" is DIP

[2]Project unit costs based on master planning level assumptions: 50% for undeveloped design detail (includes allowance for related appurtenances).

Operation and Maintenance Costs

Transmission system operations costs characterized for this cost model include electrical power costs and a unit cost per mile for equipment and labor to maintain the distribution system. The total dynamic head was calculated for a range of flows and pipe lengths to estimate the pumping costs. Regression analysis was used to provide the relationship of power costs to flow at various pipe lengths. Appendix B documents this analysis.

The cost to maintain the transmission pipe system is based on the length of the pipe. The unit cost selected, $5,500 per mile per year, is based on WWTP records for maintenance of reclaimed water transmission system for Cary, North Carolina, escalated for larger flows (CDM, 2004). It also compares reasonably to literature references (Gumerman et al, 1992)

5.4.5 Base Water Reuse System Cost Analysis Results

The cost curves developed for the base system indicate that a reclaimed water supply system can be cost competitive with potable water supplies in Minnesota. This assumes that an advanced secondary wastewater treatment plant effluent water quality is available from existing facilities and is suitable for that industry, or that industry already has a treatment system in place for its existing supply that can be used (or upgraded at a nominal cost for a reclaimed supply).

As shown in Figure 5 and tabulated in Appendix C, a reclaimed water system designed for an annual average flow of less than 0.5 mgd is not expected to be competitive with most potable water supplies, except where the industry is in close proximity to the WWTP. At 1 mgd, the cost of service is comparable or less than a typical potable water supply system cost of $2/1000 gallons for systems under 10 miles. As the system capacity increases to 5 mgd, a 10-mile system costs about $1/1000 gallons. For flows greater than 5 mgd, as shown in Figure 6, costs drop below $0.60/1000 gallons, even at a distance of 10 miles for 30 mgd.

Potable water supplies in the Minneapolis/St. Paul area range from $1-$3/1000 gallons and fluctuate around that cost in other areas of Minnesota. Some rural water systems have costs over $5.00/1000 gallon. Water reuse system costs are compared to potable water supply costs to provide a perspective on the water supply market for Minnesota. Those industries with their own water supply will typically have much lower costs than for a potable supply. A comparison to a potable supply is reasonable for smaller water using industries (less than 0.5 mgd water demand), which often use potable supplies, particularly in urban areas. If higher quality water is required, then potable supplies are also used and at higher volumes.

Technical Memorandum 1: Implementation Issues and Customer Inventory produced for this project evaluated industries within a 5-mile range of metro area WWTPs and larger ranges in the rest of Minnesota. The base system cost of service curves indicate that service to those industries within 5 miles of a WWTP with a combined reclaimed water demand of 1 mgd or more could be provided at about $1.00/1000 gallons or less, making it competitive with potable supplies.

The base system provides a water quality that could possibly be suitable for a once-through cooling process or sand and gravel washing. It would also be sufficient for irrigation of restricted areas on industrial site grounds. To meet the anticipated water requirements for much of Minnesota's industrial water demand, additional treatment at the WWTP or the industry site will be required. Given the high hardness in Minnesota's source waters and high salt concentrations in wastewater (elevated chloride concentrations have been attributed to home softening system brine discharges), additional treatment may be necessary for the intended industrial water use. The treatment costs for a range of industrial uses are the subject of Section 5.6.

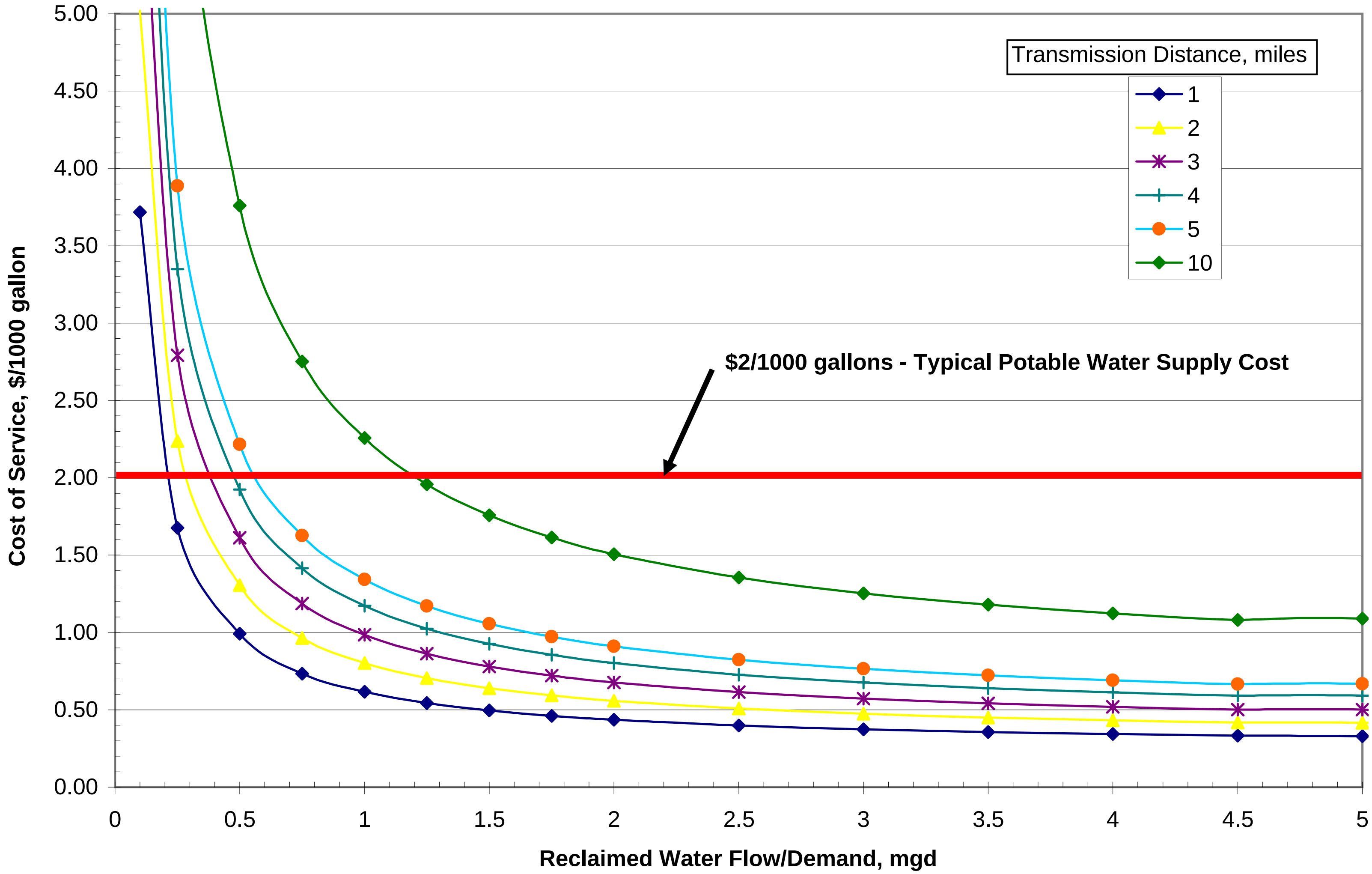

Figure 5. Water Reuse System Cost of Service for 0-5 mgd Capacity
Urban Area - Base System

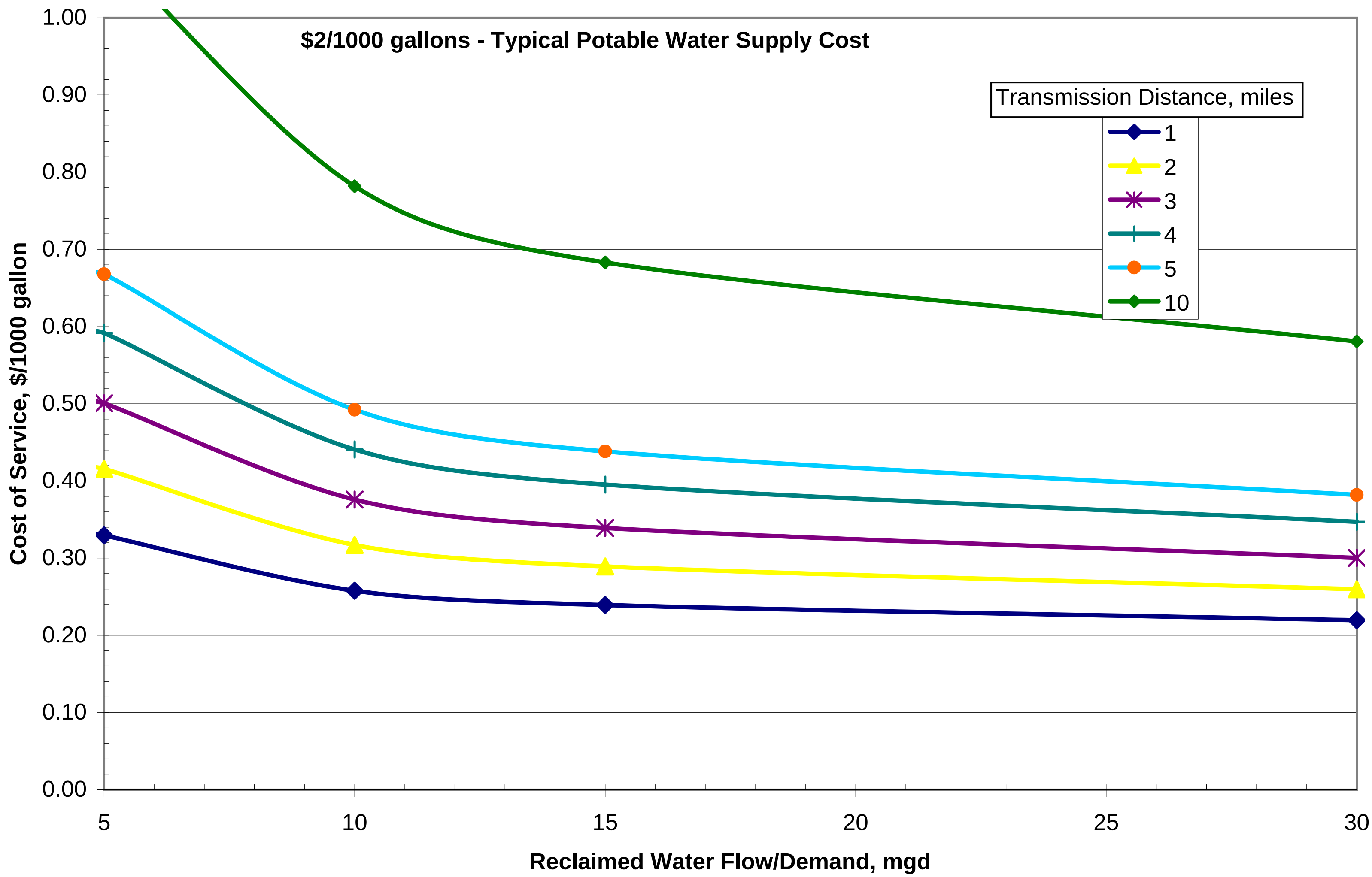

Figure 6. Water Reuse System Cost of Service for 5-30 mgd Capacity
Urban Area - Base System

5.5 Storage System Costs

Reclaimed water storage is defined as the difference in the diurnal demand and wastewater flow. While most WWTPs have a consistent diurnal pattern that varies during the weekdays and weekend, reclaimed water demand will vary with the customer or set of customers. For this study, it is assumed that 50% of the water volume produced per day will be stored. Additional storage that may be required by individual customers and located at the customer's sites was not considered in this analysis.

Storage is assumed to be provided in an underground concrete tank, for which the unit cost of construction is estimated to be $1.70/gallon of the storage. As indicated in Figure 7, the capital cost of storage is $850,000 per mgd of the annual average reclaimed water demand. When included into the cost of service, storage adds about 20 cents to the total system cost to produce 1000 gallons. Storage costs equate to about 20% of the cost of service for a 2 mgd supply pumped 5 miles.

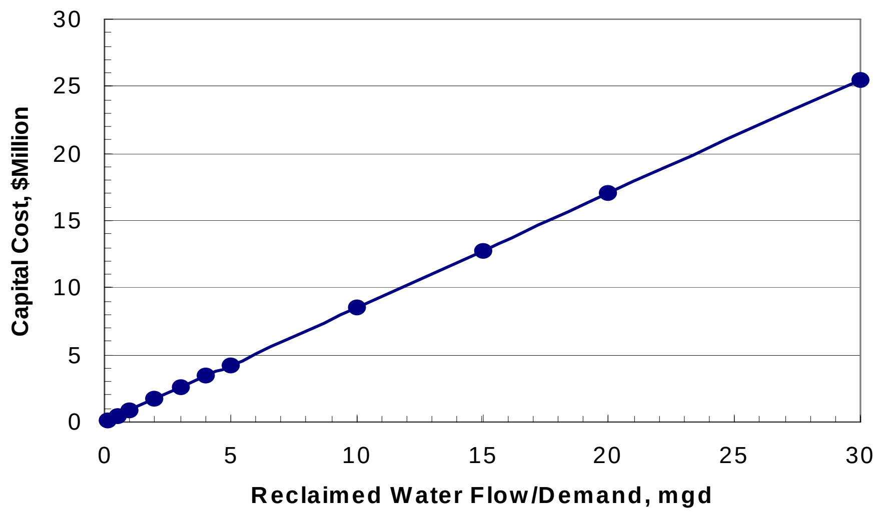

Figure 7. Storage Capital Costs

5.6 Alternative Water Reuse System Costs

5.6.1 Overview

Six levels of reclaimed water quality were evaluated to estimate the costs to treat and distribute reclaimed water to a range of industries. The costs were developed with the same cost model used to establish the base system costs. The treatment process train was the only system component modified from the base system to estimate the alternative water quality supply costs.

Water quality classifications are defined by the additional treatment provided over the base system and are referred to as Tertiary 1, 2, 3, or 4. There are three Tertiary 4 classifications, each dependent on which process follows reverse osmosis: granular activated carbon (GAC), ion exchange (IE), or ultraviolet radiation (UV) with or without hydrogen peroxide (H_2O_2).

The majority of costs presented in this study were derived from the cost curves developed in evaluation of various treatment technologies for potable water supplies under the Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule (EPA, 2005). The capital cost curves were checked against the cost of constructed projects if information was available and against manufacturer's planning level information. Theses costs include the O&M costs associated with treating the water and handling the associated waste streams and final products. All cost curve and vendor supplied information was adjusted using the Engineering News Record (ENR) Construction Cost Index to September 2006 dollars.

Cost curves were developed for each of the six types of reclaimed water quality for a range of water demands and transmission distances, as provided for the base system cost curves shown in Figures 5 and 6. The cost curves and supporting information for each water type are compiled in Appendix D.

5.6.2 Tertiary 1-Conventional

The California Water Recycling Criteria requires filtration, and possibly a coagulation process prior to filtration, for industrial uses of reclaimed water that contact humans. Many industrial water uses require the removal of dissolved solids from WWTP effluent. It is assumed for this study that coagulation and clarification are required, recognizing that filtration of advanced secondary effluent without these processes may suffice for many reuse applications. Tertiary 1 reclaimed water involves the use of chemicals such as ferric chloride to increase suspended solids and pathogen removal, and also for phosphorus removal, or the addition of lime if hardness needs to be reduced. A filtration process following sedimentation removes additional particulates and pathogens. The Tertiary 1 process train consists of chemical addition facilities, a flocculation basin, sedimentation, and filtration, as depicted in Figure 8.

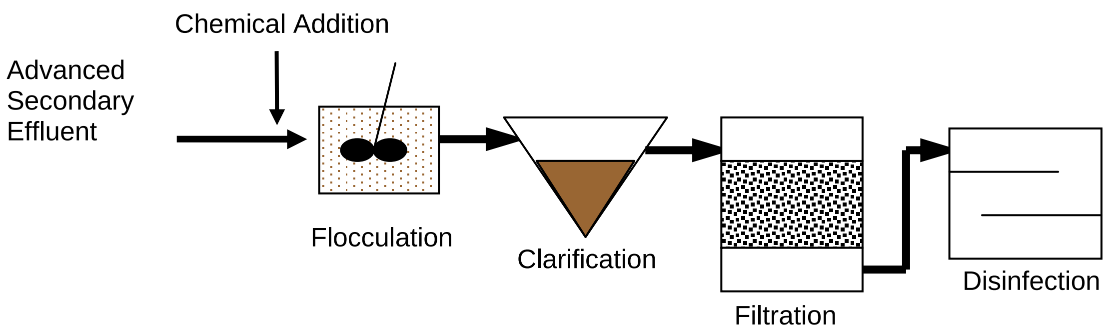

Figure 8. Tertiary 1 - Conventional Treatment

The costs presented in this study assume the use of traditional concrete basins for coagulation, flocculation, and sedimentation. A gravity filtration process with sand and anthracite is assumed. There are a variety of process enhancements and fabricated systems available that can be used for removal of particulate and dissolved solids, as indicated in Section 3.2.2. The costs for these systems will vary with the specific site conditions but generally will be of the same magnitude as concrete basins and gravity filters.

The treatment costs, estimated in terms of the cost of service (annualized capital cost plus O&M cost) in $/1000 gallons, to provide water with lower solids concentrations, reduced risk of pathogens, and if lime is used, reduced hardness and salts, is approximately $1.75/1000 gallons for a 1 mgd supply. The cost per 1000 gallons drops to less than $0.50/1000 gallons for a 30 mgd supply.

5.6.3 Tertiary 2-Membrane Filtration

Industries with water uses that have less stringent dissolved constituent limits can use membrane filtration to meet the regulatory requirements for reclaimed uses with potential for human contact. Tertiary 2 water could meet the quality requirements for some cooling water applications. However, as water is recycled internally several times in the process, concentrations will increase and WWTP effluent may not provide a suitable supply because of high chlorides or hardness. Another example industry would be cement production, which requires lower iron and manganese, but can use water with TDS as high as 600 mg/L. The process train for membrane filtration, shown in Figure 9, consists of membrane modules and the related piping for waste streams and appurtenances for chemical treatment

The treatment costs, expressed as cost of service, for membrane filtration are estimated to be $1.10/1000 gallons for a 1 mgd supply. The cost per 1000 gallons levels out after 15 mgd at around $0.75/10000 gallons.

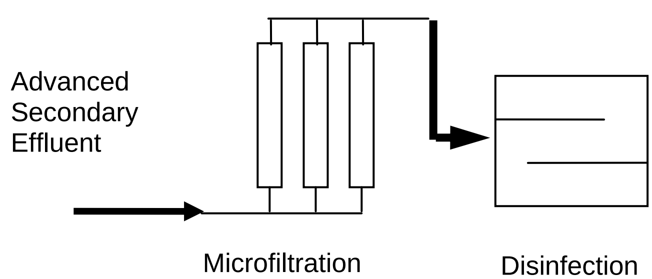

Figure 9. Tertiary 2 – Membrane Filtration

5.6.4 Tertiary 3-Membrane Softening

As discussed under Tertiary 1 water, many industrial uses require water that is at least partially softened. Section 3.2.4 identified the different membrane softening technologies available. For this study, reverse osmosis was used to estimate the costs of membrane softening. Reverse osmosis requires a pre-filtered water supply. The cost model assumes use of microfiltration and cartridge filtration, as shown in Figure 10.

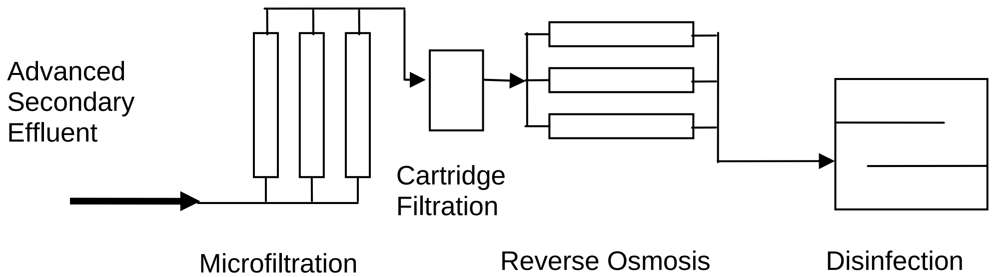

Figure 10. Tertiary 3 – Membrane Softening

Reverse osmosis produces a water quality that would be adequate for most industrial process uses, except those with very specific requirements, such as electronic and computer manufacturing facilities. It also produces a higher quality of water for cooling applications, which will allow for more recéruculation and water conservation.

Treatments costs, expressed as cost of service, about $2.50/1000 gallons for a 1 mgd supply, dropping below $2/1000 gallons for 15 mgd capacity systems.

5.6.5 Tertiary 4-Advanced

Tertiary – 4 With GAC

The Tertiary 4 classes of reclaimed water provide additional treatment to remove specific target constituents. Granular activated carbon (GAC) reactors are typically used to remove a variety of organic compounds and heavy metals. For this study's cost model, the reactor is assumed to follow the reverse osmosis process as shown in Figure 11. This process train would be for a very specific situation. A more likely scenario for application would be the use of GAC following microfiltration without an RO process. This process train would be used to target specific constituents (metals, organics) for a water reuse application that was not concerned with hardness or high salt concentrations.

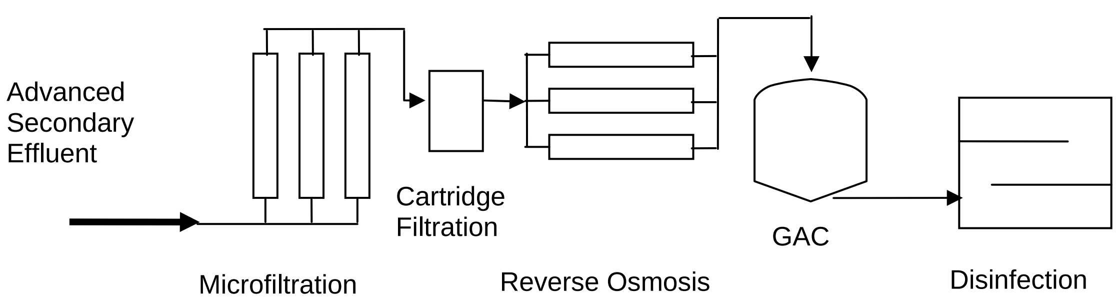

Figure 11. Tertiary 4 – Membrane Softening with GAC

This study assumed the need for carbon regeneration every 90 days, which is a conservative rate.

The use of GAC following RO increases the treatment cost, expressed as cost of service, above the base system cost to $3.70/1000 gallons for a 1 mgd supply. At 30 mgd, the cost is approximately $2.30/1000 gallons. This process train provides the highest costs of the six treatment trains evaluated. Without RO, the treatment costs would drop by approximately $1.30/1000 gallons for a 1 mgd system, assuming that microfiltration is still required.

Tertiary – 4 With Ion Exchange

Ion exchange units are commonly used at many industries that require very low levels of dissolved minerals. Similar to GAC, the ion exchange reactors would follow reverse osmosis (Figure 12).

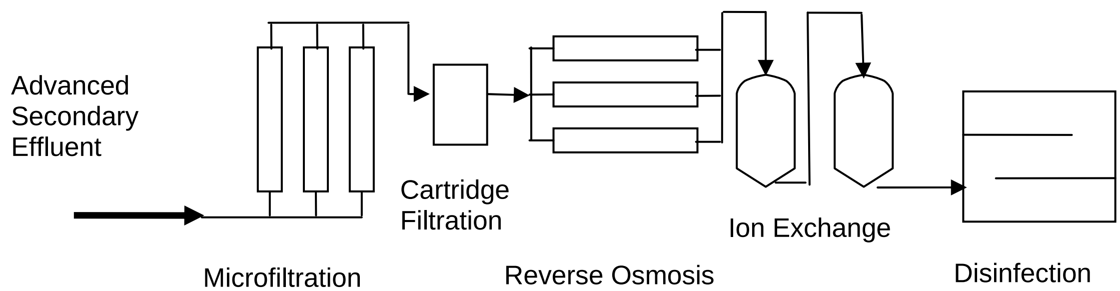

Figure 12. Tertiary 4 – Membrane Softening with Ion Exchange

Ion exchange annual costs are highly variable depending on the resin type and target constituent. The estimated cost, expressed as cost of service, for ion exchange following reverse osmosis is $3.30/1000 gallons for a 1 mgd supply and $3/1000 gallons for a 5 mgd supply. It is unlikely that larger volumes of this quality of water will be required; plus the annual costs would drive process requirements to use other technologies.

Tertiary – 4 With Ultraviolet Radiation

Additional treatment with ultraviolet radiation was included because some laboratory grade water quality is used by industry and UV provides additional pathogen protection. It can also be combined with hydrogen peroxide and other oxidants to remove persistent chemicals. In some cases, the UV and hydrogen peroxide can be used instead of reverse osmosis to target certain constituents rather than remove all constituents. UV can be pre or post-reverse osmosis, as shown in Figure 13.

Disinfection prior to the membrane RO is used to minimize biofouling of the membrane. However, there could be constituents in the water that affect the transmittance and result in less economical performance of pathogen kill. Pilot testing is often performed to optimize the process train and use each unit process to its full potential for overall quality and costs. UV treatment in this part of the process train adds only slightly to the cost. UV costs an additional $0.15/1000 gallons to the membrane softening treatment costs.

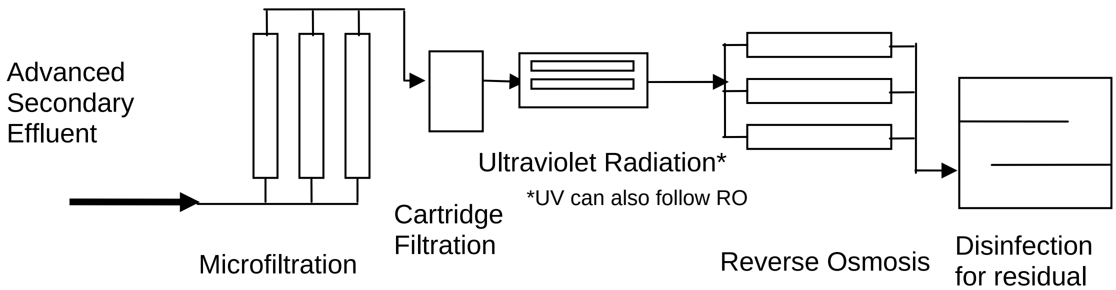

Figure 13. Tertiary 4 – Membrane Softening with UV

5.6.6 Treatment Cost Summary

The cost to treat WWTP effluent water beyond the advanced secondary treatment processes is expected to be $1.25 - $5/1000 gallons for a 0.5 mgd supply, $1.00 - $3.50/1000 gallons for a 1 mgd supply, and in the range of $0.50 - $2.50/1000 gallons for a 30 mgd supply. Figure 14 and Table 17 summarize the costs for flows from 0.1 to 30 mgd for each of the tertiary reclaimed water classifications. These costs are for treatment in addition to the base system treatment, transmission, and other system costs.

An accurate comparison of costs for the higher quality water must include the industry's onsite treatment cost and cannot be compared soley to the incoming water supply cost. Most industries requiring Tertiary 4 reclaimed water have their own onsite treatment systems to provide this water quality. In many cases, the industry provides this additional treatment to potable supplies. Some industries also have treatment processes to provide water of similar quality to Tertiary 1-3 reclaimed water. Water conservation practices have promoted cooling systems with higher levels of recirculation. However, this requires a higher quality of incoming water so that the concentrations of the recycle do not cause corrosion or scaling problems.

In comparing conventional treatment to membrane systems to soften the water and remove dissolved solids, the membrane process is more expensive except when treating smaller supplies. However, additional credit in microbial removal with membranes could offset disinfection costs. Blended supplies and treatment streams could also be considered to optimize treatment costs and meet multiple water supply needs. The costs of conventional treatment for larger supplies may be low since it is assumed that there is adequate capacity to handle the solids and for reasonably inexpensive disposal practices, such as land application of lime sludge. This may not be an option for some municipalities or industries.

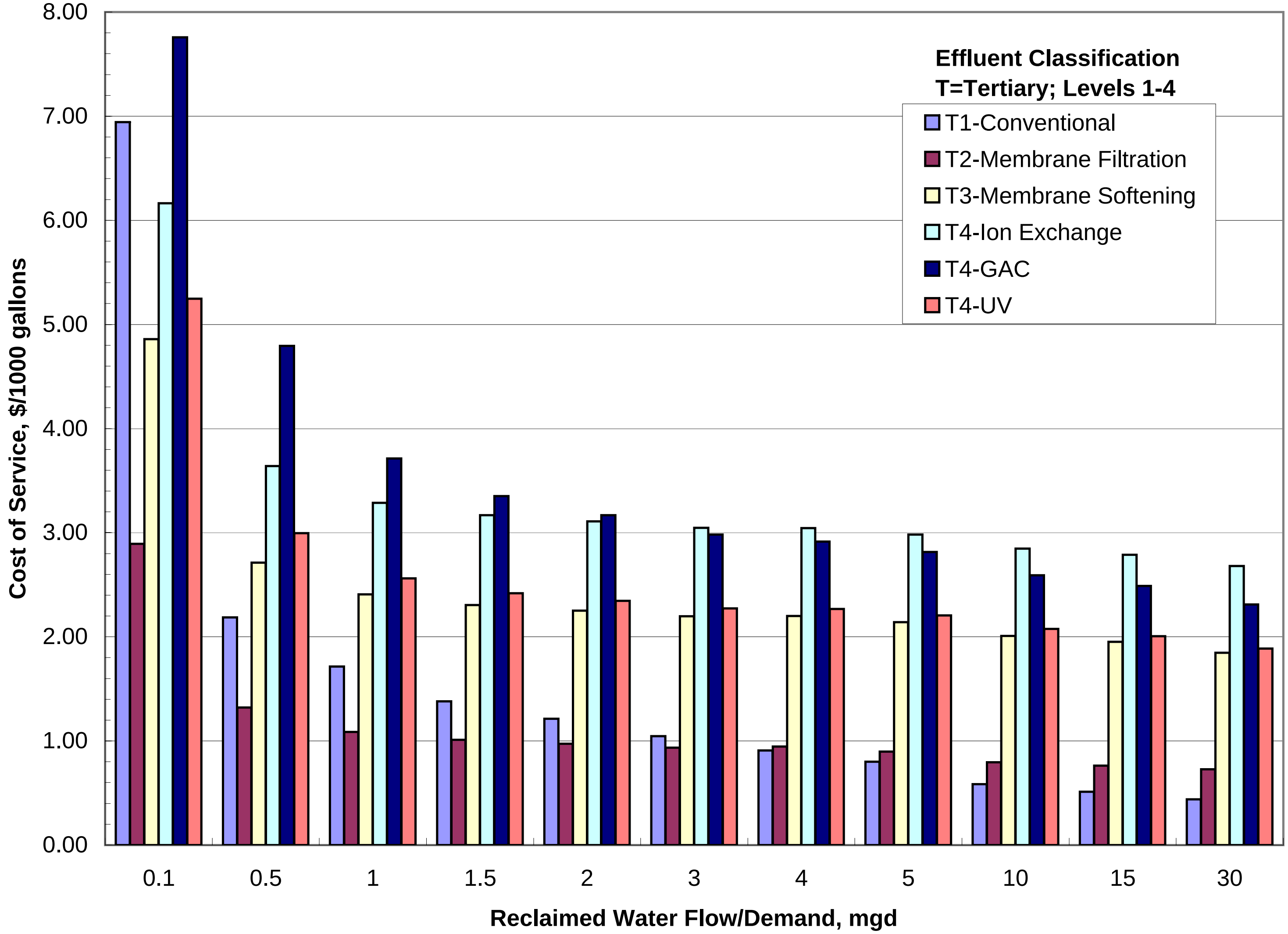

Figure 14. Comparison of Treatment Costs in Addition to Base System Costs

Table 17. Comparison of Treatment Costs for Different Reclaimed Water Quality Supplies*

Flow/ Demand, mgd	Cost of Service for Treatment, $/1000 gallons					
	Tertiary 1	Tertiary 2	Tertiary 3	Tertiary 4		
	Conven-tional	Membrane Filtration	Membrane Softening	Ion Exchange	GAC	UV
0.1	6.94	2.89	4.86	6.16	7.76	5.25
0.5	2.19	1.32	2.71	3.64	4.79	3.00
1	1.71	1.09	2.41	3.29	3.71	2.56
1.5	1.38	1.01	2.30	3.17	3.35	2.42
2	1.21	0.97	2.25	3.11	3.17	2.35
3	1.05	0.94	2.20	3.05	2.98	2.27
4	0.91	0.95	2.20	3.04	2.92	2.27
5	0.80	0.90	2.14	2.98	2.81	2.20
10	0.58	0.80	2.01	2.85	2.59	2.08
15	0.51	0.76	1.95	2.79	2.49	2.01
30	0.44	0.73	1.85	2.68	2.31	1.89

*In addition to water reuse base system costs

5.7 Cost Summary

The cost analysis indicates that there are economically viable applications to provide treated wastewater effluent as a water supply to industries. The technology is available and as competition increases in the membrane market, more economical solutions can be anticipated to meet the specific water quality needs for a spectrum of industries in Minnesota. Treatment costs were estimated to range from $0.50/1000 gallons for larger supplies (30 mgd) with water quality suitable for cooling water to over $7.00/1000 gallons for smaller supplies (0.1 mgd) treated to meet stringent industrial water requirements.

To provide a comparison of total system costs, a 5-mile transmission system was evaluated as shown in Figure 15. The cost to deliver reclaimed water, inclusive of transmission costs, and administrative/laboratory costs ranges from about $0.80 - $16.50/1000 gallons.

The potential costs for a reclaimed water supply are shown in Table 18 for the general industry categories. Costs are listed for the treatment and total system costs of a 5-mile transmission system. Appendices C (base system) and D (alternative water supplies) provide the detailed cost curves to identify specific costs for different flows and transmission distances. As expected, the range of costs is broad given the diversity of industries in these general industry categories and the variable water quality of WWTP effluent.

The higher costs reflect treatment to achieve water quality concentrations lower than in the incoming water supply of most industries. Most industries treat their own permitted supply or potable supply to achieve the higher quality of Tertiary-4 class reclaimed water and some also treat an incoming water supply to meet Tertiary 1-3 water quality levels. A comparison of reclaimed water system costs to an industry's existing water supply cost must include any onsite treatment costs currently incurred by the industry.

The cost analysis indicates that for a 1 mgd supply transmitted 5 miles, the costs for lower levels of treatment can compete with potable water supplies. Most industries with a water demand of 1 mgd or less are more likely to use a potable source, depending on their water quality requirements. For these industries, reclaimed water could provide an alternative to a potable source.

As the demand increases to 2 mgd, the total system cost for a base water quality is under $1.00/1000 gallon – similar to potable supplies provided by utilities using ground water supplies with minimal treatment. While industries with their own water supply system typically have water supply costs less than a $1.00/1000 gallons, these costs reflect areas with high quality, abundant sources close to the industry. For areas with water supply limitations, where ground water sources are a considerable distance or only a surface water source is available (which could also be a significant distance from the industry and require more treatment costs) reclaimed water could be a more economical water supply.

Another consideration in comparing reclaimed supplies to potable water supply systems is the infrastructure capacity of the potable water system and the impact on capital expenditures. Increased domestic demand can be met without expansions if a portion of the industrial sector uses reclaimed water and the total demand for the potable water system is kept constant.

The economic viability of water reuse in Minnesota will depend on the specific match of WWTP effluent quality to a customer's water quality requirements and the availability of traditional water supplies in the area. The most significant reclaimed water quality issue for Minnesota appears to be hardness and high salts. While data across the state is lacking, given the general water supply characteristics, it is expected that many WWTPs will have effluent water quality that is not suitable for a significant portion of industrial water uses without treatment for dissolved solids. The evaluation of site-specific applications with more refined cost estimating will narrow the range of costs for supplying reclaimed water to select industries in Minnesota.

6.0 References

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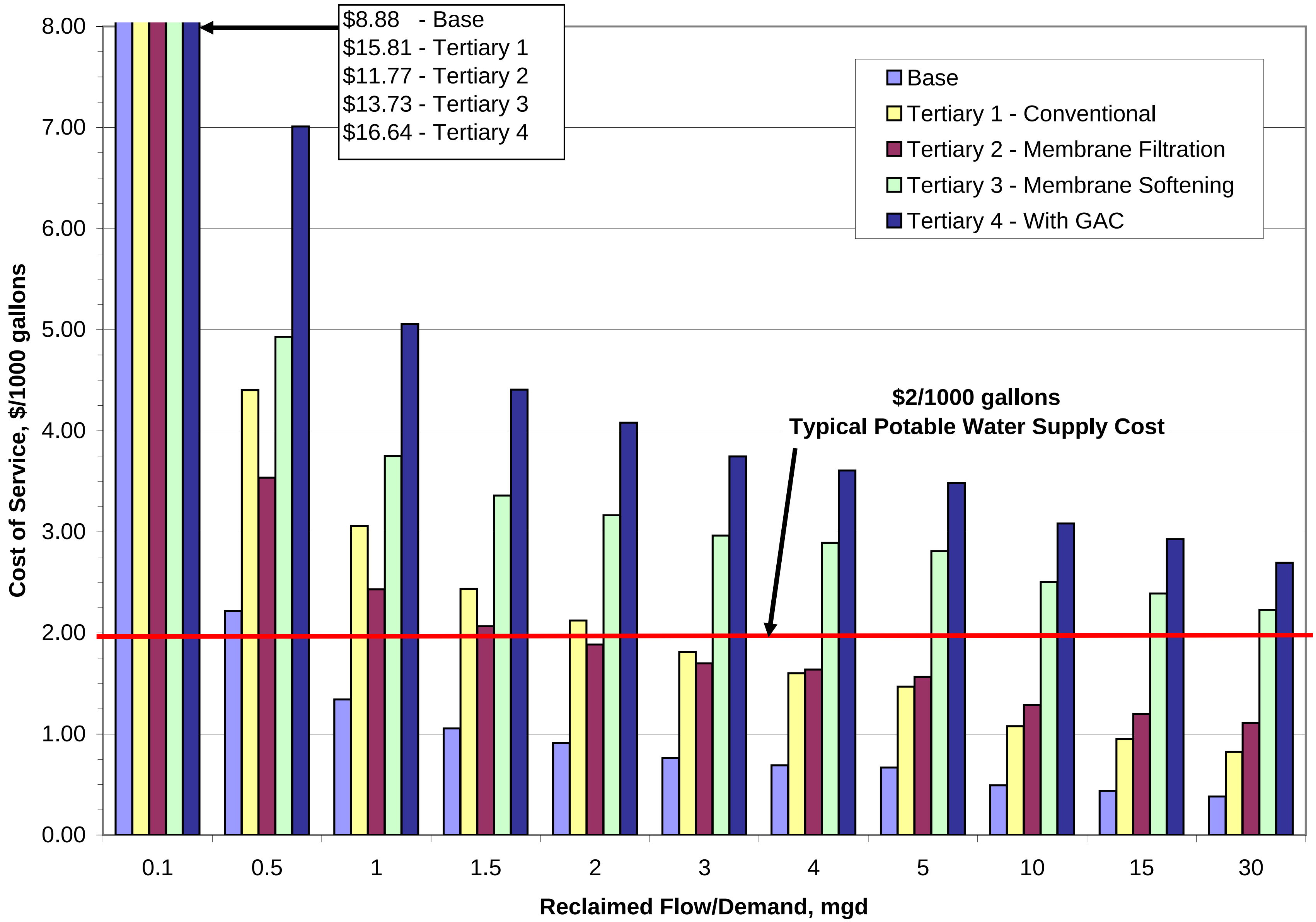

Figure 15. Cost of a 5-Mile Transmission Water Reuse System to Meet Different Water Quality Requirements

Table 18. Range of Costs to Supply Reclaimed Water to Minnesota Industries

Industry Category	Type of Water Use	Cost of Service, $/1000 gallons[1] by Reclaimed Water Quality Classification[2]					Range of Costs[3], $/1000 gallons	
		Base	Tertiary-1	Tertiary-2	Tertiary-3	Tertiary-4		
		Advanced Secondary	Conven-tional	Membrane Filtration	Membrane Softening	Advanced Processes	Treatment Above Base System	Total System
Agricultural	Cooling, Boiler Feed		$1.70/$3.05		$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Pulp & Paper	Process, Boiler Feed		$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Mining	Process, Boiler Feed	$0/$1.35	$1.70/$3.05		$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Sand & Gravel Washing	Process	$0/$1.35					$0	$1.35
Industrial Cooling-Once-Through	Cooling Water	$0/$1.35	$1.70/$3.05		$2.40/$3.75		$0-$2.40	$1.35-$3.75
Petroleum, Chemical & Ethanol	Cooling, Process, Boiler Feed		$1.70/$3.05		$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Metals	Process, Cooling, Boiler Feed		$1.70/$3.05		$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00
Non-Metals	Process, Cooling, Boiler Feed	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Other	Process	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$0-$3.70	$1.35-$5.00
Power Cooling-Once Through/Other	Cooling	$0/$1.35	$1.70/$3.05	$1.10/$2.45	$2.40/$3.75		$0-$2.40	$1.35-$3.75
Power Cooling-Recirculating	Cooling, Boiler Feed		$1.70/$3.05	$1.10/$2.45	$2.40/$3.75	$3.70/$5.00	$1.70-$3.70	$2.40-$5.00

[1]Represent the costs to provide 1 mgd of reclaimed water a distance of 5 miles. First value is the treatment cost and the seccond value is the total system cost in $/1000 gallons. (e.g. For Metals industries: the treatment costs are estimated to range from $1.70-$3.70/1000 gallons and the total system costs are estimated to range from $3.05-$5.00/1000 gallons.

[2]Refer to Table 10, Section 3.4.3 for relationship of reclaimed water classification to industry categories.

[3] This range reflects the cost to provide water to meet the water quality requirements for all uses of water by this industry sector. An accurate comparison to an industry's existing water supply costs must account for all onsite industry treatment system annualized capital and O&M costs.

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Appendix A
Water Reuse Regulatory Exhibits

Exhibit 1
California Water Recycling Criteria

Table A-1. 2000 California Water Recycling Criteria

Type of Use	Total Coliform Limits[a]	Treatment Required
Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers	▪ None required	▪ Oxidation
Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	▪ ≤23/100 ml[a] ▪ ≤240/100 ml in more than one sample in any 30-day	▪ Oxidation ▪ Disinfection
Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period	▪ Oxidation ▪ Disinfection
Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation[h] ▪ Filtration[i] ▪ Disinfection
Nonrestricted recreational impoundments	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation ▪ Clarification[j] ▪ Filtration[i] ▪ Disinfection
Groundwater recharge by spreading	▪ Case-by-case evaluation	▪ Case-by-case evaluation

[a] Based on running 7-day median; daily sampling is required.
[b] No contact between reclaimed water and edible portion of crop.
[c] Food crops that undergo commercial pathogen-destroying prior to human consumption.
[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.
[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.
[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.
[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.
[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.
[i] The turbidity after filtration through filter media cannot exceed an average of 2 nephelometric turbidity units (NTU) within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.
[j] Not required if reclaimed water is monitored for enteric viruses, *Giardia*, and *Cryptosporidium*.

Source: Adapted from State of California [2000a].

Exhibit 2
California Treatment Technology Report for Recycled Water, January 2007

Table of Contents – Provides list of Approved Technologies

(refer to full reference for additional detail, with website reference:
http://www.dhs.ca.gov/ps/ddwem/waterrecycling/PDFs/treatmenttechnology.pdf)

State of California—Health and Human Services Agency
Department of Health Services

California Department of Health Services

SANDRA SHEWRY
Director

ARNOLD SCHWARZENEGGER
Governor

STATE OF CALIFORNIA
DIVISION OF DRINKING WATER
AND
ENVIRONMENTAL MANAGEMENT

TREATMENT TECHNOLOGY REPORT
FOR
RECYCLED WATER

January 2007

This document has been developed to serve as a reference source for those seeking information concerning technologies that have been recognized by the California State Department of Health Services (CDHS) as being acceptable for compliance with treatment requirements of the California Recycled Water Criteria. This is a "living" document that will be updated periodically as needed. Readers who find errors or omissions should contact Jeff Stone of the CDHS Recycled Water Unit at jstone1@dhs.ca.gov.

Recycled Water Unit/Technical Operations Section/Technical Programs Branch
11800 Eugenia Place, Suite 200, Carpinteria, California 93013
Phone: (805) 566-1326; Fax (805) 745-8196
Internet address: http://www.dhs.ca.gov/ps/ddwem/

STATE OF CALIFORNIA
DEPARTMENT OF HEALTH SERVICES
DIVISION OF DRINKING WATER
AND
ENVIRONMENTAL MANAGEMENT

TREATMENT TECHNOLOGY REPORT FOR RECYCLED WATER

January 2007

TABLE OF CONTENTS

Other Media Type Filters

Fuzzy Filter (Schreiber LLC)

Membrane Technologies

ZENON
- -Cycle-let (Zenon Environmental, Inc.)
- -ZeeWeed/Zenogem
- -ZeeWeed 1000 UF

U.S. Filter/Memcor
- -CMF (0.2 micron-PP and 0.1 micron-PVDF)
- -CMF-Submerged (0.2 micron-PP and 0.1 micron-PVDF)

U.S. Filter/Jet Tech
- -Jet Tech Products-Memjet™

PALL Corporation
Mitsubishi
Kubota
Ionics
- -Norit X-Flow

Koch/Puron
Huber Technologies
Parkson/Dynalift

Cloth Filters

Aqua-Aerobics – rotating disk
- -102 needle felt fabric
- -PA-13 nylon pile fabric
- -MMK2-13 acrylic pile fabric

Aqua-Aerobics - AquaDiamond™

U.S. Filter-Kruger Products
- - Hydrotech Polyester media filter

4. DISINFECTION TECHNOLOGIES

Trojan Technologies
PCI–Wedeco
Wedeco-Ideal Horizons
Aquionics
Ultraguard (Service Systems)
Aquaray (Infilco-Degremont)
UltraTech

APPENDIX

‘A’ – California Department of Health Services Requirements for Demonstration of Reduction of Virus and Bacteria by Filtration and Disinfection

‘B’ – Memorandum concerning cleaning of UV quartz sleeves

Appendix B

TECHNICAL MEMORANDUM

Reclaimed Water Transmission Main

Capital Cost and Pumping Cost Analysis

Introduction

This technical memorandum presents the assumptions, methods, and results of a transmission main capital cost and power cost analysis of a general water reuse system.

Piping Capital Cost

It is assumed that all reclaimed water transmission pipes will be force mains for this master planning level of analysis. Typically, pipe materials for reclaimed water mains are polyvinyl chloride pipe (PVC) , specified as DR 18, Class 150, meeting AWWA Specifications C-900 and C-905 with push-on joints, or ductile iron pipe (DIP), Class 51, with push-on joints and cement lining on the inside and a bituminous coating (16 mils DFT) on the outside. For the purposes of this analysis, it is assumed that all mains 24 inch or less in diameter will be PVC, DR 18, Class 150; and for pipe larger than 24 inch, DIP class 51.

A pressure of 40 pound per square inch (psi) at the end of the transmission main was assumed for developing this conceptual design. No storage facilities will be required within the reclaimed water distribution network.

Pipe Sizing

The reclaimed water transmission piping is sized to convey the peak hour demand, which is assumed to be 3.0 times the annual average day reclaimed water demand, and to maintain a target velocity at the peak hour demand of 5.0 to 7.0 feet per second (ft/sec). The annual average day reclaimed water demands evaluated ranges from 0.1 to 30 mgd. The resulting peak hourly demands are in the range of 0.3 to 90 mgd.

Method

The unit costs for pipeline construction were estimated using a transmission main cost tool. The transmission main cost tool is a set of spreadsheets developed to estimate pipe construction costs. The tool includes: 1) spreadsheets for input parameters including pipe material cost and installation rate, construction unit costs for items such as pavement removal and replacement, sod, seed, and equipment costs for items such as an excavator, vibratory hand compactor, and trench box; 2) a spreadsheet for developing the unit construction cost of pipeline ($/ft), which incorporates all the costs in (1) and additional input parameters such as depth of cover for pipes, trench width, restoration width by type of restoration, and traffic control requirements. One cost tool was developed for PVC pipe and a second was developed for DIP, both presented in Exhibit 1.

The unit costs for construction of various sizes of a transmission main were developed separately for urban versus rural areas. Key assumptions used in the transmission main cost tool for this unit cost analysis are:

- Average depth of cover for transmission mains is 8 ft.

- In urban areas: 50 ft per 600 ft of pipe installation are assumed to require pavement removal and replacement to account for crossing streets. The entire length includes traffic control and one curb is replaced.
- Surface restoration is sod in urban areas and seeding in rural areas.

Unit costs at a project level were developed by applying several multipliers to the unit construction costs estimated for the transmission mains. To calculate a project cost, undeveloped design details were estimated as 50% of the construction cost, administration and legal expenses were calculated as 20% of the construction cost plus the undeveloped design details. The undeveloped design detail includes an allowance for related appurtenances including manholes, isolation valves, and combination air release/vacuum valves. The contractor's overhead and profit was included in the construction cost.

Table 1. Unit Construction and Project Costs for Force Mains[1]

	Unit Construction Cost ($/LF)		Unit Project Cost[2] ($/LF)	
	Sept. 2006 dollars		Sept. 2006 dollars	
Diameter (inches)	Urban Area	Rural Area	Urban Area	Rural Area
4	54	44	97	79
6	59	48	106	86
8	64	53	115	95
10	71	60	128	108
12	78	66	140	119
14	87	76	157	137
16	105	93	189	167
18	117	105	211	189
20	131	119	236	214
24	158	146	284	263
30	196	180	353	324
36	241	224	434	403
42	295	277	531	499
48	373	353	671	635
54	434	413	781	743
60	495	470	891	846

[1]Based on the following:
-Sept. 2006 dollars, ENR CCI = 7763
-Mean Indices, 2006 and Cost Tool with detailed unit costs (Exhibit 1)
-Average depth of installation for force mains assumed to be 8 ft.
-4 to 24" pipe is PVC; >24" is DIP

[2]Project unit costs based on master planning level assumptions: 50% for undeveloped design detail (includes allowance for related appurtenances), Contractor OH&P (included in Construction Cost), and 20% for Engineering, Admin, and Legal.

Pipeline Capital Cost

Capital costs by distance are developed based on the unit project cost for pipeline and distance of the industry from the wastewater treatment facilities (1-10 miles). Annualized capital costs are also developed based on a 20-yr debt service and presented as a cost of service, in $/1000 gallons. Regression analysis was performed to find the best fit line to estimate pipeline capital costs for a given pipe length. Exhibit 2 provides the details of these analyses for urban areas and rural areas.

Power Cost for Pumping

Annual power costs were developed for average flows of 1 to 30 mgd over transmission lengths of 1 to 10 miles, based on the total friction head and a residual pressure of 40 psi. A regression analysis was used to provide the relationship of power costs to flow for various pipe lengths. Exhibit 3 documents the details of these analyses.

Exhibit 1

Transmission Main Cost Tool

Water Reuse Pipe Line Unit Construction Cost
Pipe Material: DR 18 PVC

Start Sta.	End Sta.	length	diameter (in)	start depth (ft)	end depth (ft)	X Hor.: 1 Vert.	depth of vertical cut at bottom	average depth (ft)	design parameter key	upstream MH diameter	trench bottom width (ft)	trench top width (ft)	pavement width cut (ft)	Curb replacement (ea)	Walk replacement (ft-width)	sod replacement width (ft)	seeding width (ft)	traffic control personnel	trench support (1=yes)	dewatering wells (1=yes)	unit cost of pipeline, $/ft
Urban Applications																					
0	**550**	550	**4**	8	**8**	**1**	**10**	8.108	1	3	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$50.52
550	**600**	50	**4**	8	**8**	**1**	**10**	8.108	1	3	4	4.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$87.83
																		Weighted Average			**$53.63**
600	**1150**	550	**6**	8	**8**	**1**	**10**	8.250	2	3	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$55.20
1150	**1200**	50	**6**	8	**8**	**1**	**10**	8.250	2	3	4	4.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$92.52
																		Weighted Average			**$58.31**
1200	**1750**	550	**8**	8	**8**	**1**	**10**	8.302	3	3	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$60.17
1750	**1800**	50	**8**	8	**8**	**1**	**10**	8.302	3	3	4	4.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$97.48
																		Weighted Average			**$63.28**
1800	**2350**	550	**10**	8	**8**	**1**	**10**	8.354	4	3	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$67.16
2350	**2400**	50	**10**	8	**8**	**1**	**10**	8.354	4	3	4	4.0	**8**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$113.08
																		Weighted Average			**$70.99**
2400	**2950**	550	**12**	8	**8**	**1**	**10**	8.406	5	4	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$73.40
2950	**3000**	50	**12**	8	**8**	**1**	**10**	8.406	5	4	4	4.0	**8**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$119.32
																		Weighted Average			**$77.22**
3000	**3550**	550	**14**	8	**8**	**1**	**10**	8.458	6	4	4	4.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$82.84
3550	**3600**	50	**14**	8	**8**	**1**	**10**	8.458	6	4	4	4.0	**8**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$128.76
																		Weighted Average			**$86.67**
3600	**4150**	550	**16**	8	**8**	**1**	**10**	8.510	7	4	6	6.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$100.41
4150	**4200**	50	**16**	8	**8**	**1**	**10**	8.510	7	4	6	6.0	**10**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$154.93
																		Weighted Average			**$104.95**
4200	**4750**	550	**18**	8	**8**	**1**	**10**	8.563	8	4	6	6.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$112.44
4750	**4800**	50	**18**	8	**8**	**1**	**10**	8.563	8	4	6	6.0	**10**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$166.96
																		Weighted Average			**$116.98**
4800	**5350**	550	**20**	8	**8**	**1**	**10**	8.615	9	4	6	6.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$126.49
5350	**5400**	50	**20**	8	**8**	**1**	**10**	8.615	9	4	6	6.0	**10**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$181.01
																		Weighted Average			**$131.03**
5400	**5950**	550	**24**	8	**8**	**1**	**10**	8.723	10	5	6	6.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$153.60
5950	**6000**	50	**24**	8	**8**	**1**	**10**	8.723	10	5	6	6.0	**10**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$208.13
																		Weighted Average			**$158.15**
Rural Applications:																					
0	**600**	600	**4**	8	**8**	**1**	**10**	8.108	1	3	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$43.52**
0	**600**	600	**6**	8	**8**	**1**	**10**	8.250	2	3	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$48.02**
0	**600**	600	**8**	8	**8**	**1**	**10**	8.302	3	3	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$52.93**
0	**600**	600	**10**	8	**8**	**1**	**10**	8.354	4	3	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$59.87**
0	**600**	600	**12**	8	**8**	**1**	**10**	8.406	5	4	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$66.07**
0	**600**	600	**14**	8	**8**	**1**	**10**	8.458	6	4	4	4.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$75.49**
0	**600**	600	**16**	8	**8**	**1**	**10**	8.510	7	4	6	6.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$92.63**
0	**600**	600	**18**	8	**8**	**1**	**10**	8.563	8	4	6	6.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$104.55**
0	**600**	600	**20**	8	**8**	**1**	**10**	8.615	9	4	6	6.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$118.50**
0	**600**	600	**24**	8	**8**	**1**	**10**	8.723	10	5	6	6.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$145.43**

costs do not include:
- support and/or relocation of utilities
- permanent easement
- temporary easement
- engr and admin costs
- surveying
- geotechnical investigation
- rock excavation
- contractors mobilization, bonds, overhead and profit
- tree removal and replacement

Pipe Installation Data (DR 18 PVC Pipe)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pipe ID (in)	Key	Wall (in) - 1	Pipe OD (ft)	Pipe Area (sf)	Bed under pipe (ft)	Bottom Trench Width (ft)	Bedding Depth (ft)	Bedding Area (sf)	Excavation Rate (cy/hr) - 2	B&C of select (cy/hr) - 3	B&C of native (cy/hr) - 4	Pipe Install Rate (ft/hr) - 5	Pipe Costs ($) - 6
4	1	0.6	0.43	0.15	0.11	4	1.5	6.0	75	11	25	43.7	3.77
6	2	3	1.00	0.79	0.25	4	2.3	8.2	75	11	25	43.3	6.63
8	3	3.25	1.21	1.15	0.30	4	2.5	8.9	75	11	25	42.9	11.04
10	4	3.5	1.42	1.58	0.35	4	2.8	9.5	75	11	25	42.4	17.55
12	5	3.75	1.63	2.07	0.41	4	3.0	10.1	75	11	25	42.0	23.41
14	6	4	1.83	2.64	0.46	4	3.3	10.5	75	11	25	41.6	32.57
16	7	4.25	2.04	3.27	0.51	6	3.6	18.0	100	11	75	41.1	42.58
18	8	4.5	2.25	3.98	0.56	6	3.8	18.9	100	11	75	40.7	53.49
20	9	4.75	2.46	4.75	0.61	6	4.1	19.7	100	11	75	40.3	66.52
24	10	5.35	2.89	6.57	0.72	6	4.6	21.1	100	11	75	39.4	91.80

Notes:
1 - PVC Pipe, DR 18
2 - Means 02315.424.0200
3 - Means 02315.110.1100 - Crew A1
4 - Approximated - Crew B10G
5 - Information from Contractor
6 - Quotation from Vendor - HD Waterworks (Unit cost in this column includes mechanical joints and pipe cost; Pipe manufacturer: Diamond Plastics Corp.)

Construction Unit Costs

Item (2006 Means)	Description	Qty	Power (Hp)	Production (unit/hr)	Costs ($/unit)	St. Paul Index *	Present Cost Index	Total Cost ($/unit)	Source	Notes
Select backfill (cy)										
02315.110.0300	select backfill, no comp	1			18.21	98.5%	100.0%	17.94	Means 2006	includes O&P (material costs + 10%)
	Total							**17.94**		
Pavement Removal and Replacement (sy)										
02220.250.5050	4 - 6" bit pavement removal (sy)	1		420	6.75	98.5%	100.0%	6.65	Means 2006	includes O&P
02315.490.0550	Disposal - 10 mi rt haul - (cy)	0.167			15.00	98.5%	100.0%	2.47	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.217			70.00	98.5%	100.0%	14.94	Means 2006	includes O&P
02315.110.0300	6" select backfill, no comp (cy)	0.167			18.21	98.5%	100.0%	2.99	Means 2006	includes O&P (material costs + 10%)
02300.432.2220	Dozer - 150 haul (cy)	0.167			4.82	98.5%	100.0%	0.80	Means 2006	includes O&P
02315.310.5000	Compaction - vibrating roller 2 pass (cy)	0.167			0.35	98.5%	100.0%	0.06	Means 2006	includes O&P
02740.310.0120	Binder course - 2" thick	1		6345	5.25	98.5%	100.0%	5.18	Means 2006	includes O&P
02740.310.0380	Wearing course - 2" thick	1		6325	5.70	98.5%	100.0%	5.62	Means 2006	includes O&P
	Total							**38.71**		City Minneapolis allowance is 50$/sy
Sod (sy)										
02910.710.2620	Rough grade prep (msf)	0.009			11.7	98.5%	100.0%	0.11	Means 2006	includes O&P
02910.710.3920	Spread topsoil, 4" (msf)	0.009			470	98.5%	100.0%	4.17	Means 2006	includes O&P, includes material
02920.400.0200	Sod, bluegrass, per MSF	0.009		22	390	98.5%	100.0%	3.46	Means 2006	includes O&P
	Total							**7.74**		
Seed (sy)										
02910.710.2620	Rough grade prep (msf)	0.009			11.7	98.5%	100.0%	0.11	Means 2006	includes O&P
02910.710.3920	Spread topsoil, 4" (msf)	0.009			470	98.5%	100.0%	4.17	Means 2006	includes O&P, includes material
02920.320.320	Hydroseed w/ mulch&fert. - (msf)	0.009		80	46.5	98.5%	100.0%	0.42	Means 2006	includes O&P
	Total							**4.70**		
Trench Support (sf)										
02250.400.1800	25' deep exc, drive, extract, salvage	1		**553**	20	103.4%	100.0%	20.68	Means 2006	includes O&P
	Total							**20.68**		
Dewatering (lf)										
	Months	1								
	Depth (ft)	25								
	Spacing (ft)	200								
02240.700.0050	Wells 10-20' deep, ave	0.125			19.4	103.4%	100.0%	2.51	Means 2006	indludes O&P; lineal measure is well spacing/depth
01.54.33.40.4700	Subm pump, 2", 120 gpm -rent	0.005			192	101.8%	100.0%	0.98	Means 2006	includes O&P; qty is months rental
01.54.33.40.2700	Gen, elect, 100 kw -rent	0.005			7.2	98.5%	100.0%	0.04	Means 2006	includes O&P; qty is months-kw; cost is monthy rental per kw
01.54.33.40.2700	Gen, elect, 100 kw -operate	27.23			0.18	98.5%	100.0%	4.83	Means 2006	includes O&P; 10hp = 7.46 kw/hr, 5446 kw/mo; cost is per kw
	Total							**8.36**		
Maintenance Structure (each)										
	Base unit (10-ft)	1						**0.00**	Estimate for planning = $2000, See detailed estimate for structures	
	Extension (ft)	1						**0.00**	Estimate from special pipe costs is $150/ft, See detailed estimate for structures	
Concrete Curb Removal and Replacement (lf)										
02220.250.6100	Removal, Curbs, reinforced (lf)	1		420	4.94	98.5%	100.0%	4.87	Means 2006	includes O&P
02315.490.0550	10 mi rt haul (16.5 cy) - per yard	0.058			15.00	103.4%	100.0%	0.91	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.084			70.00	98.5%	100.0%	5.82	Means 2006	includes O&P
02315.110.0300	6" select backfill, no comp (cy)	0.019			18.21	98.5%	100.0%	0.34	Means 2006	includes O&P (material costs + 10%)
02315.310.7000	Compaction, 18" vibrate plate (cy)	0.019			1.86	98.5%	100.0%	0.04	Means 2006	includes O&P
02770.300.0300	Curb, machine form straight (lf)	1		6345	8.25	98.5%	100.0%	8.13	Means 2006	includes O&P
	Total							**20.11**		
Concrete Walk Removal and Replacement (ft-width)										
02220.240.4100	Sidewalk removal, concrete, 4" reinf. (sy)	0.111			8.45	98.5%	100.0%	0.93	Means 2006	
02315.490.0550	10 mi rt haul (16.5 cy) - per yard	0.016			15.00	103.4%	100.0%	0.25	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.023			70.00	98.5%	100.0%	1.56	Means 2006	includes O&P
02315.110.0300	3" select backfill, no comp (cy)	0.009			18.21	98.5%	100.0%	0.17	Means 2006	includes O&P (material costs + 10%)
02315.310.7000	Compaction, 18" vibrate plate (cy)	0.019			1.86	98.5%	100.0%	0.04	Means 2006	includes O&P
02775.275.0310	Sidewalk, conc. 4" (sf)	1			3.58	98.5%	100.0%	3.53	Means 2006	includes O&P
	Total							**6.48**		
* Total index except some items use intallation index.										
* Reference: RSMeans Heavy Construction Cost Data, 20th Annual Edition, 2006.										

Equipment Costs (with O&P)

Item	Description	Qty	Power (Hp)	Production (cy/hr)	Costs ($/day)	St. Paul Index *	Present Cost Index	Total Cost ($/day)	Source	Notes
Pipe Trench - Excavate, lay, backfill, compact (75 CY/HR Production)										
01.54.33.20.0150	1 CY Excavator	1	80	75	$ 570.00	101.8%	100.0%	$ 581	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 819		
Pipe Trench - Excavate, lay, backfill, compact (100 CY/HR Production)										
01.54.33.20.0200	1.5 CY Excavator	1	120	100	$ 755.00	101.8%	100.0%	$ 769	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 1,007		
Pipe Trench - Excavate, lay, backfill, compact (130 CY/HR Production)										
01.54.33.20.0300	2 CY Excavator	1	160	130	$ 950.00	101.8%	100.0%	$ 968	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 1,206		
* Total Index										

Crew Costs (with O&P)

Description	Qty	Cost/hr	St. Paul Index *	Present Cost Index	Total Cost ($/hr)	Source	Notes
Pipe Trench - Excavate, lay, backfill, compact							
crane operator	1	$ 51.00	103.4%	100%	$ 52.74	Means 2006	
equipment oiler	1	$ 49.35	103.4%	100%	$ 51.03	Means 2006	
common building laborer	2	$ 42.65	103.4%	100%	$ 88.21	Means 2006	
foreman	1	$ 54.30	103.4%	100%	$ 56.15	Means 2006	
Total					$ 248.13		
Traffic Control							
common building laborer	1	$ 42.65	103.4%	100%	$ 44.11	Means 2006	
Total					$ 44.11		
* Installation Index							

Water Reuse Pipe Line Construction Cost
Pipe Material: Ductile Iron

Start Sta.	End Sta.	length	diameter (in)	start depth (ft)	end depth (ft)	X Hor.: 1 Vert.	depth of vertical cut at bottom	average depth (ft)	design parameter key	upstream MH diameter	trench bottom width (ft)	trench top width (ft)	pavement width cut (ft)	Curb replacement (ea)	Walk replacement (ft-width)	sod replacement width (ft)	seeding width (ft)	traffic control personnel	trench support (1=yes)	dewatering wells (1=yes)	unit cost of pipeline $/ft
Urban Applications																					
0	**550**	550	**30**	8	**8**	**1**	**10**	8.865	11	5	8	8.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$192.48
550	**600**	50	**30**	8	**8**	**1**	**10**	8.865	11	5	8	8.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$229.79
																				Weighted Average	**$195.59**
600	**1150**	550	**36**	8	**8**	**1**	**10**	9.010	12	6	8	8.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$237.65
1150	**1200**	50	**36**	8	**8**	**1**	**10**	9.010	12	6	8	8.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$274.96
																				Weighted Average	**$240.76**
1200	**1750**	550	**42**	8	**8**	**1**	**10**	9.156	13	6	8	8.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$291.58
1750	**1800**	50	**42**	8	**8**	**1**	**10**	9.156	13	6	8	8.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$328.89
																				Weighted Average	**$294.69**
1800	**2350**	550	**48**	8	**8**	**1**	**10**	9.302	14	7	10	10.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$369.80
2350	**2400**	50	**48**	8	**8**	**1**	**10**	9.302	14	7	10	10.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$407.12
																				Weighted Average	**$372.91**
2400	**2950**	550	**54**	8	**8**	**1**	**10**	9.448	15	7	10	10.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$430.46
2950	**3000**	50	**54**	8	**8**	**1**	**10**	9.448	15	7	10	10.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$467.77
																				Weighted Average	**$433.57**
3000	**3550**	550	**60**	8	**8**	**1**	**10**	9.594	16	8	12	12.0	**0**	**0**	**0**	**10**	**0**	**1**	**0**	**0**	$491.26
3550	**3600**	50	**60**	8	**8**	**1**	**10**	9.594	16	8	12	12.0	**6**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	$528.57
																				Weighted Average	**$494.37**
Rural Applications:																					
0	**600**	600	**30**	8	**8**	**1**	**10**	8.865	11	5	8	8.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$179.54**
0	**600**	600	**36**	8	**8**	**1**	**10**	9.010	12	6	8	8.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$223.57**
0	**600**	600	**42**	8	**8**	**1**	**10**	9.156	13	6	8	8.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$277.03**
0	**600**	600	**48**	8	**8**	**1**	**10**	9.302	14	7	10	10.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$352.53**
0	**600**	600	**54**	8	**8**	**1**	**10**	9.448	15	7	10	10.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$412.45**
0	**600**	600	**60**	8	**8**	**1**	**10**	9.594	16	8	12	12.0	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**$469.69**

costs do not include:
- support and/or relocation of utilities
- permanent easement
- temporary easement
- engr and admin costs
- surveying
- geotechnical investigation
- rock excavation
- contractors mobilization, bonds, overhead and profit
- tree removal and replacement

Pipe Installation Data (DIP Pipe)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pipe ID (in)	Key	Wall (in) - 1	Pipe OD (ft)	Pipe Area (sf)	Bed under pipe (ft)	Bottom Trench Width (ft)	Bedding Depth (ft)	Bedding Area (sf)	Excavation Rate (cy/hr) - 2	B&C of select (cy/hr) - 3	B&C of native (cy/hr) - 4	Pipe Install Rate (ft/hr) - 5	Pipe Costs ($) - ref 10
30	11	5.75	3.46	9.39	0.86	8	5.3	33.2	100	11	75	11.0	82.65
36	12	6.25	4.04	12.83	1.01	8	6.1	35.6	130	11	75	9.0	112.50
42	13	6.75	4.63	16.80	1.16	8	6.8	37.4	130	11	75	8.5	161.60
48	14	7.25	5.21	21.31	1.30	10	7.5	53.8	130	11	75	8.0	209.77
54	15	7.75	5.79	26.34	1.45	10	8.2	56.1	130	11	75	7.3	262.81
60	16	8.25	6.38	31.92	1.59	12	9.0	75.7	130	11	75	6.5	285.00

Notes:
1 - DIP Pipe
2 - Means 02315.424.0200
3 - Means 02315.110.1100 - Crew A1
4 - Approximated - Crew B10G
5 - Means 02500.730.2200 - Crew B21, B13, B13B
6 - Quotation from Manufacturer (Unit cost in this column includes mechanical joints and pipe cost; Pipe manufacturer: American Ductile Iron Pipe)

Construction Unit Costs

Item (2006 Means)	Description	Qty	Power (Hp)	Production (unit/hr)	Costs ($/unit)	St. Paul Index *	Present Cost Index	Total Cost ($/unit)	Source	Notes
Select backfill (cy)										
02315.110.0300	select backfill, no comp	1			18.21	98.5%	100.0%	17.94	Means 2006	includes O&P (material costs + 10%)
	Total							**17.94**		
Pavement Removal and Replacement (sy)										
02220.250.5050	4 - 6" bit pavement removal (sy)	1		420	6.75	98.5%	100.0%	6.65	Means 2006	includes O&P
02315.490.0550	Disposal - 10 mi rt haul - (cy)	0.167			15.00	98.5%	100.0%	2.47	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.217			70.00	98.5%	100.0%	14.94	Means 2006	includes O&P
02315.110.0300	6" select backfill, no comp (cy)	0.167			18.21	98.5%	100.0%	2.99	Means 2006	includes O&P (material costs + 10%)
02300.432.2220	Dozer - 150 haul (cy)	0.167			4.82	98.5%	100.0%	0.80	Means 2006	includes O&P
02315.310.5000	Compaction - vibrating roller 2 pass (cy)	0.167			0.35	98.5%	100.0%	0.06	Means 2006	includes O&P
02740.310.0120	Binder course - 2" thick	1		6345	5.25	98.5%	100.0%	5.18	Means 2006	includes O&P
02740.310.0380	Wearing course - 2" thick	1		6325	5.70	98.5%	100.0%	5.62	Means 2006	includes O&P
	Total							**38.71**		City Minneapolis allowance is 50$/sy
Sod (sy)										
02910.710.2620	Rough grade prep (msf)	0.009			11.7	98.5%	100.0%	0.11	Means 2006	includes O&P
02910.710.3920	Spread topsoil, 4" (msf)	0.009			470	98.5%	100.0%	4.17	Means 2006	includes O&P, includes material
02920.400.0200	Sod, bluegrass, per MSF	0.009		22	390	98.5%	100.0%	3.46	Means 2006	includes O&P
	Total							**7.74**		
Seed (sy)										
02910.710.2620	Rough grade prep (msf)	0.009			11.7	98.5%	100.0%	0.11	Means 2006	includes O&P
02910.710.3920	Spread topsoil, 4" (msf)	0.009			470	98.5%	100.0%	4.17	Means 2006	includes O&P, includes material
02920.320.320	Hydroseed w/ mulch&fert. - (msf)	0.009		80	46.5	98.5%	100.0%	0.42	Means 2006	includes O&P
	Total							**4.70**		
Trench Support (sf)										
02250.400.1800	25' deep exc, drive, extract, salvage	1		**553**	20	103.4%	100.0%	20.68	Means 2006	includes O&P
	Total							**20.68**		
Dewatering (lf)										
	Months	1								
	Depth (ft)	25								
	Spacing (ft)	200								
02240.700.0050	Wells 10-20' deep, ave	0.125			19.4	103.4%	100.0%	2.51	Means 2006	indludes O&P; lineal measure is well spacing/depth
01.54.33.40.4700	Subm pump, 2", 120 gpm -rent	0.005			192	101.8%	100.0%	0.98	Means 2006	includes O&P; qty is months rental
01.54.33.40.2700	Gen, elect, 100 kw -rent	0.005			7.2	98.5%	100.0%	0.04	Means 2006	includes O&P; qty is months-kw; cost is monthy rental per kw
01.54.33.40.2700	Gen, elect, 100 kw -operate	27.23			0.18	98.5%	100.0%	4.83	Means 2006	includes O&P; 10hp = 7.46 kw/hr, 5446 kw/mo; cost is per kw
	Total							**8.36**		
Maintenance Structure (each)										
	Base unit (10-ft)	1						**0.00**	Estimate for planning = $2000, See detailed estimate for structures	
	Extension (ft)	1						**0.00**	Estimate from special pipe costs is $150/ft, See detailed estimate for structures	
Concrete Curb Removal and Replacement (lf)										
02220.250.6100	Removal, Curbs, reinforced (lf)	1		420	4.94	98.5%	100.0%	4.87	Means 2006	includes O&P
02315.490.0550	10 mi rt haul (16.5 cy) - per yard	0.058			15.00	103.4%	100.0%	0.91	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.084			70.00	98.5%	100.0%	5.82	Means 2006	includes O&P
02315.110.0300	6" select backfill, no comp (cy)	0.019			18.21	98.5%	100.0%	0.34	Means 2006	includes O&P (material costs + 10%)
02315.310.7000	Compaction, 18" vibrate plate (cy)	0.019			1.86	98.5%	100.0%	0.04	Means 2006	includes O&P
02770.300.0300	Curb, machine form straight (lf)	1		6345	8.25	98.5%	100.0%	8.13	Means 2006	includes O&P
	Total							**20.11**		
Concrete Walk Removal and Replacement (ft-width)										
02220.240.4100	Sidewalk removal, concrete, 4" reinf. (sy)	0.111			8.45	98.5%	100.0%	0.93	Means 2006	
02315.490.0550	10 mi rt haul (16.5 cy) - per yard	0.016			15.00	103.4%	100.0%	0.25	Means 2003	includes O&P
02220.330.0100	Disposal - tipping fee (ton)	0.023			70.00	98.5%	100.0%	1.56	Means 2006	includes O&P
02315.110.0300	3" select backfill, no comp (cy)	0.009			18.21	98.5%	100.0%	0.17	Means 2006	includes O&P (material costs + 10%)
02315.310.7000	Compaction, 18" vibrate plate (cy)	0.019			1.86	98.5%	100.0%	0.04	Means 2006	includes O&P
02775.275.0310	Sidewalk, conc. 4" (sf)	1			3.58	98.5%	100.0%	3.53	Means 2006	includes O&P
	Total							**6.48**		
* Total index except some items use intallation index.										
* Reference: RSMeans Heavy Construction Cost Data, 20th Annual Edition, 2006.										

Equipment Costs (with O&P)

Item	Description	Qty	Power (Hp)	Production (cy/hr)	Costs ($/day)	St. Paul Index *	Present Cost Index	Total Cost ($/day)	Source	Notes
Pipe Trench - Excavate, lay, backfill, compact (75 CY/HR Production)										
01.54.33.20.0150	1 CY Excavator	1	80	75	$ 570.00	101.8%	100.0%	$ 581	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 819		
Pipe Trench - Excavate, lay, backfill, compact (100 CY/HR Production)										
01.54.33.20.0200	1.5 CY Excavator	1	120	100	$ 755.00	101.8%	100.0%	$ 769	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 1,007		
Pipe Trench - Excavate, lay, backfill, compact (130 CY/HR Production)										
01.54.33.20.0300	2 CY Excavator	1	160	130	$ 950.00	101.8%	100.0%	$ 968	Means 2006	rentals are based on weekly rate
01.54.33.20.1250	Vibratory Hand Compactor	2	10		$ 38.50	101.8%	100.0%	$ 79	Means 2006	rentals are based on weekly rate
01.54.33.40.7050	Trench Box (8x16)	1			$ 156.00	101.8%	100.0%	$ 159	Means 2006	rentals are based on weekly rate
Total								$ 1,206		
* Total Index										

Crew Costs (with O&P)

Description	Qty	Cost/hr	St. Paul Index *	Present Cost Index	Total Cost ($/hr)	Source	Notes
Pipe Trench - Excavate, lay, backfill, compact							
crane operator	1	$ 51.00	103.4%	100%	$ 52.74	Means 2006	
equipment oiler	1	$ 49.35	103.4%	100%	$ 51.03	Means 2006	
common building laborer	2	$ 42.65	103.4%	100%	$ 88.21	Means 2006	
foreman	1	$ 54.30	103.4%	100%	$ 56.15	Means 2006	
Total					$ 248.13		
Traffic Control							
common building laborer	1	$ 42.65	103.4%	100%	$ 44.11	Means 2006	
Total					$ 44.11		
* Installation Index							

Exhibit 2
Water Reuse System Capital Cost

Capital PROJECT Cost Curves for Reclaimed Transmission Piping

						Urban Capital Cost by Distance - $ for 1-10 miles									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	97	512,160	768,240	1,024,320	1,280,400	1,536,480	1,792,560	2,048,640	2,304,720	2,560,800	5,121,600
6	0.20	138.80	0.60	4.73	106	559,680	839,520	1,119,360	1,399,200	1,679,040	1,958,880	2,238,720	2,518,560	2,798,400	5,596,800
6	0.27	187.38	0.81	6.38	106	559,680	839,520	1,119,360	1,399,200	1,679,040	1,958,880	2,238,720	2,518,560	2,798,400	5,596,800
8	0.40	277.60	1.20	5.32	115	607,200	910,800	1,214,400	1,518,000	1,821,600	2,125,200	2,428,800	2,732,400	3,036,000	6,072,000
8	0.47	326.18	1.41	6.25	115	607,200	910,800	1,214,400	1,518,000	1,821,600	2,125,200	2,428,800	2,732,400	3,036,000	6,072,000
8	0.53	367.82	1.59	7.05	115	607,200	910,800	1,214,400	1,518,000	1,821,600	2,125,200	2,428,800	2,732,400	3,036,000	6,072,000
10	0.60	416.40	1.80	5.11	128	675,840	1,013,760	1,351,680	1,689,600	2,027,520	2,365,440	2,703,360	3,041,280	3,379,200	6,758,400
10	0.67	464.98	2.01	5.70	128	675,840	1,013,760	1,351,680	1,689,600	2,027,520	2,365,440	2,703,360	3,041,280	3,379,200	6,758,400
10	0.83	576.02	2.49	7.06	128	675,840	1,013,760	1,351,680	1,689,600	2,027,520	2,365,440	2,703,360	3,041,280	3,379,200	6,758,400
12	0.93	645.42	2.79	5.50	140	739,200	1,108,800	1,478,400	1,848,000	2,217,600	2,587,200	2,956,800	3,326,400	3,696,000	7,392,000
12	1.00	694.00	3.00	5.91	140	739,200	1,108,800	1,478,400	1,848,000	2,217,600	2,587,200	2,956,800	3,326,400	3,696,000	7,392,000
12	1.17	811.98	3.51	6.91	140	739,200	1,108,800	1,478,400	1,848,000	2,217,600	2,587,200	2,956,800	3,326,400	3,696,000	7,392,000
14	1.33	923.02	3.99	5.77	157	828,960	1,243,440	1,657,920	2,072,400	2,486,880	2,901,360	3,315,840	3,730,320	4,144,800	8,289,600
14	1.50	1041.00	4.50	6.51	157	828,960	1,243,440	1,657,920	2,072,400	2,486,880	2,901,360	3,315,840	3,730,320	4,144,800	8,289,600
14	1.67	1158.98	5.01	7.25	157	828,960	1,243,440	1,657,920	2,072,400	2,486,880	2,901,360	3,315,840	3,730,320	4,144,800	8,289,600
16	1.83	1270.02	5.49	6.08	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
16	2.00	1388.00	6.00	6.65	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
16	2.07	1436.58	6.21	6.88	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
18	2.17	1505.98	6.51	5.70	211	1,114,080	1,671,120	2,228,160	2,785,200	3,342,240	3,899,280	4,456,320	5,013,360	5,570,400	11,140,800
18	2.33	1617.02	6.99	6.12	211	1,114,080	1,671,120	2,228,160	2,785,200	3,342,240	3,899,280	4,456,320	5,013,360	5,570,400	11,140,800
18	2.50	1735.00	7.50	6.57	211	1,114,080	1,671,120	2,228,160	2,785,200	3,342,240	3,899,280	4,456,320	5,013,360	5,570,400	11,140,800
18	2.67	1852.98	8.01	7.01	211	1,114,080	1,671,120	2,228,160	2,785,200	3,342,240	3,899,280	4,456,320	5,013,360	5,570,400	11,140,800
20	2.83	1964.02	8.49	6.02	236	1,246,080	1,869,120	2,492,160	3,115,200	3,738,240	4,361,280	4,984,320	5,607,360	6,230,400	12,460,800
20	3.00	2082.00	9.00	6.38	236	1,246,080	1,869,120	2,492,160	3,115,200	3,738,240	4,361,280	4,984,320	5,607,360	6,230,400	12,460,800
20	3.17	2199.98	9.51	6.74	236	1,246,080	1,869,120	2,492,160	3,115,200	3,738,240	4,361,280	4,984,320	5,607,360	6,230,400	12,460,800
20	3.33	2311.02	9.99	7.08	236	1,246,080	1,869,120	2,492,160	3,115,200	3,738,240	4,361,280	4,984,320	5,607,360	6,230,400	12,460,800
24	3.50	2429.00	10.50	5.17	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	3.67	2546.98	11.01	5.42	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	3.83	2658.02	11.49	5.66	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	4.00	2776.00	12.00	5.91	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	4.17	2893.98	12.51	6.16	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	4.33	3005.02	12.99	6.40	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	4.50	3123.00	13.50	6.65	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
24	4.67	3240.98	14.01	6.90	284	1,499,520	2,249,280	2,999,040	3,748,800	4,498,560	5,248,320	5,998,080	6,747,840	7,497,600	14,995,200
30	5.33	3699.02	15.99	5.04	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	5.67	3934.98	17.01	5.36	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	6.00	4164.00	18.00	5.67	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	6.33	4393.02	18.99	5.99	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	6.67	4628.98	20.01	6.31	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	7.00	4858.00	21.00	6.62	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
30	7.33	5087.02	21.99	6.93	353	1,863,840	2,795,760	3,727,680	4,659,600	5,591,520	6,523,440	7,455,360	8,387,280	9,319,200	18,638,400
36	8.00	5552.00	24.00	5.25	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	8.33	5781.02	24.99	5.47	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	8.67	6016.98	26.01	5.69	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	9.00	6246.00	27.00	5.91	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	9.33	6475.02	27.99	6.13	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	9.67	6710.98	29.01	6.35	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	10.00	6940.00	30.00	6.57	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	10.33	7169.02	30.99	6.78	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	10.50	7287.00	31.50	6.89	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
36	10.67	7404.98	32.01	7.01	434	2,291,520	3,437,280	4,583,040	5,728,800	6,874,560	8,020,320	9,166,080	10,311,840	11,457,600	22,915,200
42	11.33	7863.02	33.99	5.47	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800

Capital PROJECT Cost Curves for Reclaimed Transmission Piping

Urban Capital Cost by Distance - $ for 1-10 miles

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
42	11.67	8098.98	35.01	5.63	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	12.00	8328.00	36.00	5.79	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	12.33	8557.02	36.99	5.95	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	12.67	8792.98	38.01	6.11	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	13.00	9022.00	39.00	6.27	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	13.33	9251.02	39.99	6.43	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	13.67	9486.98	41.01	6.59	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	14.00	9716.00	42.00	6.75	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
42	14.67	10180.98	44.01	7.08	531	2,803,680	4,205,520	5,607,360	7,009,200	8,411,040	9,812,880	11,214,720	12,616,560	14,018,400	28,036,800
48	13.67	9486.98	41.01	5.05	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	14.00	9716.00	42.00	5.17	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	14.33	9945.02	42.99	5.29	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	14.67	10180.98	44.01	5.42	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	15.00	10410.00	45.00	5.54	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	15.33	10639.02	45.99	5.66	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	15.67	10874.98	47.01	5.79	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	16.00	11104.00	48.00	5.91	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	16.33	11333.02	48.99	6.03	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	16.67	11568.98	50.01	6.16	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	17.33	12027.02	51.99	6.40	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	18.00	12492.00	54.00	6.65	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	18.33	12721.02	54.99	6.77	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
48	19.00	13186.00	57.00	7.02	671	3,542,880	5,314,320	7,085,760	8,857,200	10,628,640	12,400,080	14,171,520	15,942,960	17,714,400	35,428,800
54	17.33	12027.02	51.99	5.06	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	18.00	12492.00	54.00	5.25	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	18.67	12956.98	56.01	5.45	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	19.33	13415.02	57.99	5.64	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	20.00	13880.00	60.00	5.84	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	20.67	14344.98	62.01	6.03	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	21.33	14803.02	63.99	6.22	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	22.00	15268.00	66.00	6.42	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	22.67	15732.98	68.01	6.62	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	23.33	16191.02	69.99	6.81	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
54	24.00	16656.00	72.00	7.00	781	4,123,680	6,185,520	8,247,360	10,309,200	12,371,040	14,432,880	16,494,720	18,556,560	20,618,400	41,236,800
60	21.17	14691.98	63.51	5.00	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	21.67	15038.98	65.01	5.12	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	22.33	15497.02	66.99	5.28	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	23.00	15962.00	69.00	5.44	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	23.67	16426.98	71.01	5.60	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	24.33	16885.02	72.99	5.75	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	25.00	17350.00	75.00	5.91	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	25.67	17814.98	77.01	6.07	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	26.33	18273.02	78.99	6.22	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	27.00	18738.00	81.00	6.38	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	27.67	19202.98	83.01	6.54	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	28.33	19661.02	84.99	6.70	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	29.00	20126.00	87.00	6.86	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800
60	30.00	20820.00	90.00	7.09	891	4,704,480	7,056,720	9,408,960	11,761,200	14,113,440	16,465,680	18,817,920	21,170,160	23,522,400	47,044,800

Capital PROJECT Cost Curves for Reclaimed Transmission Piping

						Urban - Annualized Capital Cost - $/yr									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	97	$39,531	$59,297	$79,063	$98,829	$118,594	$138,360	$158,126	$177,891	$197,657	$395,314
6	0.20	138.80	0.60	4.73	106	$43,199	$64,799	$86,399	$107,998	$129,598	$151,198	$172,797	$194,397	$215,997	$431,993
6	0.27	187.38	0.81	6.38	106	$43,199	$64,799	$86,399	$107,998	$129,598	$151,198	$172,797	$194,397	$215,997	$431,993
8	0.40	277.60	1.20	5.32	115	$46,867	$70,301	$93,734	$117,168	$140,602	$164,035	$187,469	$210,902	$234,336	$468,672
8	0.47	326.18	1.41	6.25	115	$46,867	$70,301	$93,734	$117,168	$140,602	$164,035	$187,469	$210,902	$234,336	$468,672
8	0.53	367.82	1.59	7.05	115	$46,867	$70,301	$93,734	$117,168	$140,602	$164,035	$187,469	$210,902	$234,336	$468,672
10	0.60	416.40	1.80	5.11	128	$52,165	$78,248	$104,330	$130,413	$156,496	$182,578	$208,661	$234,743	$260,826	$521,652
10	0.67	464.98	2.01	5.70	128	$52,165	$78,248	$104,330	$130,413	$156,496	$182,578	$208,661	$234,743	$260,826	$521,652
10	0.83	576.02	2.49	7.06	128	$52,165	$78,248	$104,330	$130,413	$156,496	$182,578	$208,661	$234,743	$260,826	$521,652
12	0.93	645.42	2.79	5.50	140	$57,056	$85,584	$114,111	$142,639	$171,167	$199,695	$228,223	$256,751	$285,278	$570,557
12	1.00	694.00	3.00	5.91	140	$57,056	$85,584	$114,111	$142,639	$171,167	$199,695	$228,223	$256,751	$285,278	$570,557
12	1.17	811.98	3.51	6.91	140	$57,056	$85,584	$114,111	$142,639	$171,167	$199,695	$228,223	$256,751	$285,278	$570,557
14	1.33	923.02	3.99	5.77	157	$63,984	$95,976	$127,968	$159,960	$191,952	$223,944	$255,936	$287,927	$319,919	$639,839
14	1.50	1041.00	4.50	6.51	157	$63,984	$95,976	$127,968	$159,960	$191,952	$223,944	$255,936	$287,927	$319,919	$639,839
14	1.67	1158.98	5.01	7.25	157	$63,984	$95,976	$127,968	$159,960	$191,952	$223,944	$255,936	$287,927	$319,919	$639,839
16	1.83	1270.02	5.49	6.08	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
16	2.00	1388.00	6.00	6.65	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
16	2.07	1436.58	6.21	6.88	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
18	2.17	1505.98	6.51	5.70	211	$85,991	$128,987	$171,982	$214,978	$257,973	$300,969	$343,964	$386,960	$429,955	$859,911
18	2.33	1617.02	6.99	6.12	211	$85,991	$128,987	$171,982	$214,978	$257,973	$300,969	$343,964	$386,960	$429,955	$859,911
18	2.50	1735.00	7.50	6.57	211	$85,991	$128,987	$171,982	$214,978	$257,973	$300,969	$343,964	$386,960	$429,955	$859,911
18	2.67	1852.98	8.01	7.01	211	$85,991	$128,987	$171,982	$214,978	$257,973	$300,969	$343,964	$386,960	$429,955	$859,911
20	2.83	1964.02	8.49	6.02	236	$96,180	$144,269	$192,359	$240,449	$288,539	$336,629	$384,718	$432,808	$480,898	$961,796
20	3.00	2082.00	9.00	6.38	236	$96,180	$144,269	$192,359	$240,449	$288,539	$336,629	$384,718	$432,808	$480,898	$961,796
20	3.17	2199.98	9.51	6.74	236	$96,180	$144,269	$192,359	$240,449	$288,539	$336,629	$384,718	$432,808	$480,898	$961,796
20	3.33	2311.02	9.99	7.08	236	$96,180	$144,269	$192,359	$240,449	$288,539	$336,629	$384,718	$432,808	$480,898	$961,796
24	3.50	2429.00	10.50	5.17	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	3.67	2546.98	11.01	5.42	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	3.83	2658.02	11.49	5.66	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	4.00	2776.00	12.00	5.91	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	4.17	2893.98	12.51	6.16	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	4.33	3005.02	12.99	6.40	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	4.50	3123.00	13.50	6.65	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
24	4.67	3240.98	14.01	6.90	284	$115,742	$173,612	$231,483	$289,354	$347,225	$405,095	$462,966	$520,837	$578,708	$1,157,415
30	5.33	3699.02	15.99	5.04	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	5.67	3934.98	17.01	5.36	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	6.00	4164.00	18.00	5.67	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	6.33	4393.02	18.99	5.99	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	6.67	4628.98	20.01	6.31	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	7.00	4858.00	21.00	6.62	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
30	7.33	5087.02	21.99	6.93	353	$143,862	$215,793	$287,724	$359,655	$431,586	$503,516	$575,447	$647,378	$719,309	$1,438,618
36	8.00	5552.00	24.00	5.25	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	8.33	5781.02	24.99	5.47	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	8.67	6016.98	26.01	5.69	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	9.00	6246.00	27.00	5.91	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	9.33	6475.02	27.99	6.13	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	9.67	6710.98	29.01	6.35	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	10.00	6940.00	30.00	6.57	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	10.33	7169.02	30.99	6.78	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	10.50	7287.00	31.50	6.89	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
36	10.67	7404.98	32.01	7.01	434	$176,873	$265,309	$353,745	$442,182	$530,618	$619,054	$707,491	$795,927	$884,363	$1,768,726
42	11.33	7863.02	33.99	5.47	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041

Capital PROJECT Cost Curves for Reclaimed Transmission Piping

Urban - Annualized Capital Cost - $/yr

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
42	11.67	8098.98	35.01	5.63	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	12.00	8328.00	36.00	5.79	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	12.33	8557.02	36.99	5.95	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	12.67	8792.98	38.01	6.11	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	13.00	9022.00	39.00	6.27	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	13.33	9251.02	39.99	6.43	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	13.67	9486.98	41.01	6.59	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	14.00	9716.00	42.00	6.75	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
42	14.67	10180.98	44.01	7.08	531	$216,404	$324,606	$432,808	$541,010	$649,212	$757,414	$865,616	$973,818	$1,082,020	$2,164,041
48	13.67	9486.98	41.01	5.05	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	14.00	9716.00	42.00	5.17	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	14.33	9945.02	42.99	5.29	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	14.67	10180.98	44.01	5.42	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	15.00	10410.00	45.00	5.54	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	15.33	10639.02	45.99	5.66	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	15.67	10874.98	47.01	5.79	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	16.00	11104.00	48.00	5.91	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	16.33	11333.02	48.99	6.03	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	16.67	11568.98	50.01	6.16	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	17.33	12027.02	51.99	6.40	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	18.00	12492.00	54.00	6.65	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	18.33	12721.02	54.99	6.77	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
48	19.00	13186.00	57.00	7.02	671	$273,460	$410,190	$546,920	$683,649	$820,379	$957,109	$1,093,839	$1,230,569	$1,367,299	$2,734,598
54	17.33	12027.02	51.99	5.06	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	18.00	12492.00	54.00	5.25	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	18.67	12956.98	56.01	5.45	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	19.33	13415.02	57.99	5.64	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	20.00	13880.00	60.00	5.84	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	20.67	14344.98	62.01	6.03	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	21.33	14803.02	63.99	6.22	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	22.00	15268.00	66.00	6.42	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	22.67	15732.98	68.01	6.62	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	23.33	16191.02	69.99	6.81	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
54	24.00	16656.00	72.00	7.00	781	$318,289	$477,434	$636,578	$795,723	$954,868	$1,114,012	$1,273,157	$1,432,302	$1,591,446	$3,182,892
60	21.17	14691.98	63.51	5.00	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	21.67	15038.98	65.01	5.12	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	22.33	15497.02	66.99	5.28	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	23.00	15962.00	69.00	5.44	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	23.67	16426.98	71.01	5.60	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	24.33	16885.02	72.99	5.75	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	25.00	17350.00	75.00	5.91	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	25.67	17814.98	77.01	6.07	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	26.33	18273.02	78.99	6.22	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	27.00	18738.00	81.00	6.38	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	27.67	19202.98	83.01	6.54	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	28.33	19661.02	84.99	6.70	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	29.00	20126.00	87.00	6.86	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187
60	30.00	20820.00	90.00	7.09	891	$363,119	$544,678	$726,237	$907,797	$1,089,356	$1,270,915	$1,452,475	$1,634,034	$1,815,594	$3,631,187

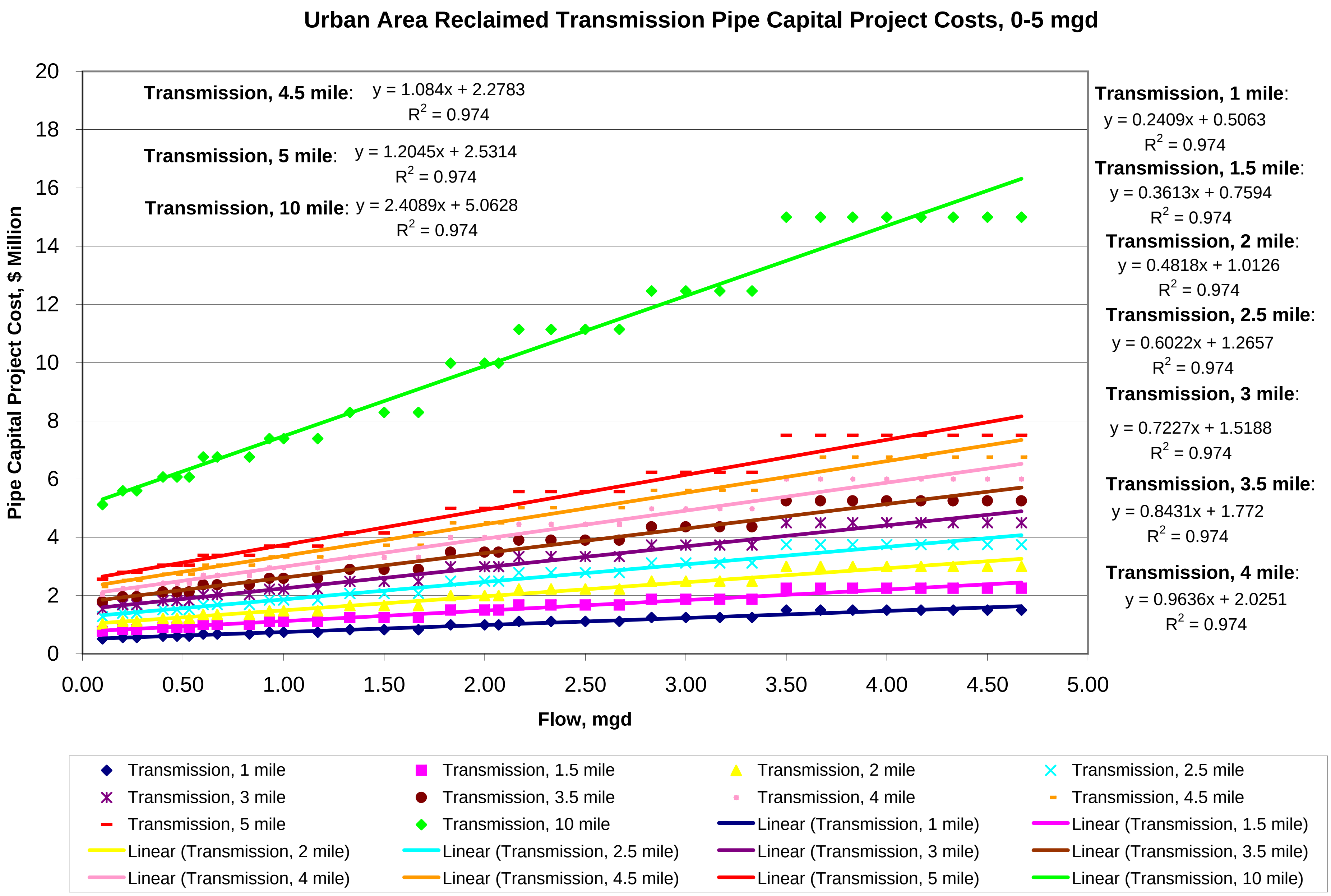
Capital PROJECT Cost Curves for Reclaimed Transmission Piping

Urban Capital Cost - Cost per 1000 gallons

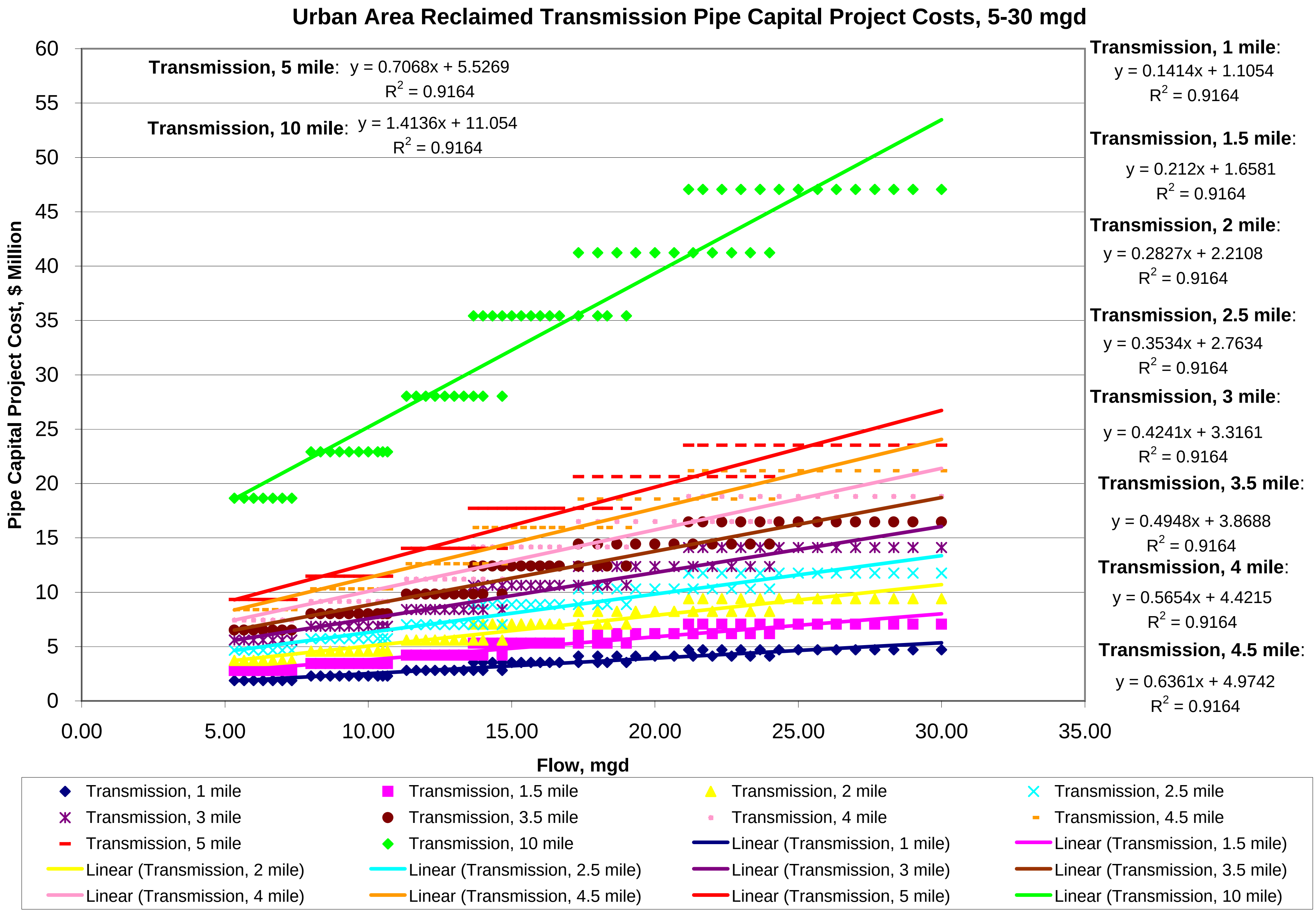
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4		5	10
4	0.10	69.40	0.30	5.32	97	$1.08	$1.62	$2.17	$2.71	$3.25	$3.79	$4.33	$4.87	$5.42	$10.83
6	0.20	138.80	0.60	4.73	106	$0.59	$0.89	$1.18	$1.48	$1.78	$2.07	$2.37	$2.66	$2.96	$5.92
6	0.27	187.38	0.81	6.38	106	$0.44	$0.66	$0.88	$1.10	$1.32	$1.53	$1.75	$1.97	$2.19	$4.38
8	0.40	277.60	1.20	5.32	115	$0.32	$0.48	$0.64	$0.80	$0.96	$1.12	$1.28	$1.44	$1.61	$3.21
8	0.47	326.18	1.41	6.25	115	$0.27	$0.41	$0.55	$0.68	$0.82	$0.96	$1.09	$1.23	$1.37	$2.73
8	0.53	367.82	1.59	7.05	115	$0.24	$0.36	$0.48	$0.61	$0.73	$0.85	$0.97	$1.09	$1.21	$2.42
10	0.60	416.40	1.80	5.11	128	$0.24	$0.36	$0.48	$0.60	$0.71	$0.83	$0.95	$1.07	$1.19	$2.38
10	0.67	464.98	2.01	5.70	128	$0.21	$0.32	$0.43	$0.53	$0.64	$0.75	$0.85	$0.96	$1.07	$2.13
10	0.83	576.02	2.49	7.06	128	$0.17	$0.26	$0.34	$0.43	$0.52	$0.60	$0.69	$0.77	$0.86	$1.72
12	0.93	645.42	2.79	5.50	140	$0.17	$0.25	$0.34	$0.42	$0.50	$0.59	$0.67	$0.76	$0.84	$1.68
12	1.00	694.00	3.00	5.91	140	$0.16	$0.23	$0.31	$0.39	$0.47	$0.55	$0.63	$0.70	$0.78	$1.56
12	1.17	811.98	3.51	6.91	140	$0.13	$0.20	$0.27	$0.33	$0.40	$0.47	$0.53	$0.60	$0.67	$1.34
14	1.33	923.02	3.99	5.77	157	$0.13	$0.20	$0.26	$0.33	$0.40	$0.46	$0.53	$0.59	$0.66	$1.32
14	1.50	1041.00	4.50	6.51	157	$0.12	$0.18	$0.23	$0.29	$0.35	$0.41	$0.47	$0.53	$0.58	$1.17
14	1.67	1158.98	5.01	7.25	157	$0.10	$0.16	$0.21	$0.26	$0.31	$0.37	$0.42	$0.47	$0.52	$1.05
16	1.83	1270.02	5.49	6.08	189	$0.12	$0.17	$0.23	$0.29	$0.35	$0.40	$0.46	$0.52	$0.58	$1.15
16	2.00	1388.00	6.00	6.65	189	$0.11	$0.16	$0.21	$0.26	$0.32	$0.37	$0.42	$0.47	$0.53	$1.06
16	2.07	1436.58	6.21	6.88	189	$0.10	$0.15	$0.20	$0.25	$0.31	$0.36	$0.41	$0.46	$0.51	$1.02
18	2.17	1505.98	6.51	5.70	211	$0.11	$0.16	$0.22	$0.27	$0.33	$0.38	$0.43	$0.49	$0.54	$1.09
18	2.33	1617.02	6.99	6.12	211	$0.10	$0.15	$0.20	$0.25	$0.30	$0.35	$0.40	$0.46	$0.51	$1.01
18	2.50	1735.00	7.50	6.57	211	$0.09	$0.14	$0.19	$0.24	$0.28	$0.33	$0.38	$0.42	$0.47	$0.94
18	2.67	1852.98	8.01	7.01	211	$0.09	$0.13	$0.18	$0.22	$0.26	$0.31	$0.35	$0.40	$0.44	$0.88
20	2.83	1964.02	8.49	6.02	236	$0.09	$0.14	$0.19	$0.23	$0.28	$0.33	$0.37	$0.42	$0.47	$0.93
20	3.00	2082.00	9.00	6.38	236	$0.09	$0.13	$0.18	$0.22	$0.26	$0.31	$0.35	$0.40	$0.44	$0.88
20	3.17	2199.98	9.51	6.74	236	$0.08	$0.12	$0.17	$0.21	$0.25	$0.29	$0.33	$0.37	$0.42	$0.83
20	3.33	2311.02	9.99	7.08	236	$0.08	$0.12	$0.16	$0.20	$0.24	$0.28	$0.32	$0.36	$0.40	$0.79
24	3.50	2429.00	10.50	5.17	284	$0.09	$0.14	$0.18	$0.23	$0.27	$0.32	$0.36	$0.41	$0.45	$0.91
24	3.67	2546.98	11.01	5.42	284	$0.09	$0.13	$0.17	$0.22	$0.26	$0.30	$0.35	$0.39	$0.43	$0.86
24	3.83	2658.02	11.49	5.66	284	$0.08	$0.12	$0.17	$0.21	$0.25	$0.29	$0.33	$0.37	$0.41	$0.83
24	4.00	2776.00	12.00	5.91	284	$0.08	$0.12	$0.16	$0.20	$0.24	$0.28	$0.32	$0.36	$0.40	$0.79
24	4.17	2893.98	12.51	6.16	284	$0.08	$0.11	$0.15	$0.19	$0.23	$0.27	$0.30	$0.34	$0.38	$0.76
24	4.33	3005.02	12.99	6.40	284	$0.07	$0.11	$0.15	$0.18	$0.22	$0.26	$0.29	$0.33	$0.37	$0.73
24	4.50	3123.00	13.50	6.65	284	$0.07	$0.11	$0.14	$0.18	$0.21	$0.25	$0.28	$0.32	$0.35	$0.70
24	4.67	3240.98	14.01	6.90	284	$0.07	$0.10	$0.14	$0.17	$0.20	$0.24	$0.27	$0.31	$0.34	$0.68
30	5.33	3699.02	15.99	5.04	353	$0.07	$0.11	$0.15	$0.18	$0.22	$0.26	$0.30	$0.33	$0.37	$0.74
30	5.67	3934.98	17.01	5.36	353	$0.07	$0.10	$0.14	$0.17	$0.21	$0.24	$0.28	$0.31	$0.35	$0.70
30	6.00	4164.00	18.00	5.67	353	$0.07	$0.10	$0.13	$0.16	$0.20	$0.23	$0.26	$0.30	$0.33	$0.66
30	6.33	4393.02	18.99	5.99	353	$0.06	$0.09	$0.12	$0.16	$0.19	$0.22	$0.25	$0.28	$0.31	$0.62
30	6.67	4628.98	20.01	6.31	353	$0.06	$0.09	$0.12	$0.15	$0.18	$0.21	$0.24	$0.27	$0.30	$0.59
30	7.00	4858.00	21.00	6.62	353	$0.06	$0.08	$0.11	$0.14	$0.17	$0.20	$0.23	$0.25	$0.28	$0.56
30	7.33	5087.02	21.99	6.93	353	$0.05	$0.08	$0.11	$0.13	$0.16	$0.19	$0.22	$0.24	$0.27	$0.54
36	8.00	5552.00	24.00	5.25	434	$0.06	$0.09	$0.12	$0.15	$0.18	$0.21	$0.24	$0.27	$0.30	$0.61
36	8.33	5781.02	24.99	5.47	434	$0.06	$0.09	$0.12	$0.15	$0.17	$0.20	$0.23	$0.26	$0.29	$0.58
36	8.67	6016.98	26.01	5.69	434	$0.06	$0.08	$0.11	$0.14	$0.17	$0.20	$0.22	$0.25	$0.28	$0.56
36	9.00	6246.00	27.00	5.91	434	$0.05	$0.08	$0.11	$0.13	$0.16	$0.19	$0.22	$0.24	$0.27	$0.54
36	9.33	6475.02	27.99	6.13	434	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.23	$0.26	$0.52
36	9.67	6710.98	29.01	6.35	434	$0.05	$0.08	$0.10	$0.13	$0.15	$0.18	$0.20	$0.23	$0.25	$0.50
36	10.00	6940.00	30.00	6.57	434	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.19	$0.22	$0.24	$0.48
36	10.33	7169.02	30.99	6.78	434	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
36	10.50	7287.00	31.50	6.89	434	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
36	10.67	7404.98	32.01	7.01	434	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.20	$0.23	$0.45
42	11.33	7863.02	33.99	5.47	531	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.24	$0.26	$0.52

Capital PROJECT Cost Curves for Reclaimed Transmission Piping

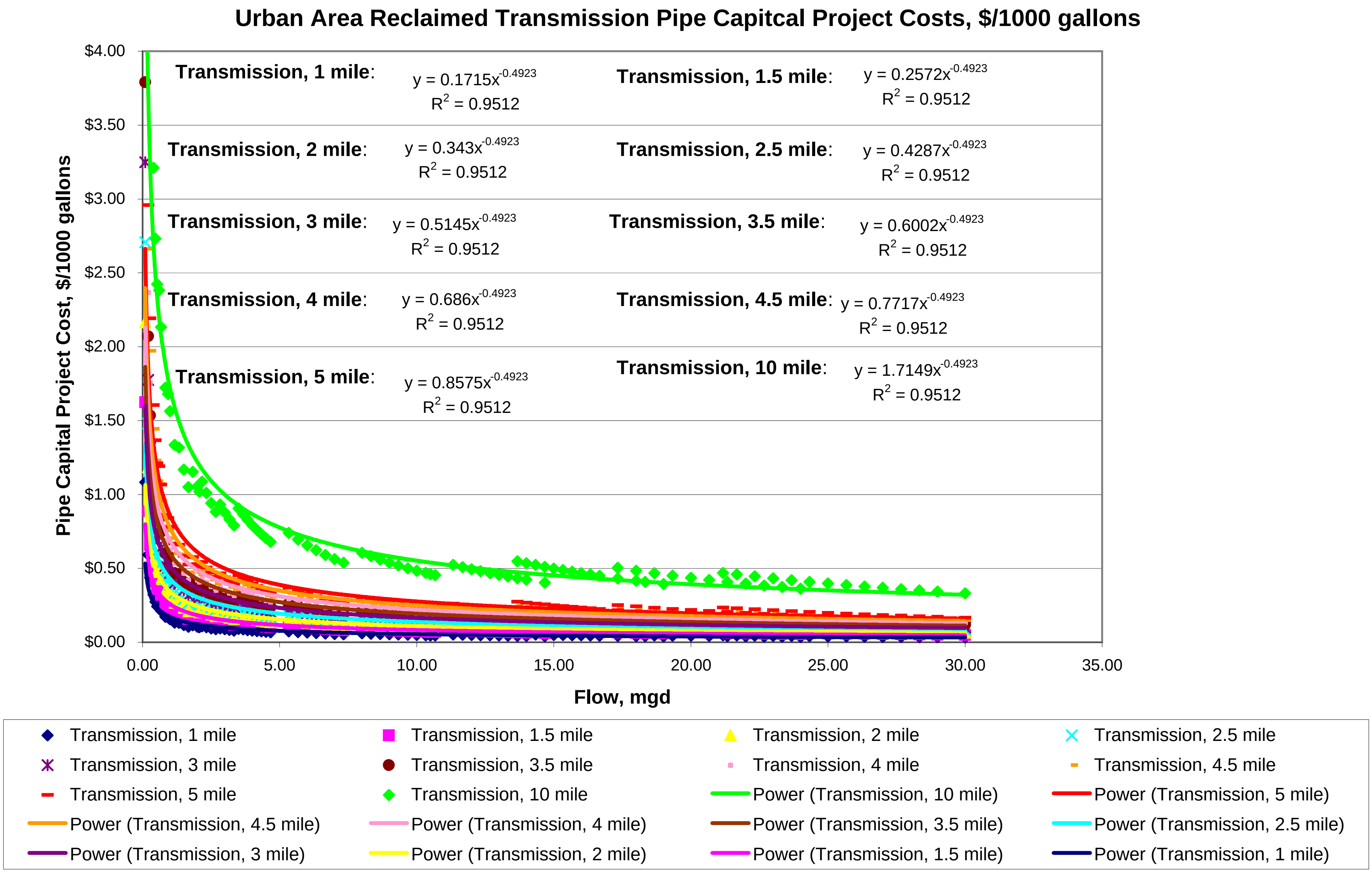
						Urban Capital Cost - Cost per 1000 gallons									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4		5	10
42	11.67	8098.98	35.01	5.63	531	$0.05	$0.08	$0.10	$0.13	$0.15	$0.18	$0.20	$0.23	$0.25	$0.51
42	12.00	8328.00	36.00	5.79	531	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.49
42	12.33	8557.02	36.99	5.95	531	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.22	$0.24	$0.48
42	12.67	8792.98	38.01	6.11	531	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
42	13.00	9022.00	39.00	6.27	531	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
42	13.33	9251.02	39.99	6.43	531	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.44
42	13.67	9486.98	41.01	6.59	531	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.20	$0.22	$0.43
42	14.00	9716.00	42.00	6.75	531	$0.04	$0.06	$0.08	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42
42	14.67	10180.98	44.01	7.08	531	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
48	13.67	9486.98	41.01	5.05	671	$0.05	$0.08	$0.11	$0.14	$0.16	$0.19	$0.22	$0.25	$0.27	$0.55
48	14.00	9716.00	42.00	5.17	671	$0.05	$0.08	$0.11	$0.13	$0.16	$0.19	$0.21	$0.24	$0.27	$0.54
48	14.33	9945.02	42.99	5.29	671	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.24	$0.26	$0.52
48	14.67	10180.98	44.01	5.42	671	$0.05	$0.08	$0.10	$0.13	$0.15	$0.18	$0.20	$0.23	$0.26	$0.51
48	15.00	10410.00	45.00	5.54	671	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.50
48	15.33	10639.02	45.99	5.66	671	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.24	$0.49
48	15.67	10874.98	47.01	5.79	671	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.22	$0.24	$0.48
48	16.00	11104.00	48.00	5.91	671	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
48	16.33	11333.02	48.99	6.03	671	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
48	16.67	11568.98	50.01	6.16	671	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.45
48	17.33	12027.02	51.99	6.40	671	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.22	$0.43
48	18.00	12492.00	54.00	6.65	671	$0.04	$0.06	$0.08	$0.10	$0.12	$0.15	$0.17	$0.19	$0.21	$0.42
48	18.33	12721.02	54.99	6.77	671	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.41
48	19.00	13186.00	57.00	7.02	671	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.39
54	17.33	12027.02	51.99	5.06	781	$0.05	$0.08	$0.10	$0.13	$0.15	$0.18	$0.20	$0.23	$0.25	$0.50
54	18.00	12492.00	54.00	5.25	781	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.19	$0.22	$0.24	$0.48
54	18.67	12956.98	56.01	5.45	781	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
54	19.33	13415.02	57.99	5.64	781	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.20	$0.23	$0.45
54	20.00	13880.00	60.00	5.84	781	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.20	$0.22	$0.44
54	20.67	14344.98	62.01	6.03	781	$0.04	$0.06	$0.08	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42
54	21.33	14803.02	63.99	6.22	781	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.41
54	22.00	15268.00	66.00	6.42	781	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
54	22.67	15732.98	68.01	6.62	781	$0.04	$0.06	$0.08	$0.10	$0.12	$0.13	$0.15	$0.17	$0.19	$0.38
54	23.33	16191.02	69.99	6.81	781	$0.04	$0.06	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.37
54	24.00	16656.00	72.00	7.00	781	$0.04	$0.05	$0.07	$0.09	$0.11	$0.13	$0.15	$0.16	$0.18	$0.36
60	21.17	14691.98	63.51	5.00	891	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
60	21.67	15038.98	65.01	5.12	891	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
60	22.33	15497.02	66.99	5.28	891	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.45
60	23.00	15962.00	69.00	5.44	891	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.22	$0.43
60	23.67	16426.98	71.01	5.60	891	$0.04	$0.06	$0.08	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42
60	24.33	16885.02	72.99	5.75	891	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.41
60	25.00	17350.00	75.00	5.91	891	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
60	25.67	17814.98	77.01	6.07	891	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.17	$0.19	$0.39
60	26.33	18273.02	78.99	6.22	891	$0.04	$0.06	$0.08	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.38
60	27.00	18738.00	81.00	6.38	891	$0.04	$0.06	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.18	$0.37
60	27.67	19202.98	83.01	6.54	891	$0.04	$0.05	$0.07	$0.09	$0.11	$0.13	$0.14	$0.16	$0.18	$0.36
60	28.33	19661.02	84.99	6.70	891	$0.04	$0.05	$0.07	$0.09	$0.11	$0.12	$0.14	$0.16	$0.18	$0.35
60	29.00	20126.00	87.00	6.86	891	$0.03	$0.05	$0.07	$0.09	$0.10	$0.12	$0.14	$0.15	$0.17	$0.34
60	30.00	20820.00	90.00	7.09	891	$0.03	$0.05	$0.07	$0.08	$0.10	$0.12	$0.13	$0.15	$0.17	$0.33



Urban Area Reclaimed Transmission Pipe Capital Project Costs, 0-5 mgd
Pipe Capital Project Cost, $ Million
Flow, mgd
Transmission, 4.5 mile: y = 1.084x + 2.2783
R2 = 0.974
Transmission, 5 mile: y = 1.2045x + 2.5314
R2 = 0.974
Transmission, 10 mile: y = 2.4089x + 5.0628
R2 = 0.974
Transmission, 1 mile: y = 0.2409x + 0.5063
R2 = 0.974
Transmission, 1.5 mile: y = 0.3613x + 0.7594
R2 = 0.974
Transmission, 2 mile: y = 0.4818x + 1.0126
R2 = 0.974
Transmission, 2.5 mile: y = 0.6022x + 1.2657
R2 = 0.974
Transmission, 3 mile: y = 0.7227x + 1.5188
R2 = 0.974
Transmission, 3.5 mile: y = 0.8431x + 1.772
R2 = 0.974
Transmission, 4 mile: y = 0.9636x + 2.0251
R2 = 0.974
0 2 4 6 8 10 12 14 16 18 20
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Linear (Transmission, 1 mile)
Linear (Transmission, 1.5 mile)
Linear (Transmission, 2 mile)
Linear (Transmission, 2.5 mile)
Linear (Transmission, 3 mile)
Linear (Transmission, 3.5 mile)
Linear (Transmission, 4 mile)
Linear (Transmission, 4.5 mile)
Linear (Transmission, 5 mile)
Linear (Transmission, 10 mile)



Urban Area Reclaimed Transmission Pipe Capital Project Costs, 5-30 mgd
Transmission, 5 mile: y = 0.7068x + 5.5269
R2 = 0.9164
Transmission, 10 mile: y = 1.4136x + 11.054
R2 = 0.9164
Transmission, 1 mile:
y = 0.1414x + 1.1054
R2 = 0.9164
Transmission, 1.5 mile:
y = 0.212x + 1.6581
R2 = 0.9164
Transmission, 2 mile:
y = 0.2827x + 2.2108
R2 = 0.9164
Transmission, 2.5 mile:
y = 0.3534x + 2.7634
R2 = 0.9164
Transmission, 3 mile:
y = 0.4241x + 3.3161
R2 = 0.9164
Transmission, 3.5 mile:
y = 0.4948x + 3.8688
R2 = 0.9164
Transmission, 4 mile:
y = 0.5654x + 4.4215
R2 = 0.9164
Transmission, 4.5 mile:
y = 0.6361x + 4.9742
R2 = 0.9164
Pipe Capital Project Cost, $ Million
60
55
50
45
40
35
30
25
20
15
10
5
0
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Flow, mgd
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Linear (Transmission, 1 mile)
Linear (Transmission, 1.5 mile)
Linear (Transmission, 2 mile)
Linear (Transmission, 2.5 mile)
Linear (Transmission, 3 mile)
Linear (Transmission, 3.5 mile)
Linear (Transmission, 4 mile)
Linear (Transmission, 4.5 mile)
Linear (Transmission, 5 mile)
Linear (Transmission, 10 mile)


Urban Area Reclaimed Transmission Pipe Capitcal Project Costs, $/1000 gallons
Transmission, 1 mile: y = 0.1715x^-0.4923 R^2 = 0.9512
Transmission, 1.5 mile: y = 0.2572x^-0.4923 R^2 = 0.9512
Transmission, 2 mile: y = 0.343x^-0.4923 R^2 = 0.9512
Transmission, 2.5 mile: y = 0.4287x^-0.4923 R^2 = 0.9512
Transmission, 3 mile: y = 0.5145x^-0.4923 R^2 = 0.9512
Transmission, 3.5 mile: y = 0.6002x^-0.4923 R^2 = 0.9512
Transmission, 4 mile: y = 0.686x^-0.4923 R^2 = 0.9512
Transmission, 4.5 mile: y = 0.7717x^-0.4923 R^2 = 0.9512
Transmission, 5 mile: y = 0.8575x^-0.4923 R^2 = 0.9512
Transmission, 10 mile: y = 1.7149x^-0.4923 R^2 = 0.9512
Pipe Capital Project Cost, $/1000 gallons
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Flow, mgd
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Power (Transmission, 10 mile)
Power (Transmission, 5 mile)
Power (Transmission, 4.5 mile)
Power (Transmission, 4 mile)
Power (Transmission, 3.5 mile)
Power (Transmission, 2.5 mile)
Power (Transmission, 3 mile)
Power (Transmission, 2 mile)
Power (Transmission, 1.5 mile)
Power (Transmission, 1 mile)

Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

						Rural Capital Cost by Distance - $ for 1-10 miles									
Diam (in)	**Annual Average Day Flow (mgd)**	**Annual Average Day Flow (gpm)**	**Peak Hourly Flow (mgd)**	**Pipe Velocity at Peak Hourly Flow (fps)**	**Pipe Unit Project Cost ($/ft)**	1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	79	417,120	625,680	834,240	1,042,800	1,251,360	1,459,920	1,668,480	1,877,040	2,085,600	4,171,200
6	0.20	138.80	0.60	4.73	86	454,080	681,120	908,160	1,135,200	1,362,240	1,589,280	1,816,320	2,043,360	2,270,400	4,540,800
6	0.27	187.38	0.81	6.38	86	454,080	681,120	908,160	1,135,200	1,362,240	1,589,280	1,816,320	2,043,360	2,270,400	4,540,800
8	0.40	277.60	1.20	5.32	95	501,600	752,400	1,003,200	1,254,000	1,504,800	1,755,600	2,006,400	2,257,200	2,508,000	5,016,000
8	0.47	326.18	1.41	6.25	95	501,600	752,400	1,003,200	1,254,000	1,504,800	1,755,600	2,006,400	2,257,200	2,508,000	5,016,000
8	0.53	367.82	1.59	7.05	95	501,600	752,400	1,003,200	1,254,000	1,504,800	1,755,600	2,006,400	2,257,200	2,508,000	5,016,000
10	0.60	416.40	1.80	5.11	108	570,240	855,360	1,140,480	1,425,600	1,710,720	1,995,840	2,280,960	2,566,080	2,851,200	5,702,400
10	0.67	464.98	2.01	5.70	108	570,240	855,360	1,140,480	1,425,600	1,710,720	1,995,840	2,280,960	2,566,080	2,851,200	5,702,400
10	0.83	576.02	2.49	7.06	108	570,240	855,360	1,140,480	1,425,600	1,710,720	1,995,840	2,280,960	2,566,080	2,851,200	5,702,400
12	0.93	645.42	2.79	5.50	119	628,320	942,480	1,256,640	1,570,800	1,884,960	2,199,120	2,513,280	2,827,440	3,141,600	6,283,200
12	1.00	694.00	3.00	5.91	119	628,320	942,480	1,256,640	1,570,800	1,884,960	2,199,120	2,513,280	2,827,440	3,141,600	6,283,200
12	1.17	811.98	3.51	6.91	119	628,320	942,480	1,256,640	1,570,800	1,884,960	2,199,120	2,513,280	2,827,440	3,141,600	6,283,200
14	1.33	923.02	3.99	5.77	137	723,360	1,085,040	1,446,720	1,808,400	2,170,080	2,531,760	2,893,440	3,255,120	3,616,800	7,233,600
14	1.50	1041.00	4.50	6.51	137	723,360	1,085,040	1,446,720	1,808,400	2,170,080	2,531,760	2,893,440	3,255,120	3,616,800	7,233,600
14	1.67	1158.98	5.01	7.25	137	723,360	1,085,040	1,446,720	1,808,400	2,170,080	2,531,760	2,893,440	3,255,120	3,616,800	7,233,600
16	1.83	1270.02	5.49	6.08	167	881,760	1,322,640	1,763,520	2,204,400	2,645,280	3,086,160	3,527,040	3,967,920	4,408,800	8,817,600
16	2.00	1388.00	6.00	6.65	167	881,760	1,322,640	1,763,520	2,204,400	2,645,280	3,086,160	3,527,040	3,967,920	4,408,800	8,817,600
16	2.07	1436.58	6.21	6.88	167	881,760	1,322,640	1,763,520	2,204,400	2,645,280	3,086,160	3,527,040	3,967,920	4,408,800	8,817,600
18	2.17	1505.98	6.51	5.70	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
18	2.33	1617.02	6.99	6.12	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
18	2.50	1735.00	7.50	6.57	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
18	2.67	1852.98	8.01	7.01	189	997,920	1,496,880	1,995,840	2,494,800	2,993,760	3,492,720	3,991,680	4,490,640	4,989,600	9,979,200
20	2.83	1964.02	8.49	6.02	214	1,129,920	1,694,880	2,259,840	2,824,800	3,389,760	3,954,720	4,519,680	5,084,640	5,649,600	11,299,200
20	3.00	2082.00	9.00	6.38	214	1,129,920	1,694,880	2,259,840	2,824,800	3,389,760	3,954,720	4,519,680	5,084,640	5,649,600	11,299,200
20	3.17	2199.98	9.51	6.74	214	1,129,920	1,694,880	2,259,840	2,824,800	3,389,760	3,954,720	4,519,680	5,084,640	5,649,600	11,299,200
20	3.33	2311.02	9.99	7.08	214	1,129,920	1,694,880	2,259,840	2,824,800	3,389,760	3,954,720	4,519,680	5,084,640	5,649,600	11,299,200
24	3.50	2429.00	10.50	5.17	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	3.67	2546.98	11.01	5.42	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	3.83	2658.02	11.49	5.66	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	4.00	2776.00	12.00	5.91	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	4.17	2893.98	12.51	6.16	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	4.33	3005.02	12.99	6.40	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	4.50	3123.00	13.50	6.65	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
24	4.67	3240.98	14.01	6.90	263	1,388,640	2,082,960	2,777,280	3,471,600	4,165,920	4,860,240	5,554,560	6,248,880	6,943,200	13,886,400
30	5.33	3699.02	15.99	5.04	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	5.67	3934.98	17.01	5.36	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	6.00	4164.00	18.00	5.67	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	6.33	4393.02	18.99	5.99	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	6.67	4628.98	20.01	6.31	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	7.00	4858.00	21.00	6.62	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
30	7.33	5087.02	21.99	6.93	324	1,710,720	2,566,080	3,421,440	4,276,800	5,132,160	5,987,520	6,842,880	7,698,240	8,553,600	17,107,200
36	8.00	5552.00	24.00	5.25	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	8.33	5781.02	24.99	5.47	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	8.67	6016.98	26.01	5.69	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	9.00	6246.00	27.00	5.91	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	9.33	6475.02	27.99	6.13	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	9.67	6710.98	29.01	6.35	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	10.00	6940.00	30.00	6.57	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	10.33	7169.02	30.99	6.78	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	10.50	7287.00	31.50	6.89	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400
36	10.67	7404.98	32.01	7.01	403	2,127,840	3,191,760	4,255,680	5,319,600	6,383,520	7,447,440	8,511,360	9,575,280	10,639,200	21,278,400

Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

						Rural Capital Cost by Distance - $ for 1-10 miles									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
42	11.33	7863.02	33.99	5.47	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	11.67	8098.98	35.01	5.63	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	12.00	8328.00	36.00	5.79	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	12.33	8557.02	36.99	5.95	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	12.67	8792.98	38.01	6.11	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	13.00	9022.00	39.00	6.27	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	13.33	9251.02	39.99	6.43	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	13.67	9486.98	41.01	6.59	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	14.00	9716.00	42.00	6.75	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
42	14.67	10180.98	44.01	7.08	499	2,634,720	3,952,080	5,269,440	6,586,800	7,904,160	9,221,520	10,538,880	11,856,240	13,173,600	26,347,200
48	13.67	9486.98	41.01	5.05	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	14.00	9716.00	42.00	5.17	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	14.33	9945.02	42.99	5.29	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	14.67	10180.98	44.01	5.42	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	15.00	10410.00	45.00	5.54	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	15.33	10639.02	45.99	5.66	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	15.67	10874.98	47.01	5.79	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	16.00	11104.00	48.00	5.91	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	16.33	11333.02	48.99	6.03	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	16.67	11568.98	50.01	6.16	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	17.33	12027.02	51.99	6.40	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	18.00	12492.00	54.00	6.65	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	18.33	12721.02	54.99	6.77	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
48	19.00	13186.00	57.00	7.02	635	3,352,800	5,029,200	6,705,600	8,382,000	10,058,400	11,734,800	13,411,200	15,087,600	16,764,000	33,528,000
54	17.33	12027.02	51.99	5.06	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	18.00	12492.00	54.00	5.25	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	18.67	12956.98	56.01	5.45	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	19.33	13415.02	57.99	5.64	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	20.00	13880.00	60.00	5.84	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	20.67	14344.98	62.01	6.03	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	21.33	14803.02	63.99	6.22	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	22.00	15268.00	66.00	6.42	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	22.67	15732.98	68.01	6.62	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	23.33	16191.02	69.99	6.81	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
54	24.00	16656.00	72.00	7.00	743	3,923,040	5,884,560	7,846,080	9,807,600	11,769,120	13,730,640	15,692,160	17,653,680	19,615,200	39,230,400
60	21.17	14691.98	63.51	5.00	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	21.67	15038.98	65.01	5.12	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	22.33	15497.02	66.99	5.28	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	23.00	15962.00	69.00	5.44	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	23.67	16426.98	71.01	5.60	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	24.33	16885.02	72.99	5.75	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	25.00	17350.00	75.00	5.91	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	25.67	17814.98	77.01	6.07	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	26.33	18273.02	78.99	6.22	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	27.00	18738.00	81.00	6.38	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	27.67	19202.98	83.01	6.54	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	28.33	19661.02	84.99	6.70	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	29.00	20126.00	87.00	6.86	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800
60	30.00	20820.00	90.00	7.09	846	4,466,880	6,700,320	8,933,760	11,167,200	13,400,640	15,634,080	17,867,520	20,100,960	22,334,400	44,668,800

Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

Rural - Annualized Capital Cost, Sep 2006

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	79	$32,196	$48,294	$64,391	$80,489	$96,587	$112,685	$128,783	$144,881	$160,979	$321,957
6	0.20	138.80	0.60	4.73	86	$35,048	$52,573	$70,097	$87,621	$105,145	$122,670	$140,194	$157,718	$175,242	$350,485
6	0.27	187.38	0.81	6.38	86	$35,048	$52,573	$70,097	$87,621	$105,145	$122,670	$140,194	$157,718	$175,242	$350,485
8	0.40	277.60	1.20	5.32	95	$38,716	$58,075	$77,433	$96,791	$116,149	$135,507	$154,865	$174,224	$193,582	$387,164
8	0.47	326.18	1.41	6.25	95	$38,716	$58,075	$77,433	$96,791	$116,149	$135,507	$154,865	$174,224	$193,582	$387,164
8	0.53	367.82	1.59	7.05	95	$38,716	$58,075	$77,433	$96,791	$116,149	$135,507	$154,865	$174,224	$193,582	$387,164
10	0.60	416.40	1.80	5.11	108	$44,014	$66,022	$88,029	$110,036	$132,043	$154,050	$176,058	$198,065	$220,072	$440,144
10	0.67	464.98	2.01	5.70	108	$44,014	$66,022	$88,029	$110,036	$132,043	$154,050	$176,058	$198,065	$220,072	$440,144
10	0.83	576.02	2.49	7.06	108	$44,014	$66,022	$88,029	$110,036	$132,043	$154,050	$176,058	$198,065	$220,072	$440,144
12	0.93	645.42	2.79	5.50	119	$48,497	$72,746	$96,995	$121,243	$145,492	$169,741	$193,989	$218,238	$242,487	$484,973
12	1.00	694.00	3.00	5.91	119	$48,497	$72,746	$96,995	$121,243	$145,492	$169,741	$193,989	$218,238	$242,487	$484,973
12	1.17	811.98	3.51	6.91	119	$48,497	$72,746	$96,995	$121,243	$145,492	$169,741	$193,989	$218,238	$242,487	$484,973
14	1.33	923.02	3.99	5.77	137	$55,833	$83,750	$111,666	$139,583	$167,499	$195,416	$223,332	$251,249	$279,165	$558,331
14	1.50	1041.00	4.50	6.51	137	$55,833	$83,750	$111,666	$139,583	$167,499	$195,416	$223,332	$251,249	$279,165	$558,331
14	1.67	1158.98	5.01	7.25	137	$55,833	$83,750	$111,666	$139,583	$167,499	$195,416	$223,332	$251,249	$279,165	$558,331
16	1.83	1270.02	5.49	6.08	167	$68,059	$102,089	$136,119	$170,148	$204,178	$238,208	$272,237	$306,267	$340,296	$680,593
16	2.00	1388.00	6.00	6.65	167	$68,059	$102,089	$136,119	$170,148	$204,178	$238,208	$272,237	$306,267	$340,296	$680,593
16	2.07	1436.58	6.21	6.88	167	$68,059	$102,089	$136,119	$170,148	$204,178	$238,208	$272,237	$306,267	$340,296	$680,593
18	2.17	1505.98	6.51	5.70	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
18	2.33	1617.02	6.99	6.12	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
18	2.50	1735.00	7.50	6.57	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
18	2.67	1852.98	8.01	7.01	189	$77,025	$115,538	$154,050	$192,563	$231,076	$269,588	$308,101	$346,613	$385,126	$770,252
20	2.83	1964.02	8.49	6.02	214	$87,214	$130,821	$174,427	$218,034	$261,641	$305,248	$348,855	$392,462	$436,068	$872,137
20	3.00	2082.00	9.00	6.38	214	$87,214	$130,821	$174,427	$218,034	$261,641	$305,248	$348,855	$392,462	$436,068	$872,137
20	3.17	2199.98	9.51	6.74	214	$87,214	$130,821	$174,427	$218,034	$261,641	$305,248	$348,855	$392,462	$436,068	$872,137
20	3.33	2311.02	9.99	7.08	214	$87,214	$130,821	$174,427	$218,034	$261,641	$305,248	$348,855	$392,462	$436,068	$872,137
24	3.50	2429.00	10.50	5.17	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	3.67	2546.98	11.01	5.42	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	3.83	2658.02	11.49	5.66	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	4.00	2776.00	12.00	5.91	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	4.17	2893.98	12.51	6.16	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	4.33	3005.02	12.99	6.40	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	4.50	3123.00	13.50	6.65	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
24	4.67	3240.98	14.01	6.90	263	$107,183	$160,775	$214,366	$267,958	$321,550	$375,141	$428,733	$482,324	$535,916	$1,071,832
30	5.33	3699.02	15.99	5.04	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	5.67	3934.98	17.01	5.36	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	6.00	4164.00	18.00	5.67	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	6.33	4393.02	18.99	5.99	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	6.67	4628.98	20.01	6.31	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	7.00	4858.00	21.00	6.62	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
30	7.33	5087.02	21.99	6.93	324	$132,043	$198,065	$264,086	$330,108	$396,129	$462,151	$528,173	$594,194	$660,216	$1,320,432
36	8.00	5552.00	24.00	5.25	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	8.33	5781.02	24.99	5.47	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	8.67	6016.98	26.01	5.69	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	9.00	6246.00	27.00	5.91	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	9.33	6475.02	27.99	6.13	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	9.67	6710.98	29.01	6.35	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	10.00	6940.00	30.00	6.57	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	10.33	7169.02	30.99	6.78	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	10.50	7287.00	31.50	6.89	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389
36	10.67	7404.98	32.01	7.01	403	$164,239	$246,358	$328,478	$410,597	$492,717	$574,836	$656,956	$739,075	$821,194	$1,642,389

Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

Rural - Annualized Capital Cost, Sep 2006

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
42	11.33	7863.02	33.99	5.47	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	11.67	8098.98	35.01	5.63	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	12.00	8328.00	36.00	5.79	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	12.33	8557.02	36.99	5.95	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	12.67	8792.98	38.01	6.11	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	13.00	9022.00	39.00	6.27	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	13.33	9251.02	39.99	6.43	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	13.67	9486.98	41.01	6.59	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	14.00	9716.00	42.00	6.75	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
42	14.67	10180.98	44.01	7.08	499	$203,363	$305,044	$406,726	$508,407	$610,088	$711,770	$813,451	$915,133	$1,016,814	$2,033,628
48	13.67	9486.98	41.01	5.05	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	14.00	9716.00	42.00	5.17	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	14.33	9945.02	42.99	5.29	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	14.67	10180.98	44.01	5.42	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	15.00	10410.00	45.00	5.54	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	15.33	10639.02	45.99	5.66	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	15.67	10874.98	47.01	5.79	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	16.00	11104.00	48.00	5.91	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	16.33	11333.02	48.99	6.03	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	16.67	11568.98	50.01	6.16	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	17.33	12027.02	51.99	6.40	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	18.00	12492.00	54.00	6.65	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	18.33	12721.02	54.99	6.77	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
48	19.00	13186.00	57.00	7.02	635	$258,788	$388,182	$517,577	$646,971	$776,365	$905,759	$1,035,153	$1,164,547	$1,293,942	$2,587,883
54	17.33	12027.02	51.99	5.06	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	18.00	12492.00	54.00	5.25	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	18.67	12956.98	56.01	5.45	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	19.33	13415.02	57.99	5.64	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	20.00	13880.00	60.00	5.84	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	20.67	14344.98	62.01	6.03	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	21.33	14803.02	63.99	6.22	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	22.00	15268.00	66.00	6.42	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	22.67	15732.98	68.01	6.62	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	23.33	16191.02	69.99	6.81	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
54	24.00	16656.00	72.00	7.00	743	$302,803	$454,204	$605,605	$757,007	$908,408	$1,059,809	$1,211,211	$1,362,612	$1,514,013	$3,028,027
60	21.17	14691.98	63.51	5.00	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	21.67	15038.98	65.01	5.12	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	22.33	15497.02	66.99	5.28	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	23.00	15962.00	69.00	5.44	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	23.67	16426.98	71.01	5.60	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	24.33	16885.02	72.99	5.75	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	25.00	17350.00	75.00	5.91	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	25.67	17814.98	77.01	6.07	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	26.33	18273.02	78.99	6.22	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	27.00	18738.00	81.00	6.38	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	27.67	19202.98	83.01	6.54	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	28.33	19661.02	84.99	6.70	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	29.00	20126.00	87.00	6.86	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794
60	30.00	20820.00	90.00	7.09	846	$344,779	$517,169	$689,559	$861,948	$1,034,338	$1,206,728	$1,379,118	$1,551,507	$1,723,897	$3,447,794

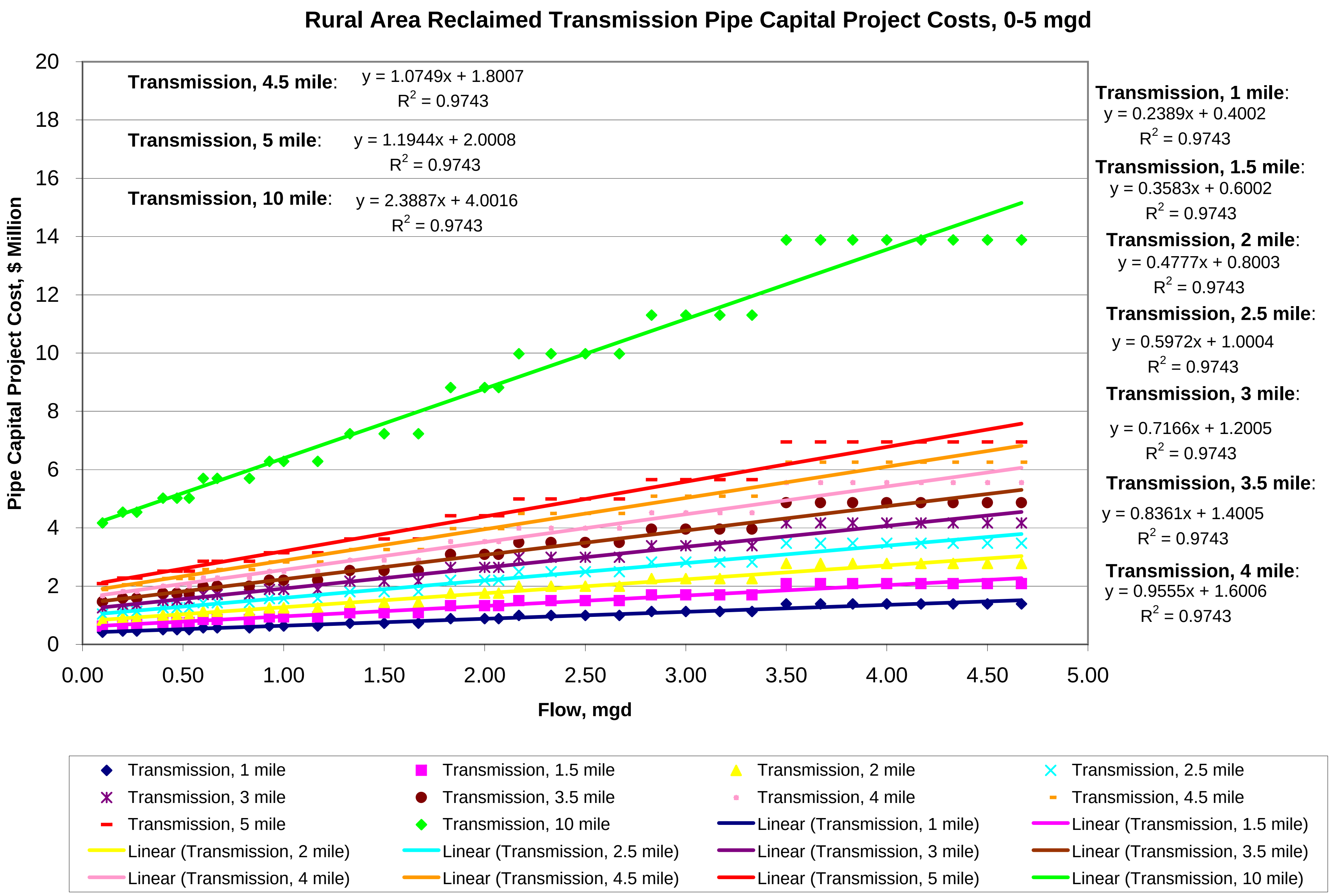
Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

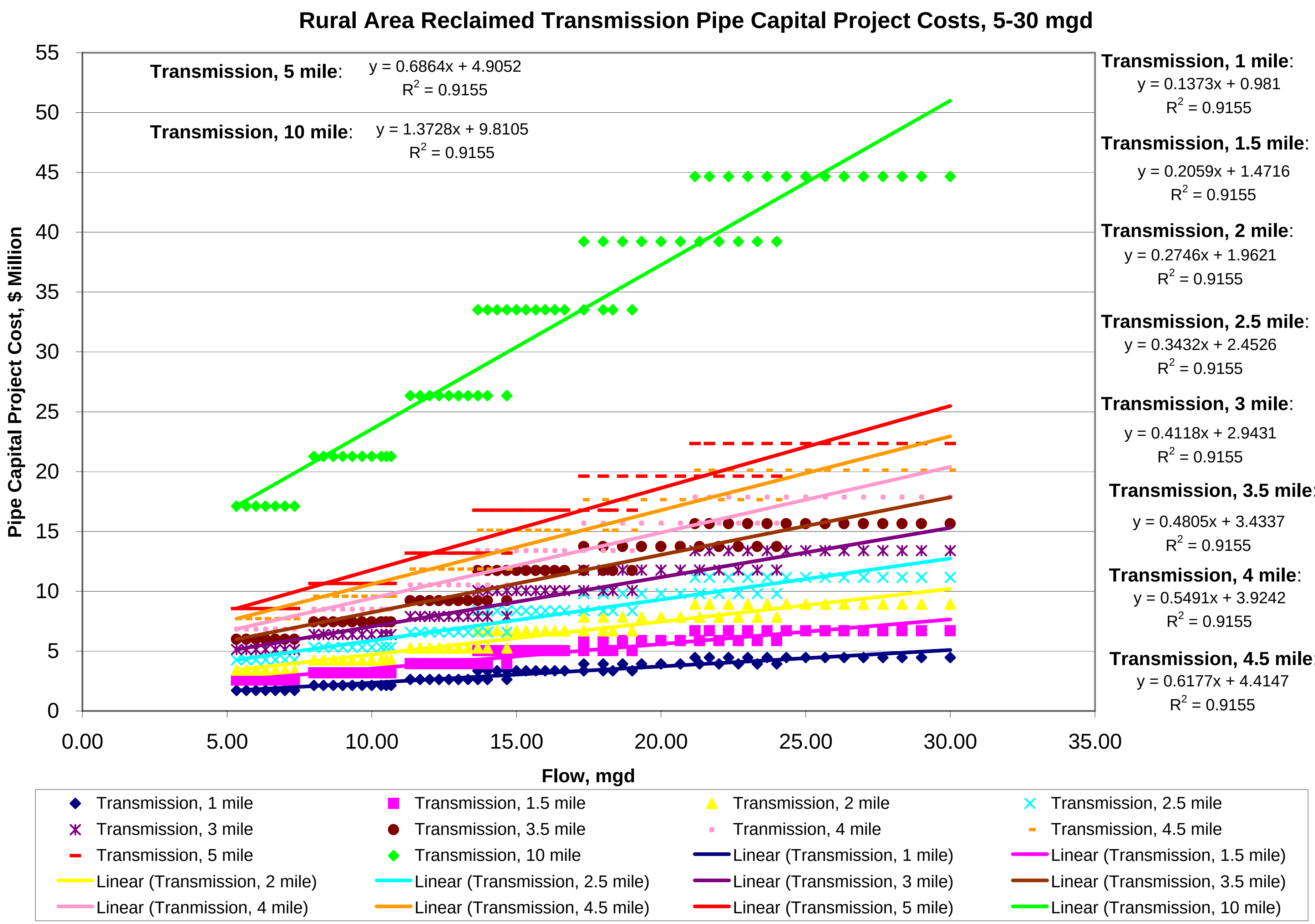
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	Rural Capital Cost - Cost per 1000 gallons									
						1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	79	$0.88	$1.32	$1.76	$2.21	$2.65	$3.09	$3.53	$3.97	$4.41	$8.82
6	0.20	138.80	0.60	4.73	86	$0.48	$0.72	$0.96	$1.20	$1.44	$1.68	$1.92	$2.16	$2.40	$4.80
6	0.27	187.38	0.81	6.38	86	$0.36	$0.53	$0.71	$0.89	$1.07	$1.24	$1.42	$1.60	$1.78	$3.56
8	0.40	277.60	1.20	5.32	95	$0.27	$0.40	$0.53	$0.66	$0.80	$0.93	$1.06	$1.19	$1.33	$2.65
8	0.47	326.18	1.41	6.25	95	$0.23	$0.34	$0.45	$0.56	$0.68	$0.79	$0.90	$1.02	$1.13	$2.26
8	0.53	367.82	1.59	7.05	95	$0.20	$0.30	$0.40	$0.50	$0.60	$0.70	$0.80	$0.90	$1.00	$2.00
10	0.60	416.40	1.80	5.11	108	$0.20	$0.30	$0.40	$0.50	$0.60	$0.70	$0.80	$0.90	$1.00	$2.01
10	0.67	464.98	2.01	5.70	108	$0.18	$0.27	$0.36	$0.45	$0.54	$0.63	$0.72	$0.81	$0.90	$1.80
10	0.83	576.02	2.49	7.06	108	$0.15	$0.22	$0.29	$0.36	$0.44	$0.51	$0.58	$0.65	$0.73	$1.45
12	0.93	645.42	2.79	5.50	119	$0.14	$0.21	$0.29	$0.36	$0.43	$0.50	$0.57	$0.64	$0.71	$1.43
12	1.00	694.00	3.00	5.91	119	$0.13	$0.20	$0.27	$0.33	$0.40	$0.47	$0.53	$0.60	$0.66	$1.33
12	1.17	811.98	3.51	6.91	119	$0.11	$0.17	$0.23	$0.28	$0.34	$0.40	$0.45	$0.51	$0.57	$1.14
14	1.33	923.02	3.99	5.77	137	$0.12	$0.17	$0.23	$0.29	$0.35	$0.40	$0.46	$0.52	$0.58	$1.15
14	1.50	1041.00	4.50	6.51	137	$0.10	$0.15	$0.20	$0.25	$0.31	$0.36	$0.41	$0.46	$0.51	$1.02
14	1.67	1158.98	5.01	7.25	137	$0.09	$0.14	$0.18	$0.23	$0.27	$0.32	$0.37	$0.41	$0.46	$0.92
16	1.83	1270.02	5.49	6.08	167	$0.10	$0.15	$0.20	$0.25	$0.31	$0.36	$0.41	$0.46	$0.51	$1.02
16	2.00	1388.00	6.00	6.65	167	$0.09	$0.14	$0.19	$0.23	$0.28	$0.33	$0.37	$0.42	$0.47	$0.93
16	2.07	1436.58	6.21	6.88	167	$0.09	$0.14	$0.18	$0.23	$0.27	$0.32	$0.36	$0.41	$0.45	$0.90
18	2.17	1505.98	6.51	5.70	189	$0.10	$0.15	$0.19	$0.24	$0.29	$0.34	$0.39	$0.44	$0.49	$0.97
18	2.33	1617.02	6.99	6.12	189	$0.09	$0.14	$0.18	$0.23	$0.27	$0.32	$0.36	$0.41	$0.45	$0.91
18	2.50	1735.00	7.50	6.57	189	$0.08	$0.13	$0.17	$0.21	$0.25	$0.30	$0.34	$0.38	$0.42	$0.84
18	2.67	1852.98	8.01	7.01	189	$0.08	$0.12	$0.16	$0.20	$0.24	$0.28	$0.32	$0.36	$0.40	$0.79
20	2.83	1964.02	8.49	6.02	214	$0.08	$0.13	$0.17	$0.21	$0.25	$0.30	$0.34	$0.38	$0.42	$0.84
20	3.00	2082.00	9.00	6.38	214	$0.08	$0.12	$0.16	$0.20	$0.24	$0.28	$0.32	$0.36	$0.40	$0.80
20	3.17	2199.98	9.51	6.74	214	$0.08	$0.11	$0.15	$0.19	$0.23	$0.26	$0.30	$0.34	$0.38	$0.75
20	3.33	2311.02	9.99	7.08	214	$0.07	$0.11	$0.14	$0.18	$0.22	$0.25	$0.29	$0.32	$0.36	$0.72
24	3.50	2429.00	10.50	5.17	263	$0.08	$0.13	$0.17	$0.21	$0.25	$0.29	$0.34	$0.38	$0.42	$0.84
24	3.67	2546.98	11.01	5.42	263	$0.08	$0.12	$0.16	$0.20	$0.24	$0.28	$0.32	$0.36	$0.40	$0.80
24	3.83	2658.02	11.49	5.66	263	$0.08	$0.12	$0.15	$0.19	$0.23	$0.27	$0.31	$0.35	$0.38	$0.77
24	4.00	2776.00	12.00	5.91	263	$0.07	$0.11	$0.15	$0.18	$0.22	$0.26	$0.29	$0.33	$0.37	$0.73
24	4.17	2893.98	12.51	6.16	263	$0.07	$0.11	$0.14	$0.18	$0.21	$0.25	$0.28	$0.32	$0.35	$0.70
24	4.33	3005.02	12.99	6.40	263	$0.07	$0.10	$0.14	$0.17	$0.20	$0.24	$0.27	$0.31	$0.34	$0.68
24	4.50	3123.00	13.50	6.65	263	$0.07	$0.10	$0.13	$0.16	$0.20	$0.23	$0.26	$0.29	$0.33	$0.65
24	4.67	3240.98	14.01	6.90	263	$0.06	$0.09	$0.13	$0.16	$0.19	$0.22	$0.25	$0.28	$0.31	$0.63
30	5.33	3699.02	15.99	5.04	324	$0.07	$0.10	$0.14	$0.17	$0.20	$0.24	$0.27	$0.31	$0.34	$0.68
30	5.67	3934.98	17.01	5.36	324	$0.06	$0.10	$0.13	$0.16	$0.19	$0.22	$0.26	$0.29	$0.32	$0.64
30	6.00	4164.00	18.00	5.67	324	$0.06	$0.09	$0.12	$0.15	$0.18	$0.21	$0.24	$0.27	$0.30	$0.60
30	6.33	4393.02	18.99	5.99	324	$0.06	$0.09	$0.11	$0.14	$0.17	$0.20	$0.23	$0.26	$0.29	$0.57
30	6.67	4628.98	20.01	6.31	324	$0.05	$0.08	$0.11	$0.14	$0.16	$0.19	$0.22	$0.24	$0.27	$0.54
30	7.00	4858.00	21.00	6.62	324	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.23	$0.26	$0.52
30	7.33	5087.02	21.99	6.93	324	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.49
36	8.00	5552.00	24.00	5.25	403	$0.06	$0.08	$0.11	$0.14	$0.17	$0.20	$0.22	$0.25	$0.28	$0.56
36	8.33	5781.02	24.99	5.47	403	$0.05	$0.08	$0.11	$0.14	$0.16	$0.19	$0.22	$0.24	$0.27	$0.54
36	8.67	6016.98	26.01	5.69	403	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.23	$0.26	$0.52
36	9.00	6246.00	27.00	5.91	403	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.50
36	9.33	6475.02	27.99	6.13	403	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.22	$0.24	$0.48
36	9.67	6710.98	29.01	6.35	403	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.47
36	10.00	6940.00	30.00	6.57	403	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.45
36	10.33	7169.02	30.99	6.78	403	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.20	$0.22	$0.44
36	10.50	7287.00	31.50	6.89	403	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.43
36	10.67	7404.98	32.01	7.01	403	$0.04	$0.06	$0.08	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42

Capital PROJECT Cost Curves for Reclaimed Water Transmission Piping

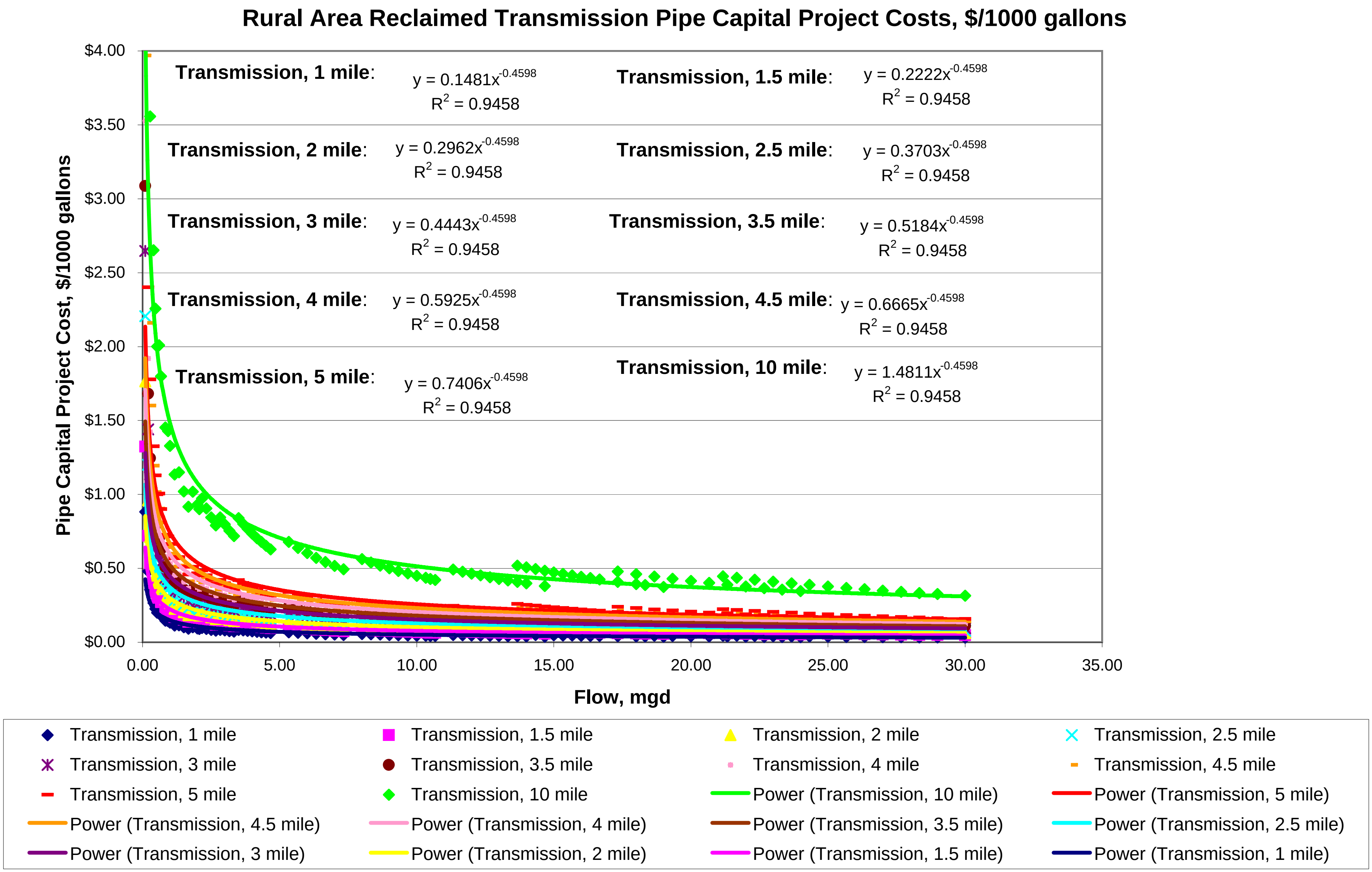
Rural Capital Cost - Cost per 1000 gallons

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (fps)	Pipe Unit Project Cost ($/ft)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
42	11.33	7863.02	33.99	5.47	499	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.49
42	11.67	8098.98	35.01	5.63	499	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.21	$0.24	$0.48
42	12.00	8328.00	36.00	5.79	499	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.19	$0.21	$0.23	$0.46
42	12.33	8557.02	36.99	5.95	499	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.20	$0.23	$0.45
42	12.67	8792.98	38.01	6.11	499	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.18	$0.20	$0.22	$0.44
42	13.00	9022.00	39.00	6.27	499	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.43
42	13.33	9251.02	39.99	6.43	499	$0.04	$0.06	$0.08	$0.10	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42
42	13.67	9486.98	41.01	6.59	499	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.41
42	14.00	9716.00	42.00	6.75	499	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
42	14.67	10180.98	44.01	7.08	499	$0.04	$0.06	$0.08	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.38
48	13.67	9486.98	41.01	5.05	635	$0.05	$0.08	$0.10	$0.13	$0.16	$0.18	$0.21	$0.23	$0.26	$0.52
48	14.00	9716.00	42.00	5.17	635	$0.05	$0.08	$0.10	$0.13	$0.15	$0.18	$0.20	$0.23	$0.25	$0.51
48	14.33	9945.02	42.99	5.29	635	$0.05	$0.07	$0.10	$0.12	$0.15	$0.17	$0.20	$0.22	$0.25	$0.49
48	14.67	10180.98	44.01	5.42	635	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.22	$0.24	$0.48
48	15.00	10410.00	45.00	5.54	635	$0.05	$0.07	$0.09	$0.12	$0.14	$0.17	$0.19	$0.21	$0.24	$0.47
48	15.33	10639.02	45.99	5.66	635	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
48	15.67	10874.98	47.01	5.79	635	$0.05	$0.07	$0.09	$0.11	$0.14	$0.16	$0.18	$0.20	$0.23	$0.45
48	16.00	11104.00	48.00	5.91	635	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.44
48	16.33	11333.02	48.99	6.03	635	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.20	$0.22	$0.43
48	16.67	11568.98	50.01	6.16	635	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.43
48	17.33	12027.02	51.99	6.40	635	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.41
48	18.00	12492.00	54.00	6.65	635	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.39
48	18.33	12721.02	54.99	6.77	635	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.15	$0.17	$0.19	$0.39
48	19.00	13186.00	57.00	7.02	635	$0.04	$0.06	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.37
54	17.33	12027.02	51.99	5.06	743	$0.05	$0.07	$0.10	$0.12	$0.14	$0.17	$0.19	$0.22	$0.24	$0.48
54	18.00	12492.00	54.00	5.25	743	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.18	$0.21	$0.23	$0.46
54	18.67	12956.98	56.01	5.45	743	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.44
54	19.33	13415.02	57.99	5.64	743	$0.04	$0.06	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.43
54	20.00	13880.00	60.00	5.84	743	$0.04	$0.06	$0.08	$0.10	$0.12	$0.15	$0.17	$0.19	$0.21	$0.41
54	20.67	14344.98	62.01	6.03	743	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
54	21.33	14803.02	63.99	6.22	743	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.19	$0.39
54	22.00	15268.00	66.00	6.42	743	$0.04	$0.06	$0.08	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.38
54	22.67	15732.98	68.01	6.62	743	$0.04	$0.05	$0.07	$0.09	$0.11	$0.13	$0.15	$0.16	$0.18	$0.37
54	23.33	16191.02	69.99	6.81	743	$0.04	$0.05	$0.07	$0.09	$0.11	$0.12	$0.14	$0.16	$0.18	$0.36
54	24.00	16656.00	72.00	7.00	743	$0.03	$0.05	$0.07	$0.09	$0.10	$0.12	$0.14	$0.16	$0.17	$0.35
60	21.17	14691.98	63.51	5.00	846	$0.04	$0.07	$0.09	$0.11	$0.13	$0.16	$0.18	$0.20	$0.22	$0.45
60	21.67	15038.98	65.01	5.12	846	$0.04	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.20	$0.22	$0.44
60	22.33	15497.02	66.99	5.28	846	$0.04	$0.06	$0.08	$0.11	$0.13	$0.15	$0.17	$0.19	$0.21	$0.42
60	23.00	15962.00	69.00	5.44	846	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.21	$0.41
60	23.67	16426.98	71.01	5.60	846	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.40
60	24.33	16885.02	72.99	5.75	846	$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.17	$0.19	$0.39
60	25.00	17350.00	75.00	5.91	846	$0.04	$0.06	$0.08	$0.09	$0.11	$0.13	$0.15	$0.17	$0.19	$0.38
60	25.67	17814.98	77.01	6.07	846	$0.04	$0.06	$0.07	$0.09	$0.11	$0.13	$0.15	$0.17	$0.18	$0.37
60	26.33	18273.02	78.99	6.22	846	$0.04	$0.05	$0.07	$0.09	$0.11	$0.13	$0.14	$0.16	$0.18	$0.36
60	27.00	18738.00	81.00	6.38	846	$0.03	$0.05	$0.07	$0.09	$0.10	$0.12	$0.14	$0.16	$0.17	$0.35
60	27.67	19202.98	83.01	6.54	846	$0.03	$0.05	$0.07	$0.09	$0.10	$0.12	$0.14	$0.15	$0.17	$0.34
60	28.33	19661.02	84.99	6.70	846	$0.03	$0.05	$0.07	$0.08	$0.10	$0.12	$0.13	$0.15	$0.17	$0.33
60	29.00	20126.00	87.00	6.86	846	$0.03	$0.05	$0.07	$0.08	$0.10	$0.11	$0.13	$0.15	$0.16	$0.33
60	30.00	20820.00	90.00	7.09	846	$0.03	$0.05	$0.06	$0.08	$0.09	$0.11	$0.13	$0.14	$0.16	$0.31


Rural Area Reclaimed Transmission Pipe Capital Project Costs, 0-5 mgd
Transmission, 4.5 mile: y = 1.0749x + 1.8007
R2 = 0.9743
Transmission, 5 mile: y = 1.1944x + 2.0008
R2 = 0.9743
Transmission, 10 mile: y = 2.3887x + 4.0016
R2 = 0.9743
Transmission, 1 mile: y = 0.2389x + 0.4002
R2 = 0.9743
Transmission, 1.5 mile: y = 0.3583x + 0.6002
R2 = 0.9743
Transmission, 2 mile: y = 0.4777x + 0.8003
R2 = 0.9743
Transmission, 2.5 mile: y = 0.5972x + 1.0004
R2 = 0.9743
Transmission, 3 mile: y = 0.7166x + 1.2005
R2 = 0.9743
Transmission, 3.5 mile: y = 0.8361x + 1.4005
R2 = 0.9743
Transmission, 4 mile: y = 0.9555x + 1.6006
R2 = 0.9743
Pipe Capital Project Cost, $ Million
Flow, mgd
0
2
4
6
8
10
12
14
16
18
20
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Linear (Transmission, 1 mile)
Linear (Transmission, 1.5 mile)
Linear (Transmission, 2 mile)
Linear (Transmission, 2.5 mile)
Linear (Transmission, 3 mile)
Linear (Transmission, 3.5 mile)
Linear (Transmission, 4 mile)
Linear (Transmission, 4.5 mile)
Linear (Transmission, 5 mile)
Linear (Transmission, 10 mile)



Rural Area Reclaimed Transmission Pipe Capital Project Costs, 5-30 mgd
Transmission, 5 mile: y = 0.6864x + 4.9052
R2 = 0.9155
Transmission, 10 mile: y = 1.3728x + 9.8105
R2 = 0.9155
Transmission, 1 mile: y = 0.1373x + 0.981
R2 = 0.9155
Transmission, 1.5 mile: y = 0.2059x + 1.4716
R2 = 0.9155
Transmission, 2 mile: y = 0.2746x + 1.9621
R2 = 0.9155
Transmission, 2.5 mile: y = 0.3432x + 2.4526
R2 = 0.9155
Transmission, 3 mile: y = 0.4118x + 2.9431
R2 = 0.9155
Transmission, 3.5 mile: y = 0.4805x + 3.4337
R2 = 0.9155
Transmission, 4 mile: y = 0.5491x + 3.9242
R2 = 0.9155
Transmission, 4.5 mile: y = 0.6177x + 4.4147
R2 = 0.9155
Pipe Capital Project Cost, $ Million
0
5
10
15
20
25
30
35
40
45
50
55
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Flow, mgd
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Tranmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Linear (Transmission, 1 mile)
Linear (Transmission, 1.5 mile)
Linear (Transmission, 2 mile)
Linear (Transmission, 2.5 mile)
Linear (Transmission, 3 mile)
Linear (Transmission, 3.5 mile)
Linear (Tranmission, 4 mile)
Linear (Transmission, 4.5 mile)
Linear (Transmission, 5 mile)
Linear (Transmission, 10 mile)



Rural Area Reclaimed Transmission Pipe Capital Project Costs, $/1000 gallons
Transmission, 1 mile: y = 0.1481x^-0.4598 R^2 = 0.9458
Transmission, 1.5 mile: y = 0.2222x^-0.4598 R^2 = 0.9458
Transmission, 2 mile: y = 0.2962x^-0.4598 R^2 = 0.9458
Transmission, 2.5 mile: y = 0.3703x^-0.4598 R^2 = 0.9458
Transmission, 3 mile: y = 0.4443x^-0.4598 R^2 = 0.9458
Transmission, 3.5 mile: y = 0.5184x^-0.4598 R^2 = 0.9458
Transmission, 4 mile: y = 0.5925x^-0.4598 R^2 = 0.9458
Transmission, 4.5 mile: y = 0.6665x^-0.4598 R^2 = 0.9458
Transmission, 5 mile: y = 0.7406x^-0.4598 R^2 = 0.9458
Transmission, 10 mile: y = 1.4811x^-0.4598 R^2 = 0.9458
Pipe Capital Project Cost, $/1000 gallons
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Flow, mgd
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Power (Transmission, 10 mile)
Power (Transmission, 5 mile)
Power (Transmission, 4.5 mile)
Power (Transmission, 4 mile)
Power (Transmission, 3.5 mile)
Power (Transmission, 2.5 mile)
Power (Transmission, 3 mile)
Power (Transmission, 2 mile)
Power (Transmission, 1.5 mile)
Power (Transmission, 1 mile)

Exhibit 3

Water Reuse System O&M Cost

Pumping Power Cost Curves for Reclaimed Water Conveyance

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Distance (ft)	Peak Hourly Demand (gpm)	Friction Loss (ft/1000ft)	Minor Loss (ft/1000 ft)	Pressure at Delivery (psi)	Total Dynamic Head (ft) for Pipe Length Listed (miles) 1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	1000	208.2	29.4	0.077	40.0	247.8									
6	0.20	138.80	0.60	4.73	1000	416.4	14.7	0.061	40.0	170.4	209.3	248.5							
6	0.27	185.07	0.80	6.30	1000	555.2	25.1	0.108	40.0	225.3	291.5								
8	0.40	277.60	1.20	5.32	1000	832.8	13.1	0.077	40.0	161.9	196.5	231.4	266.2						
8	0.47	323.87	1.40	6.21	1001	971.6	17.4	0.105	40.0	185.0	231.0	277.5							
8	0.53	370.13	1.60	7.09	1000	1110.4	22.3	0.137	40.0	210.8	269.6	329.2							
10	0.60	416.40	1.80	5.11	1000	1249.2	9.4	0.071	40.0	142.2	166.9	192.0	216.9	241.7					
10	0.67	462.67	2.00	5.67	1000	1388.0	11.4	0.087	40.0	152.9	182.9	213.4	243.7						
10	0.83	578.33	2.50	7.09	1000	1735.0	17.2	0.137	40.0	183.8	229.2	275.3	321.0						
12	0.93	647.73	2.80	5.52	1001	1943.2	8.7	0.083	40.0	139.0	162.0	185.5	208.8	232.1					
12	1.00	694.00	3.00	5.91	1000	2082.0	9.9	0.095	40.0	145.3	171.4	198.1	224.5	251.0					
12	1.17	809.67	3.50	6.89	1000	2429.0	13.2	0.129	40.0	162.7	197.5	233.0	268.2						
14	1.33	925.33	4.00	5.79	1001	2776.0	8.0	0.091	40.0	135.0	156.1	177.7	199.0	220.3					
14	1.50	1041.00	4.50	6.51	1000	3123.0	9.9	0.115	40.0	145.4	171.6	198.3	224.8	251.3					
14	1.67	1156.67	5.00	7.24	1000	3470.0	12.1	0.142	40.0	156.8	188.6	221.2	253.4						
16	1.83	1272.33	5.50	6.09	1001	3817.0	7.5	0.101	40.0	132.6	152.4	172.8	192.9	213.0					
16	2.00	1388.00	6.00	6.65	1000	4164.0	8.8	0.120	40.0	139.6	162.9	186.8	210.4	234.0					
16	2.07	1434.27	6.20	6.87	1000	4302.8	9.4	0.128	40.0	142.5	167.3	192.7	217.8	242.8					
18	2.17	1503.67	6.50	5.69	1000	4511.0	5.8	0.088	40.0	123.3	138.5	154.2	169.7	185.1	200.6	216.0	231.5		
18	2.33	1619.33	7.00	6.13	1000	4858.0	6.6	0.102	40.0	127.8	145.3	163.3	181.0	198.7	216.5	234.2	251.9		
18	2.50	1735.00	7.50	6.57	1000	5205.0	7.5	0.117	40.0	132.7	152.5	173.0	193.1	213.2	233.4	253.5			
18	2.67	1850.67	8.00	7.00	1000	5552.0	8.5	0.133	40.0	137.8	160.1	183.2	205.9	228.6	251.3	274.0			
20	2.83	1966.33	8.50	6.03	1000	5899.0	5.7	0.099	40.0	122.9	137.8	153.3	168.6	183.8	199.0	214.3	229.5		
20	3.00	2082.00	9.00	6.38	1000	6246.0	6.3	0.111	40.0	126.3	142.9	160.1	177.1	194.0	210.9	227.9	244.8		
20	3.17	2197.67	9.50	6.74	1000	6593.0	7.0	0.123	40.0	129.8	148.2	167.3	186.0	204.7	223.4	242.1			
20	3.33	2313.33	10.00	7.09	1000	6940.0	7.7	0.137	40.0	133.6	153.8	174.7	195.3	215.9	236.5	257.1			
24	3.50	2429.00	10.50	5.17	1000	7287.0	3.5	0.073	40.0	111.0	120.1	129.6	138.9	148.2	157.6	166.9	176.2	185.5	
24	3.67	2544.67	11.00	5.42	1000	7634.0	3.8	0.080	40.0	112.7	122.6	133.0	143.1	153.3	163.4	173.6	183.7	193.9	
24	3.83	2660.33	11.50	5.66	1000	7981.0	4.1	0.087	40.0	114.4	125.2	136.5	147.5	158.5	169.5	180.5	191.6	202.6	
24	4.00	2776.00	12.00	5.91	1000	8328.0	4.4	0.095	40.0	116.2	127.9	140.1	152.0	163.9	175.8	187.8	199.7	211.6	
24	4.17	2891.67	12.50	6.16	1000	8675.0	4.8	0.103	40.0	118.1	130.7	143.8	156.7	169.5	182.4	195.3	208.1	221.0	
24	4.33	3007.33	13.00	6.40	1000	9022.0	5.1	0.111	40.0	120.1	133.6	147.7	161.5	175.4	189.2	203.0	216.8	230.7	
24	4.50	3123.00	13.50	6.65	1000	9369.0	5.5	0.120	40.0	122.1	136.6	151.7	166.5	181.4	196.2	211.0	225.9	240.7	
24	4.67	3238.67	14.00	6.89	1000	9716.0	5.9	0.129	40.0	124.1	139.6	155.9	171.7	187.6	203.4	219.3	235.2	251.0	
30	5.33	3701.33	16.00	5.04	1000	11104.0	2.5	0.069	40.0	106.2	112.9	120.0	126.9	133.8	140.6	147.5	154.4	161.3	
30	6.00	4164.00	18.00	5.67	1000	12492.0	3.2	0.087	40.0	109.5	117.9	126.7	135.3	143.8	152.4	161.0	169.6	178.1	
30	6.67	4626.67	20.00	6.30	1000	13880.0	3.8	0.108	40.0	113.2	123.4	134.1	144.5	154.9	165.4	175.8	186.2	196.6	
30	7.33	5089.33	22.00	6.93	1000	15268.0	4.6	0.131	40.0	117.3	129.4	142.2	154.6	167.0	179.5	191.9	204.4	216.8	
36	8.00	5552.00	24.00	5.25	1000	16656.0	2.2	0.075	40.0	104.5	110.3	116.6	122.6	128.7	134.7	140.8	146.8	152.9	213.4
36	8.67	6014.67	26.00	5.69	1000	18044.0	2.6	0.088	40.0	106.4	113.2	120.5	127.5	134.5	141.5	148.5	155.6	162.6	232.7
36	9.33	6477.33	28.00	6.13	1000	19432.0	2.9	0.102	40.0	108.5	116.3	124.6	132.7	140.7	148.8	156.8	164.9	172.9	253.4
36	10.00	6940.00	30.00	6.57	1000	20820.0	3.3	0.117	40.0	110.7	119.5	129.0	138.2	147.3	156.5	165.6	174.8	183.9	275.4
36	10.67	7402.67	32.00	7.00	1000	22208.0	3.8	0.133	40.0	113.0	123.0	133.7	144.0	154.3	164.6	174.9	185.2	195.5	298.7
42	11.33	7865.33	34.00	5.47	1000	23596.0	2.0	0.081	40.0	103.4	108.6	114.3	119.8	125.3	130.8	136.2	141.7	147.2	202.0
42	12.00	8328.00	36.00	5.79	1000	24984.0	2.2	0.091	40.0	104.6	110.4	116.8	122.9	129.0	135.0	141.1	147.2	153.3	214.2
42	12.67	8790.67	38.00	6.11	1000	26372.0	2.4	0.101	40.0	105.9	112.3	119.3	126.1	132.8	139.5	146.3	153.0	159.7	227.1
42	13.33	9253.33	40.00	6.43	1000	27760.0	2.7	0.112	40.0	107.2	114.3	122.0	129.4	136.8	144.3	151.7	159.1	166.5	240.6
42	14.00	9716.00	42.00	6.75	1000	29148.0	2.9	0.124	40.0	108.6	116.4	124.8	132.9	141.1	149.2	157.3	165.4	173.5	254.6
42	14.67	10178.67	44.00	7.08	1000	30536.0	3.2	0.136	40.0	110.1	118.6	127.8	136.6	145.4	154.3	163.1	172.0	180.8	269.2
48	13.67	9484.67	41.00	5.05	1000	28454.0	1.5	0.069	40.0	100.5	104.4	108.7	112.7	116.8	120.9	125.0	129.0	133.1	173.8
48	14.00	9716.00	42.00	5.17	1000	29148.0	1.5	0.073	40.0	100.9	105.0	109.4	113.7	117.9	122.2	126.4	130.7	135.0	177.5
48	14.33	9947.33	43.00	5.29	1000	29842.0	1.6	0.076	40.0	101.3	105.5	110.2	114.6	119.1	123.5	128.0	132.4	136.9	181.3
48	14.67	10178.67	44.00	5.42	1000	30536.0	1.7	0.080	40.0	101.7	106.1	111.0	115.6	120.2	124.9	129.5	134.2	138.8	185.2
48	15.00	10410.00	45.00	5.54	1000	31230.0	1.7	0.083	40.0	102.1	106.7	111.7	116.6	121.4	126.3	131.1	135.9	140.8	189.1
48	15.33	10641.33	46.00	5.66	1000	31924.0	1.8	0.087	40.0	102.5	107.3	112.6	117.6	122.6	127.7	132.7	137.8	142.8	193.2
48	15.67	10872.67	47.00	5.79	1000	32618.0	1.9	0.091	40.0	102.9	107.9	113.4	118.6	123.9	129.1	134.4	139.6	144.8	197.3
48	16.00	11104.00	48.00	5.91	1000	33312.0	2.0	0.095	40.0	103.3	108.5	114.2	119.7	125.1	130.6	136.0	141.5	146.9	201.5
48	16.33	11335.33	49.00	6.03	1000	34006.0	2.0	0.099	40.0	103.7	109.1	115.1	120.7	126.4	132.1	137.7	143.4	149.1	205.7
48	16.67	11566.67	50.00	6.16	1000	34700.0	2.1	0.103	40.0	104.2	109.8	115.9	121.8	127.7	133.6	139.5	145.3	151.2	210.1
48	17.33	12029.33	52.00	6.40	1000	36088.0	2.3	0.111	40.0	105.1	111.1	117.7	124.0	130.4	136.7	143.0	149.3	155.7	218.9
48	18.00	12492.00	54.00	6.65	1000	37476.0	2.5	0.120	40.0	106.0	112.4	119.5	126.3	133.1	139.9	146.7	153.5	160.3	228.1
48	18.33	12723.33	55.00	6.77	1000	38170.0	2.5	0.125	40.0	106.4	113.1	120.5	127.5	134.5	141.6	148.6	155.6	162.6	232.8

Pumping Power Cost Curves for Reclaimed Water Conveyance

										Total Dynamic Head (ft) for Pipe Length Listed (miles)									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Distance (ft)	Peak Hourly Demand (gpm)	Friction Loss (ft/1000ft)	Minor Loss (ft/1000 ft)	Pressure at Delivery (psi)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
48	19.00	13186.00	57.00	7.02	1000	39558.0	2.7	0.134	40.0	107.4	114.6	122.4	129.9	137.4	144.9	152.4	159.9	167.4	242.5
54	17.33	12029.33	52.00	5.06	1000	36088.0	1.3	0.070	40.0	99.6	103.0	106.7	110.3	113.9	117.5	121.1	124.7	128.3	164.1
54	18.00	12492.00	54.00	5.25	1000	37476.0	1.4	0.075	40.0	100.1	103.7	107.8	111.6	115.5	119.3	123.2	127.0	130.9	169.3
54	18.67	12954.67	56.00	5.45	1000	38864.0	1.5	0.081	40.0	100.6	104.5	108.9	113.0	117.1	121.2	125.3	129.4	133.5	174.7
54	19.33	13417.33	58.00	5.64	1000	40252.0	1.6	0.087	40.0	101.2	105.3	110.0	114.4	118.7	123.1	127.5	131.9	136.3	180.2
54	20.00	13880.00	60.00	5.84	1000	41640.0	1.7	0.093	40.0	101.8	106.2	111.1	115.8	120.5	125.1	129.8	134.5	139.2	185.9
54	20.67	14342.67	62.00	6.03	1000	43028.0	1.8	0.099	40.0	102.3	107.1	112.3	117.3	122.2	127.2	132.2	137.1	142.1	191.8
54	21.33	14805.33	64.00	6.23	1000	44416.0	1.9	0.105	40.0	102.9	107.9	113.5	118.8	124.0	129.3	134.6	139.9	145.1	197.9
54	22.00	15268.00	66.00	6.42	1000	45804.0	2.0	0.112	40.0	103.6	108.9	114.7	120.3	125.9	131.5	137.1	142.6	148.2	204.1
54	22.67	15730.67	68.00	6.61	1000	47192.0	2.1	0.119	40.0	104.2	109.8	116.0	121.9	127.8	133.7	139.6	145.5	151.4	210.4
54	23.33	16193.33	70.00	6.81	1000	48580.0	2.2	0.126	40.0	104.9	110.8	117.3	123.5	129.8	136.0	142.2	148.4	154.7	217.0
54	24.00	16656.00	72.00	7.00	1000	49968.0	2.4	0.133	40.0	105.5	111.7	118.6	125.2	131.8	138.3	144.9	151.5	158.0	223.6
60	21.17	14689.67	63.50	5.00	1000	44069.0	1.1	0.068	40.0	98.7	101.6	104.9	108.0	111.2	114.3	117.4	120.6	123.7	155.0
60	21.67	15036.67	65.00	5.12	1000	45110.0	1.2	0.071	40.0	98.9	102.0	105.5	108.7	112.0	115.3	118.5	121.8	125.1	157.7
60	22.33	15499.33	67.00	5.28	1000	46498.0	1.2	0.076	40.0	99.3	102.6	106.2	109.7	113.1	116.6	120.0	123.5	127.0	161.5
60	23.00	15962.00	69.00	5.44	1000	47886.0	1.3	0.080	40.0	99.7	103.1	107.0	110.7	114.3	118.0	121.6	125.3	128.9	165.4
60	23.67	16424.67	71.00	5.59	1000	49274.0	1.4	0.085	40.0	100.1	103.7	107.8	111.6	115.5	119.3	123.2	127.0	130.9	169.4
60	24.33	16887.33	73.00	5.75	1000	50662.0	1.4	0.090	40.0	100.5	104.3	108.6	112.7	116.7	120.8	124.8	128.9	132.9	173.5
60	25.00	17350.00	75.00	5.91	1000	52050.0	1.5	0.095	40.0	100.9	104.9	109.4	113.7	118.0	122.2	126.5	130.8	135.0	177.6
60	25.67	17812.67	77.00	6.07	1000	53438.0	1.6	0.100	40.0	101.4	105.6	110.3	114.8	119.3	123.7	128.2	132.7	137.2	181.9
60	26.33	18275.33	79.00	6.22	1000	54826.0	1.7	0.105	40.0	101.8	106.2	111.2	115.9	120.6	125.3	130.0	134.6	139.3	186.3
60	27.00	18738.00	81.00	6.38	1000	56214.0	1.8	0.111	40.0	102.2	106.9	112.1	117.0	121.9	126.8	131.7	136.7	141.6	190.7
60	27.67	19200.67	83.00	6.54	1000	57602.0	1.8	0.116	40.0	102.7	107.5	113.0	118.1	123.3	128.4	133.6	138.7	143.9	195.3
60	28.33	19663.33	85.00	6.70	1000	58990.0	1.9	0.122	40.0	103.2	108.2	113.9	119.3	124.7	130.0	135.4	140.8	146.2	200.0
60	29.00	20126.00	87.00	6.86	1000	60378.0	2.0	0.128	40.0	103.6	108.9	114.9	120.5	126.1	131.7	137.3	142.9	148.6	204.7
60	30.00	20820.00	90.00	7.09	1000	62460.0	2.1	0.137	40.0	104.4	110.0	116.3	122.3	128.3	134.3	140.3	146.2	152.2	212.0

Pumping Power Cost Curves for Reclaimed Water Conveyance

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Power Requirement (kw) for Pipe Length Listed (miles) 1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	6.10									
6	0.20	138.80	0.60	4.73	8.38	10.30	12.22							
6	0.27	185.07	0.80	6.30	14.78	19.12	0.00							
8	0.40	277.60	1.20	5.32	15.93	19.33	22.77	26.19						
8	0.47	323.87	1.40	6.21	21.23	26.51	31.86							
8	0.53	370.13	1.60	7.09	27.65	35.37	43.19							
10	0.60	416.40	1.80	5.11	20.98	24.63	28.33	32.00	35.68					
10	0.67	462.67	2.00	5.67	25.07	30.00	34.99	39.96						
10	0.83	578.33	2.50	7.09	37.68	46.98	56.43	65.80						
12	0.93	647.73	2.80	5.52	31.90	37.20	42.59	47.94	53.28					
12	1.00	694.00	3.00	5.91	35.73	42.17	48.73	55.23	61.73					
12	1.17	809.67	3.50	6.89	46.69	56.68	66.87	76.96						
14	1.33	925.33	4.00	5.79	44.28	51.20	58.27	65.26	72.25					
14	1.50	1041.00	4.50	6.51	53.63	63.29	73.18	82.95	92.72					
14	1.67	1156.67	5.00	7.24	64.27	77.31	90.67	103.86						
16	1.83	1272.33	5.50	6.09	59.80	68.74	77.93	87.00	96.06					
16	2.00	1388.00	6.00	6.65	68.67	80.12	91.89	103.49	115.10					
16	2.07	1434.27	6.20	6.87	72.46	85.03	97.95	110.70	123.44					
18	2.17	1503.67	6.50	5.69	65.71	73.82	82.18	90.42	98.65	106.88	115.12	123.35		
18	2.33	1619.33	7.00	6.13	73.38	83.39	93.72	103.89	114.07	124.24	134.41	144.59		
18	2.50	1735.00	7.50	6.57	81.59	93.78	106.36	118.74	131.13	143.51	155.90			
18	2.67	1850.67	8.00	7.00	90.38	105.04	120.16	135.05	149.94	164.83	179.71			
20	2.83	1966.33	8.50	6.03	85.63	96.06	106.86	117.47	128.09	138.71	149.32	159.94		
20	3.00	2082.00	9.00	6.38	93.17	105.45	118.17	130.66	143.16	155.65	168.15	180.65		
20	3.17	2197.67	9.50	6.74	101.13	115.46	130.29	144.87	159.45	174.03	188.61			
20	3.33	2313.33	10.00	7.09	109.51	126.09	143.27	160.14	177.02	193.90	210.78			
24	3.50	2429.00	10.50	5.17	95.57	103.42	111.60	119.61	127.62	135.64	143.65	151.66	159.68	
24	3.67	2544.67	11.00	5.42	101.63	110.60	119.94	129.09	138.24	147.39	156.54	165.69	174.84	
24	3.83	2660.33	11.50	5.66	107.90	118.07	128.67	139.06	149.45	159.84	170.22	180.61	191.00	
24	4.00	2776.00	12.00	5.91	114.37	125.85	137.83	149.55	161.28	173.01	184.74	196.47	208.20	
24	4.17	2891.67	12.50	6.16	121.05	133.95	147.41	160.59	173.76	186.94	200.12	213.30	226.47	
24	4.33	3007.33	13.00	6.40	127.96	142.39	157.44	172.18	186.91	201.65	216.39	231.13	245.87	
24	4.50	3123.00	13.50	6.65	135.10	151.16	167.93	184.34	200.76	217.17	233.58	250.00	266.41	
24	4.67	3238.67	14.00	6.89	142.48	160.29	178.89	197.10	215.31	233.52	251.73	269.94	288.14	
30	5.33	3701.33	16.00	5.04	139.30	148.10	157.38	166.42	175.46	184.50	193.55	202.59	211.63	
30	6.00	4164.00	18.00	5.67	161.67	173.99	186.98	199.64	212.29	224.94	237.60	250.25	262.91	
30	6.67	4626.67	20.00	6.30	185.70	202.33	219.89	236.98	254.08	271.17	288.26	305.36	322.45	
30	7.33	5089.33	22.00	6.93	211.54	233.36	256.42	278.85	301.29	323.73	346.16	368.60	391.04	
36	8.00	5552.00	24.00	5.25	205.63	217.14	229.43	241.33	253.24	265.14	277.04	288.94	300.85	419.87
36	8.67	6014.67	26.00	5.69	226.89	241.35	256.81	271.76	286.72	301.68	316.64	331.60	346.56	496.14
36	9.33	6477.33	28.00	6.13	249.09	266.95	286.06	304.54	323.02	341.51	359.99	378.47	396.95	581.79
36	10.00	6940.00	30.00	6.57	272.29	294.04	317.30	339.81	362.32	384.83	407.33	429.84	452.35	677.42
36	10.67	7402.67	32.00	7.00	296.55	322.69	350.67	377.73	404.79	431.85	458.92	485.98	513.04	783.65
42	11.33	7865.33	34.00	5.47	288.12	302.80	318.67	333.94	349.21	364.49	379.76	395.03	410.31	563.03
42	12.00	8328.00	36.00	5.79	308.69	325.96	344.65	362.63	380.62	398.60	416.58	434.56	452.54	632.35
42	12.67	8790.67	38.00	6.11	329.85	350.00	371.81	392.80	413.78	434.76	455.75	476.73	497.71	707.55
42	13.33	9253.33	40.00	6.43	351.62	374.94	400.21	424.50	448.80	473.09	497.38	521.68	545.97	788.91
42	14.00	9716.00	42.00	6.75	374.04	400.84	429.89	457.82	485.74	513.67	541.59	569.52	597.45	876.71
42	14.67	10178.67	44.00	7.08	397.13	427.72	460.91	492.81	524.70	556.60	588.49	620.39	652.28	971.22
48	13.67	9484.67	41.00	5.05	337.97	351.04	365.33	379.01	392.69	406.37	420.05	433.73	447.41	584.22
48	14.00	9716.00	42.00	5.17	347.50	361.49	376.81	391.46	406.12	420.77	435.43	450.08	464.74	611.29
48	14.33	9947.33	43.00	5.29	357.11	372.07	388.46	404.13	419.81	435.48	451.15	466.83	482.50	639.25
48	14.67	10178.67	44.00	5.42	366.81	382.79	400.29	417.03	433.77	450.50	467.24	483.98	500.72	668.10
48	15.00	10410.00	45.00	5.54	376.61	393.64	412.30	430.15	448.00	465.85	483.70	501.55	519.39	697.87
48	15.33	10641.33	46.00	5.66	386.50	404.63	424.51	443.51	462.52	481.52	500.53	519.53	538.54	728.58
48	15.67	10872.67	47.00	5.79	396.48	415.77	436.90	457.11	477.32	497.53	517.74	537.94	558.15	760.24
48	16.00	11104.00	48.00	5.91	406.56	427.04	449.49	470.95	492.41	513.87	535.33	556.80	578.26	792.88
48	16.33	11335.33	49.00	6.03	416.74	438.46	462.27	485.04	507.80	530.56	553.33	576.09	598.86	826.50
48	16.67	11566.67	50.00	6.16	427.02	450.03	475.26	499.37	523.49	547.61	571.72	595.84	619.96	861.12
48	17.33	12029.33	52.00	6.40	447.90	473.62	501.85	528.82	555.80	582.78	609.75	636.73	663.70	933.46
48	18.00	12492.00	54.00	6.65	469.19	497.83	529.28	559.33	589.38	619.43	649.47	679.52	709.57	1010.04
48	18.33	12723.33	55.00	6.77	480.00	510.18	543.33	574.99	606.66	638.32	669.99	701.65	733.32	1049.96

Pumping Power Cost Curves for Reclaimed Water Conveyance

					Power Requirement (kw) for Pipe Length Listed (miles)									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
48	19.00	13186.00	57.00	7.02	501.96	535.37	572.09	607.15	642.22	677.29	712.35	747.42	782.49	1133.15
54	17.33	12029.33	52.00	5.06	424.51	439.01	455.08	470.37	485.65	500.94	516.22	531.51	546.79	699.64
54	18.00	12492.00	54.00	5.25	443.15	459.29	477.20	494.22	511.25	528.27	545.30	562.32	579.35	749.60
54	18.67	12954.67	56.00	5.45	462.03	479.94	499.81	518.70	537.59	556.48	575.37	594.26	613.15	802.05
54	19.33	13417.33	58.00	5.64	481.16	500.96	522.93	543.81	564.69	585.58	606.46	627.34	648.22	857.05
54	20.00	13880.00	60.00	5.84	500.56	522.37	546.58	569.58	592.59	615.60	638.61	661.61	684.62	914.69
54	20.67	14342.67	62.00	6.03	520.24	544.18	570.77	596.04	621.30	646.57	671.84	697.11	722.37	975.05
54	21.33	14805.33	64.00	6.23	540.19	566.40	595.52	623.19	650.86	678.52	706.19	733.86	761.52	1038.19
54	22.00	15268.00	66.00	6.42	560.43	589.04	620.85	651.06	681.27	711.48	741.69	771.90	802.11	1104.21
54	22.67	15730.67	68.00	6.61	580.96	612.11	646.76	679.66	712.56	745.46	778.36	811.27	844.17	1173.18
54	23.33	16193.33	70.00	6.81	601.79	635.63	673.28	709.02	744.77	780.51	816.25	851.99	887.74	1245.17
54	24.00	16656.00	72.00	7.00	622.94	659.60	700.42	739.16	777.90	816.64	855.38	894.12	932.86	1320.25
60	21.17	14689.67	63.50	5.00	513.63	528.98	546.20	562.49	578.77	595.06	611.34	627.63	643.91	806.75
60	21.67	15036.67	65.00	5.12	527.25	543.65	562.06	579.47	596.88	614.29	631.70	649.10	666.51	840.60
60	22.33	15499.33	67.00	5.28	545.55	563.43	583.52	602.50	621.48	640.47	659.45	678.43	697.42	887.26
60	23.00	15962.00	69.00	5.44	564.03	583.48	605.33	625.98	646.63	667.28	687.93	708.57	729.22	935.71
60	23.67	16424.67	71.00	5.59	582.70	603.80	627.51	649.92	672.32	694.73	717.14	739.54	761.95	986.02
60	24.33	16887.33	73.00	5.75	601.55	624.39	650.07	674.33	698.59	722.85	747.10	771.36	795.62	1038.21
60	25.00	17350.00	75.00	5.91	620.60	645.27	673.02	699.22	725.43	751.64	777.85	804.05	830.26	1092.33
60	25.67	17812.67	77.00	6.07	639.85	666.44	696.36	724.61	752.87	781.13	809.38	837.64	865.89	1148.44
60	26.33	18275.33	79.00	6.22	659.30	687.90	720.11	750.51	780.92	811.32	841.73	872.13	902.53	1206.58
60	27.00	18738.00	81.00	6.38	678.96	709.67	744.27	776.93	809.58	842.24	874.90	907.56	940.21	1266.78
60	27.67	19200.67	83.00	6.54	698.83	731.75	768.86	803.87	838.89	873.90	908.92	943.93	978.95	1329.11
60	28.33	19663.33	85.00	6.70	718.91	754.15	793.87	831.36	868.84	906.32	943.80	981.29	1018.77	1393.59
60	29.00	20126.00	87.00	6.86	739.22	776.87	819.33	859.39	899.45	939.51	979.57	1019.63	1059.69	1460.28
60	30.00	20820.00	90.00	7.09	770.10	811.57	858.37	902.51	946.64	990.78	1034.92	1079.05	1123.19	1564.55

Pumping Power Cost Curves for Reclaimed Water Conveyance

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Power Cost ($/year) for Pipe Length Listed (miles)									
					1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	2,403.00									
6	0.20	138.80	0.60	4.73	3,305.23	4,058.82	4,818.63							
6	0.27	185.07	0.80	6.30	5,825.54	7,536.39								
8	0.40	277.60	1.20	5.32	6,279.88	7,620.12	8,976.10	10,324.20						
8	0.47	323.87	1.40	6.21	8,369.30	10,450.98	12,557.66							
8	0.53	370.13	1.60	7.09	10,900.90	13,943.59	17,023.58							
10	0.60	416.40	1.80	5.11	8,271.72	9,708.95	11,167.94	12,616.05	14,064.16					
10	0.67	462.67	2.00	5.67	9,883.82	11,824.41	13,794.86	15,750.38						
10	0.83	578.33	2.50	7.09	14,855.19	18,520.65	22,244.41	25,939.01						
12	0.93	647.73	2.80	5.52	12,575.92	14,663.19	16,789.95	18,896.96	21,003.98					
12	1.00	694.00	3.00	5.91	14,084.30	16,622.58	19,209.43	21,772.00	24,334.56					
12	1.17	809.67	3.50	6.89	18,406.63	22,345.18	26,360.88	30,338.01						
14	1.33	925.33	4.00	5.79	17,457.12	20,181.82	22,968.68	25,724.45	28,480.23					
14	1.50	1041.00	4.50	6.51	21,142.78	24,950.53	28,846.79	32,698.80	36,550.80					
14	1.67	1156.67	5.00	7.24	25,336.08	30,477.43	35,740.20	40,942.26						
16	1.83	1272.33	5.50	6.09	23,572.51	27,098.82	30,719.86	34,293.54	37,867.22					
16	2.00	1388.00	6.00	6.65	27,069.80	31,584.04	36,221.25	40,796.98	45,372.71					
16	2.07	1434.27	6.20	6.87	28,564.19	33,520.63	38,612.76	43,637.04	48,661.32					
18	2.17	1503.67	6.50	5.69	25,903.62	29,100.85	32,395.69	35,641.72	38,887.76	42,133.79	45,379.83	48,625.86		
18	2.33	1619.33	7.00	6.13	28,924.89	32,874.01	36,945.04	40,955.12	44,965.20	48,975.27	52,985.35	56,995.42		
18	2.50	1735.00	7.50	6.57	32,162.36	36,969.59	41,926.78	46,808.99	51,691.20	56,573.41	61,455.62			
18	2.67	1850.67	8.00	7.00	35,629.11	41,407.10	47,367.08	53,236.07	59,105.06	64,974.05	70,843.03			
20	2.83	1966.33	8.50	6.03	33,753.98	37,867.19	42,123.63	46,308.45	50,493.28	54,678.10	58,862.93	63,047.75		
20	3.00	2082.00	9.00	6.38	36,729.39	41,570.32	46,581.26	51,507.19	56,433.12	61,359.05	66,284.99	71,210.92		
20	3.17	2197.67	9.50	6.74	39,865.50	45,512.92	51,360.28	57,107.67	62,855.06	68,602.45	74,349.84			
20	3.33	2313.33	10.00	7.09	43,169.89	49,706.27	56,475.86	63,128.85	69,781.84	76,434.83	83,087.81			
24	3.50	2429.00	10.50	5.17	37,674.60	40,768.24	43,992.08	47,150.82	50,309.57	53,468.31	56,627.05	59,785.79	62,944.54	
24	3.67	2544.67	11.00	5.42	40,064.48	43,596.72	47,278.65	50,885.74	54,492.83	58,099.91	61,707.00	65,314.08	68,921.17	
24	3.83	2660.33	11.50	5.66	42,533.18	46,542.49	50,722.85	54,817.68	58,912.52	63,007.36	67,102.19	71,197.03	75,291.86	
24	4.00	2776.00	12.00	5.91	45,083.73	49,610.08	54,330.76	58,954.28	63,577.79	68,201.31	72,824.82	77,448.34	82,071.85	
24	4.17	2891.67	12.50	6.16	47,719.17	52,803.98	58,108.45	63,303.09	68,497.73	73,692.37	78,887.00	84,081.64	89,276.28	
24	4.33	3007.33	13.00	6.40	50,442.51	56,128.68	62,061.94	67,871.65	73,681.36	79,491.07	85,300.78	91,110.49	96,920.20	
24	4.50	3123.00	13.50	6.65	53,256.74	59,588.62	66,197.20	72,667.43	79,137.66	85,607.89	92,078.12	98,548.35	105,018.58	
24	4.67	3238.67	14.00	6.89	56,164.84	63,188.22	70,520.20	77,697.88	84,875.56	92,053.24	99,230.92	106,408.60	113,586.29	
30	5.33	3701.33	16.00	5.04	54,910.60	58,380.42	62,038.93	65,603.10	69,167.26	72,731.43	76,295.60	79,859.76	83,423.93	
30	6.00	4164.00	18.00	5.67	63,731.53	68,585.45	73,708.02	78,696.26	83,684.50	88,672.74	93,660.98	98,649.23	103,637.47	
30	6.67	4626.67	20.00	6.30	73,204.19	79,758.11	86,680.55	93,418.73	100,156.91	106,895.09	113,633.27	120,371.45	127,109.63	
30	7.33	5089.33	22.00	6.93	83,390.00	91,989.44	101,079.38	109,924.08	118,768.77	127,613.46	136,458.15	145,302.85	154,147.54	
36	8.00	5552.00	24.00	5.25	81,057.48	85,595.97	90,441.56	95,133.60	99,825.64	104,517.68	109,209.72	113,901.76	118,593.80	165,514.19
36	8.67	6014.67	26.00	5.69	89,439.48	95,140.90	101,232.78	107,129.43	113,026.08	118,922.73	124,819.38	130,716.03	136,612.68	195,579.17
36	9.33	6477.33	28.00	6.13	98,191.07	105,233.29	112,763.18	120,049.23	127,335.29	134,621.34	141,907.39	149,193.45	156,479.50	229,340.04
36	10.00	6940.00	30.00	6.57	107,336.45	115,908.90	125,081.15	133,953.50	142,825.85	151,698.20	160,570.56	169,442.91	178,315.26	267,038.77
36	10.67	7402.67	32.00	7.00	116,899.57	127,203.11	138,234.60	148,902.12	159,569.64	170,237.15	180,904.67	191,572.19	202,239.70	308,914.88
42	11.33	7865.33	34.00	5.47	113,578.38	119,363.26	125,619.45	131,639.98	137,660.51	143,681.04	149,701.58	155,722.11	161,742.64	221,947.97
42	12.00	8328.00	36.00	5.79	121,686.25	128,494.60	135,862.41	142,950.49	150,038.57	157,126.64	164,214.72	171,302.80	178,390.88	249,271.66
42	12.67	8790.67	38.00	6.11	130,026.07	137,968.67	146,569.25	154,840.85	163,112.44	171,384.03	179,655.63	187,927.22	196,198.81	278,914.74
42	13.33	9253.33	40.00	6.43	138,608.82	147,801.67	157,761.97	167,338.55	176,915.12	186,491.70	196,068.28	205,644.85	215,221.43	310,987.19
42	14.00	9716.00	42.00	6.75	147,445.42	158,009.70	169,462.39	180,470.88	191,479.36	202,487.85	213,496.33	224,504.82	235,513.30	
42	14.67	10178.67	44.00	7.08	156,546.71	168,608.72	181,692.19	194,264.93	206,837.67	219,410.41	231,983.15	244,555.89	257,128.63	
48	13.67	9484.67	41.00	5.05	133,227.61	138,378.16	144,013.16	149,405.93	154,798.71	160,191.48	165,584.26	170,977.03	176,369.81	230,297.56
48	14.00	9716.00	42.00	5.17	136,982.63	142,499.35	148,536.82	154,313.92	160,091.01	165,868.11	171,645.20	177,422.29	183,199.39	240,970.33
48	14.33	9947.33	43.00	5.29	140,772.41	146,671.77	153,129.99	159,308.78	165,487.56	171,666.35	177,845.14	184,023.93	190,202.71	251,990.59
48	14.67	10178.67	44.00	5.42	144,597.65	150,896.48	157,794.07	164,392.28	170,990.49	177,588.70	184,186.91	190,785.12	197,383.33	263,365.43
48	15.00	10410.00	45.00	5.54	148,459.05	155,174.51	162,530.48	169,566.19	176,601.91	183,637.62	190,673.34	197,709.05	204,744.77	275,101.91
48	15.33	10641.33	46.00	5.66	152,357.32	159,506.88	167,340.62	174,832.28	182,323.93	189,815.58	197,307.23	204,798.89	212,290.54	287,207.07
48	15.67	10872.67	47.00	5.79	156,293.16	163,894.64	172,225.91	180,192.28	188,158.66	196,125.03	204,091.41	212,057.79	220,024.16	299,687.92
48	16.00	11104.00	48.00	5.91	160,267.26	168,338.82	177,187.73	185,647.96	194,108.19	202,568.43	211,028.66	219,488.89	227,949.13	312,551.46
48	16.33	11335.33	49.00	6.03	164,280.33	172,840.43	182,227.48	191,201.06	200,174.63	209,148.20	218,121.78	227,095.35	236,068.92	325,804.66
48	16.67	11566.67	50.00	6.16	168,333.07	177,400.50	187,346.56	196,853.30	206,360.05	215,866.79	225,373.54	234,880.28	244,387.03	339,454.48
48	17.33	12029.33	52.00	6.40	176,560.29	186,700.09	197,828.23	208,462.19	219,096.16	229,730.12	240,364.09	250,998.06	261,632.02	367,971.68
48	18.00	12492.00	54.00	6.65	184,954.46	196,245.71	208,643.78	220,488.43	232,333.09	244,177.75	256,022.41	267,867.06	279,711.72	
48	18.33	12723.33	55.00	6.77	189,215.86	201,113.30	214,180.19	226,662.36	239,144.52	251,626.69	264,108.85	276,591.01	289,073.18	

Pumping Power Cost Curves for Reclaimed Water Conveyance

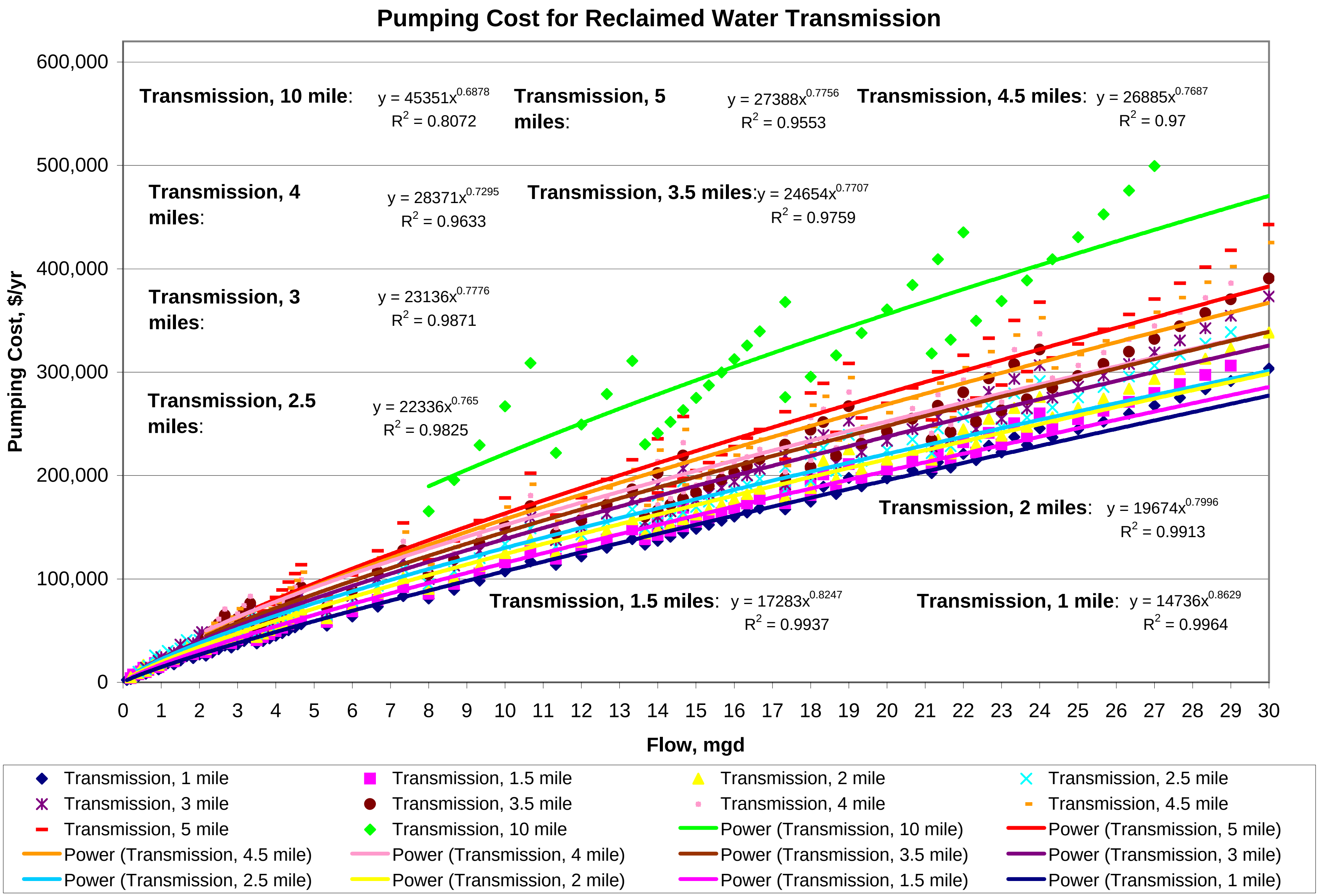
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Power Cost ($/year) for Pipe Length Listed (miles)									
					1	1.5	2	2.5	3	3.5	4	4.5	5	10
48	19.00	13186.00	57.00	7.02	197,870.74	211,043.08	225,517.15	239,340.36	253,163.57	266,986.77	280,809.98	294,633.19	308,456.40	
54	17.33	12029.33	52.00	5.06	167,342.81	173,059.53	179,393.26	185,418.48	191,443.70	197,468.93	203,494.15	209,519.38	215,544.60	275,796.84
54	18.00	12492.00	54.00	5.25	174,687.91	181,053.81	188,110.68	194,822.07	201,533.45	208,244.83	214,956.22	221,667.60	228,378.99	295,492.83
54	18.67	12954.67	56.00	5.45	182,130.79	189,191.90	197,023.64	204,470.07	211,916.50	219,362.93	226,809.36	234,255.79	241,702.21	316,166.50
54	19.33	13417.33	58.00	5.64	189,674.53	197,478.34	206,138.34	214,370.25	222,602.16	230,834.07	239,065.98	247,297.89	255,529.79	337,848.88
54	20.00	13880.00	60.00	5.84	197,322.23	205,917.67	215,460.96	224,530.32	233,599.69	242,669.06	251,738.42	260,807.79	269,877.15	360,570.81
54	20.67	14342.67	62.00	6.03	205,076.95	214,514.38	224,997.63	234,957.97	244,918.30	254,878.64	264,838.98	274,799.32	284,759.65	384,363.03
54	21.33	14805.33	64.00	6.23	212,941.76	223,272.95	234,754.47	245,660.82	256,567.17	267,473.52	278,379.87	289,286.23	300,192.58	409,256.10
54	22.00	15268.00	66.00	6.42	220,919.70	232,197.84	244,737.56	256,646.49	268,555.42	280,464.35	292,373.28	304,282.21	316,191.14	435,280.44
54	22.67	15730.67	68.00	6.61	229,013.80	241,293.50	254,952.98	267,922.56	280,892.15	293,861.74	306,831.32	319,800.91	332,770.50	
54	23.33	16193.33	70.00	6.81	237,227.07	250,564.33	265,406.74	279,496.57	293,586.40	307,676.24	321,766.07	335,855.90	349,945.73	
54	24.00	16656.00	72.00	7.00	245,562.53	260,014.76	276,104.86	291,376.03	306,647.20	321,918.36	337,189.53	352,460.70	367,731.87	
60	21.17	14689.67	63.50	5.00	202,474.55	208,525.30	215,313.23	221,732.58	228,151.92	234,571.26	240,990.60	247,409.94	253,829.29	318,022.70
60	21.67	15036.67	65.00	5.12	207,840.25	214,307.31	221,565.05	228,427.45	235,289.84	242,152.24	249,014.64	255,877.04	262,739.44	331,363.42
60	22.33	15499.33	67.00	5.28	215,055.07	222,105.53	230,021.91	237,505.33	244,988.75	252,472.17	259,955.58	267,439.00	274,922.42	349,756.61
60	23.00	15962.00	69.00	5.44	222,340.77	230,007.75	238,620.53	246,760.40	254,900.28	263,040.16	271,180.04	279,319.91	287,459.79	368,858.56
60	23.67	16424.67	71.00	5.59	229,699.17	238,016.62	247,364.53	256,197.21	265,029.89	273,862.58	282,695.26	291,527.94	300,360.62	388,687.44
60	24.33	16887.33	73.00	5.75	237,132.06	246,134.79	256,257.53	265,820.27	275,383.01	284,945.75	294,508.48	304,071.22	313,633.96	409,261.33
60	25.00	17350.00	75.00	5.91	244,641.25	254,364.89	265,303.14	275,634.08	285,965.03	296,295.97	306,626.91	316,957.86	327,288.80	430,598.23
60	25.67	17812.67	77.00	6.07	252,228.55	262,709.55	274,504.94	285,643.14	296,781.34	307,919.53	319,057.73	330,195.93	341,334.13	452,716.10
60	26.33	18275.33	79.00	6.22	259,895.72	271,171.37	283,866.51	295,851.90	307,837.30	319,822.69	331,808.08	343,793.48	355,778.87	475,632.81
60	27.00	18738.00	81.00	6.38	267,644.56	279,752.95	293,391.41	306,264.83	319,138.25	332,011.67	344,885.10	357,758.52	370,631.94	499,366.16
60	27.67	19200.67	83.00	6.54	275,476.84	288,456.90	303,083.18	316,886.35	330,689.53	344,492.70	358,295.87	372,099.04	385,902.21	
60	28.33	19663.33	85.00	6.70	283,394.33	297,285.80	312,945.38	327,720.90	342,496.43	357,271.95	372,047.48	386,823.00	401,598.52	
60	29.00	20126.00	87.00	6.86	291,398.79	306,242.21	322,981.52	338,772.88	354,564.25	370,355.61	386,146.97	401,938.33	417,729.70	
60	30.00	20820.00	90.00	7.09	303,572.40	319,921.55	338,369.56	355,768.14	373,166.72	390,565.30	407,963.88	425,362.46	442,761.04	

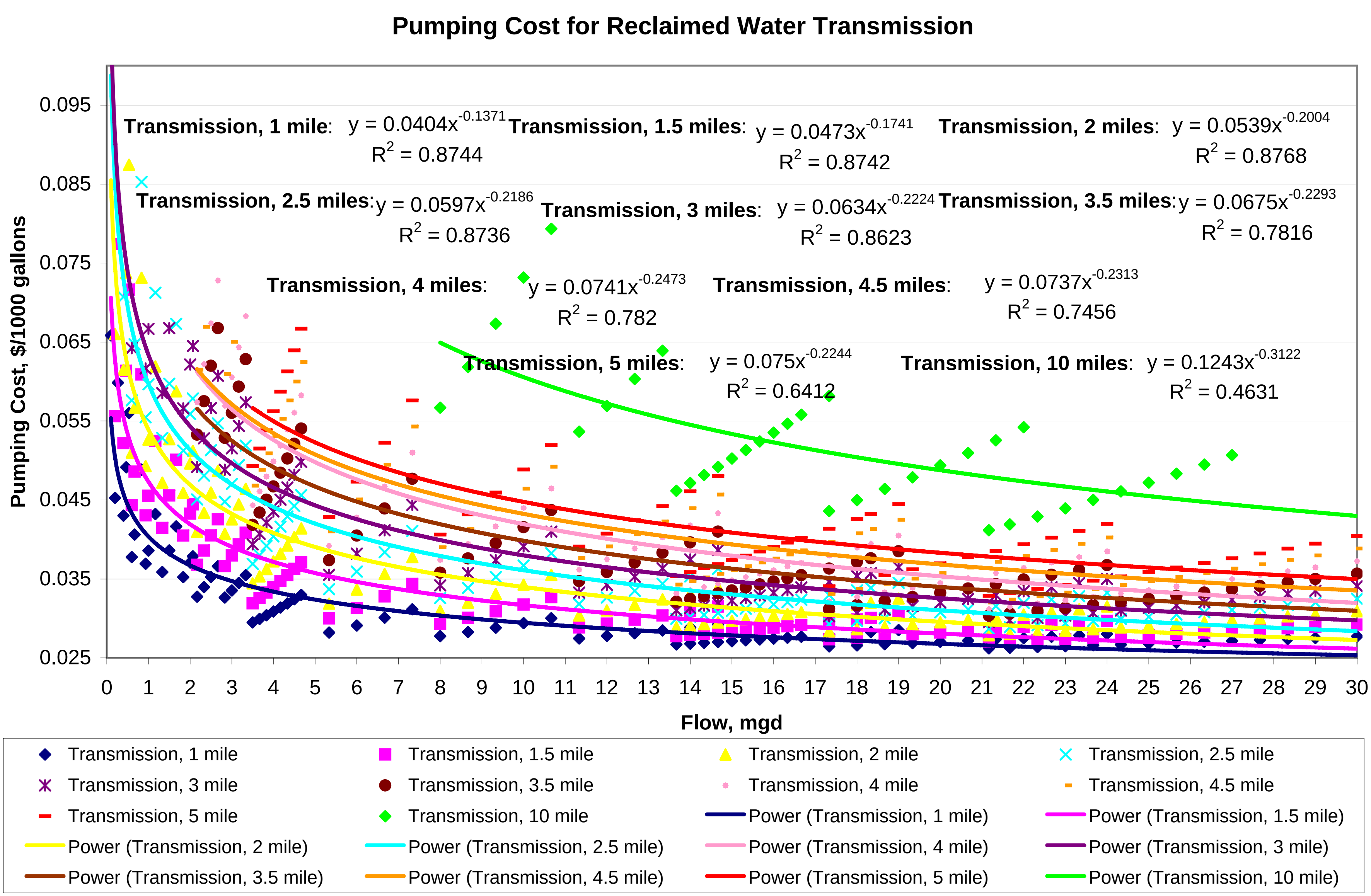
Pumping Power Cost Curves for Reclaimed Water Conveyance

					Power Cost of Service ($/1000 gallons) for Pipe Length Listed (miles)									
Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	1	1.5	2	2.5	3	3.5	4	4.5	5	10
4	0.10	69.40	0.30	5.32	0.066									
6	0.20	138.80	0.60	4.73	0.045	0.056	0.066							
6	0.27	185.07	0.80	6.30	0.060	0.077								
8	0.40	277.60	1.20	5.32	0.043	0.052	0.061	0.071						
8	0.47	323.87	1.40	6.21	0.049	0.061	0.074							
8	0.53	370.13	1.60	7.09	0.056	0.072	0.087							
10	0.60	416.40	1.80	5.11	0.038	0.044	0.051	0.058	0.064					
10	0.67	462.67	2.00	5.67	0.041	0.049	0.057	0.065						
10	0.83	578.33	2.50	7.09	0.049	0.061	0.073	0.085						
12	0.93	647.73	2.80	5.52	0.037	0.043	0.049	0.055	0.062					
12	1.00	694.00	3.00	5.91	0.039	0.046	0.053	0.060	0.067					
12	1.17	809.67	3.50	6.89	0.043	0.052	0.062	0.071						
14	1.33	925.33	4.00	5.79	0.036	0.041	0.047	0.053	0.059					
14	1.50	1041.00	4.50	6.51	0.039	0.046	0.053	0.060	0.067					
14	1.67	1156.67	5.00	7.24	0.042	0.050	0.059	0.067						
16	1.83	1272.33	5.50	6.09	0.035	0.040	0.046	0.051	0.057					
16	2.00	1388.00	6.00	6.65	0.037	0.043	0.050	0.056	0.062					
16	2.07	1434.27	6.20	6.87	0.038	0.044	0.051	0.058	0.065					
18	2.17	1503.67	6.50	5.69	0.033	0.037	0.041	0.045	0.049	0.053	0.057	0.061		
18	2.33	1619.33	7.00	6.13	0.034	0.039	0.043	0.048	0.053	0.058	0.062	0.067		
18	2.50	1735.00	7.50	6.57	0.035	0.041	0.046	0.051	0.057	0.062	0.067			
18	2.67	1850.67	8.00	7.00	0.037	0.043	0.049	0.055	0.061	0.067	0.073			
20	2.83	1966.33	8.50	6.03	0.033	0.037	0.041	0.045	0.049	0.053	0.057	0.061		
20	3.00	2082.00	9.00	6.38	0.034	0.038	0.043	0.047	0.052	0.056	0.061	0.065		
20	3.17	2197.67	9.50	6.74	0.034	0.039	0.044	0.049	0.054	0.059	0.064			
20	3.33	2313.33	10.00	7.09	0.035	0.041	0.046	0.052	0.057	0.063	0.068			
24	3.50	2429.00	10.50	5.17	0.029	0.032	0.034	0.037	0.039	0.042	0.044	0.047	0.049	
24	3.67	2544.67	11.00	5.42	0.030	0.033	0.035	0.038	0.041	0.043	0.046	0.049	0.051	
24	3.83	2660.33	11.50	5.66	0.030	0.033	0.036	0.039	0.042	0.045	0.048	0.051	0.054	
24	4.00	2776.00	12.00	5.91	0.031	0.034	0.037	0.040	0.044	0.047	0.050	0.053	0.056	
24	4.17	2891.67	12.50	6.16	0.031	0.035	0.038	0.042	0.045	0.048	0.052	0.055	0.059	
24	4.33	3007.33	13.00	6.40	0.032	0.035	0.039	0.043	0.047	0.050	0.054	0.058	0.061	
24	4.50	3123.00	13.50	6.65	0.032	0.036	0.040	0.044	0.048	0.052	0.056	0.060	0.064	
24	4.67	3238.67	14.00	6.89	0.033	0.037	0.041	0.046	0.050	0.054	0.058	0.062	0.067	
30	5.33	3701.33	16.00	5.04	0.028	0.030	0.032	0.034	0.036	0.037	0.039	0.041	0.043	
30	6.00	4164.00	18.00	5.67	0.029	0.031	0.034	0.036	0.038	0.040	0.043	0.045	0.047	
30	6.67	4626.67	20.00	6.30	0.030	0.033	0.036	0.038	0.041	0.044	0.047	0.049	0.052	
30	7.33	5089.33	22.00	6.93	0.031	0.034	0.038	0.041	0.044	0.048	0.051	0.054	0.058	
36	8.00	5552.00	24.00	5.25	0.028	0.029	0.031	0.033	0.034	0.036	0.037	0.039	0.041	0.057
36	8.67	6014.67	26.00	5.69	0.028	0.030	0.032	0.034	0.036	0.038	0.039	0.041	0.043	0.062
36	9.33	6477.33	28.00	6.13	0.029	0.031	0.033	0.035	0.037	0.040	0.042	0.044	0.046	0.067
36	10.00	6940.00	30.00	6.57	0.029	0.032	0.034	0.037	0.039	0.042	0.044	0.046	0.049	0.073
36	10.67	7402.67	32.00	7.00	0.030	0.033	0.036	0.038	0.041	0.044	0.046	0.049	0.052	0.079
42	11.33	7865.33	34.00	5.47	0.027	0.029	0.030	0.032	0.033	0.035	0.036	0.038	0.039	0.054
42	12.00	8328.00	36.00	5.79	0.028	0.029	0.031	0.033	0.034	0.036	0.037	0.039	0.041	0.057
42	12.67	8790.67	38.00	6.11	0.028	0.030	0.032	0.033	0.035	0.037	0.039	0.041	0.042	0.060
42	13.33	9253.33	40.00	6.43	0.028	0.030	0.032	0.034	0.036	0.038	0.040	0.042	0.044	0.064
42	14.00	9716.00	42.00	6.75	0.029	0.031	0.033	0.035	0.037	0.040	0.042	0.044	0.046	
42	14.67	10178.67	44.00	7.08	0.029	0.031	0.034	0.036	0.039	0.041	0.043	0.046	0.048	
48	13.67	9484.67	41.00	5.05	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.035	0.046
48	14.00	9716.00	42.00	5.17	0.027	0.028	0.029	0.030	0.031	0.032	0.034	0.035	0.036	0.047
48	14.33	9947.33	43.00	5.29	0.027	0.028	0.029	0.030	0.032	0.033	0.034	0.035	0.036	0.048
48	14.67	10178.67	44.00	5.42	0.027	0.028	0.029	0.031	0.032	0.033	0.034	0.036	0.037	0.049
48	15.00	10410.00	45.00	5.54	0.027	0.028	0.030	0.031	0.032	0.034	0.035	0.036	0.037	0.050
48	15.33	10641.33	46.00	5.66	0.027	0.029	0.030	0.031	0.033	0.034	0.035	0.037	0.038	0.051
48	15.67	10872.67	47.00	5.79	0.027	0.029	0.030	0.032	0.033	0.034	0.036	0.037	0.038	0.052
48	16.00	11104.00	48.00	5.91	0.027	0.029	0.030	0.032	0.033	0.035	0.036	0.038	0.039	0.054
48	16.33	11335.33	49.00	6.03	0.028	0.029	0.031	0.032	0.034	0.035	0.037	0.038	0.040	0.055
48	16.67	11566.67	50.00	6.16	0.028	0.029	0.031	0.032	0.034	0.035	0.037	0.039	0.040	0.056
48	17.33	12029.33	52.00	6.40	0.028	0.030	0.031	0.033	0.035	0.036	0.038	0.040	0.041	0.058
48	18.00	12492.00	54.00	6.65	0.028	0.030	0.032	0.034	0.035	0.037	0.039	0.041	0.043	
48	18.33	12723.33	55.00	6.77	0.028	0.030	0.032	0.034	0.036	0.038	0.039	0.041	0.043	

Pumping Power Cost Curves for Reclaimed Water Conveyance

Diam (in)	Annual Average Day Flow (mgd)	Annual Average Day Flow (gpm)	Peak Hourly Flow (mgd)	Pipe Velocity at Peak Hourly Flow (ft/s)	Power Cost of Service ($/1000 gallons) for Pipe Length Listed (miles)									
					1	1.5	2	2.5	3	3.5	4	4.5	5	10
48	19.00	13186.00	57.00	7.02	0.029	0.030	0.033	0.035	0.037	0.038	0.040	0.042	0.044	
54	17.33	12029.33	52.00	5.06	0.026	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.044
54	18.00	12492.00	54.00	5.25	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.035	0.045
54	18.67	12954.67	56.00	5.45	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.035	0.046
54	19.33	13417.33	58.00	5.64	0.027	0.028	0.029	0.030	0.032	0.033	0.034	0.035	0.036	0.048
54	20.00	13880.00	60.00	5.84	0.027	0.028	0.030	0.031	0.032	0.033	0.034	0.036	0.037	0.049
54	20.67	14342.67	62.00	6.03	0.027	0.028	0.030	0.031	0.032	0.034	0.035	0.036	0.038	0.051
54	21.33	14805.33	64.00	6.23	0.027	0.029	0.030	0.032	0.033	0.034	0.036	0.037	0.039	0.053
54	22.00	15268.00	66.00	6.42	0.028	0.029	0.030	0.032	0.033	0.035	0.036	0.038	0.039	0.054
54	22.67	15730.67	68.00	6.61	0.028	0.029	0.031	0.032	0.034	0.036	0.037	0.039	0.040	
54	23.33	16193.33	70.00	6.81	0.028	0.029	0.031	0.033	0.034	0.036	0.038	0.039	0.041	
54	24.00	16656.00	72.00	7.00	0.028	0.030	0.032	0.033	0.035	0.037	0.038	0.040	0.042	
60	21.17	14689.67	63.50	5.00	0.026	0.027	0.028	0.029	0.030	0.030	0.031	0.032	0.033	0.041
60	21.67	15036.67	65.00	5.12	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033	0.042
60	22.33	15499.33	67.00	5.28	0.026	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.043
60	23.00	15962.00	69.00	5.44	0.026	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.044
60	23.67	16424.67	71.00	5.59	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.035	0.045
60	24.33	16887.33	73.00	5.75	0.027	0.028	0.029	0.030	0.031	0.032	0.033	0.034	0.035	0.046
60	25.00	17350.00	75.00	5.91	0.027	0.028	0.029	0.030	0.031	0.032	0.034	0.035	0.036	0.047
60	25.67	17812.67	77.00	6.07	0.027	0.028	0.029	0.030	0.032	0.033	0.034	0.035	0.036	0.048
60	26.33	18275.33	79.00	6.22	0.027	0.028	0.030	0.031	0.032	0.033	0.035	0.036	0.037	0.049
60	27.00	18738.00	81.00	6.38	0.027	0.028	0.030	0.031	0.032	0.034	0.035	0.036	0.038	0.051
60	27.67	19200.67	83.00	6.54	0.027	0.029	0.030	0.031	0.033	0.034	0.035	0.037	0.038	
60	28.33	19663.33	85.00	6.70	0.027	0.029	0.030	0.032	0.033	0.035	0.036	0.037	0.039	
60	29.00	20126.00	87.00	6.86	0.028	0.029	0.031	0.032	0.033	0.035	0.036	0.038	0.039	
60	30.00	20820.00	90.00	7.09	0.028	0.029	0.031	0.032	0.034	0.036	0.037	0.039	0.040	


Pumping Cost for Reclaimed Water Transmission
Transmission, 10 mile: y = 45351x^0.6878 R^2 = 0.8072
Transmission, 5 miles: y = 27388x^0.7756 R^2 = 0.9553
Transmission, 4.5 miles: y = 26885x^0.7687 R^2 = 0.97
Transmission, 4 miles: y = 28371x^0.7295 R^2 = 0.9633
Transmission, 3.5 miles: y = 24654x^0.7707 R^2 = 0.9759
Transmission, 3 miles: y = 23136x^0.7776 R^2 = 0.9871
Transmission, 2.5 miles: y = 22336x^0.765 R^2 = 0.9825
Transmission, 2 miles: y = 19674x^0.7996 R^2 = 0.9913
Transmission, 1.5 miles: y = 17283x^0.8247 R^2 = 0.9937
Transmission, 1 mile: y = 14736x^0.8629 R^2 = 0.9964
Pumping Cost, $/yr
600,000
500,000
400,000
300,000
200,000
100,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Flow, mgd
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Power (Transmission, 10 mile)
Power (Transmission, 5 mile)
Power (Transmission, 4.5 mile)
Power (Transmission, 4 mile)
Power (Transmission, 3.5 mile)
Power (Transmission, 3 mile)
Power (Transmission, 2.5 mile)
Power (Transmission, 2 mile)
Power (Transmission, 1.5 mile)
Power (Transmission, 1 mile)



Pumping Cost for Reclaimed Water Transmission
Transmission, 1 mile: y = 0.0404x^-0.1371 R^2 = 0.8744
Transmission, 1.5 miles: y = 0.0473x^-0.1741 R^2 = 0.8742
Transmission, 2 miles: y = 0.0539x^-0.2004 R^2 = 0.8768
Transmission, 2.5 miles: y = 0.0597x^-0.2186 R^2 = 0.8736
Transmission, 3 miles: y = 0.0634x^-0.2224 R^2 = 0.8623
Transmission, 3.5 miles: y = 0.0675x^-0.2293 R^2 = 0.7816
Transmission, 4 miles: y = 0.0741x^-0.2473 R^2 = 0.782
Transmission, 4.5 miles: y = 0.0737x^-0.2313 R^2 = 0.7456
Transmission, 5 miles: y = 0.075x^-0.2244 R^2 = 0.6412
Transmission, 10 miles: y = 0.1243x^-0.3122 R^2 = 0.4631
Pumping Cost, $/1000 gallons
0.025
0.035
0.045
0.055
0.065
0.075
0.085
0.095
Flow, mgd
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Transmission, 1 mile
Transmission, 1.5 mile
Transmission, 2 mile
Transmission, 2.5 mile
Transmission, 3 mile
Transmission, 3.5 mile
Transmission, 4 mile
Transmission, 4.5 mile
Transmission, 5 mile
Transmission, 10 mile
Power (Transmission, 1 mile)
Power (Transmission, 1.5 mile)
Power (Transmission, 2 mile)
Power (Transmission, 2.5 mile)
Power (Transmission, 4 mile)
Power (Transmission, 3 mile)
Power (Transmission, 3.5 mile)
Power (Transmission, 4.5 mile)
Power (Transmission, 5 mile)
Power (Transmission, 10 mile)

Appendix C
Water Reuse System Cost Model
Base System Cost of Service
Summary Tables

Water Reuse System Estimated Cost of Service, $/1000 gallons

BASE SYSTEM

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	3.72	4.37	5.02	5.68	6.31	6.96	7.60	8.24	8.88	15.37
0.25	1.68	1.96	2.24	2.52	2.79	3.07	3.35	3.62	3.89	6.67
0.5	0.99	1.15	1.31	1.46	1.61	1.77	1.92	2.07	2.22	3.76
0.75	0.73	0.85	0.96	1.08	1.19	1.30	1.42	1.52	1.63	2.75
1	0.62	0.71	0.80	0.90	0.99	1.08	1.17	1.25	1.34	2.26
1.25	0.54	0.62	0.70	0.79	0.86	0.94	1.02	1.10	1.17	1.96
1.5	0.50	0.57	0.64	0.71	0.78	0.85	0.93	0.99	1.06	1.76
1.75	0.46	0.53	0.59	0.66	0.72	0.79	0.86	0.91	0.97	1.61
2	0.44	0.50	0.56	0.62	0.68	0.74	0.80	0.85	0.91	1.51
2.5	0.40	0.45	0.51	0.56	0.61	0.67	0.73	0.77	0.82	1.35
3	0.37	0.42	0.47	0.52	0.57	0.62	0.68	0.72	0.77	1.25
3.5	0.36	0.40	0.45	0.50	0.54	0.59	0.64	0.68	0.72	1.18
4	0.34	0.39	0.43	0.48	0.52	0.56	0.61	0.65	0.69	1.12
4.5	0.33	0.38	0.42	0.46	0.50	0.54	0.59	0.63	0.67	1.08
5	0.33	0.37	0.42	0.46	0.50	0.54	0.59	0.63	0.67	1.09
10	0.26	0.29	0.32	0.35	0.38	0.41	0.44	0.46	0.49	0.78
15	0.24	0.26	0.29	0.31	0.34	0.36	0.40	0.41	0.44	0.68
30	0.22	0.24	0.26	0.28	0.30	0.32	0.35	0.36	0.38	0.58

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Base System

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	110,000	27,000	701,100	81,600	2,822,700	106,200
0.25	125,000	29,900	843,300	87,900	3,109,400	114,700
0.5	150,000	34,700	1,080,300	97,900	3,587,300	127,800
0.75	172,500	39,400	1,223,700	106,600	3,971,600	139,000
1	180,000	43,400	1,412,900	115,800	4,401,700	150,400
1.25	187,500	47,400	1,602,000	124,600	4,831,700	161,300
1.5	195,000	51,300	1,791,200	133,300	5,261,700	171,900
1.75	202,500	55,300	1,980,300	141,900	5,691,800	182,300
2	210,000	59,200	2,169,400	150,500	6,121,800	192,600
2.5	225,000	67,200	2,547,700	167,500	6,981,900	212,700
3	240,000	75,100	2,926,000	184,300	7,841,900	232,500
3.5	255,000	83,000	3,304,200	201,000	8,702,000	252,000
4	270,000	90,900	3,682,500	217,700	9,562,100	271,200
4.5	285,000	98,800	4,060,800	234,200	10,422,100	290,200
5	300,000	106,800	4,540,400	250,600	11,789,100	309,000
10	400,000	183,500	6,965,900	403,100	17,041,900	481,000
15	475,000	258,900	9,771,200	555,900	22,674,300	649,100
30	700,000	485,300	18,187,000	999,900	39,571,700	1,127,600

WATER REUSE SYSTEM COST OF SERVICE TABLE

BASE SYSTEM

Blue = Values to input

Capital Cost and Debt Financing Assumptions	
Total Capital Cost	Variable
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

General Items	
Lab Costs, $	$20,000
Sodium Hypochloride, $/gal of 12.5%	0.70
Chlorine Dose, mg/L (year-round, see Note A)	7
Electrical Power, $/kwhr	0.045
FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

Maintenance	
Pump System Labor, hrs/wk	4
Pump System Equip, % capital	1%
Treatment Facilities, % capital	5%
Distribution System, $/mile	5500

Length of Distribution System (mi) 1.0

Summary of Capital Cost Estimates

Annual Avg Flow/Demand (MGD)	0.1	0.25	0.5	0.75	1	1.25	1.5	1.75
Description	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost
Treatment Facilities	$110,000	$125,000	$150,000	$172,500	$180,000	$187,500	$195,000	$202,500
Storage Facilities	$0	$0	$0	$0	$0	$0	$0	$0
Pump Station	$60,704	$151,759	$303,519	$364,223	$485,630	$607,038	$728,446	$849,853
Piping	$530,385	$566,521	$626,749	$686,976	$747,203	$807,430	$867,658	$927,885
TOTAL CAPITAL	$701,089	$843,281	$1,080,267	$1,223,699	$1,412,833	$1,601,968	$1,791,103	$1,980,238

	Cost Components	Basis/Methodology	0.1 Year 1 Cost, $	0.1 $/1000 gallons	0.25 Year 1 Cost, $	0.25 $/1000 gallons	0.5 Year 1 Cost, $	0.5 $/1000 gallons	0.75 Year 1 Cost, $	0.75 $/1000 gallons	1 Year 1 Cost, $	1 $/1000 gallons	1.25 Year 1 Cost, $	1.25 $/1000 gallons	1.5 Year 1 Cost, $	1.5 $/1000 gallons	1.75 Year 1 Cost, $	1.75 $/1000 gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$54,114	**$1.48**	$65,089	**$0.71**	$83,381	**$0.46**	$94,452	**$0.35**	$109,051	**$0.30**	$123,649	**$0.27**	$138,248	**$0.25**	$152,846	**$0.24**
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$2,021	$0.06	$4,455	$0.05	$8,103	$0.04	$11,497	$0.04	$14,736	$0.04	$17,865	$0.04	$20,909	$0.04	$23,883	$0.04
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$5,500	$0.15	$5,500	$0.06	$5,500	$0.03	$5,500	$0.02	$5,500	$0.02	$5,500	$0.01	$5,500	$0.01	$5,500	$0.01
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$3.72**		**$1.68**		**$0.99**		**$0.73**		**$0.62**		**$0.54**		**$0.50**		**$0.46**

Length of Distribution System (mi) 1.5

Summary of Capital Cost Estimates

Annual Avg Flow/Demand (MGD)	0.1	0.25	0.5	0.75	1	1.25	1.5	1.75
Description	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost
Treatment Facilities	$110,000	$125,000	$150,000	$172,500	$180,000	$187,500	$195,000	$202,500
Storage Facilities	$0	$0	$0	$0	$0	$0	$0	$0
Pump Station	$60,704	$151,759	$303,519	$364,223	$485,630	$607,038	$728,446	$849,853
Piping	$795,576	$849,781	$940,122	$1,030,463	$1,120,804	$1,211,145	$1,301,486	$1,391,827
TOTAL CAPITAL	$966,280	$1,126,540	$1,393,641	$1,567,186	$1,786,434	$2,005,683	$2,224,932	$2,444,180

	Cost Components	Basis/Methodology	0.1 Year 1 Cost, $	0.1 $/1000 gallons	0.25 Year 1 Cost, $	0.25 $/1000 gallons	0.5 Year 1 Cost, $	0.5 $/1000 gallons	0.75 Year 1 Cost, $	0.75 $/1000 gallons	1 Year 1 Cost, $	1 $/1000 gallons	1.25 Year 1 Cost, $	1.25 $/1000 gallons	1.5 Year 1 Cost, $	1.5 $/1000 gallons	1.75 Year 1 Cost, $	1.75 $/1000 gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$74,583	**$2.04**	$86,953	**$0.95**	$107,569	**$0.59**	$120,964	**$0.44**	$137,887	**$0.38**	$154,810	**$0.34**	$171,733	**$0.31**	$188,656	**$0.30**
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$2,588	$0.07	$5,509	$0.06	$9,758	$0.05	$13,633	$0.05	$17,283	$0.05	$20,775	$0.05	$24,146	$0.04	$27,419	$0.04
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$8,250	$0.23	$8,250	$0.09	$8,250	$0.05	$8,250	$0.03	$8,250	$0.02	$8,250	$0.02	$8,250	$0.02	$8,250	$0.01
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$4.37**		**$1.96**		**$1.15**		**$0.85**		**$0.71**		**$0.62**		**$0.57**		**$0.53**

Blue = Values to input

Capital Cost and Debt Financing Assumptions		General Items		Maintenance	
Total Capital Cost	Variable	Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Amount of Grant Funding	$0	Sodium Hypochloride, $/gal of 12.5%	0.70	Pump System Equip, % capital	1%
Municipal % of Up-Front Capital	100%	Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Other % of Up-Front Capital	0%	Electrical Power, $/kwhr	0.045	Distribution System, $/mile	5500
Debt Term (Years)	20				
Annual Interest Rate	5.00%	*FTE Annual Salary with Benefits, $*			
Issuance Costs, % of Capital	1%	Finance, Operations, Cust Service	$80,000		
		Legal	$150,000		
		Engineering	$100,000		

		Annual Avg Flow/Demand (MGD)	0.1		0.25		0.5		0.75		1		1.25		1.5		1.75	
Length of Distribution System (mi)	2.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$1,060,780		$1,133,050		$1,253,500		$1,373,950		$1,494,400		$1,614,850		$1,735,300		$1,855,750	
		TOTAL CAPITAL	$1,231,484		$1,409,809		$1,707,019		$1,910,673		$2,160,030		$2,409,388		$2,658,746		$2,908,103	
	Cost Components	Basis/Methodology																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$95,053	$2.60	$108,817	$1.19	$131,758	$0.72	$147,477	$0.54	$166,724	$0.46	$185,970	$0.41	$205,217	$0.37	$224,464	$0.35
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$3,121	$0.09	$6,494	$0.07	$11,303	$0.06	$15,631	$0.06	$19,674	$0.05	$23,517	$0.05	$27,208	$0.05	$30,777	$0.05
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$11,000	$0.30	$11,000	$0.12	$11,000	$0.06	$11,000	$0.04	$11,000	$0.03	$11,000	$0.02	$11,000	$0.02	$11,000	$0.02
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$5.02**		**$2.24**		**$1.31**		**$0.96**		**$0.80**		**$0.70**		**$0.64**		**$0.59**

		Annual Avg Flow/Demand (MGD)	0.1		0.25		0.5		0.75		1		1.25		1.5		1.75	
Length of Distribution System (mi)	2.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$1,325,930		$1,416,275		$1,566,850		$1,717,425		$1,868,000		$2,018,575		$2,169,150		$2,319,725	
		TOTAL CAPITAL	$1,496,634		$1,693,034		$2,020,369		$2,254,148		$2,533,630		$2,813,113		$3,092,596		$3,372,078	
	Cost Components	Basis/Methodology																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$115,519	$3.16	$130,678	$1.43	$155,944	$0.85	$173,988	$0.64	$195,560	$0.54	$217,132	$0.48	$238,704	$0.44	$260,276	$0.41
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$3,837	$0.11	$7,734	$0.08	$13,144	$0.07	$17,924	$0.07	$22,336	$0.06	$26,494	$0.06	$30,459	$0.06	$34,271	$0.05
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$13,750	$0.38	$13,750	$0.15	$13,750	$0.08	$13,750	$0.05	$13,750	$0.04	$13,750	$0.03	$13,750	$0.03	$13,750	$0.02
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$5.68**		**$2.52**		**$1.46**		**$1.08**		**$0.90**		**$0.79**		**$0.71**		**$0.66**

Blue = Values to input

Capital Cost and Debt Financing Assumptions		General Items		Maintenance	
Total Capital Cost	Variable	Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Amount of Grant Funding	$0	Sodium Hypochloride, $/gal of 12.5%	0.70	Pump System Equip, % capital	1%
Municipal % of Up-Front Capital	100%	Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Other % of Up-Front Capital	0%	Electrical Power, $/kwhr	0.045	Distribution System, $/mile	5500
Debt Term (Years)	20				
Annual Interest Rate	5.00%	*FTE Annual Salary with Benefits, $*			
Issuance Costs, % of Capital	1%	Finance, Operations, Cust Service	$80,000		
		Legal	$150,000		
		Engineering	$100,000		

Length of Distribution System (mi) 3.0

Summary of Capital Cost Estimates

Annual Avg Flow/Demand (MGD)	0.1	0.25	0.5	0.75	1	1.25	1.5	1.75
Description	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost
Treatment Facilities	$110,000	$125,000	$150,000	$172,500	$180,000	$187,500	$195,000	$202,500
Storage Facilities	$0	$0	$0	$0	$0	$0	$0	$0
Pump Station	$60,704	$151,759	$303,519	$364,223	$485,630	$607,038	$728,446	$849,853
Piping	$1,591,170	$1,699,575	$1,880,250	$2,060,925	$2,241,600	$2,422,275	$2,602,950	$2,783,625
TOTAL CAPITAL	$1,761,874	$1,976,334	$2,333,769	$2,597,648	$2,907,230	$3,216,813	$3,526,396	$3,835,978

	Cost Components	Basis/Methodology	0.1 Year 1 Cost, $	0.1 $/1000 gallons	0.25 Year 1 Cost, $	0.25 $/1000 gallons	0.5 Year 1 Cost, $	0.5 $/1000 gallons	0.75 Year 1 Cost, $	0.75 $/1000 gallons	1 Year 1 Cost, $	1 $/1000 gallons	1.25 Year 1 Cost, $	1.25 $/1000 gallons	1.5 Year 1 Cost, $	1.5 $/1000 gallons	1.75 Year 1 Cost, $	1.75 $/1000 gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$135,992	$3.73	$152,545	$1.67	$180,134	$0.99	$200,501	$0.73	$224,397	$0.61	$248,292	$0.54	$272,187	$0.50	$296,083	$0.46
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$3,861	$0.11	$7,873	$0.09	$13,496	$0.07	$18,498	$0.07	$23,136	$0.06	$27,520	$0.06	$31,712	$0.06	$35,750	$0.06
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$16,500	$0.45	$16,500	$0.18	$16,500	$0.09	$16,500	$0.06	$16,500	$0.05	$16,500	$0.04	$16,500	$0.03	$16,500	$0.03
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$6.31**		**$2.79**		**$1.61**		**$1.19**		**$0.99**		**$0.86**		**$0.78**		**$0.72**

Length of Distribution System (mi) 3.5

Summary of Capital Cost Estimates

Annual Avg Flow/Demand (MGD)	0.1	0.25	0.5	0.75	1	1.25	1.5	1.75
Description	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost	Capital Cost
Treatment Facilities	$110,000	$125,000	$150,000	$172,500	$180,000	$187,500	$195,000	$202,500
Storage Facilities	$0	$0	$0	$0	$0	$0	$0	$0
Pump Station	$60,704	$151,759	$303,519	$364,223	$485,630	$607,038	$728,446	$849,853
Piping	$1,856,320	$1,982,800	$2,193,600	$2,404,400	$2,615,200	$2,826,000	$3,036,800	$3,247,600
TOTAL CAPITAL	$2,027,024	$2,259,559	$2,647,119	$2,941,123	$3,280,830	$3,620,538	$3,960,246	$4,299,953

	Cost Components	Basis/Methodology	0.1 Year 1 Cost, $	0.1 $/1000 gallons	0.25 Year 1 Cost, $	0.25 $/1000 gallons	0.5 Year 1 Cost, $	0.5 $/1000 gallons	0.75 Year 1 Cost, $	0.75 $/1000 gallons	1 Year 1 Cost, $	1 $/1000 gallons	1.25 Year 1 Cost, $	1.25 $/1000 gallons	1.5 Year 1 Cost, $	1.5 $/1000 gallons	1.75 Year 1 Cost, $	1.75 $/1000 gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$156,457	$4.29	$174,406	$1.91	$204,320	$1.12	$227,013	$0.83	$253,233	$0.69	$279,454	$0.61	$305,674	$0.56	$331,895	$0.52
OPERATION AND MAINTENANCE	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
	Electrical Power	Based on per Kwh rate input; see Note C	$4,180	$0.11	$8,470	$0.09	$14,451	$0.08	$19,751	$0.07	$24,654	$0.07	$29,280	$0.06	$33,698	$0.06	$37,949	$0.06
	Reuse Treatment at WWTP																	
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$19,250	$0.53	$19,250	$0.21	$19,250	$0.11	$19,250	$0.07	$19,250	$0.05	$19,250	$0.04	$19,250	$0.04	$19,250	$0.03
GENERAL AND ADMINISTRATIVE	General System Management																	
	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$6.96**		**$3.07**		**$1.77**		**$1.30**		**$1.08**		**$0.94**		**$0.85**		**$0.79**

WATER REUSE SYSTEM COST OF SERVICE TABLE

BASE SYSTEM

Blue = Values to input

Capital Cost and Debt Financing Assumptions		General Items		Maintenance	
Total Capital Cost	Variable	Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Amount of Grant Funding	$0	Sodium Hypochloride, $/gal of 12.5%	0.70	Pump System Equip, % capital	1%
Municipal % of Up-Front Capital	100%	Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Other % of Up-Front Capital	0%	Electrical Power, $/kwhr	0.045	Distribution System, $/mile	5500
Debt Term (Years)	20				
Annual Interest Rate	5.00%	*FTE Annual Salary with Benefits, $*			
Issuance Costs, % of Capital	1%	Finance, Operations, Cust Service	$80,000		
		Legal	$150,000		
		Engineering	$100,000		

		Annual Avg Flow/Demand (MGD)	0.1		0.25		0.5		0.75		1		1.25		1.5		1.75	
Length of Distribution System (mi)	4.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$2,121,560		$2,266,100		$2,507,000		$2,747,900		$2,988,800		$3,229,700		$3,470,600		$3,711,500	
		TOTAL CAPITAL	$2,292,264		$2,542,859		$2,960,519		$3,284,623		$3,654,430		$4,024,238		$4,394,046		$4,763,853	
	Cost Components	**Basis/Methodology**																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$176,930	$4.85	$196,272	$2.15	$228,510	$1.25	$253,526	$0.93	$282,070	$0.77	$310,614	$0.68	$339,158	$0.62	$367,701	$0.58
	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
OPERATION	Electrical Power	Based on per Kwh rate input; see Note C	$4,575	$0.13	$9,457	$0.10	$16,380	$0.09	$22,587	$0.08	$28,371	$0.08	$33,859	$0.07	$39,123	$0.07	$44,206	$0.07
AND	Reuse Treatment at WWTP																	
MAINTENANCE	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$22,000	$0.60	$22,000	$0.24	$22,000	$0.12	$22,000	$0.08	$22,000	$0.06	$22,000	$0.05	$22,000	$0.04	$22,000	$0.03
	General System Management																	
GENERAL	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
AND	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
ADMINISTRATIVE	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$7.60**		**$3.35**		**$1.92**		**$1.42**		**$1.17**		**$1.02**		**$0.93**		**$0.86**

		Annual Avg Flow/Demand (MGD)	0.1		0.25		0.5		0.75		1		1.25		1.5		1.75	
Length of Distribution System (mi)	4.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$2,386,710		$2,549,325		$2,820,350		$3,091,375		$3,362,400		$3,633,425		$3,904,450		$4,175,475	
		TOTAL CAPITAL	$2,557,414		$2,826,084		$3,273,869		$3,628,098		$4,028,030		$4,427,963		$4,827,896		$5,227,828	
	Cost Components	**Basis/Methodology**																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$197,396	$5.41	$218,133	$2.39	$252,696	$1.38	$280,037	$1.02	$310,906	$0.85	$341,776	$0.75	$372,645	$0.68	$403,514	$0.63
	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
OPERATION	Electrical Power	Based on per Kwh rate input; see Note C	$4,579	$0.13	$9,262	$0.10	$15,780	$0.09	$21,551	$0.08	$26,885	$0.07	$31,916	$0.07	$36,717	$0.07	$41,336	$0.06
AND	Reuse Treatment at WWTP																	
MAINTENANCE	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$24,750	$0.68	$24,750	$0.27	$24,750	$0.14	$24,750	$0.09	$24,750	$0.07	$24,750	$0.05	$24,750	$0.05	$24,750	$0.04
	General System Management																	
GENERAL	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
AND	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
ADMINISTRATIVE	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$8.24**		**$3.62**		**$2.07**		**$1.52**		**$1.25**		**$1.10**		**$0.99**		**$0.91**

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	Variable
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

General Items

Lab Costs, $	$20,000
Sodium Hypochloride, $/gal of 12.5%	0.70
Chlorine Dose, mg/L (year-round, see Note A)	7
Electrical Power, $/kwhr	0.045

FTE Annual Salary with Benefits, $

Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

Maintenance

Pump System Labor, hrs/wk	4
Pump System Equip, % capital	1%
Treatment Facilities, % capital	5%
Distribution System, $/mile	5500

		Annual Avg Flow/Demand (MGD)	**0.1**		**0.25**		**0.5**		**0.75**		**1**		**1.25**		**1.5**		**1.75**	
Length of Distribution System (mi)	5.0		**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$2,651,950		$2,832,625		$3,133,750		$3,434,875		$3,736,000		$4,037,125		$4,338,250		$4,639,375	
		TOTAL CAPITAL	$2,822,654		$3,109,384		$3,587,269		$3,971,598		$4,401,630		$4,831,663		$5,261,696		$5,691,728	
	Cost Components	**Basis/Methodology**																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$217,869	**$5.97**	$240,000	**$2.63**	$276,886	**$1.52**	$306,551	**$1.12**	$339,743	**$0.93**	$372,935	**$0.82**	$406,128	**$0.74**	$439,320	**$0.69**
	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
OPERATION	Electrical Power	Based on per Kwh rate input; see Note C	$4,592	$0.13	$9,346	$0.10	$15,999	$0.09	$21,911	$0.08	$27,388	$0.08	$32,563	$0.07	$37,509	$0.07	$42,273	$0.07
AND	Reuse Treatment at WWTP																	
MAINTENANCE	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	$0.75	$27,500	$0.30	$27,500	$0.15	$27,500	$0.10	$27,500	$0.08	$27,500	$0.06	$27,500	$0.05	$27,500	$0.04
	General System Management																	
GENERAL	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
AND	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
ADMINISTRATIVE	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$8.88**		**$3.89**		**$2.22**		**$1.63**		**$1.34**		**$1.17**		**$1.06**		**$0.97**

		Annual Avg Flow/Demand (MGD)	**0.1**		**0.25**		**0.5**		**0.75**		**1**		**1.25**		**1.5**		**1.75**	
Length of Distribution System (mi)	10.0		**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**	**Year 1 Cost, $**	**$/1000 gallons**
		Summary of Capital Cost Estimates																
		Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
		Treatment Facilities	$110,000		$125,000		$150,000		$172,500		$180,000		$187,500		$195,000		$202,500	
		Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0	
		Pump Station	$60,704		$151,759		$303,519		$364,223		$485,630		$607,038		$728,446		$849,853	
		Piping	$5,303,690		$5,665,025		$6,267,250		$6,869,475		$7,471,700		$8,073,925		$8,676,150		$9,278,375	
		TOTAL CAPITAL	$5,474,394		$5,941,784		$6,720,769		$7,406,198		$8,137,330		$8,868,463		$9,599,596		$10,330,728	
	Cost Components	**Basis/Methodology**																
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$422,545	**$11.58**	$458,621	**$5.03**	$518,747	**$2.84**	$571,653	**$2.09**	$628,086	**$1.72**	$684,519	**$1.50**	$740,952	**$1.35**	$797,385	**$1.25**
	Pumping System																	
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,000	$0.22	$8,000	$0.09	$8,000	$0.04	$8,000	$0.03	$8,800	$0.02	$8,800	$0.02	$8,800	$0.02	$8,800	$0.01
	Equipment Maintenance	Based on % of capital cost input	$607	$0.02	$1,518	$0.02	$3,035	$0.02	$3,642	$0.01	$4,856	$0.01	$6,070	$0.01	$7,284	$0.01	$8,499	$0.01
OPERATION	Electrical Power	Based on per Kwh rate input; see Note C	$9,307	$0.25	$17,478	$0.19	$28,154	$0.15	$37,210	$0.14	$45,351	$0.12	$52,874	$0.12	$59,938	$0.11	$66,642	$0.10
AND	Reuse Treatment at WWTP																	
MAINTENANCE	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$1,434	$0.04	$3,586	$0.04	$7,171	$0.04	$10,757	$0.04	$14,342	$0.04	$17,928	$0.04	$21,514	$0.04	$25,099	$0.04
	Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Laboratory	Lab cost input	$20,000	$0.55	$20,000	$0.22	$20,000	$0.11	$20,000	$0.07	$20,000	$0.05	$20,000	$0.04	$20,000	$0.04	$20,000	$0.03
	Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
	Equipment Maintenance&Labor	Based on % of capital cost input	$5,500	$0.15	$6,250	$0.07	$7,500	$0.04	$8,625	$0.03	$9,000	$0.02	$9,375	$0.02	$9,750	$0.02	$10,125	$0.02
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$55,000	$1.51	$55,000	$0.60	$55,000	$0.30	$55,000	$0.20	$55,000	$0.15	$55,000	$0.12	$55,000	$0.10	$55,000	$0.09
	General System Management																	
GENERAL	Engineering	0.15 FTE base; .05% increase per mgd	$15,000	$0.41	$15,000	$0.16	$15,000	$0.08	$15,000	$0.05	$15,000	$0.04	$15,188	$0.03	$15,375	$0.03	$15,563	$0.02
AND	Finance and Accounting	0.15 FTE	$12,000	$0.33	$12,000	$0.13	$12,000	$0.07	$12,000	$0.04	$12,000	$0.03	$12,150	$0.03	$12,300	$0.02	$12,450	$0.02
ADMINISTRATIVE	Legal	0.05 FTE	$7,500	$0.21	$7,500	$0.08	$7,500	$0.04	$7,500	$0.03	$7,500	$0.02	$7,594	$0.02	$7,688	$0.01	$7,781	$0.01
	Customer Service	0.05 FTE	$4,000	$0.11	$4,000	$0.04	$4,000	$0.02	$4,000	$0.01	$4,000	$0.01	$4,050	$0.01	$4,100	$0.01	$4,150	$0.01
	TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$15.37**		**$6.67**		**$3.76**		**$2.75**		**$2.26**		**$1.96**		**$1.76**		**$1.61**

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
1.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$988,112		$1,108,567		$1,229,021		$1,349,476		$1,469,930		$1,590,385		$1,812,174		$2,518,974		$3,225,774		$5,346,174	
	TOTAL CAPITAL	$2,169,373		$2,547,642		$2,925,912		$3,304,182		$3,682,452		$4,060,721		$4,540,326		$6,965,894		$9,771,154		$18,186,933	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$167,445	$0.23	$196,642	$0.22	$225,839	$0.21	$255,036	$0.20	$284,233	$0.19	$313,430	$0.19	$350,448	$0.19	$537,668	$0.15	$754,194	$0.14	$1,403,772	$0.13
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$26,800	$0.04	$32,491	$0.04	$38,027	$0.03	$43,437	$0.03	$48,741	$0.03	$53,956	$0.03	$59,091	$0.03	$107,468	$0.03	$152,486	$0.03	$277,324	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$5,500	$0.01	$5,500	$0.01	$5,500	$0.01	$5,500	$0.00	$5,500	$0.00	$5,500	$0.00	$5,500	$0.00	$5,500	$0.00	$5,500	$0.00	$5,500	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.44**		**$0.40**		**$0.37**		**$0.36**		**$0.34**		**$0.33**		**$0.33**		**$0.26**		**$0.24**		**$0.22**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
1.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$1,482,168		$1,662,850		$1,843,532		$2,024,214		$2,204,896		$2,385,578		$2,718,260		$3,778,460		$4,838,660		$8,019,260	
	TOTAL CAPITAL	$2,663,429		$3,101,926		$3,540,423		$3,978,920		$4,417,418		$4,855,915		$5,446,412		$8,225,380		$11,384,040		$20,860,019	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$205,579	$0.28	$239,424	$0.26	$273,270	$0.25	$307,116	$0.24	$340,962	$0.23	$374,807	$0.23	$420,385	$0.23	$634,882	$0.17	$878,685	$0.16	$1,610,096	$0.15
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$30,611	$0.04	$36,796	$0.04	$42,766	$0.04	$48,564	$0.04	$54,217	$0.04	$59,748	$0.04	$65,172	$0.04	$115,430	$0.03	$161,266	$0.03	$285,628	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$8,250	$0.01	$8,250	$0.01	$8,250	$0.01	$8,250	$0.01	$8,250	$0.01	$8,250	$0.01	$8,250	$0.00	$8,250	$0.00	$8,250	$0.00	$8,250	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.50**		**$0.45**		**$0.42**		**$0.40**		**$0.39**		**$0.38**		**$0.37**		**$0.29**		**$0.26**		**$0.24**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
2.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$1,976,200		$2,217,100		$2,458,000		$2,698,900		$2,939,800		$3,180,700		$3,624,200		$5,037,700		$6,451,200		$10,691,700	
	TOTAL CAPITAL	$3,157,461		$3,656,176		$4,154,891		$4,653,606		$5,152,322		$5,651,037		$6,352,352		$9,484,620		$12,996,580		$23,532,459	
Cost Components	**Basis/Methodology**																				
Debt Service (Capital Cost)	Based on debt service payment	$243,711	**$0.33**	$282,205	**$0.31**	$320,698	**$0.29**	$359,192	**$0.28**	$397,686	**$0.27**	$436,179	**$0.27**	$490,311	**$0.27**	$732,077	**$0.20**	$1,003,150	**$0.18**	$1,816,370	**$0.17**
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$34,245	$0.05	$40,934	$0.04	$47,359	$0.04	$53,571	$0.04	$59,607	$0.04	$65,494	$0.04	$71,251	$0.04	$124,020	$0.03	$171,512	$0.03	$298,537	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$11,000	$0.02	$11,000	$0.01	$11,000	$0.01	$11,000	$0.01	$11,000	$0.01	$11,000	$0.01	$11,000	$0.01	$11,000	$0.00	$11,000	$0.00	$11,000	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.56**		**$0.51**		**$0.47**		**$0.45**		**$0.43**		**$0.42**		**$0.42**		**$0.32**		**$0.29**		**$0.26**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
2.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$2,470,300		$2,771,450		$3,072,600		$3,373,750		$3,674,900		$3,976,050		$4,530,400		$6,297,400		$8,064,400		$13,365,400	
	TOTAL CAPITAL	$3,651,561		$4,210,526		$4,769,491		$5,328,456		$5,887,422		$6,446,387		$7,258,552		$10,744,320		$14,609,780		$26,206,159	
Cost Components	**Basis/Methodology**																				
Debt Service (Capital Cost)	Based on debt service payment	$281,848	**$0.39**	$324,993	**$0.36**	$368,137	**$0.34**	$411,281	**$0.32**	$454,425	**$0.31**	$497,569	**$0.30**	$560,257	**$0.31**	$829,308	**$0.23**	$1,127,666	**$0.21**	$2,022,741	**$0.18**
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$37,957	$0.05	$45,022	$0.05	$51,761	$0.05	$58,239	$0.05	$64,503	$0.04	$70,585	$0.04	$76,510	$0.04	$130,019	$0.04	$177,303	$0.03	$301,303	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$13,750	$0.02	$13,750	$0.02	$13,750	$0.01	$13,750	$0.01	$13,750	$0.01	$13,750	$0.01	$13,750	$0.01	$13,750	$0.00	$13,750	$0.00	$13,750	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.62**		**$0.56**		**$0.52**		**$0.50**		**$0.48**		**$0.46**		**$0.46**		**$0.35**		**$0.31**		**$0.28**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
3.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$2,964,300		$3,325,650		$3,687,000		$4,048,350		$4,409,700		$4,771,050		$5,436,600		$7,557,100		$9,677,600		$16,039,100	
	TOTAL CAPITAL	$4,145,561		$4,764,726		$5,383,891		$6,003,056		$6,622,222		$7,241,387		$8,164,752		$12,004,020		$16,222,980		$28,879,859	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$319,978	$0.44	$367,769	$0.40	$415,560	$0.38	$463,350	$0.36	$511,141	$0.35	$558,932	$0.34	$630,202	$0.35	$926,539	$0.25	$1,252,182	$0.23	$2,229,113	$0.20
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$39,662	$0.05	$47,177	$0.05	$54,362	$0.05	$61,285	$0.05	$67,991	$0.05	$74,512	$0.05	$80,874	$0.04	$138,640	$0.04	$190,028	$0.03	$325,760	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$16,500	$0.02	$16,500	$0.02	$16,500	$0.02	$16,500	$0.01	$16,500	$0.01	$16,500	$0.01	$16,500	$0.01	$16,500	$0.00	$16,500	$0.00	$16,500	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.68**		**$0.61**		**$0.57**		**$0.54**		**$0.52**		**$0.50**		**$0.50**		**$0.38**		**$0.34**		**$0.30**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
3.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$3,458,400		$3,880,000		$4,301,600		$4,723,200		$5,144,800		$5,566,400		$6,342,800		$8,816,800		$11,290,800		$18,712,800	
	TOTAL CAPITAL	$4,639,661		$5,319,076		$5,998,491		$6,677,906		$7,357,322		$8,036,737		$9,070,952		$13,263,720		$17,836,180		$31,553,559	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$358,116	$0.49	$410,557	$0.45	$462,998	$0.42	$515,439	$0.40	$567,880	$0.39	$620,321	$0.38	$700,148	$0.38	$1,023,770	$0.28	$1,376,698	$0.25	$2,435,484	$0.22
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$42,062	$0.06	$49,955	$0.05	$57,492	$0.05	$64,744	$0.05	$71,762	$0.05	$78,581	$0.05	$85,228	$0.05	$145,408	$0.04	$198,747	$0.04	$339,082	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$19,250	$0.03	$19,250	$0.02	$19,250	$0.02	$19,250	$0.02	$19,250	$0.01	$19,250	$0.01	$19,250	$0.01	$19,250	$0.01	$19,250	$0.00	$19,250	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.74**		**$0.67**		**$0.62**		**$0.59**		**$0.56**		**$0.54**		**$0.54**		**$0.41**		**$0.36**		**$0.32**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
4.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$3,952,400		$4,434,200		$4,916,000		$5,397,800		$5,879,600		$6,361,400		$7,248,500		$10,075,500		$12,902,500		$21,383,500	
	TOTAL CAPITAL	$5,133,661		$5,873,276		$6,612,891		$7,352,506		$8,092,122		$8,831,737		$9,976,652		$14,522,420		$19,447,880		$34,224,259	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$396,245	$0.54	$453,333	$0.50	$510,421	$0.47	$567,509	$0.44	$624,596	$0.43	$681,684	$0.42	$770,055	$0.42	$1,120,924	$0.31	$1,501,099	$0.27	$2,641,624	$0.24
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$49,141	$0.07	$58,647	$0.06	$67,763	$0.06	$76,568	$0.06	$85,115	$0.06	$93,443	$0.06	$101,580	$0.06	$175,944	$0.05	$242,620	$0.04	$420,236	$0.04
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$22,000	$0.03	$22,000	$0.02	$22,000	$0.02	$22,000	$0.02	$22,000	$0.02	$22,000	$0.01	$22,000	$0.01	$22,000	$0.01	$22,000	$0.00	$22,000	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.80**		**$0.73**		**$0.68**		**$0.64**		**$0.61**		**$0.59**		**$0.59**		**$0.44**		**$0.40**		**$0.35**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
4.5		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$4,446,500		$4,988,550		$5,530,600		$6,072,650		$6,614,700		$7,156,750		$8,154,700		$11,335,200		$14,515,700		$24,057,200	
	TOTAL CAPITAL	$5,627,761		$6,427,626		$7,227,491		$8,027,356		$8,827,222		$9,627,087		$10,882,852		$15,782,120		$21,061,080		$36,897,959	
Cost Components	Basis/Methodology																				
Debt Service (Capital Cost)	Based on debt service payment	$434,383	$0.60	$496,121	$0.54	$557,859	$0.51	$619,597	$0.49	$681,336	$0.47	$743,074	$0.45	$840,001	$0.46	$1,218,154	$0.33	$1,625,615	$0.30	$2,847,996	$0.26
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$45,805	$0.06	$54,376	$0.06	$62,557	$0.06	$70,426	$0.06	$78,039	$0.05	$85,435	$0.05	$92,642	$0.05	$157,837	$0.04	$215,562	$0.04	$367,260	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$24,750	$0.03	$24,750	$0.03	$24,750	$0.02	$24,750	$0.02	$24,750	$0.02	$24,750	$0.02	$24,750	$0.01	$24,750	$0.01	$24,750	$0.00	$24,750	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.85**		**$0.77**		**$0.72**		**$0.68**		**$0.65**		**$0.63**		**$0.63**		**$0.46**		**$0.41**		**$0.36**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
5.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$4,940,500		$5,542,750		$6,145,000		$6,747,250		$7,349,500		$7,951,750		$9,060,900		$12,594,900		$16,128,900		$26,730,900	
	TOTAL CAPITAL	$6,121,761		$6,981,826		$7,841,891		$8,701,956		$9,562,022		$10,422,087		$11,789,052		$17,041,820		$22,674,280		$39,571,659	
Cost Components	**Basis/Methodology**																				
Debt Service (Capital Cost)	Based on debt service payment	$472,513	**$0.65**	$538,897	**$0.59**	$605,282	**$0.55**	$671,667	**$0.53**	$738,052	**$0.51**	$804,436	**$0.49**	$909,947	**$0.50**	$1,315,385	**$0.36**	$1,750,131	**$0.32**	$3,054,367	**$0.28**
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$46,886	$0.06	$55,745	$0.06	$64,212	$0.06	$72,367	$0.06	$80,263	$0.05	$87,941	$0.05	$95,429	$0.05	$163,365	$0.04	$223,736	$0.04	$383,015	$0.03
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	$0.04	$27,500	$0.03	$27,500	$0.03	$27,500	$0.02	$27,500	$0.02	$27,500	$0.02	$27,500	$0.02	$27,500	$0.01	$27,500	$0.01	$27,500	$0.00
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$0.91**		**$0.82**		**$0.77**		**$0.72**		**$0.69**		**$0.67**		**$0.67**		**$0.49**		**$0.44**		**$0.38**

Length of Distribution System (mi)	Annual Avg Flow/Demand (MGD)	2		2.5		3		3.5		4		4.5		5		10		15		30	
10.0		Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons	Year 1 Cost, $	$/1000 gallons
	Summary of Capital Cost Estimates																				
	Description	Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost		Capital Cost	
	Treatment Facilities	$210,000		$225,000		$240,000		$255,000		$270,000		$285,000		$300,000		$400,000		$475,000		$700,000	
	Storage Facilities	$0		$0		$0		$0		$0		$0		$0		$0		$0		$0	
	Pump Station	$971,261		$1,214,076		$1,456,891		$1,699,706		$1,942,522		$2,185,337		$2,428,152		$4,046,920		$6,070,380		$12,140,759	
	Piping	$9,880,600		$11,085,050		$12,289,500		$13,493,950		$14,698,400		$15,902,850		$18,122,000		$25,190,000		$32,258,000		$53,462,000	
	TOTAL CAPITAL	$11,061,861		$12,524,126		$13,986,391		$15,448,656		$16,910,922		$18,373,187		$20,850,152		$29,636,920		$38,803,380		$66,302,759	
Cost Components	**Basis/Methodology**																				
Debt Service (Capital Cost)	Based on debt service payment	$853,818	**$1.17**	$966,684	**$1.06**	$1,079,550	**$0.99**	$1,192,416	**$0.93**	$1,305,282	**$0.89**	$1,418,148	**$0.86**	$1,609,334	**$0.88**	$2,287,547	**$0.63**	$2,995,067	**$0.55**	$5,117,627	**$0.47**
Pumping System																					
Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.01	$8,800	$0.00	$10,400	$0.00	$12,800	$0.00	$16,000	$0.00
Equipment Maintenance	Based on % of capital cost input	$9,713	$0.01	$12,141	$0.01	$14,569	$0.01	$16,997	$0.01	$19,425	$0.01	$21,853	$0.01	$24,282	$0.01	$40,469	$0.01	$60,704	$0.01	$121,408	$0.01
Electrical Power	Based on per Kwh rate input; see Note C	$73,053	$0.10	$85,171	$0.09	$96,550	$0.09	$107,349	$0.08	$117,675	$0.08	$127,605	$0.08	$137,195	$0.08	$220,997	$0.06	$292,080	$0.05	$470,491	$0.04
Reuse Treatment at WWTP																					
Chlorine Disinfection	$/gallon at %Conc input; see Note A	$28,685	$0.04	$35,856	$0.04	$43,027	$0.04	$50,198	$0.04	$57,370	$0.04	$64,541	$0.04	$71,712	$0.04	$143,424	$0.04	$215,136	$0.04	$430,272	$0.04
Other	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Laboratory	Lab cost input	$20,000	$0.03	$20,000	$0.02	$20,000	$0.02	$20,000	$0.02	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.01	$20,000	$0.00	$20,000	$0.00
Electrical Power	From Treatment Module	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00	$0	$0.00
Equipment Maintenance&Labor	Based on % of capital cost input	$10,500	$0.01	$11,250	$0.01	$12,000	$0.01	$12,750	$0.01	$13,500	$0.01	$14,250	$0.01	$15,000	$0.01	$20,000	$0.01	$23,750	$0.00	$35,000	$0.00
Distribution System Maintenance	Equals water system cost/mile-see Note B	$55,000	$0.08	$55,000	$0.06	$55,000	$0.05	$55,000	$0.04	$55,000	$0.04	$55,000	$0.03	$55,000	$0.03	$55,000	$0.02	$55,000	$0.01	$55,000	$0.01
General System Management																					
Engineering	0.15 FTE base; .05% increase per mgd	$15,750	$0.02	$16,125	$0.02	$16,500	$0.02	$16,875	$0.01	$17,250	$0.01	$17,625	$0.01	$18,000	$0.01	$21,750	$0.01	$25,500	$0.00	$36,750	$0.00
Finance and Accounting	0.15 FTE	$12,600	$0.02	$12,900	$0.01	$13,200	$0.01	$13,500	$0.01	$13,800	$0.01	$14,100	$0.01	$14,400	$0.01	$17,400	$0.00	$20,400	$0.00	$29,400	$0.00
Legal	0.05 FTE	$7,875	$0.01	$8,063	$0.01	$8,250	$0.01	$8,438	$0.01	$8,625	$0.01	$8,813	$0.01	$9,000	$0.00	$10,875	$0.00	$12,750	$0.00	$18,375	$0.00
Customer Service	0.05 FTE	$4,200	$0.01	$4,300	$0.00	$4,400	$0.00	$4,500	$0.00	$4,600	$0.00	$4,700	$0.00	$4,800	$0.00	$5,800	$0.00	$6,800	$0.00	$9,800	$0.00
TOTAL OF ALL COST COMPONENTS FOR RECLAIMED WATER:			**$1.51**		**$1.35**		**$1.25**		**$1.18**		**$1.12**		**$1.08**		**$1.09**		**$0.78**		**$0.68**		**$0.58**

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Appendix D-1
Water Reuse System Costs
Tertiary 1 – Conventional Treatment

Water Reuse System Estimated Cost of Service, $/1000 gallons

Tertiary 1 - Conventional

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	10.66	11.31	11.96	12.62	13.25	13.90	14.55	15.18	15.82	22.31
0.25	5.25	5.53	5.81	6.09	6.36	6.64	6.92	7.19	7.46	10.24
0.5	3.18	3.34	3.49	3.65	3.80	3.95	4.11	4.25	4.40	5.95
0.75	2.78	2.90	3.01	3.13	3.24	3.35	3.47	3.57	3.68	4.80
1	2.33	2.42	2.52	2.61	2.70	2.79	2.89	2.97	3.06	3.97
1.25	2.06	2.14	2.22	2.30	2.38	2.45	2.54	2.61	2.68	3.47
1.5	1.88	1.95	2.02	2.09	2.16	2.23	2.31	2.37	2.44	3.14
1.75	1.75	1.81	1.88	1.94	2.01	2.07	2.14	2.20	2.26	2.90
2	1.65	1.71	1.77	1.83	1.89	1.95	2.02	2.07	2.12	2.72
2.5	1.51	1.57	1.62	1.68	1.73	1.78	1.84	1.89	1.94	2.47
3	1.42	1.47	1.52	1.57	1.62	1.67	1.72	1.76	1.81	2.30
3.5	1.34	1.39	1.44	1.48	1.53	1.58	1.63	1.67	1.71	2.17
4	1.25	1.30	1.34	1.39	1.43	1.47	1.52	1.56	1.60	2.03
4.5	1.18	1.23	1.27	1.31	1.35	1.39	1.44	1.48	1.52	1.93
5	1.13	1.17	1.22	1.26	1.30	1.34	1.39	1.43	1.47	1.89
10	0.84	0.87	0.90	0.93	0.96	0.99	1.02	1.05	1.08	1.37
15	0.75	0.78	0.80	0.83	0.85	0.88	0.91	0.93	0.95	1.20
30	0.66	0.68	0.70	0.72	0.74	0.76	0.79	0.80	0.82	1.02

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Tertiary 1 - Conventional

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	2,024,700	132,600	2,615,800	187,200	4,737,300	211,800
0.25	2,570,600	167,000	3,288,900	224,900	5,555,000	251,800
0.5	3,232,900	195,800	4,163,100	258,900	6,670,100	288,800
0.75	4,400,700	274,100	5,451,800	341,200	8,199,700	373,600
1	4,999,200	297,400	6,232,100	369,700	9,220,900	404,400
1.25	5,597,800	320,600	7,012,300	397,800	10,242,000	434,500
1.5	6,196,400	343,900	7,792,500	425,900	11,263,100	464,500
1.75	6,795,000	367,200	8,572,700	453,800	12,284,200	494,200
2	7,393,600	390,500	9,352,900	481,700	13,305,300	523,800
2.5	8,590,700	437,000	10,913,400	537,300	15,347,600	582,600
3	9,787,900	483,500	12,473,800	592,800	17,389,800	641,000
3.5	10,985,000	516,100	14,034,200	634,100	19,432,000	685,100
4	11,619,600	543,000	15,032,000	669,800	20,911,600	723,300
4.5	12,254,100	570,000	16,029,800	705,300	22,391,200	761,300
5	12,888,600	596,900	17,128,900	740,700	24,377,600	799,100
10	19,183,600	865,600	25,749,500	1,085,300	35,825,500	1,163,200
15	25,453,700	1,134,100	34,749,900	1,431,100	47,653,000	1,524,300
30	44,263,900	1,939,600	61,750,900	2,454,200	83,135,600	2,581,900

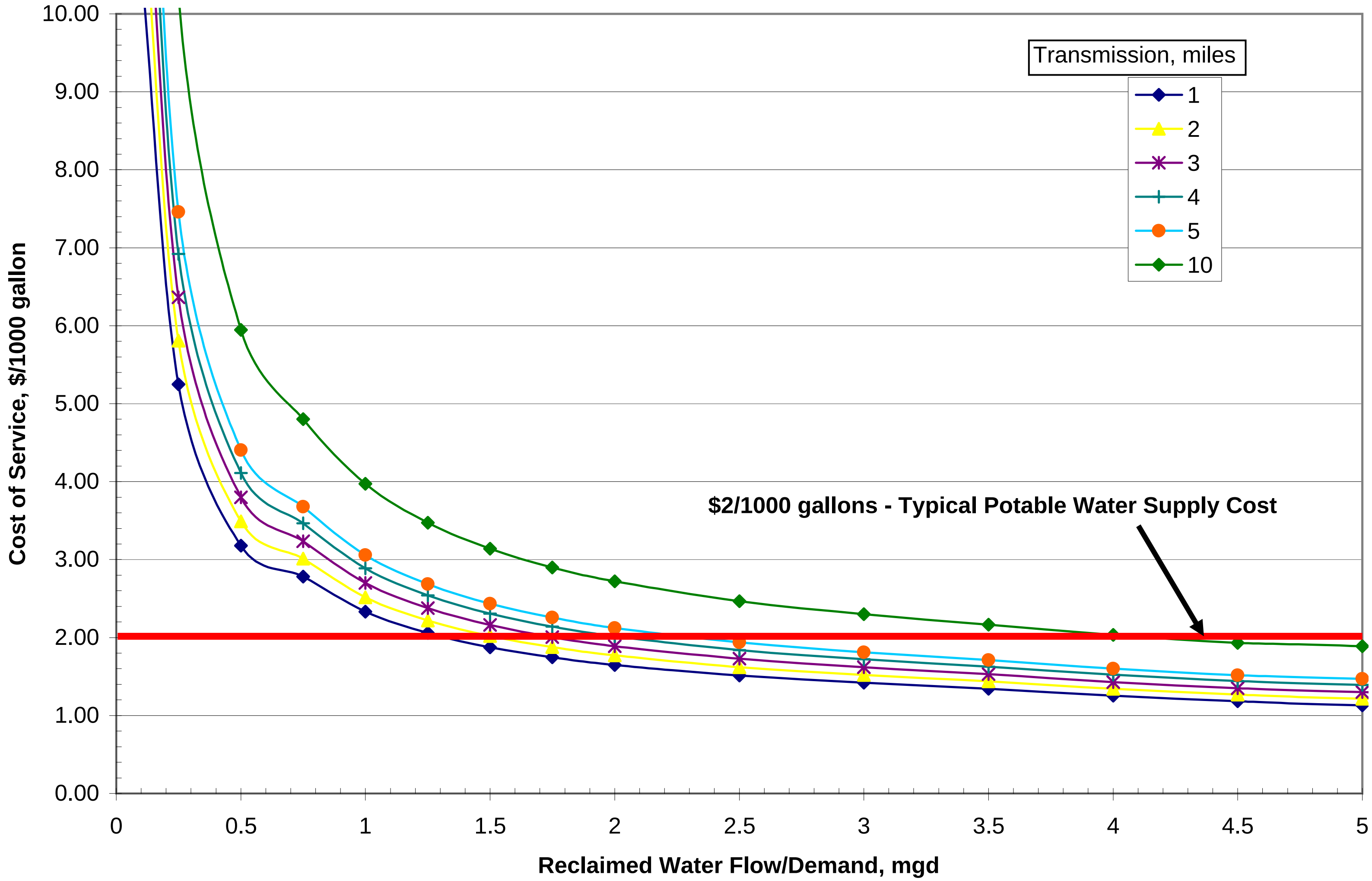


Figure D-1a. Reclaimed Water System Cost of Service for 0-5 mgd Capacity
Urban Area - Treatment: Tertiary 1 - Conventional

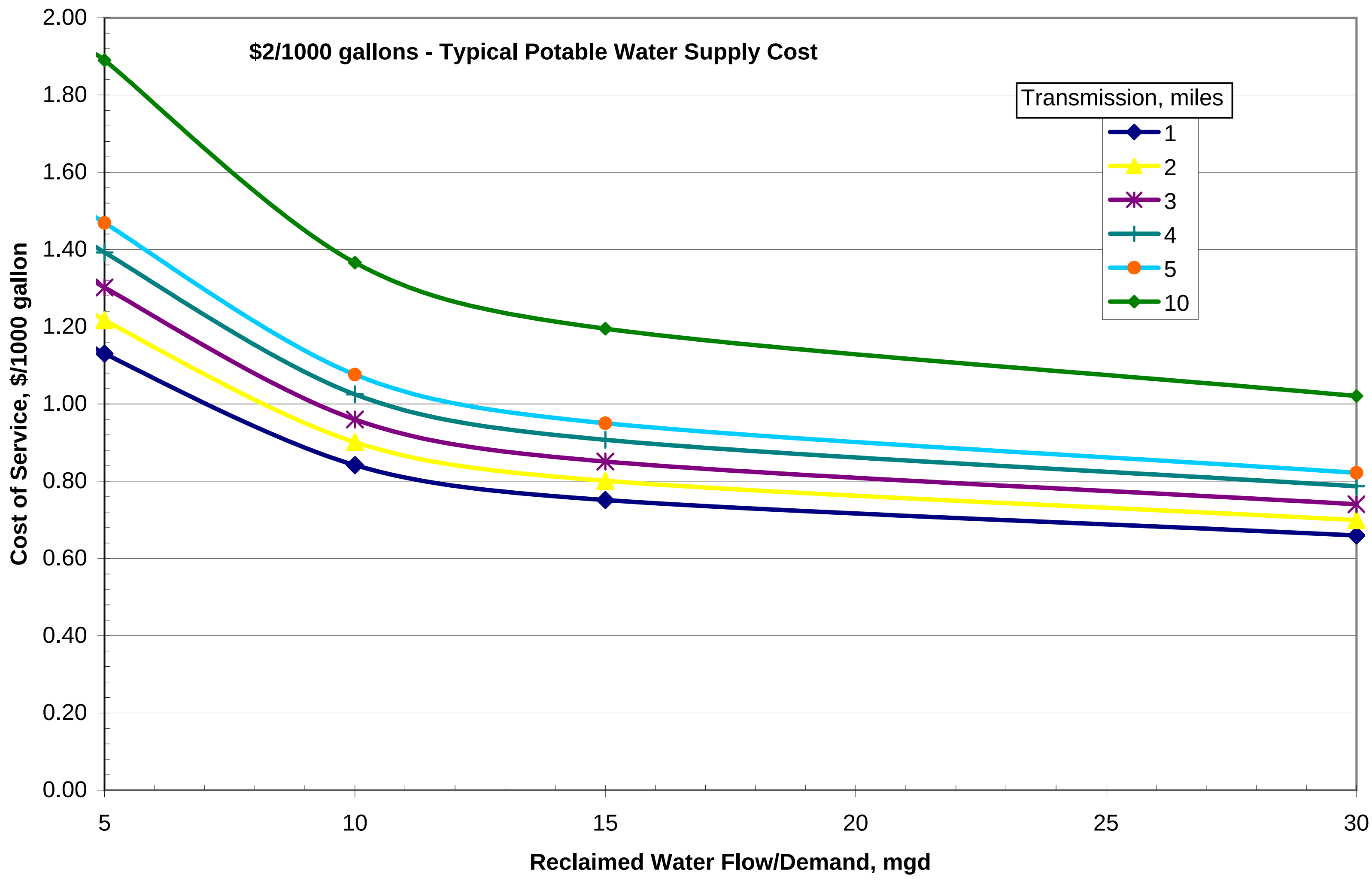
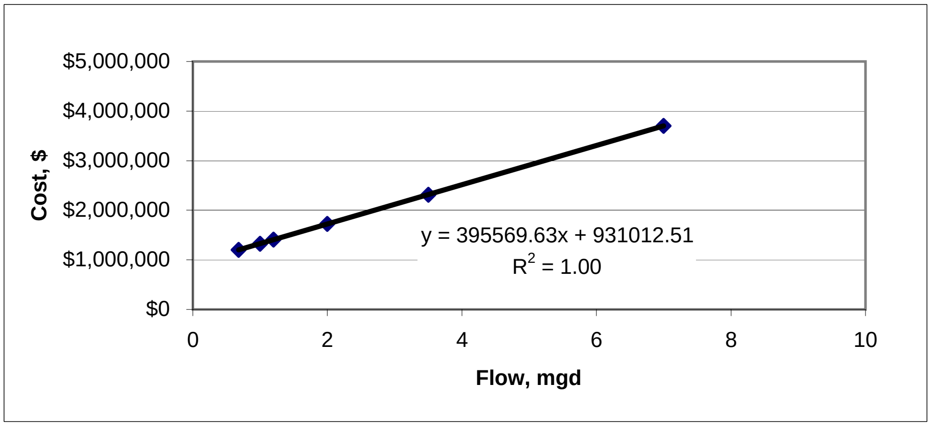


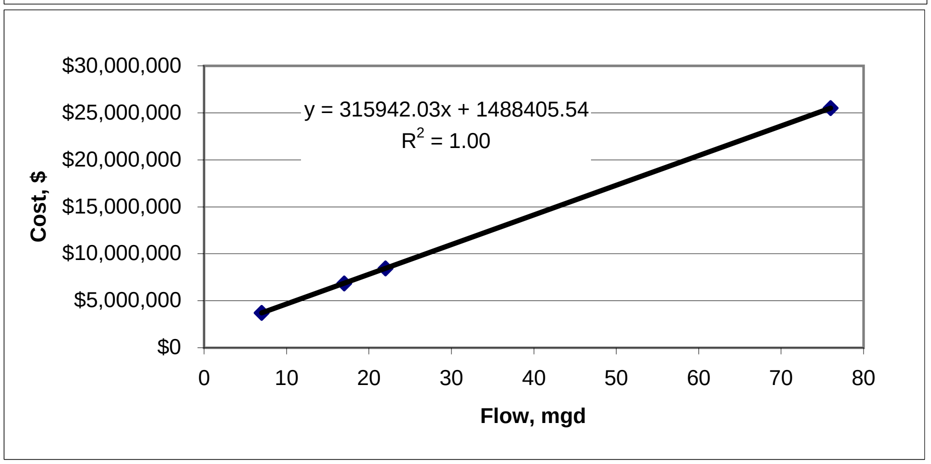
Figure D-1b. Reclaimed Water System Cost of Service for 5-30 mgd Capacity
Urban Area - Treatment: Tertiary 1 - Conventional

Cost Curves as Basis for Tertiary 1-Conventional Treatment Costs*
Coagulant Addition/Flocculation/Sedimentation

Capital Cost

Design Flow (mgd)	Capital Cost ($)
0.0001	$1,200,000
0.007	$1,200,000
0.022	$1,200,000
0.037	$1,200,000
0.091	$1,200,000
0.18	$1,200,000
0.27	$1,200,000
0.36	$1,200,000
0.68	$1,200,000
1	$1,326,582
1.2	$1,405,696
2	$1,722,152
3.5	$2,315,506
7	$3,700,000
17	$6,859,420
22	$8,439,130
76	$25,500,000
210	$67,836,232
430	$137,343,478
520	$165,778,261
1,500.00	$475,401,449





Curve fit equations		
CCI Index	**1.16**	
Avg Flow Range (O&M)	0.23-3.0 mgd	>3-30 mgd
Design Flow Range (Capital)	0.68-07.0 mgd	>7-60 mgd
Design/Avg Flow Ratio	2	

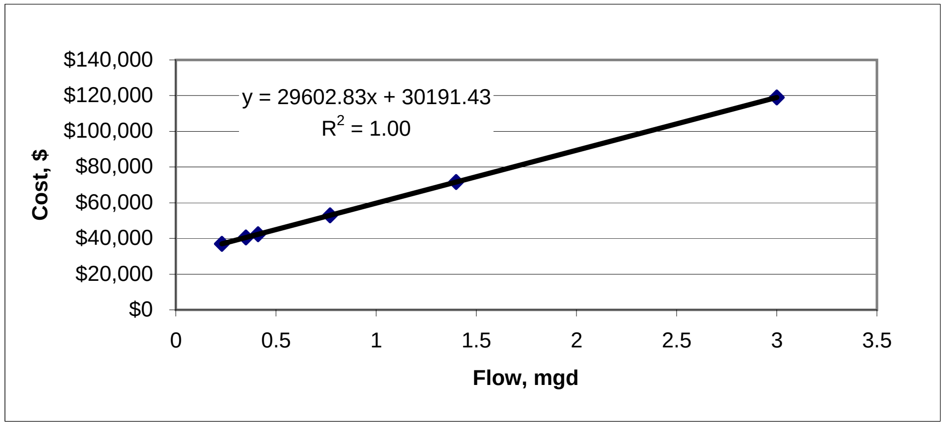
Note: Adustments were made with vendor supplied costs for lower flows and to evaluate application of these costs for treated wastewater effluent (developed for potable supply).

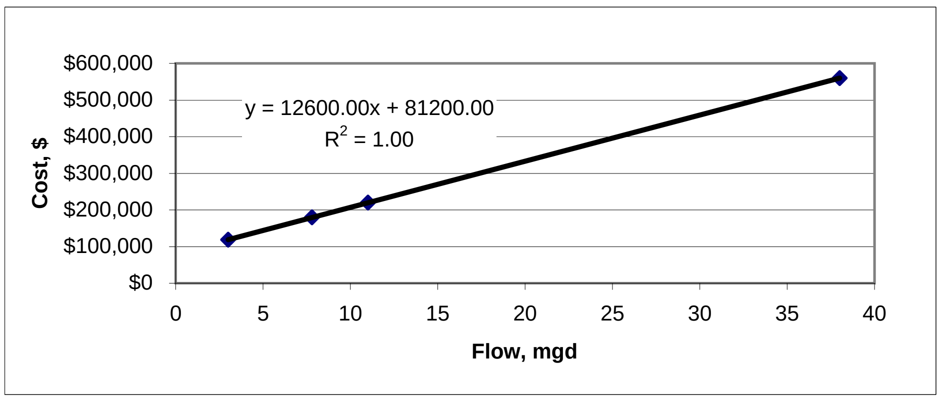
*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 1-Conventional Treatment Costs*
Coagulant Addition/Flocculation/Sedimentation

O&M Cost

Design Flow (mgd)	O&M Cost ($)
0.00005	$37,000
0.0015	$37,000
0.0054	$37,000
0.0095	$37,000
0.025	$37,000
0.054	$37,000
0.084	$37,000
0.11	$37,000
0.23	$37,000
0.35	$40,552
0.41	$42,329
0.77	$52,986
1.4	$71,635
3	$119,000
7.8	$179,480
11	$219,800
38	$560,000
120	$1,593,200
270	$3,483,200
350	$4,491,200
750	$9,531,200



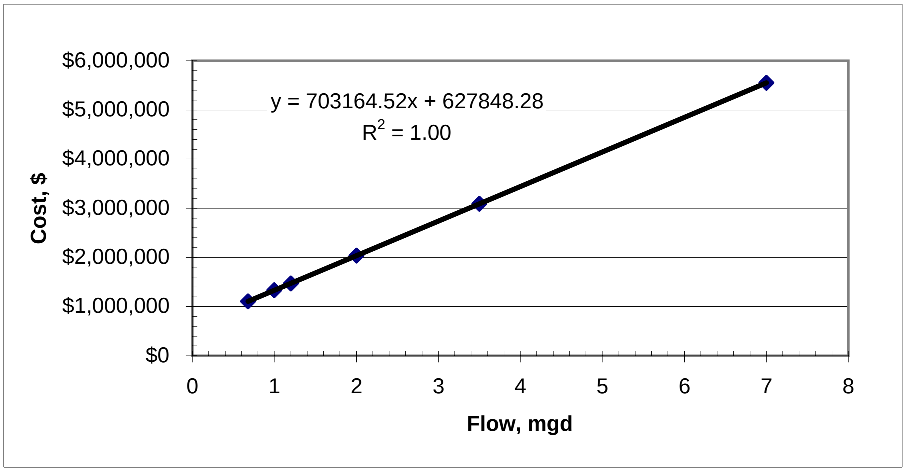


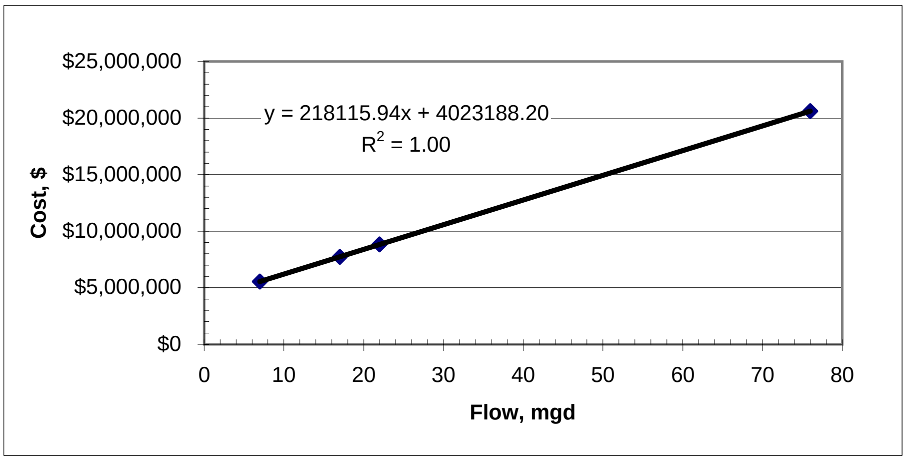
*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 1-Conventional Treatment Costs*
Gravity Filtration

Capital Cost

Design Flow (mgd)	Capital Cost ($)
0.0001	$1,106,000
0.007	$1,106,000
0.022	$1,106,000
0.037	$1,106,000
0.091	$1,106,000
0.18	$1,106,000
0.27	$1,106,000
0.36	$1,106,000
0.68	$1,106,000
1	$1,331,013
1.2	$1,471,646
2	$2,034,177
3.5	$3,088,924
7	$5,550,000
17	$7,731,159
22	$8,821,739
76	$20,600,000
210	$49,827,536
430	$97,813,043
520	$117,443,478
1,500.00	$331,197,101





Curve fit equations		
CCI Index Multiplier	**1.16**	
Avg Flow Range	0.23-3.0 mgd	>3-30 mgd
Design Flow Range	0.68-07.0 mgd	>7-60 mgd
Design/Avg Flow Ratio	2	

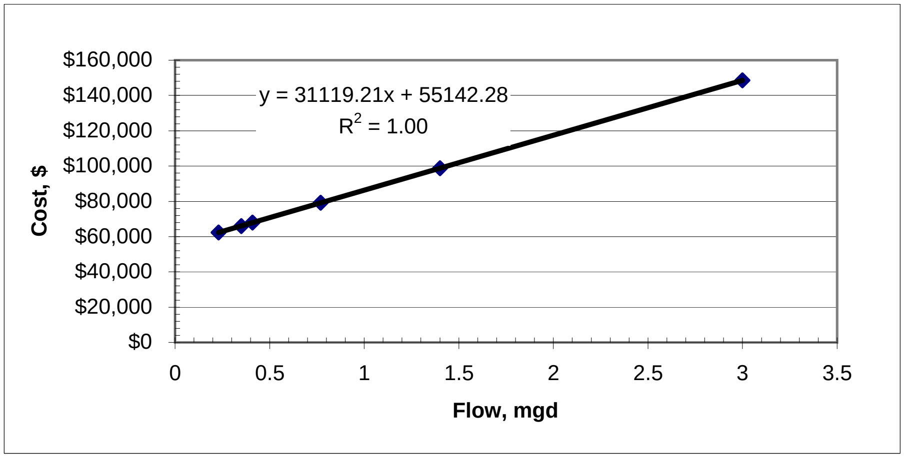
Note: Adustments were made with vendor supplied costs for lower flows and to evaluate application of these costs for treated wastewater effluent (developed for potable supply).

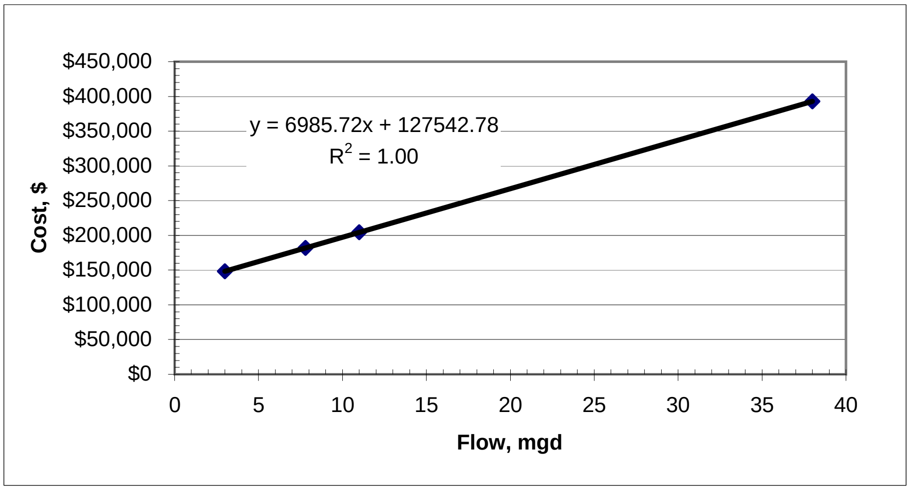
*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 1-Conventional Treatment Costs*
Gravity Filtration

O&M Cost

Design Flow (mgd)	O&M Cost ($)
0.00005	$62,300
0.0015	$62,300
0.0054	$62,300
0.0095	$62,300
0.025	$62,300
0.054	$62,300
0.084	$62,300
0.11	$62,300
0.23	$62,300
0.35	$66,034
0.41	$67,901
0.77	$79,104
1.4	$98,709
3	$148,500
7.8	$182,031
11	$204,386
38	$393,000
120	$965,829
270	$2,013,686
350	$2,572,543
750	$5,366,829





*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-2
Water Reuse System Costs
Tertiary 2 – Membrane Filtration

Water Reuse System Estimated Cost of Service, $/1000 gallons
Tertiary 2 - Membrane Filtration

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	6.61	7.26	7.91	8.57	9.21	9.85	10.50	11.13	11.77	18.26
0.25	3.46	3.75	4.03	4.31	4.58	4.86	5.14	5.41	5.68	8.46
0.5	2.31	2.47	2.63	2.78	2.93	3.09	3.24	3.39	3.54	5.08
0.75	1.90	2.01	2.13	2.24	2.35	2.46	2.58	2.68	2.79	3.92
1	1.70	1.80	1.89	1.98	2.07	2.16	2.26	2.34	2.43	3.35
1.25	1.59	1.67	1.75	1.83	1.90	1.98	2.07	2.14	2.21	3.00
1.5	1.51	1.58	1.65	1.72	1.79	1.86	1.94	2.00	2.07	2.77
1.75	1.45	1.52	1.58	1.65	1.71	1.78	1.85	1.90	1.96	2.60
2	1.41	1.47	1.53	1.59	1.65	1.71	1.78	1.83	1.88	2.48
2.5	1.35	1.40	1.46	1.51	1.57	1.62	1.68	1.72	1.77	2.31
3	1.31	1.36	1.41	1.46	1.51	1.56	1.61	1.65	1.70	2.19
3.5	1.28	1.33	1.38	1.42	1.47	1.51	1.56	1.60	1.65	2.10
4	1.29	1.34	1.38	1.42	1.47	1.51	1.56	1.60	1.64	2.07
4.5	1.25	1.30	1.34	1.38	1.42	1.46	1.51	1.55	1.59	2.00
5	1.23	1.27	1.31	1.35	1.40	1.44	1.49	1.52	1.56	1.99
10	1.05	1.08	1.11	1.14	1.17	1.20	1.24	1.26	1.29	1.58
15	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.18	1.20	1.44
30	0.95	0.97	0.99	1.01	1.03	1.05	1.08	1.09	1.11	1.31

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Tertiary 2 - Membrane Filtration

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	874,200	73,600	1,465,300	128,300	3,586,800	152,800
0.25	1,369,900	97,000	2,088,200	155,000	4,354,300	181,900
0.5	1,966,000	135,500	2,896,200	198,600	5,403,200	228,500
0.75	2,559,600	173,900	3,610,800	241,000	6,358,700	273,500
1	3,138,100	212,200	4,371,000	284,600	7,359,800	319,200
1.25	3,716,700	250,400	5,131,200	327,700	8,360,900	364,400
1.5	4,295,300	288,700	5,891,400	370,700	9,362,000	409,300
1.75	4,873,900	327,000	6,651,700	413,600	10,363,200	454,000
2	5,452,500	365,200	7,411,900	456,500	11,364,300	498,600
2.5	6,609,700	441,800	8,932,300	542,100	13,366,500	587,300
3	7,766,900	518,300	10,452,800	627,600	15,368,800	675,700
3.5	8,924,100	594,800	11,973,300	712,900	17,371,000	763,800
4	10,436,700	689,600	13,849,100	816,300	19,728,700	869,900
4.5	11,347,800	754,800	15,123,500	890,200	21,484,900	946,200
5	12,258,900	820,100	16,499,200	963,900	23,747,900	1,022,300
10	21,319,900	1,471,800	27,885,800	1,691,500	37,961,700	1,769,400
15	30,355,900	2,123,400	39,652,000	2,420,300	52,555,100	2,513,600
30	57,463,800	4,078,000	74,950,700	4,592,500	96,335,500	4,720,200

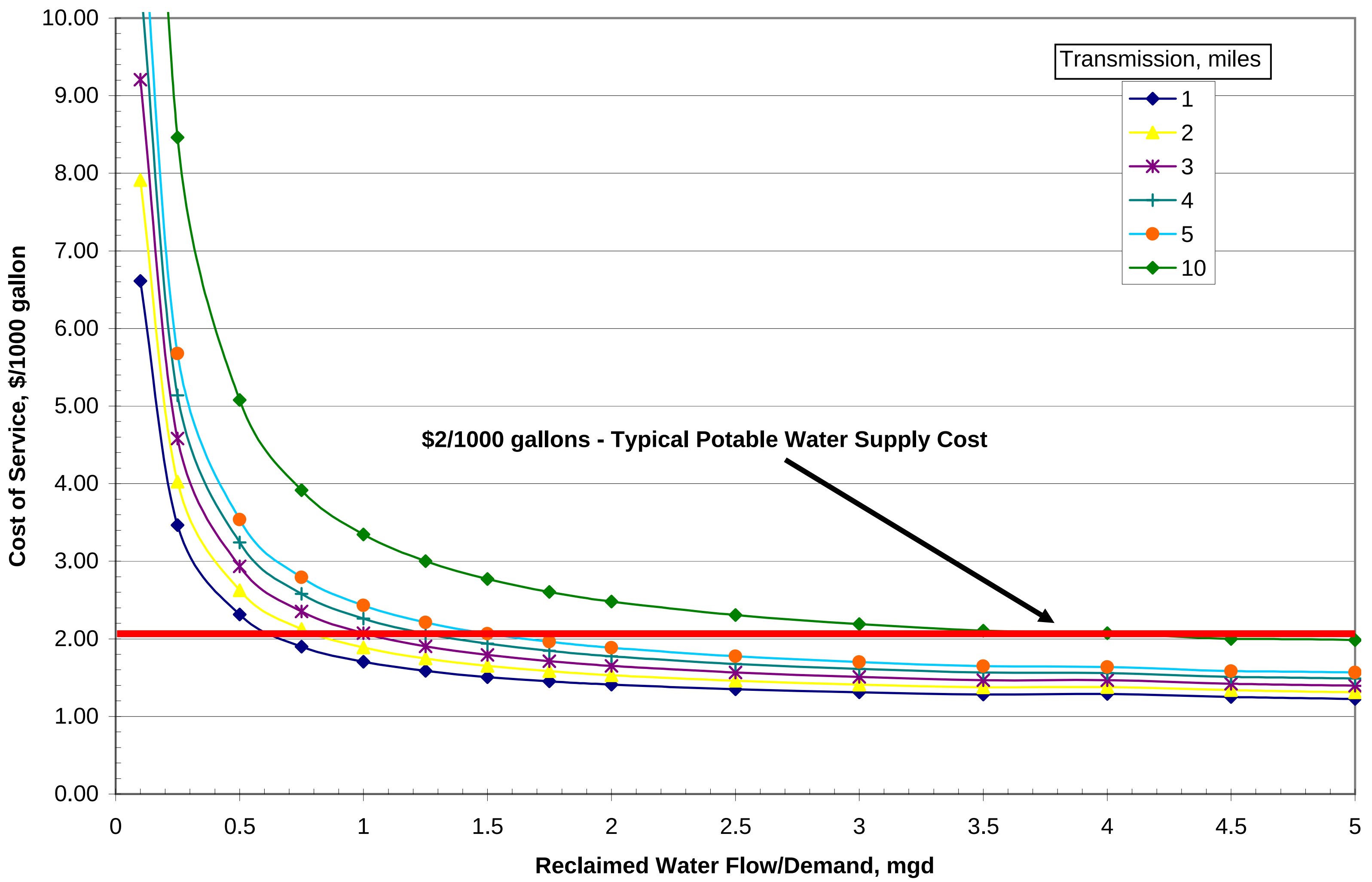


Figure D-2a. Reclaimed Water System Probable Cost of Service for 0-5 mgd Capacity
Urban Area - Treatment: Tertiary 2 - Membrane Filtration

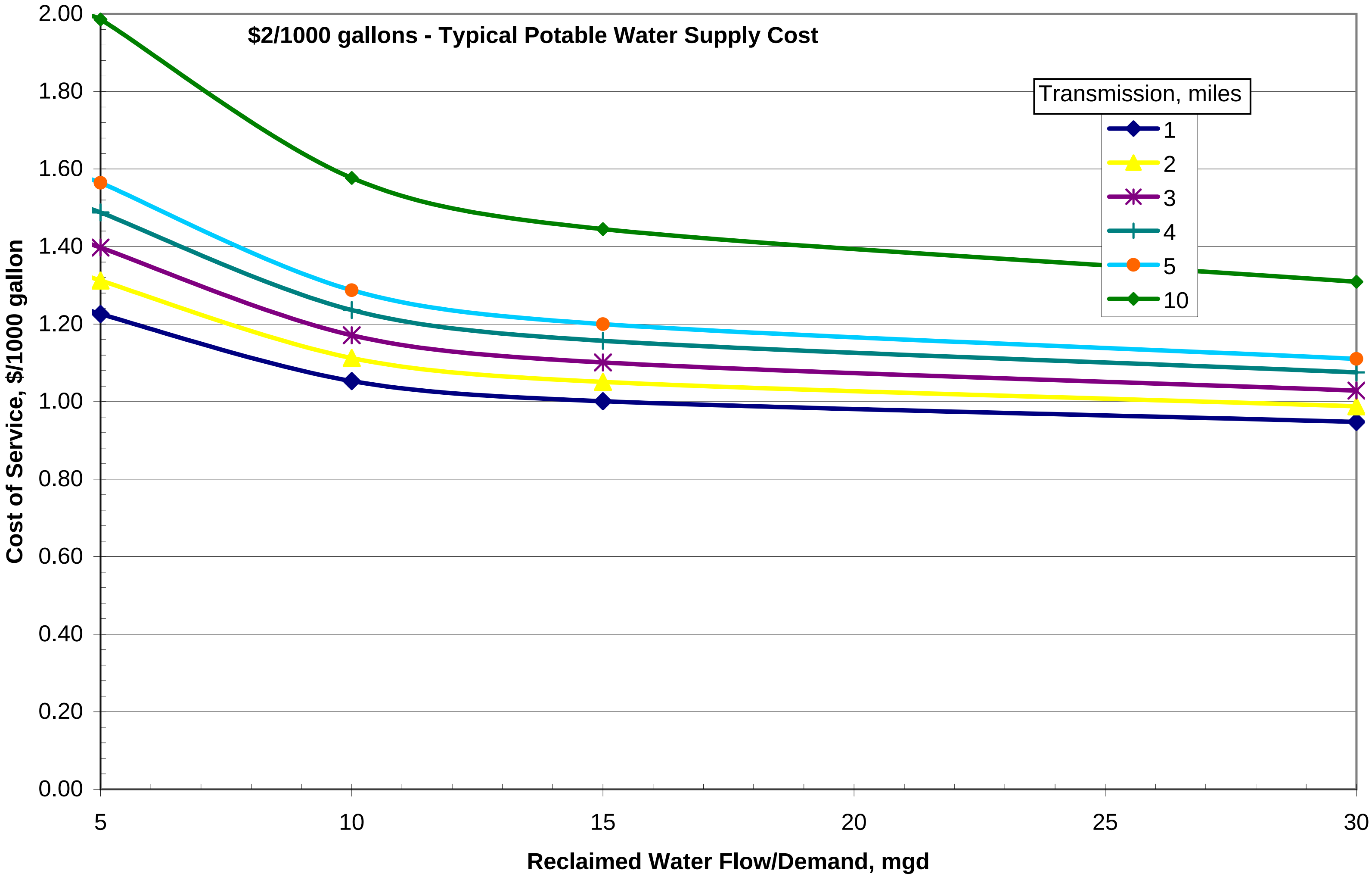
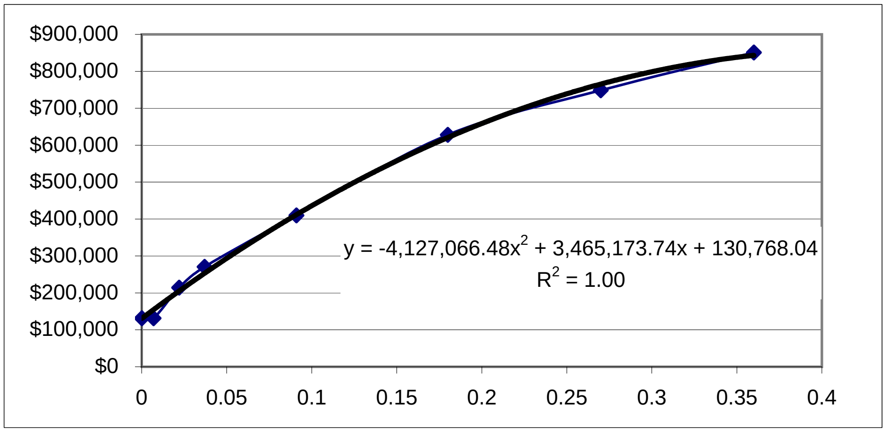


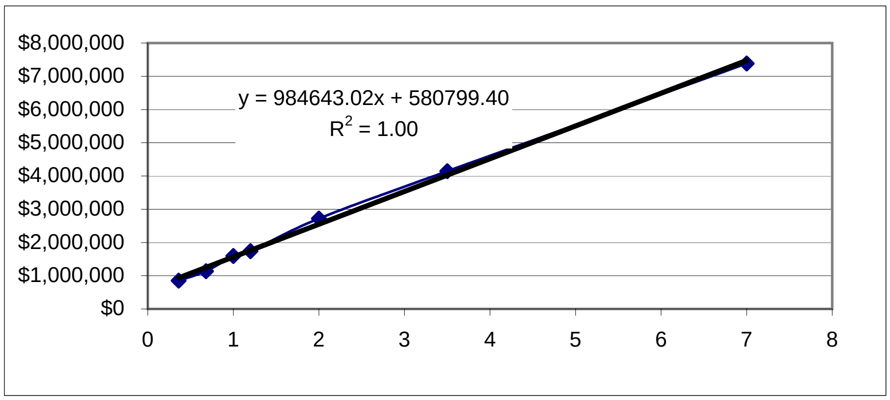
Figure D-2b. Reclaimed Water System Probable Cost of Service for 5-30 mgd Capacity
Urban Area - Treatment: Tertiary 2 - Membrane Filtration

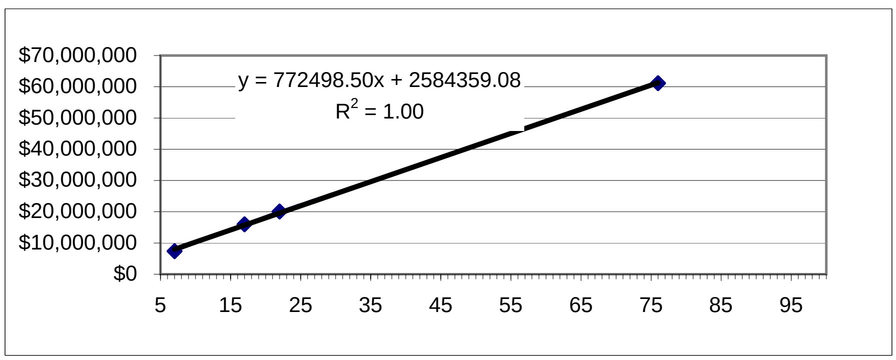
Cost Curves as Basis for Tertiary 2 - Membrane Filtration Costs*
Microfiltration

Capital Costs

Design Flow (mgd)	Cost ($)
0.0001	$131,478
0.007	$131,478
0.022	$214,432
0.037	$270,819
0.091	$409,983
0.18	$628,117
0.27	$748,563
0.36	$850,970
0.68	$1,133,988
1	$1,594,911
1.2	$1,738,505
2	$2,720,593
3.5	$4,142,559
7	$7,382,351
17	$15,991,348
22	$20,058,196
76	$61,150,358
210	$153,184,031
430	$293,759,889
520	$349,252,221
1,500.00	$953,502,064





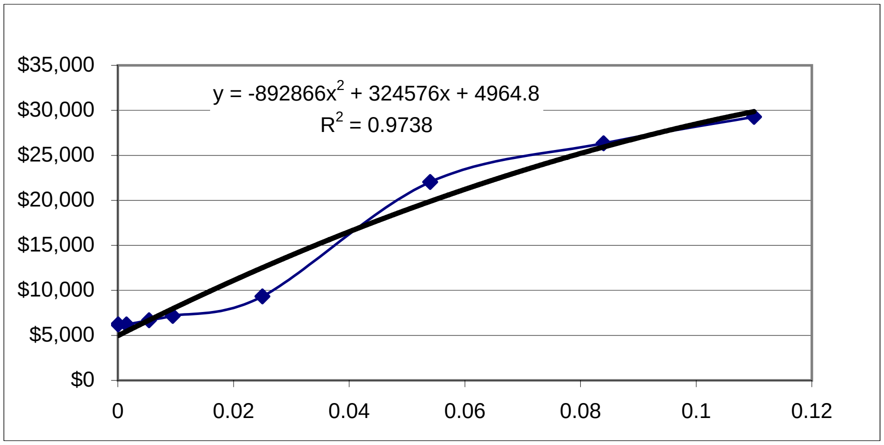


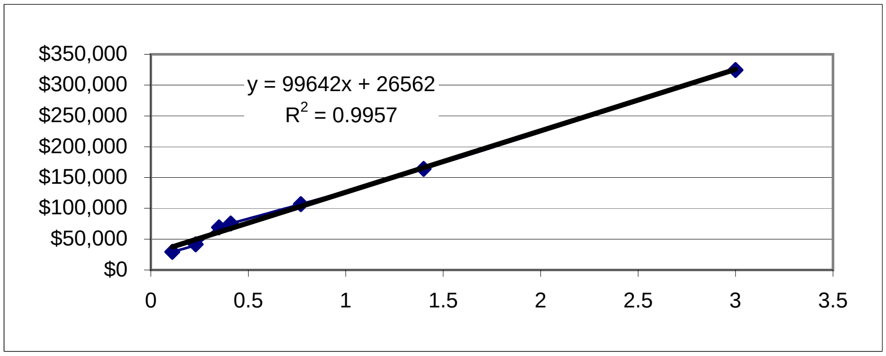
Curve fit equations			
CCI Index Multiplier	**1.16**		
Avg Flow Range	0-0.11mgd	>0.11-3mgd	>3-30mgd
Design Flow Range	0-0.36mgd	>0.36-7 mgd	>7-90 mgd
Design/Avg Flow Ratio	2		

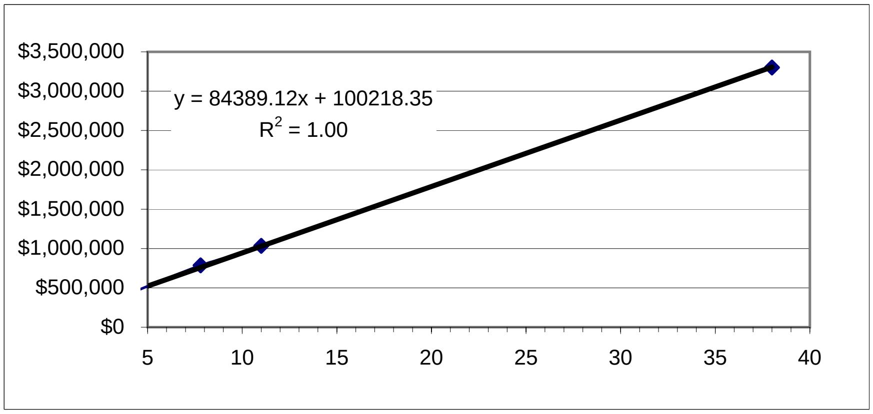
*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 2 - Membrane Filtration Costs*
Microfiltration
O&M Costs

Average Flow	Cost
(mgd)	($)
0.00005	$6,230
0.0015	$6,230
0.0054	$6,686
0.0095	$7,156
0.025	$9,329
0.054	$22,042
0.084	$26,348
0.11	$29,272
0.23	$41,522
0.35	$69,214
0.41	$75,317
0.77	$106,798
1.4	$164,173
3	$324,393
7.8	$786,427
11	$1,034,793
38	$3,301,730
120	$9,888,387
270	$21,519,157
350	$27,300,426
750	$56,206,770







*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-3
Water Reuse System Costs
Tertiary 3 – Membrane Softening

Water Reuse System Estimated Cost of Service, $/1000 gallons
Tertiary 3 - Membrane Softening

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	8.58	9.23	9.88	10.53	11.17	11.81	12.46	13.10	13.73	20.22
0.25	5.00	5.28	5.56	5.85	6.12	6.39	6.67	6.94	7.21	10.00
0.5	3.71	3.86	4.02	4.18	4.33	4.48	4.64	4.78	4.93	6.47
0.75	3.24	3.36	3.47	3.59	3.70	3.81	3.92	4.03	4.14	5.26
1	3.02	3.12	3.21	3.30	3.39	3.48	3.58	3.66	3.75	4.66
1.25	2.89	2.97	3.05	3.13	3.21	3.29	3.37	3.44	3.52	4.30
1.5	2.80	2.87	2.94	3.02	3.09	3.16	3.23	3.29	3.36	4.06
1.75	2.74	2.80	2.87	2.93	3.00	3.06	3.13	3.19	3.25	3.89
2	2.69	2.75	2.81	2.87	2.93	2.99	3.05	3.11	3.16	3.76
2.5	2.62	2.67	2.73	2.78	2.84	2.89	2.95	2.99	3.04	3.58
3	2.57	2.62	2.67	2.72	2.77	2.82	2.87	2.92	2.96	3.45
3.5	2.54	2.59	2.63	2.68	2.72	2.77	2.82	2.86	2.90	3.36
4	2.54	2.59	2.63	2.68	2.72	2.76	2.81	2.85	2.89	3.32
4.5	2.50	2.54	2.59	2.63	2.67	2.71	2.76	2.79	2.83	3.25
5	2.47	2.51	2.56	2.60	2.64	2.68	2.73	2.77	2.81	3.23
10	2.27	2.30	2.33	2.36	2.39	2.41	2.45	2.47	2.50	2.79
15	2.19	2.22	2.24	2.26	2.29	2.31	2.35	2.36	2.39	2.63
30	2.07	2.09	2.11	2.13	2.15	2.17	2.19	2.21	2.23	2.43

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Tertiary 3 - Membrane Softening

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	1,145,200	124,400	1,736,300	179,000	3,857,900	203,600
0.25	1,973,500	190,600	2,691,800	248,600	4,957,900	275,500
0.5	3,122,800	300,400	4,053,100	363,500	6,560,100	393,400
0.75	4,268,000	410,000	5,319,200	477,100	8,067,100	509,600
1	5,396,700	519,400	6,629,500	591,800	9,618,300	626,400
1.25	6,523,800	628,700	7,938,300	705,900	11,168,000	742,600
1.5	7,649,400	737,900	9,245,600	819,900	12,716,100	858,500
1.75	8,773,500	847,000	10,551,300	933,700	14,262,800	974,100
2	9,896,100	956,100	11,855,400	1,047,300	15,807,800	1,089,400
2.5	12,136,600	1,173,900	14,459,200	1,274,200	18,893,400	1,319,400
3	14,370,900	1,391,300	17,056,800	1,500,600	21,972,800	1,548,700
3.5	16,599,200	1,608,400	19,648,300	1,726,400	25,046,100	1,777,400
4	19,176,700	1,843,300	22,589,100	1,970,100	28,468,700	2,023,600
4.5	21,146,500	2,048,400	24,922,300	2,183,800	31,283,600	2,239,700
5	23,110,300	2,253,100	27,350,600	2,397,000	34,599,300	2,455,300
10	42,360,300	4,279,900	48,926,200	4,499,600	59,002,100	4,577,500
15	60,971,800	6,270,700	70,268,000	6,567,600	83,171,100	6,660,900
30	113,126,100	12,028,000	130,613,000	12,542,600	151,997,800	12,670,300

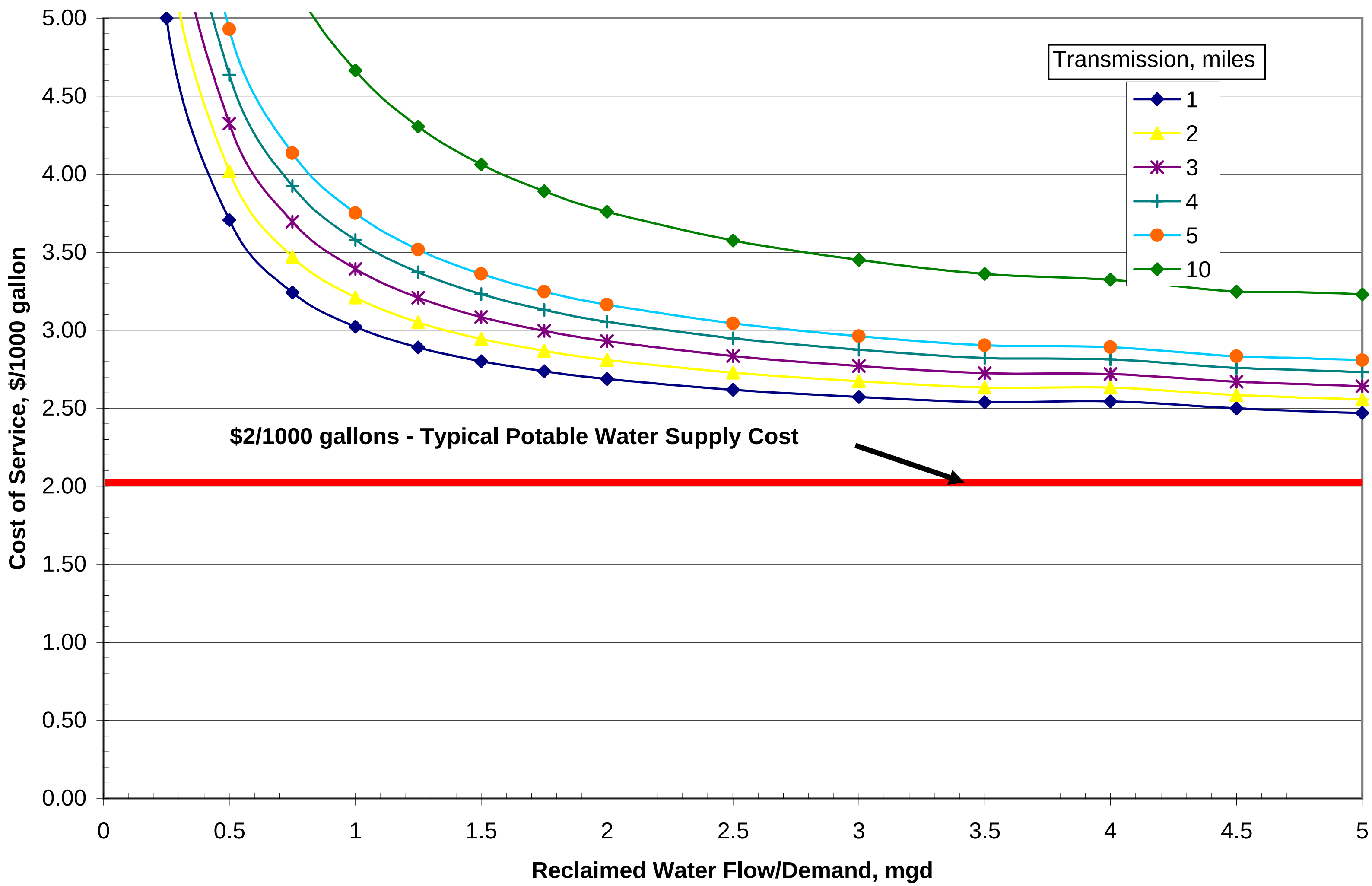


Figure D-3a. Reclaimed Water System Probable Cost of Service for 0-5 mgd Capacity
Urban Area - Treatment: Tertiary 3 - Membrane Softening

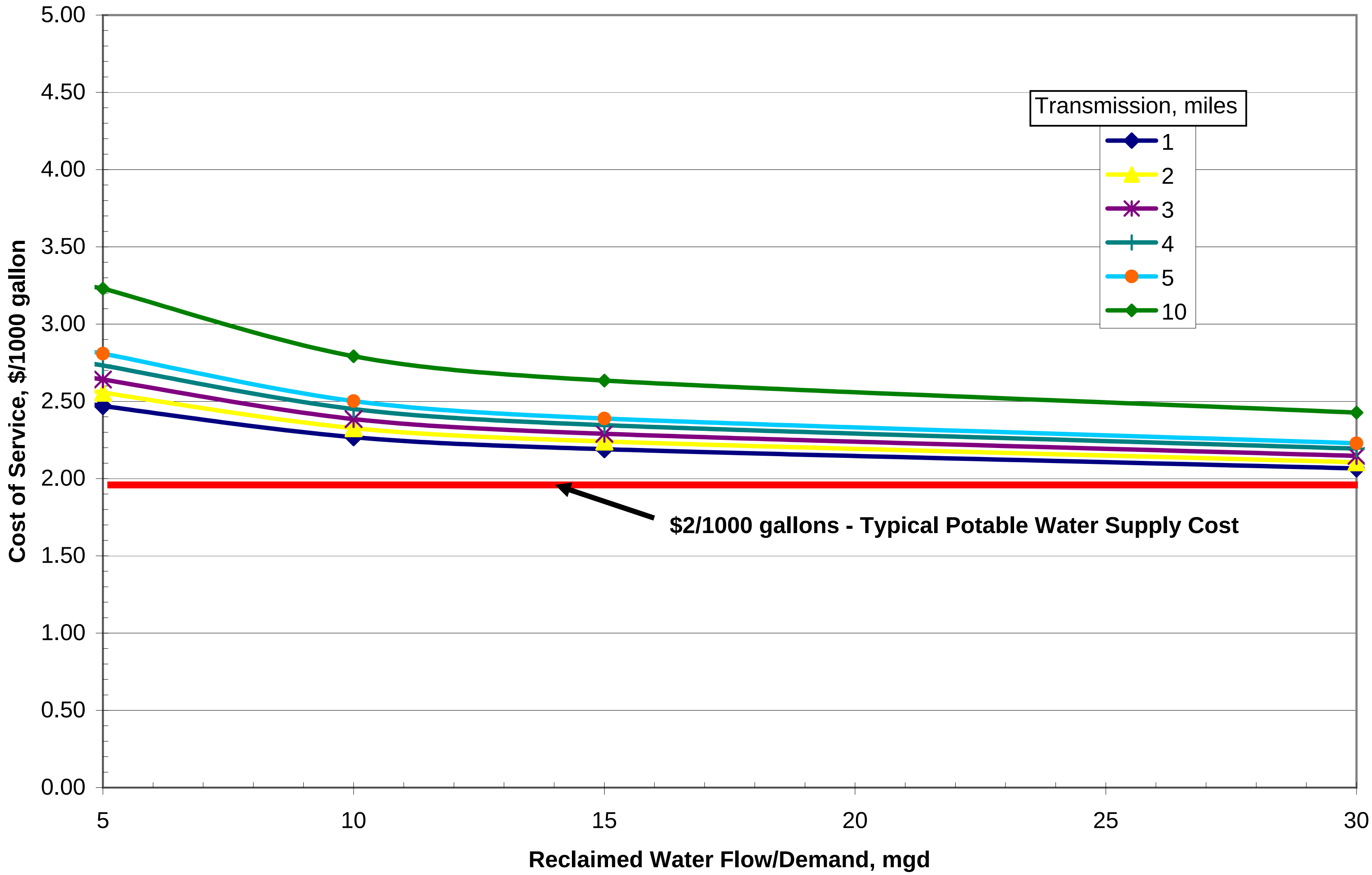
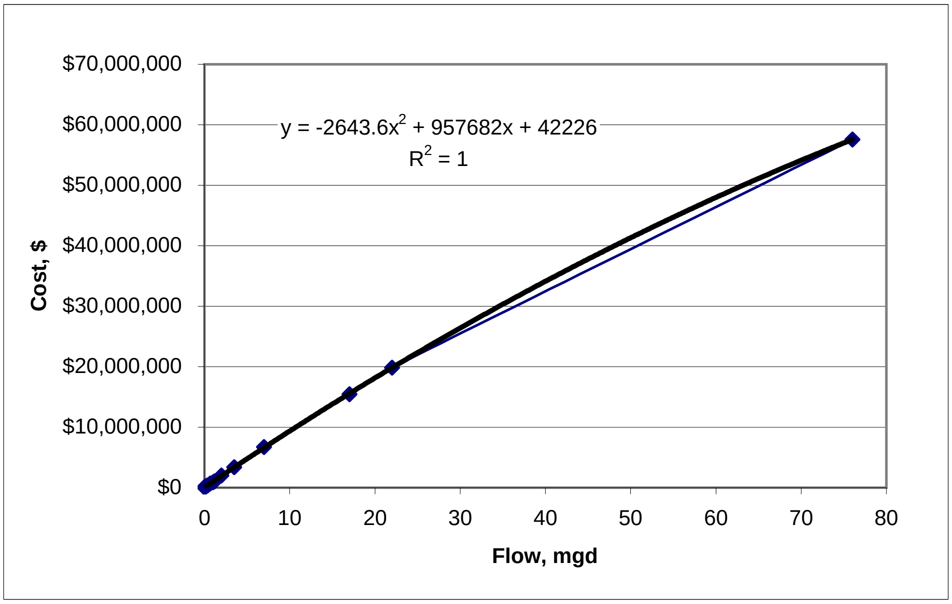


Figure D-3b. Reclaimed Water System Probable Cost of Service for 5-30 mgd Capacity
Urban Area - Treatment: Tertiary 3 - Membrane Softening

Cost Curves as Basis for Tertiary 3 - Reverse Osmosis Costs*

Capital Costs

Design (mgd)	Capital Cost ($)
0.0001	$51,894
0.007	$51,894
0.022	$69,241
0.037	$86,588
0.091	$156,079
0.18	$222,829
0.27	$315,937
0.36	$357,087
0.68	$663,375
1	$912,423
1.2	$1,080,532
2	$2,018,579
3.5	$3,404,129
7	$6,745,258
17	$15,456,118
22	$19,862,964
76	$57,558,238
210	$129,659,099
430	$265,356,059
520	$318,914,577
1,500.00	$902,107,327



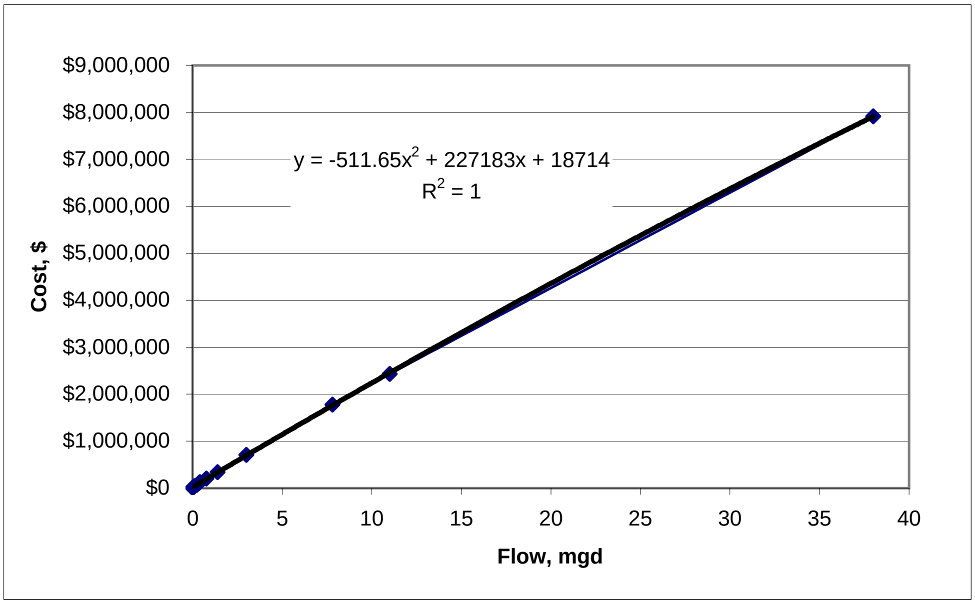
Curve fit equations	
CCI Index Multiplier	1.16
Avg Flow Range	0-30 mgd
Design Flow Range	0-60mgd
Design/Avg Flow Ratio	2

*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 3 - Reverse Osmosis Costs*

O&M Costs

Average Flow	O&M Cost
(mgd)	($)
0.00005	$6,909
0.0015	$6,909
0.0054	$7,937
0.0095	$9,025
0.025	$13,703
0.054	$29,539
0.084	$37,904
0.11	$43,223
0.23	$70,725
0.35	$112,309
0.41	$126,572
0.77	$205,817
1.4	$343,298
3	$710,894
7.8	$1,780,761
11	$2,429,844
38	$7,914,024
120	$23,845,168
270	$52,975,344
350	$68,097,181
750	$143,706,367



*Source: Environmental Protection Agency (EPA), 2003. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-4
Water Reuse System Costs
Tertiary 4 – Membrane Softening and GAC

Water Reuse System Estimated Cost of Service, $/1000 gallons
Tertiary 4 - Advanced with GAC

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	11.48	12.13	12.78	13.43	14.07	14.72	15.36	16.00	16.64	23.13
0.25	7.30	7.58	7.86	8.14	8.41	8.69	8.97	9.24	9.51	12.29
0.5	5.79	5.94	6.10	6.26	6.41	6.56	6.72	6.86	7.01	8.55
0.75	4.81	4.92	5.04	5.15	5.26	5.37	5.49	5.59	5.70	6.82
1	4.33	4.42	4.52	4.61	4.70	4.79	4.89	4.97	5.06	5.97
1.25	4.04	4.12	4.20	4.28	4.36	4.44	4.52	4.59	4.67	5.45
1.5	3.85	3.92	3.99	4.06	4.13	4.20	4.28	4.34	4.41	5.11
1.75	3.71	3.77	3.84	3.91	3.97	4.03	4.10	4.16	4.22	4.86
2	3.60	3.67	3.73	3.79	3.85	3.90	3.97	4.02	4.08	4.68
2.5	3.46	3.51	3.57	3.62	3.67	3.72	3.78	3.83	3.88	4.41
3	3.36	3.41	3.46	3.51	3.55	3.60	3.66	3.70	3.75	4.23
3.5	3.28	3.33	3.38	3.42	3.47	3.51	3.57	3.61	3.65	4.11
4	3.26	3.30	3.35	3.39	3.44	3.48	3.53	3.56	3.61	4.04
4.5	3.19	3.24	3.28	3.32	3.36	3.40	3.45	3.49	3.53	3.94
5	3.14	3.19	3.23	3.27	3.32	3.36	3.41	3.44	3.48	3.90
10	2.85	2.88	2.91	2.94	2.97	3.00	3.03	3.05	3.08	3.37
15	2.73	2.75	2.78	2.80	2.83	2.85	2.89	2.90	2.93	3.17
30	2.53	2.55	2.57	2.59	2.61	2.63	2.66	2.67	2.69	2.89

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Tertiary 4 - GAC

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	1,430,100	208,300	2,021,200	262,900	4,142,800	287,500
0.25	2,627,700	349,700	3,346,000	407,600	5,612,100	434,500
0.5	5,100,600	527,500	6,030,900	590,600	8,537,900	620,500
0.75	6,581,000	659,700	7,632,200	726,800	10,380,100	759,300
1	8,043,300	791,700	9,276,200	864,100	12,265,000	898,700
1.25	9,502,800	923,500	10,917,200	1,000,800	14,146,900	1,037,500
1.5	10,959,300	1,055,300	12,555,400	1,137,200	16,026,000	1,175,800
1.75	12,412,800	1,186,900	14,190,600	1,273,500	17,902,100	1,313,900
2	13,863,500	1,318,300	15,822,800	1,409,600	19,775,200	1,451,700
2.5	16,755,900	1,580,900	19,078,500	1,681,200	23,512,700	1,726,500
3	19,636,500	1,842,900	22,322,500	1,952,200	27,238,400	2,000,400
3.5	22,505,400	2,104,500	25,554,600	2,222,500	30,952,400	2,273,500
4	25,718,000	2,383,800	29,130,500	2,510,500	35,010,000	2,564,000
4.5	28,317,300	2,633,000	32,093,100	2,768,300	38,454,400	2,824,300
5	30,904,900	2,881,700	35,145,200	3,025,600	42,393,900	3,083,900
10	56,083,700	5,340,600	62,649,600	5,560,200	72,725,500	5,638,100
15	80,061,700	7,748,500	89,357,800	8,045,400	102,261,000	8,138,700
30	144,941,100	14,668,300	162,428,000	15,182,900	183,812,700	15,310,600

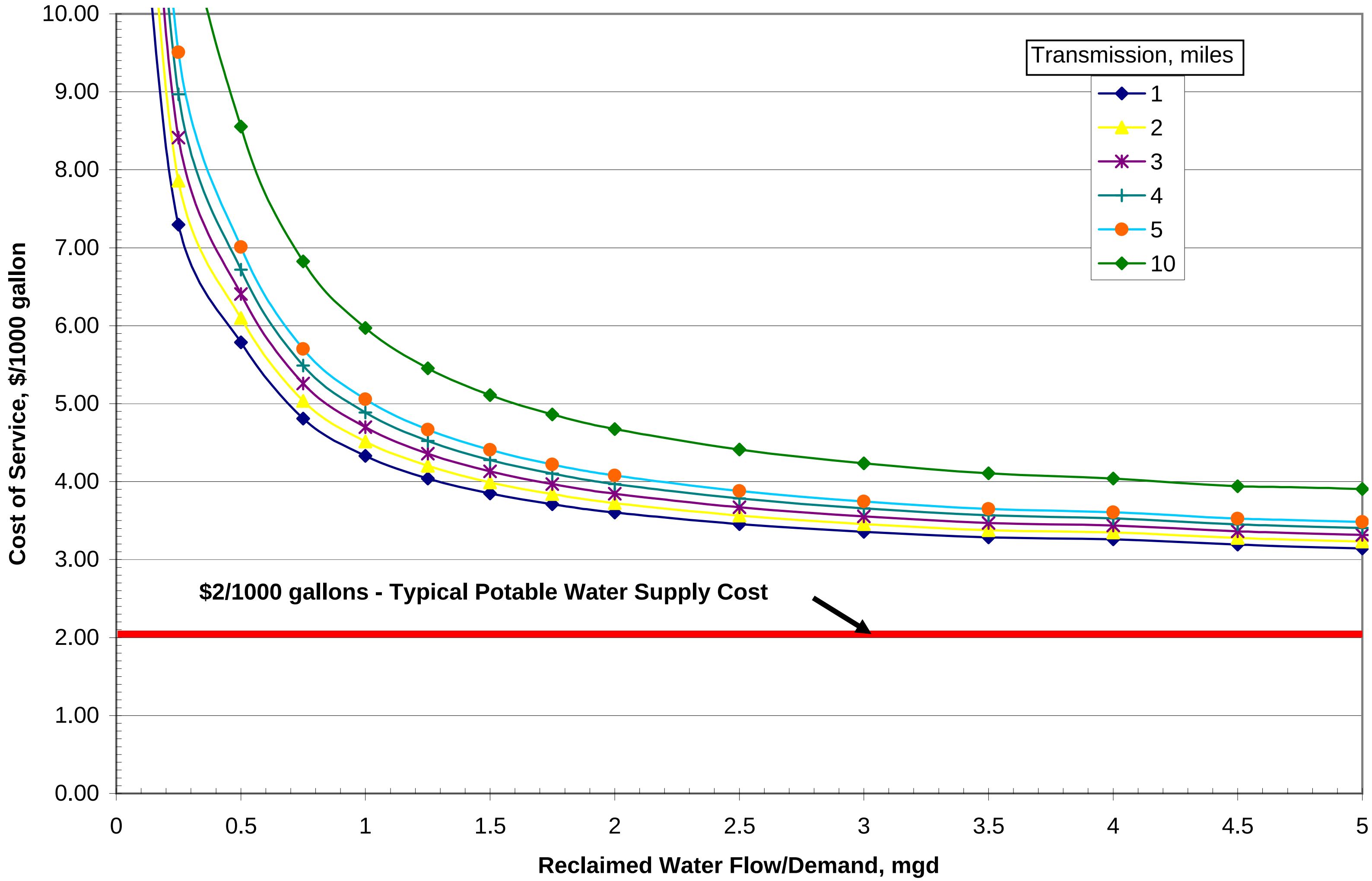


Figure D-4a. Reclaimed Water System Cost of Service for 0-5 mgd Capacity Urban Area - Tertiary 4 with GAC

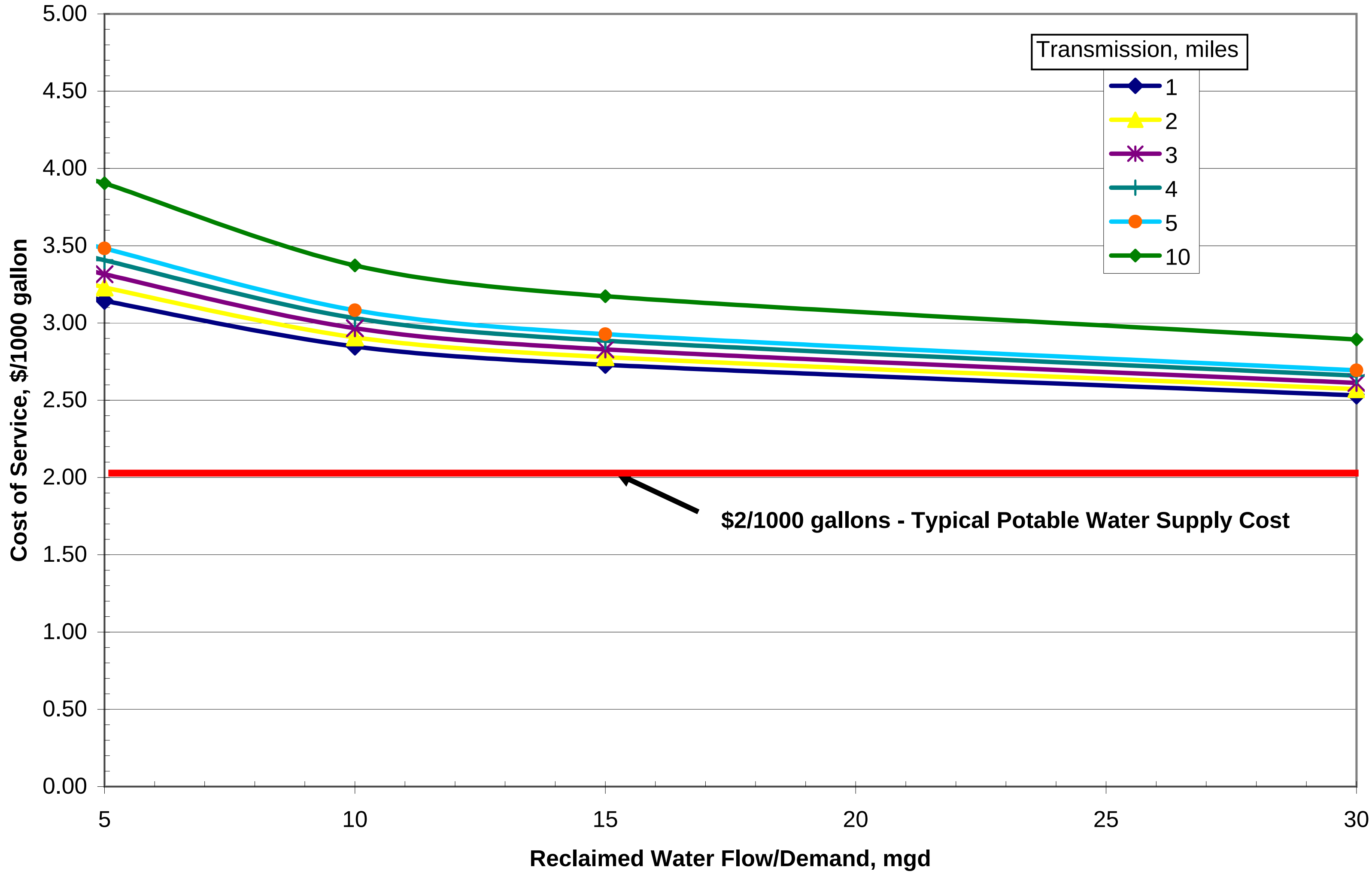
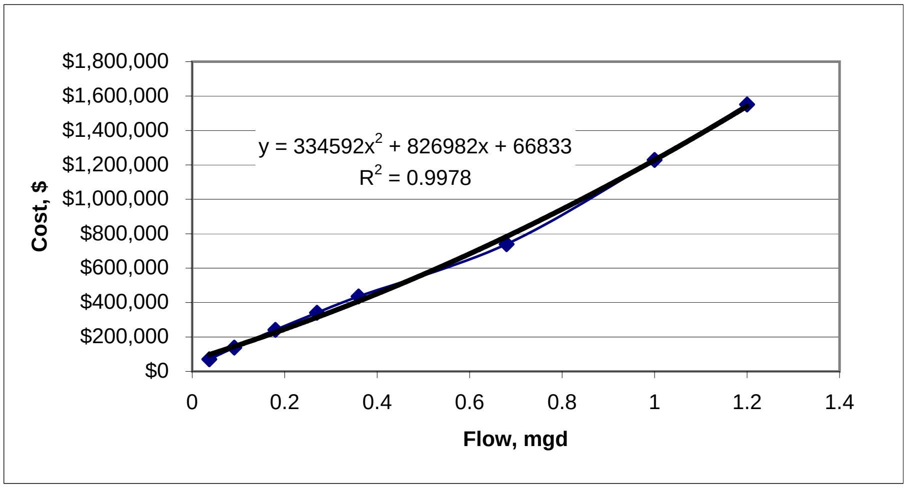


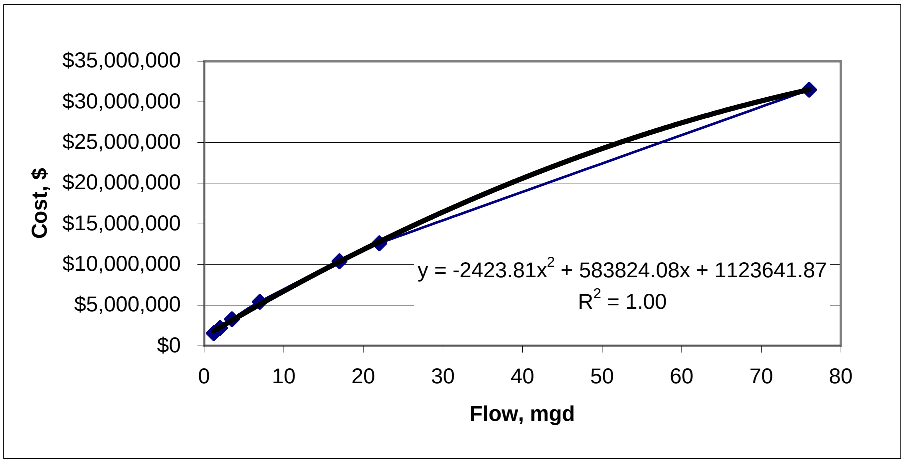
Figure D-4b. Reclaimed Water System Cost of Service for 5-30 mgd Capacity
Urban Area - Tertiary 4 with GAC

Cost Curves as Basis for Tertiary 4 - GAC*

Capital Cost

Design Flow (mgd)	Capital Cost ($)
0.0001	$36,117
0.007	$36,117
0.022	$53,091
0.037	$70,491
0.091	$137,932
0.18	$241,793
0.27	$340,528
0.36	$435,155
0.68	$739,387
1	$1,228,620
1.2	$1,551,122
2	$2,203,728
3.5	$3,275,153
7	$5,411,638
17	$10,411,502
22	$12,611,714
76	$31,503,622
210	$67,096,117
430	$114,813,572
520	$132,437,789
1,500.00	$324,345,925





Curve fit equations		
CCI Index	**1.16**	
Avg Flow Range	0.037-0.35 mgd	>0.35-30 mgd
Design Flow Range	0.037-1.2 mgd	>1.2-60 mgd
Design/Avg Flow Ratio	2	

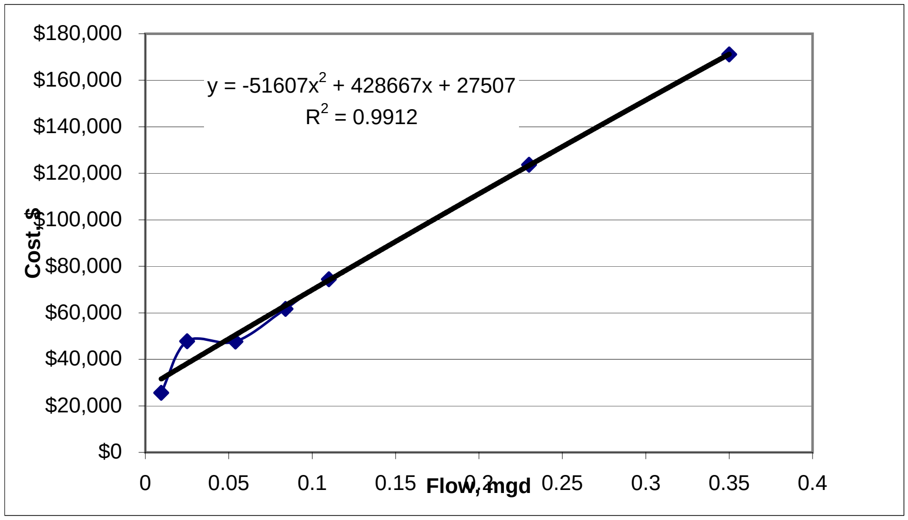
Note: Based on GAC reactivation frequency of 90 days (GAC-20 designation in EPA, 2005).

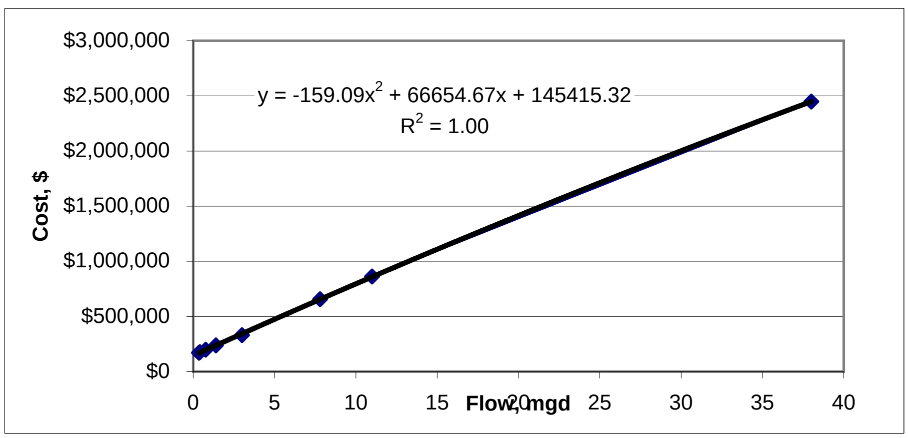
*Source: Environmental Protection Agency (EPA), 2005. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Cost Curves as Basis for Tertiary 4 - GAC*

O&M Cost

Design Flow (mgd)	O&M Cost ($)
0.00005	$9,222
0.0015	$9,222
0.0054	$18,223
0.0095	$25,644
0.025	$47,782
0.054	$47,639
0.084	$61,728
0.11	$74,417
0.23	$123,691
0.35	$171,149
0.41	$177,242
0.77	$199,489
1.4	$237,836
3	$330,703
7.8	$656,235
11	$863,063
38	$2,448,311
120	$6,727,479
270	$14,362,281
350	$18,123,898
750	$36,931,984





Note: Based on GAC reactivation frequency of 90 days (GAC-20 designation in EPA, 2005).

*Source: Environmental Protection Agency (EPA), 2005. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-5
Water Reuse System Costs
Tertiary 4 – Membrane Softening and Ion Exchange

Water Reuse System Estimated Cost of Service, $/1000 gallons
Tertiary 4 - Membrane Softening with Ion Exchange

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	9.88	10.53	11.18	11.84	12.48	13.12	13.77	14.40	15.04	21.53
0.25	6.02	6.30	6.58	6.87	7.14	7.42	7.70	7.96	8.23	11.02
0.5	4.63	4.79	4.95	5.10	5.25	5.41	5.56	5.71	5.86	7.40
0.75	4.14	4.25	4.37	4.48	4.59	4.70	4.82	4.92	5.03	6.16
1	3.90	4.00	4.09	4.18	4.27	4.36	4.46	4.54	4.63	5.54
1.25	3.76	3.84	3.92	4.00	4.08	4.16	4.24	4.31	4.39	5.18
1.5	3.67	3.74	3.81	3.88	3.95	4.02	4.10	4.16	4.23	4.93
1.75	3.60	3.66	3.73	3.79	3.86	3.92	3.99	4.05	4.11	4.75
2	3.54	3.61	3.67	3.73	3.79	3.85	3.91	3.96	4.02	4.62
2.5	3.47	3.53	3.58	3.63	3.69	3.74	3.80	3.84	3.90	4.43
3	3.42	3.47	3.52	3.57	3.62	3.67	3.72	3.76	3.81	4.30
3.5	3.38	3.43	3.48	3.53	3.57	3.62	3.67	3.71	3.75	4.21
4	3.39	3.43	3.48	3.52	3.56	3.61	3.66	3.69	3.74	4.17
4.5	3.34	3.39	3.43	3.47	3.51	3.55	3.60	3.64	3.68	4.09
5	3.31	3.36	3.40	3.44	3.48	3.53	3.57	3.61	3.65	4.07
10	3.11	3.13	3.16	3.19	3.22	3.25	3.29	3.31	3.34	3.63
15	3.03	3.05	3.08	3.10	3.13	3.15	3.18	3.20	3.23	3.47
30	2.90	2.92	2.94	2.96	2.98	3.00	3.03	3.04	3.06	3.26

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance

Tertiary 4 - Ion Exchange

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	Capital, $	O&M, $	Capital, $	O&M, $	Capital, $	O&M, $
0.1	1,400,300	152,400	1,991,300	207,000	4,112,900	231,600
0.25	2,314,600	257,600	3,032,900	315,500	5,299,000	342,400
0.5	3,607,200	432,200	4,537,500	495,400	7,044,500	525,300
0.75	4,895,800	606,800	5,947,000	674,000	8,694,900	706,400
1	6,167,800	781,200	7,400,700	853,500	10,389,500	888,200
1.25	7,438,400	955,400	8,852,800	1,032,600	12,082,500	1,069,300
1.5	8,707,300	1,129,600	10,303,400	1,211,500	13,774,000	1,250,100
1.75	9,974,800	1,303,600	11,752,500	1,390,200	15,464,000	1,430,600
2	11,240,700	1,477,600	13,200,100	1,568,800	17,152,400	1,610,900
2.5	13,767,900	1,825,300	16,090,600	1,925,600	20,524,700	1,970,900
3	16,289,000	2,172,600	18,974,900	2,281,900	23,890,900	2,330,000
3.5	18,804,000	2,519,600	21,853,100	2,637,600	27,250,900	2,688,600
4	21,668,200	2,884,400	25,080,700	3,011,200	30,960,200	3,064,700
4.5	23,924,800	3,219,400	27,700,500	3,354,700	34,061,900	3,410,700
5	26,175,300	3,554,000	30,415,600	3,697,800	37,664,300	3,756,200
10	48,292,500	6,879,600	54,858,400	7,099,300	64,934,400	7,177,200
15	69,771,400	10,169,300	79,067,500	10,466,200	91,970,700	10,559,500
30	130,527,500	19,823,300	148,014,500	20,337,800	169,399,200	20,465,500

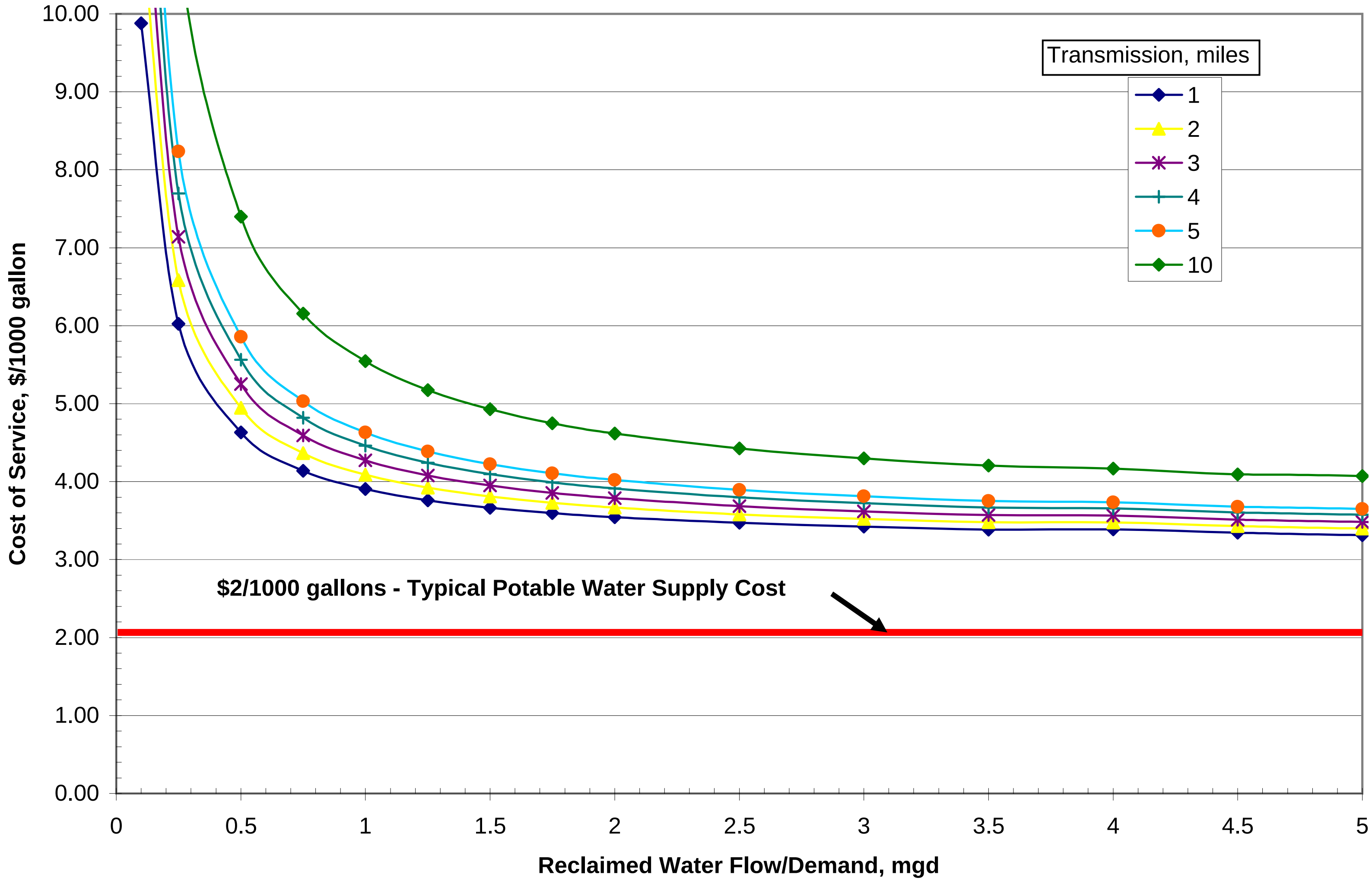


Figure D-4a. Reclaimed Water System Cost of Service for 0-5 mgd Capacity Urban Area - Tertiary 4 with Ion Exchange

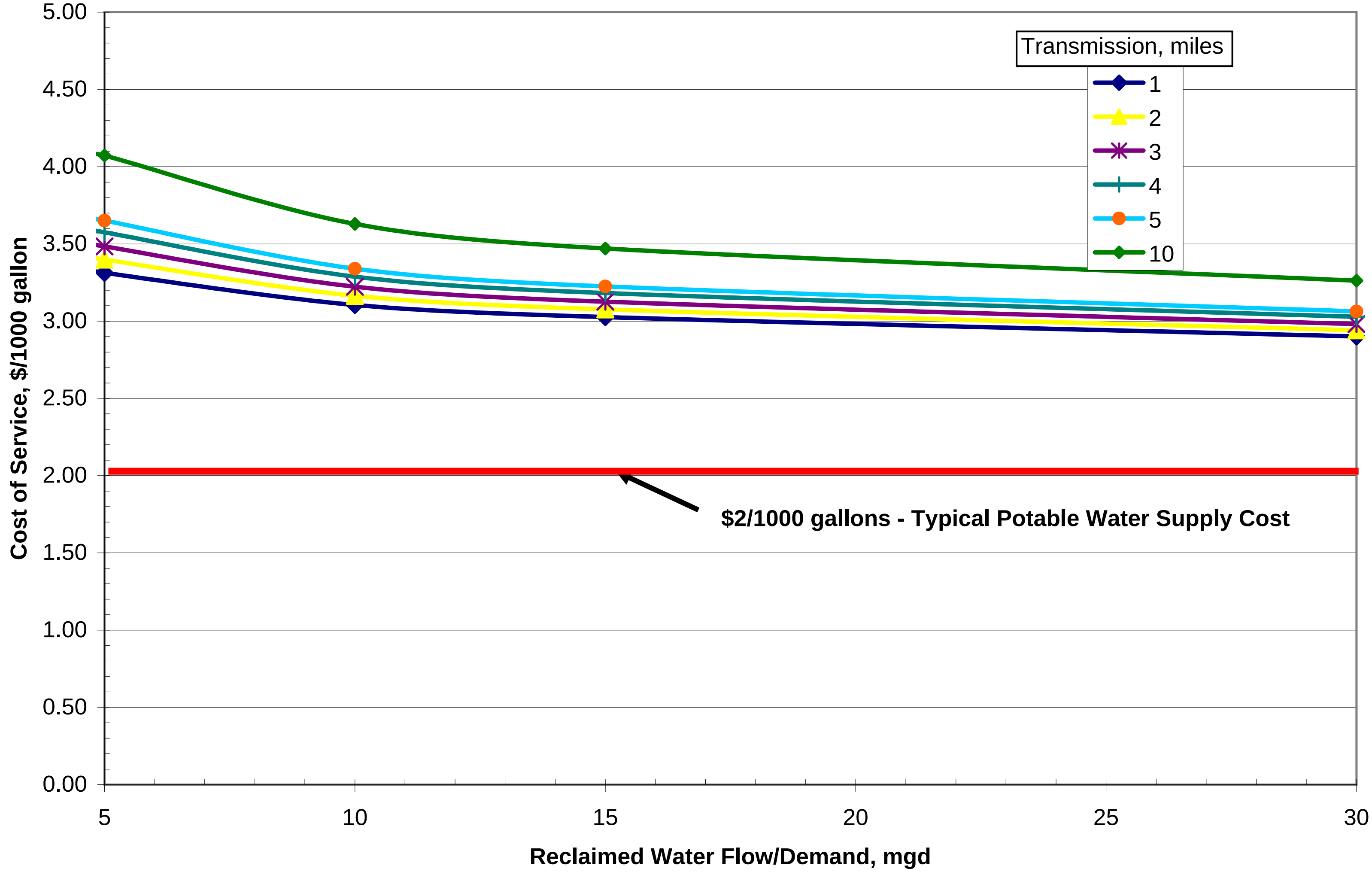


Figure D-4b. Reclaimed Water System Cost of Service for 5-30 mgd Capacity
Urban Area - Tertiary 4 with Ion Exchange

Cost Curves as Basis for Tertiary 4 - Ion Exchange*

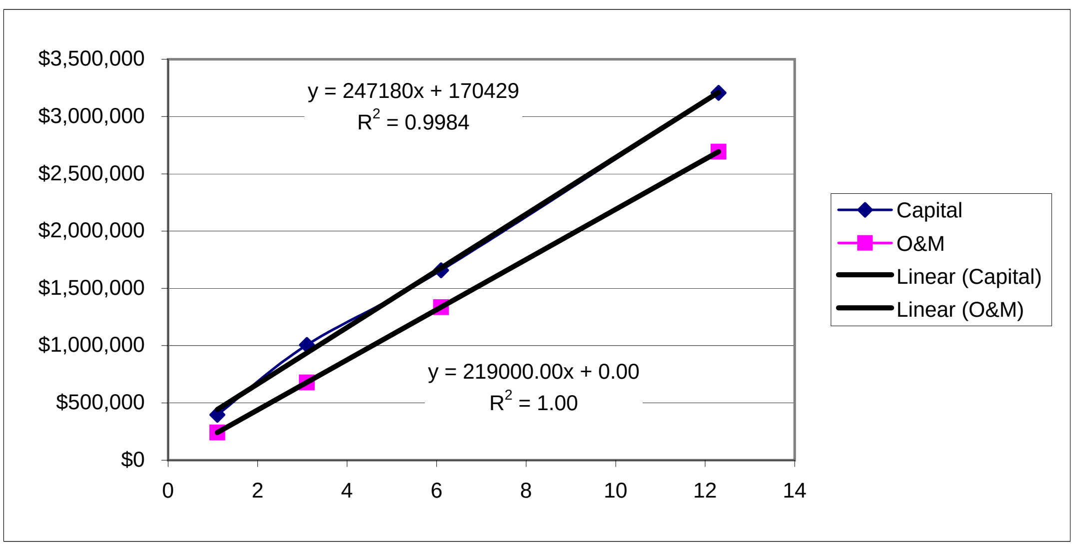
Plant Capacity, mgd	1.1	3.1	6.1	12.3
Excavation	740	1140	1470	1970
Manufactured	$39,960	$89,580	$137,770	$258,230
Media	$92,790	$313,160	$521,940	$1,043,880
Concrete	$2,410	$3,580	$4,750	$6,320
Steel	$3,830	$5,680	$7,530	$9,950
Labor	$17,420	$33,510	$61,460	$125,080
Pipes	$14,040	$38,780	$69,740	$139,480
Electrical	$27,700	$38,510	$60,820	$120,210
Housing	$21,920	$35,660	$57,440	$79,820
Contingencies	$33,120	$83,940	$138,440	$267,740
Total	$253,930	$643,540	$1,061,360	$2,052,680

	Total 2000	2006Sep	W/ Contg	O&M		O&M
Plant Capacity, mgd				Chemicals	Labor	Total
1.1	$253,930	$317,412.50	$396,766	$240,900	$10,000	$250,900
3.1	$643,540	$804,425.00	$1,005,531	$678,900	$10,000	$688,900
6.1	$1,061,360	$1,326,700.00	$1,658,375	$1,335,900	$15,000	$1,350,900
12.3	$2,052,680	$2,565,850.00	$3,207,313	$2,693,700	$15,000	$2,708,700

Flow	Cap Cost	O&M cost
1.1	$396,766	$240,900
3.1	$1,005,531	$678,900
6.1	$1,658,375	$1,335,900
12.3	$3,207,313	$2,693,700

Chemical cost= 0.0006 $/gal

Curve fit equations	
CCI Index	**1.16**
Avg Flow Range	0-15
Design Flow Range	0-30
Design/Avg Flow Ratio	2



*Source: Environmental Protection Agency (EPA), 2005. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-6
Water Reuse System Costs
Tertiary 4 – Membrane Softening and Ultraviolet Radiation

Water Reuse System Estimated Cost of Service, $/1000 gallons

Tertiary 4 - Membrane Softening with UV

	Pipe Length, Miles									
Flow, mgd	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**10**
0.1	8.96	9.61	10.27	10.92	11.56	12.20	12.85	13.49	14.12	20.61
0.25	5.24	5.52	5.80	6.08	6.36	6.63	6.91	7.18	7.45	10.24
0.5	3.99	4.15	4.30	4.46	4.61	4.76	4.92	5.07	5.21	6.76
0.75	3.44	3.56	3.67	3.78	3.89	4.01	4.12	4.23	4.33	5.46
1	3.18	3.27	3.36	3.46	3.55	3.64	3.73	3.82	3.91	4.82
1.25	3.02	3.10	3.18	3.26	3.34	3.42	3.50	3.57	3.65	4.43
1.5	2.91	2.99	3.06	3.13	3.20	3.27	3.34	3.41	3.47	4.18
1.75	2.84	2.90	2.97	3.04	3.10	3.16	3.23	3.29	3.35	3.99
2	2.78	2.84	2.90	2.96	3.02	3.08	3.15	3.20	3.26	3.85
2.5	2.70	2.76	2.81	2.86	2.92	2.97	3.03	3.07	3.13	3.66
3	2.65	2.70	2.75	2.80	2.85	2.89	2.95	2.99	3.04	3.53
3.5	2.61	2.66	2.70	2.75	2.79	2.84	2.89	2.93	2.97	3.43
4	2.61	2.65	2.70	2.74	2.79	2.83	2.88	2.92	2.96	3.39
4.5	2.57	2.61	2.65	2.69	2.73	2.78	2.82	2.86	2.90	3.31
5	2.53	2.58	2.62	2.66	2.70	2.75	2.80	2.83	2.87	3.29
10	2.33	2.36	2.39	2.42	2.45	2.48	2.52	2.54	2.57	2.86
15	2.25	2.27	2.30	2.32	2.35	2.37	2.40	2.42	2.45	2.69
30	2.11	2.13	2.15	2.17	2.19	2.21	2.23	2.25	2.27	2.47

Water Reuse System Estimates of Probable Cost - Capital and Operation and Maintenance
Tertiary 4 - UV

	Treatment Facilities		Total System-1 mile		Total System-5 mile	
Flow, mgd	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**	**Capital, $**	**O&M, $**
0.1	1,206,500	133,800	1,797,600	188,500	3,919,200	213,000
0.25	2,090,200	203,300	2,808,500	261,300	5,074,600	288,200
0.5	3,550,400	319,200	4,480,700	382,300	6,987,700	412,200
0.75	4,712,900	429,800	5,764,100	497,000	8,512,000	529,400
1	5,860,600	540,200	7,093,400	612,600	10,082,200	647,300
1.25	7,008,600	650,600	8,423,100	727,800	11,652,800	764,500
1.5	8,156,900	760,800	9,753,000	842,800	13,223,600	881,400
1.75	9,305,400	870,900	11,083,200	957,600	14,794,600	998,000
2	10,454,200	981,000	12,413,600	1,072,300	16,366,000	1,114,300
2.5	12,752,700	1,200,900	15,075,300	1,301,200	19,509,500	1,346,500
3	15,052,300	1,420,400	17,738,200	1,529,700	22,654,200	1,577,900
3.5	17,352,900	1,639,600	20,402,100	1,757,700	25,799,900	1,808,600
4	20,010,100	1,876,700	23,422,600	2,003,400	29,302,100	2,057,000
4.5	22,066,900	2,083,900	25,842,600	2,219,200	32,204,000	2,275,200
5	24,124,700	2,290,800	28,365,100	2,434,600	35,613,800	2,493,000
10	44,713,800	4,340,200	51,279,700	4,559,900	61,355,600	4,637,800
15	63,975,700	6,347,400	73,271,800	6,644,300	86,175,000	6,737,600
30	117,245,800	12,146,400	134,732,800	12,661,000	156,117,500	12,788,700

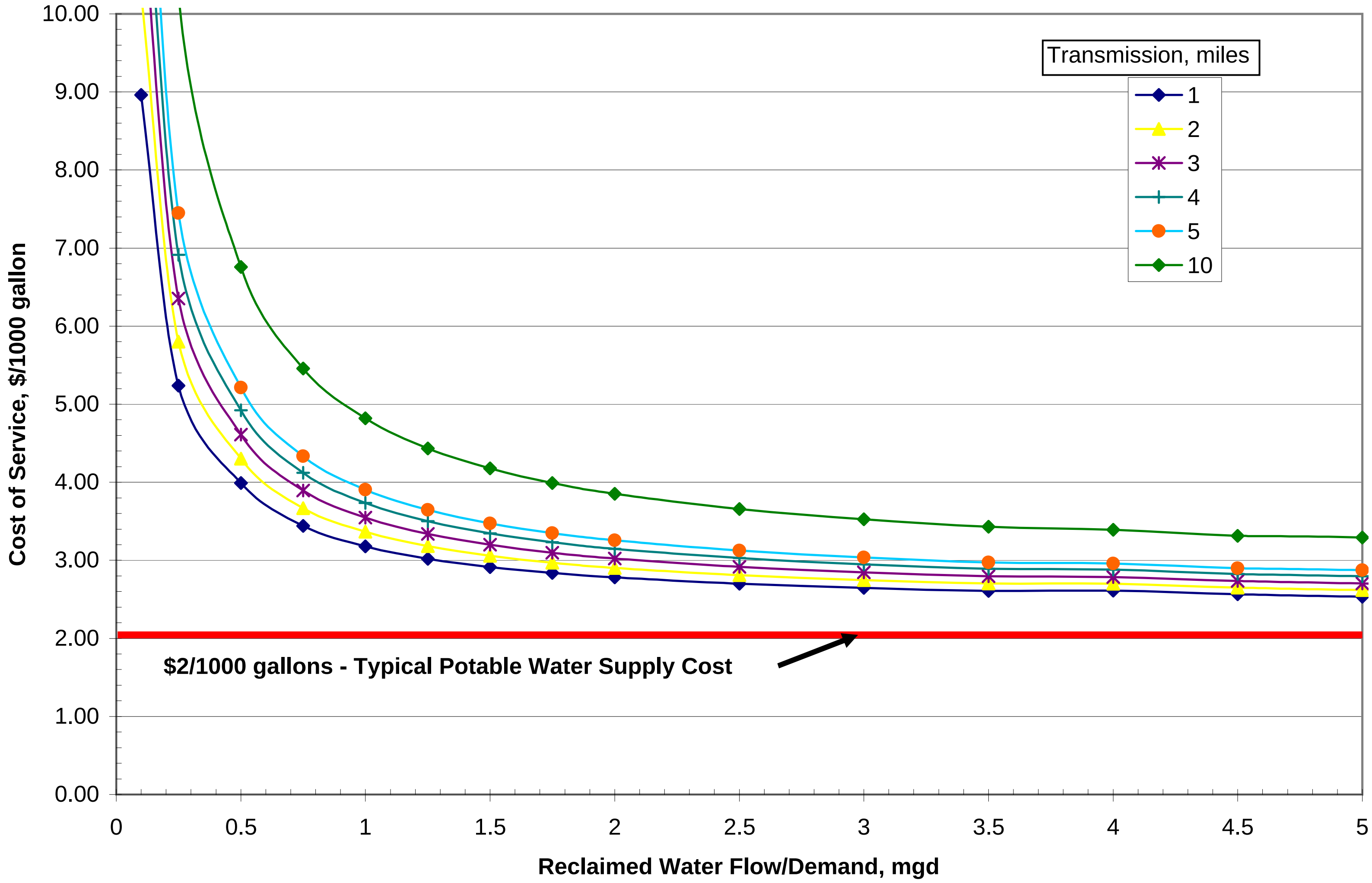


Figure D-6a. Reclaimed Water System Cost of Service for 0-5 mgd Capacity Urban Area - Tertiary 4 with UV

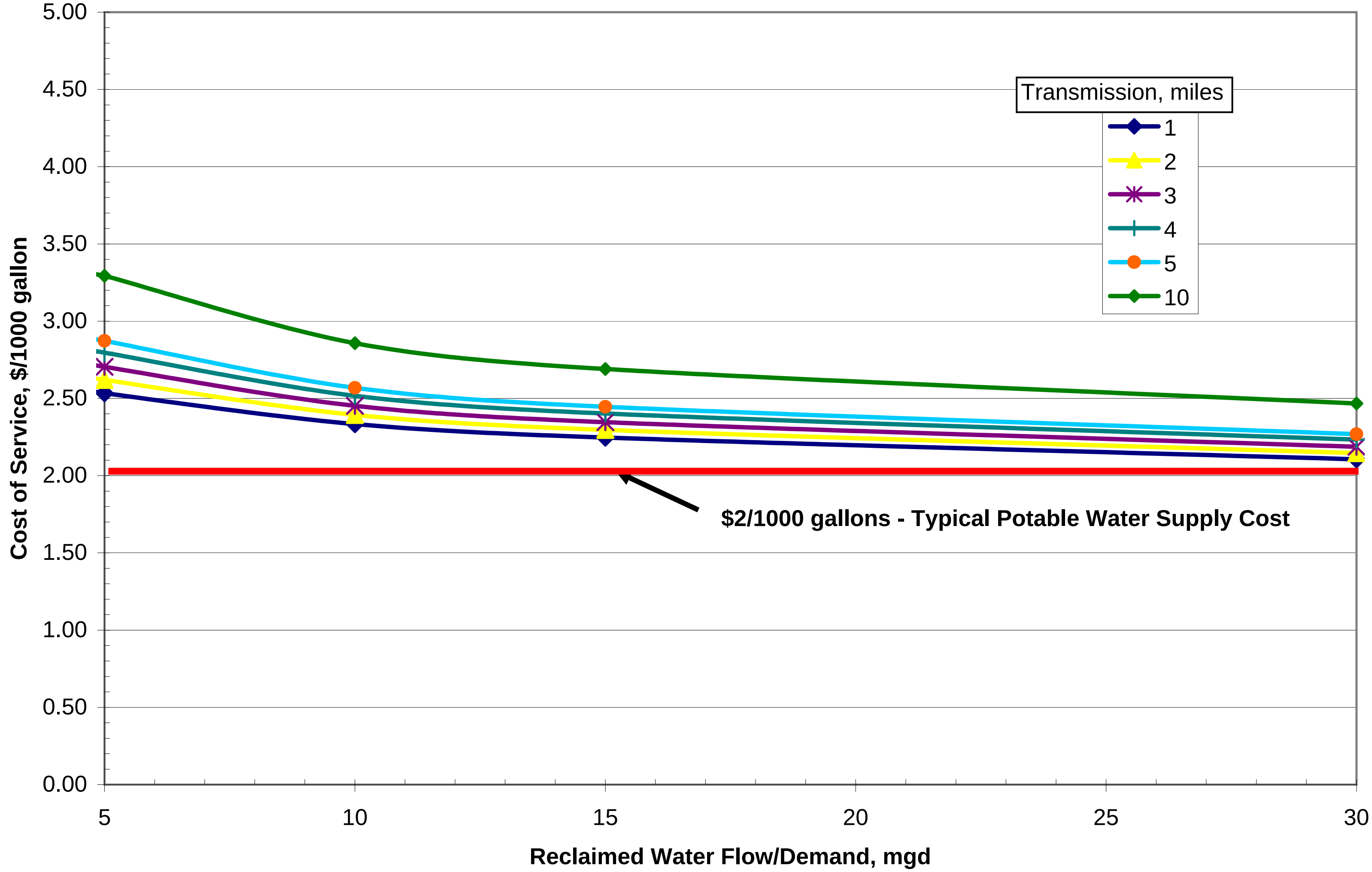
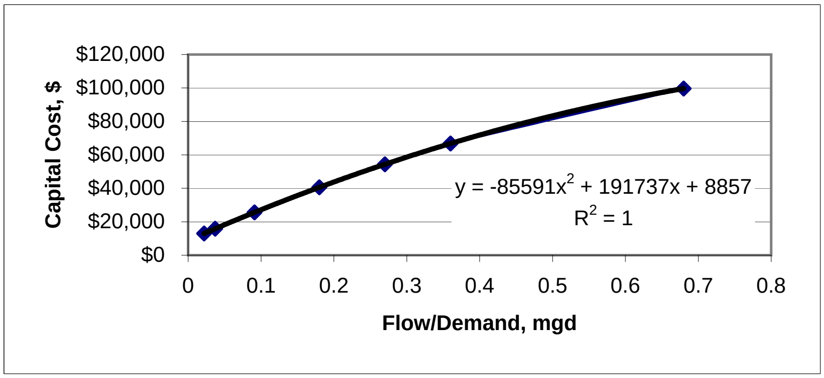


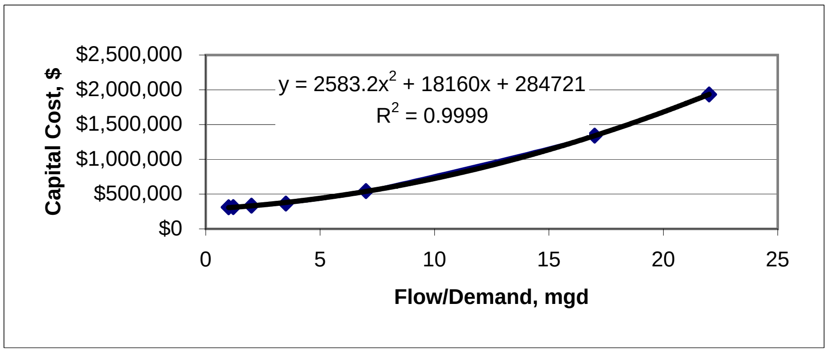
Figure D-6b. Reclaimed Water System Cost of Service for 5-30 mgd Capacity Urban Area - Tertiary 4 with UV

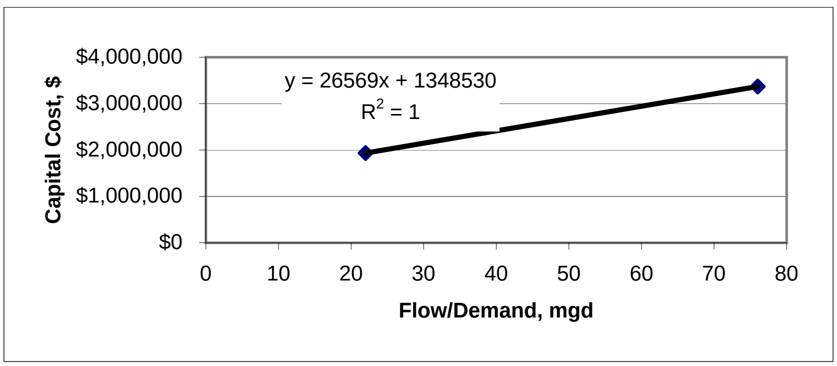
Cost Curves as Basis for Tertiary 4 - Ultraviolet Radiation*

Capital Cost

Design Flow (mgd)	Capital Cost ($)
0.0001	$10,195
0.007	$10,195
0.022	$13,034
0.037	$15,834
0.091	$25,596
0.18	$40,597
0.27	$54,386
0.36	$66,790
0.68	$99,661
1	$310,154
1.2	$313,662
2	$333,331
3.5	$362,965
7	$544,728
17	$1,342,022
22	$1,933,041
76	$3,367,751
210	$8,074,450
430	$15,798,603
520	$18,601,681
1,500.00	$49,124,085







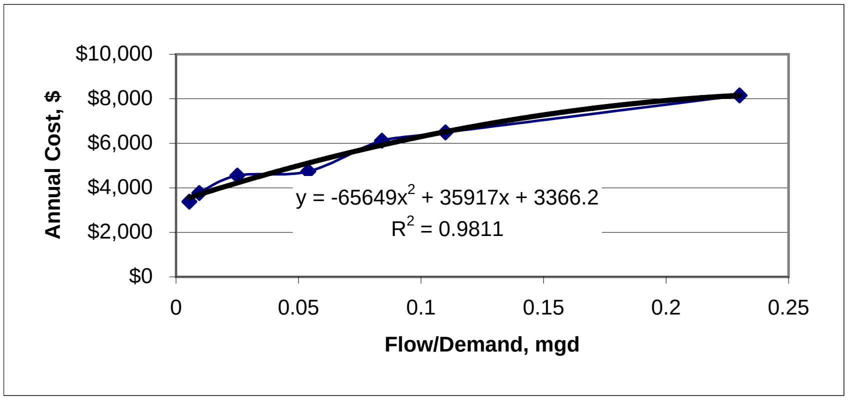
Curve fit equations			
CCI Index	**1.16**		
Avg Flow Range	0.005-0.35	0.35-11	11-38
Design Flow Range	0.022-0.99	1-22	22-76
Design/Avg Flow Ratio	2		

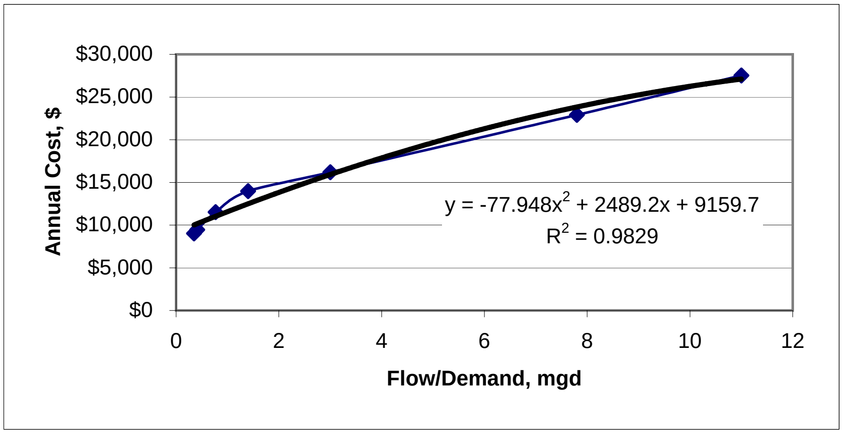
*Source: Environmental Protection Agency (EPA), 2005. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

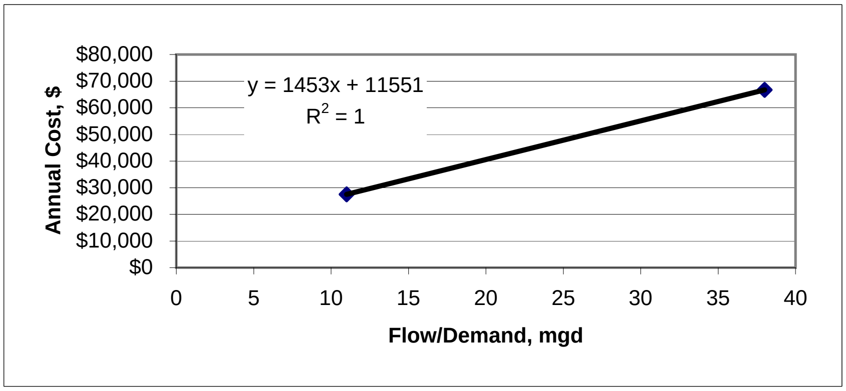
Cost Curves as Basis for Tertiary 4 - Ultraviolet Radiation*

O&M Cost

Design Flow (mgd)	O&M Cost ($)
0.00005	$3,350
0.0015	$3,350
0.0054	$3,380
0.0095	$3,769
0.025	$4,549
0.054	$4,736
0.084	$6,115
0.11	$6,493
0.23	$8,152
0.35	$9,016
0.41	$9,450
0.77	$11,512
1.4	$13,979
3	$16,183
7.8	$22,908
11	$27,531
38	$66,755
120	$188,219
270	$422,455
350	$551,123
750	$1,194,464

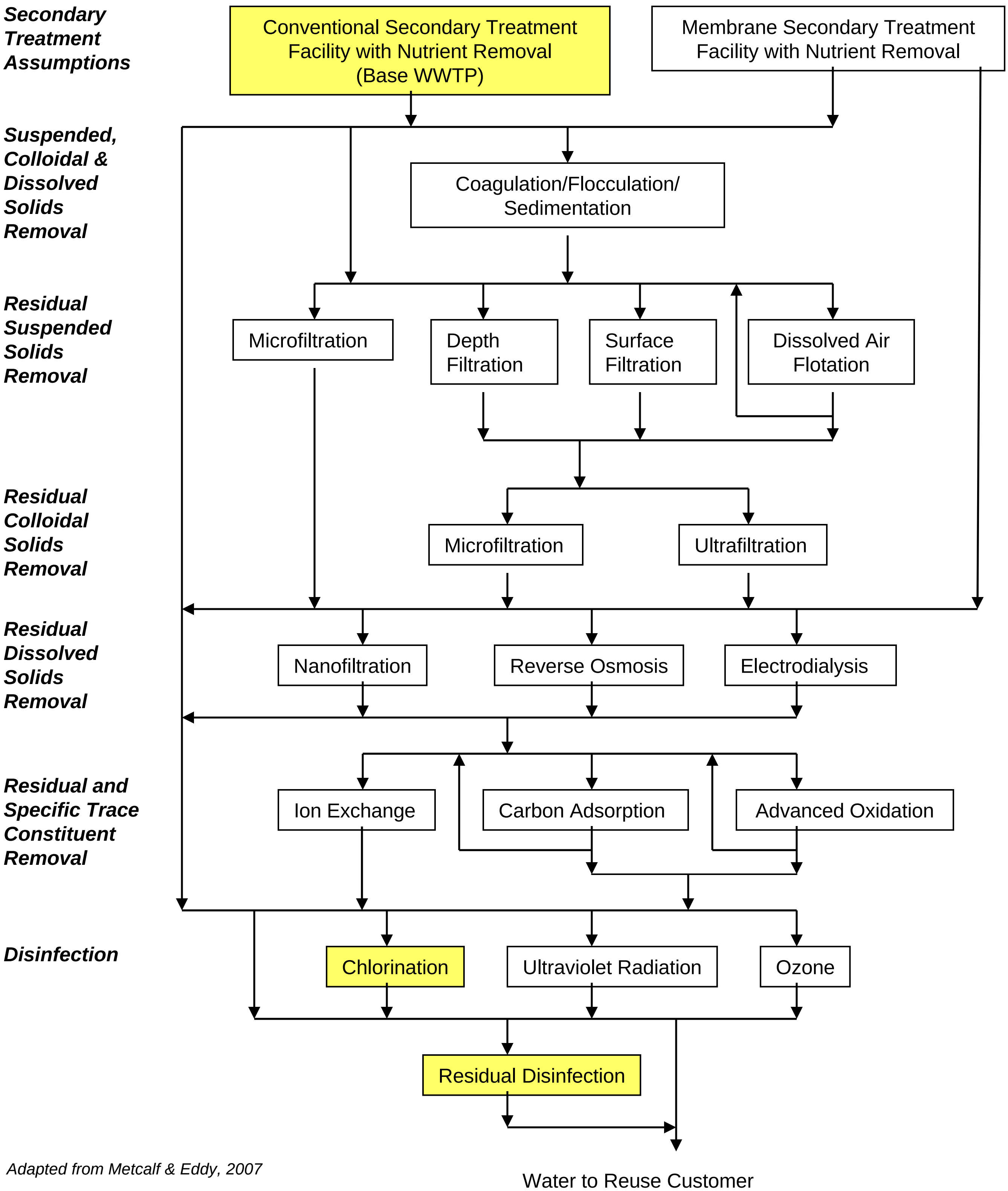






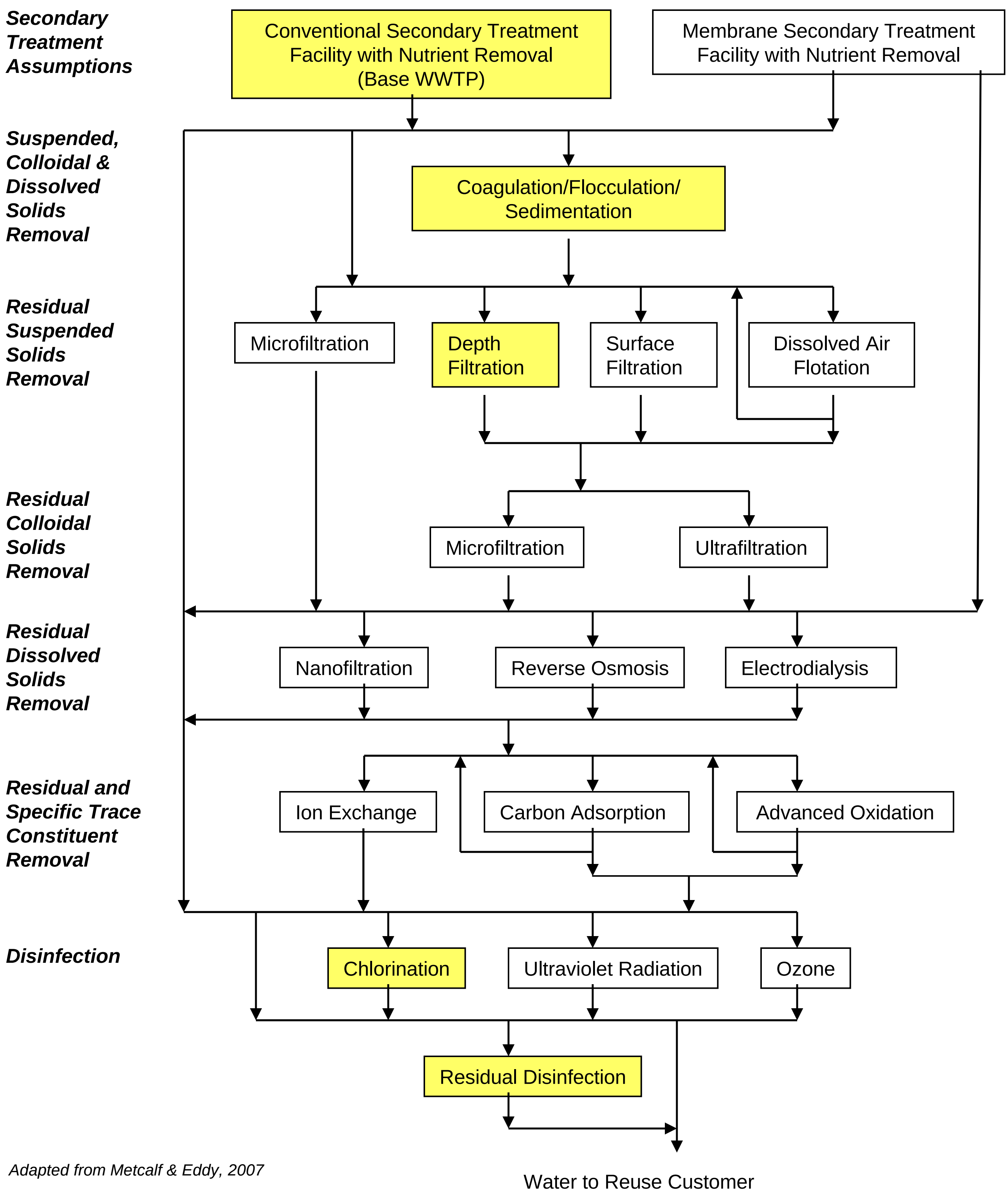
*Source: Environmental Protection Agency (EPA), 2005. Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule. December. EPA 815-R-05-013.

Appendix D-7
Water Reuse Treatment Process Schematics for Reclaimed Water Quality Classifications (Base and Tertiary 1-4)



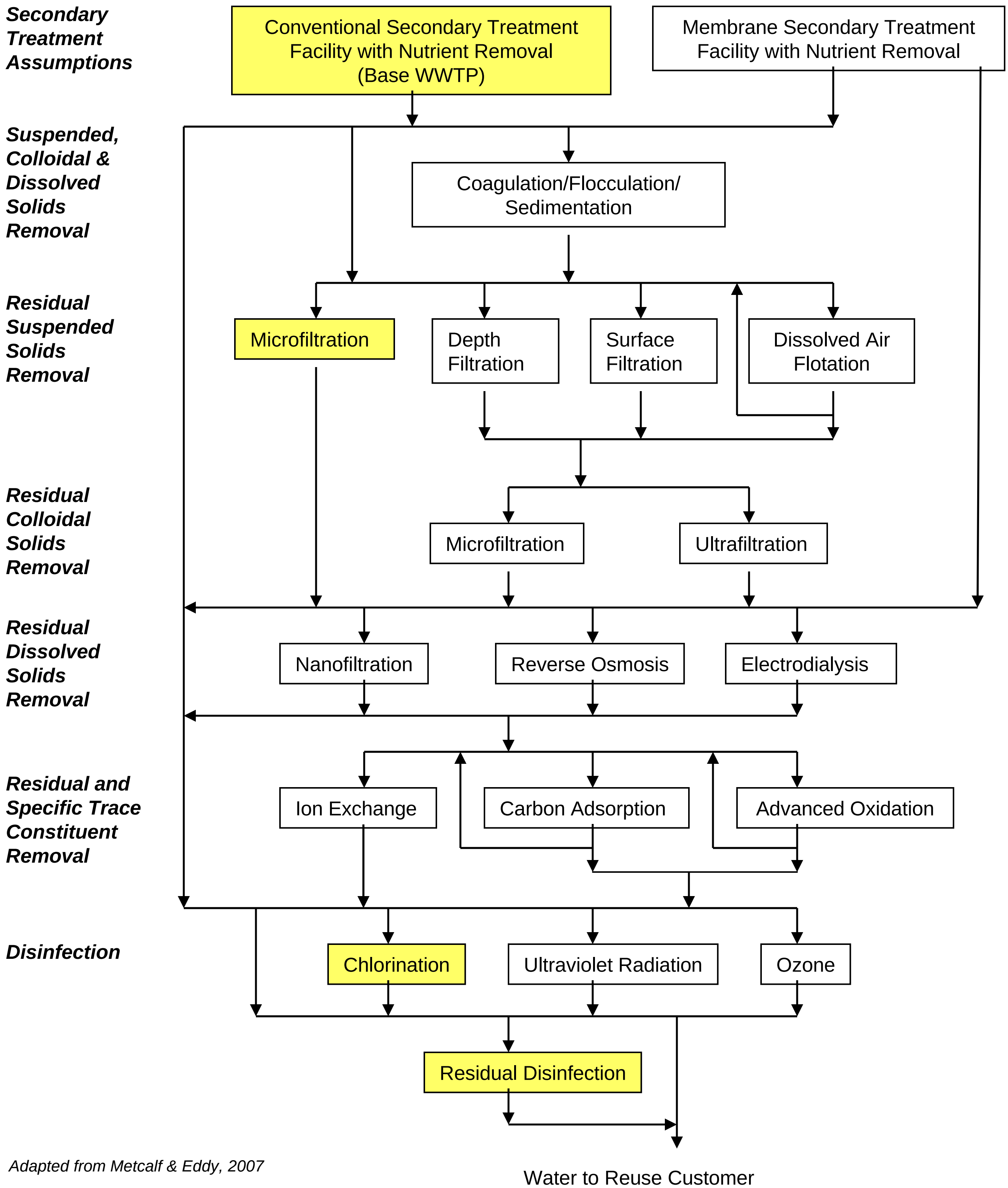
Adapted from Metcalf & Eddy, 2007

Figure D-7a. Base System Treatment Train as Basis of Cost



Adapted from Metcalf & Eddy, 2007

Figure D-7b. Tertiary 1 - Conventional Treatment Train as Basis of Cost



Adapted from Metcalf & Eddy, 2007

Figure D-7c. Tertiary 2 – Membrane Filtration Treatment Train as Basis of Cost

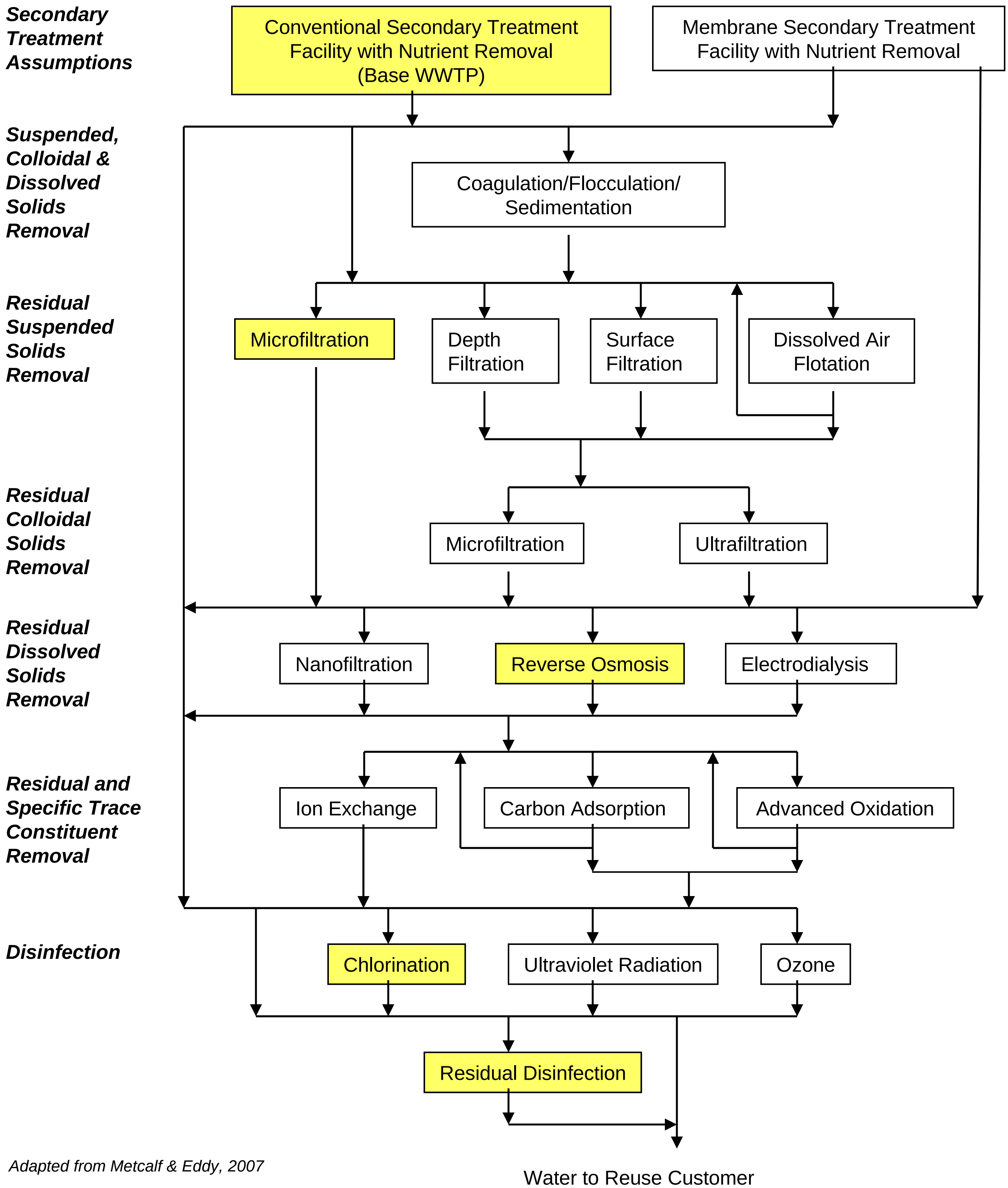
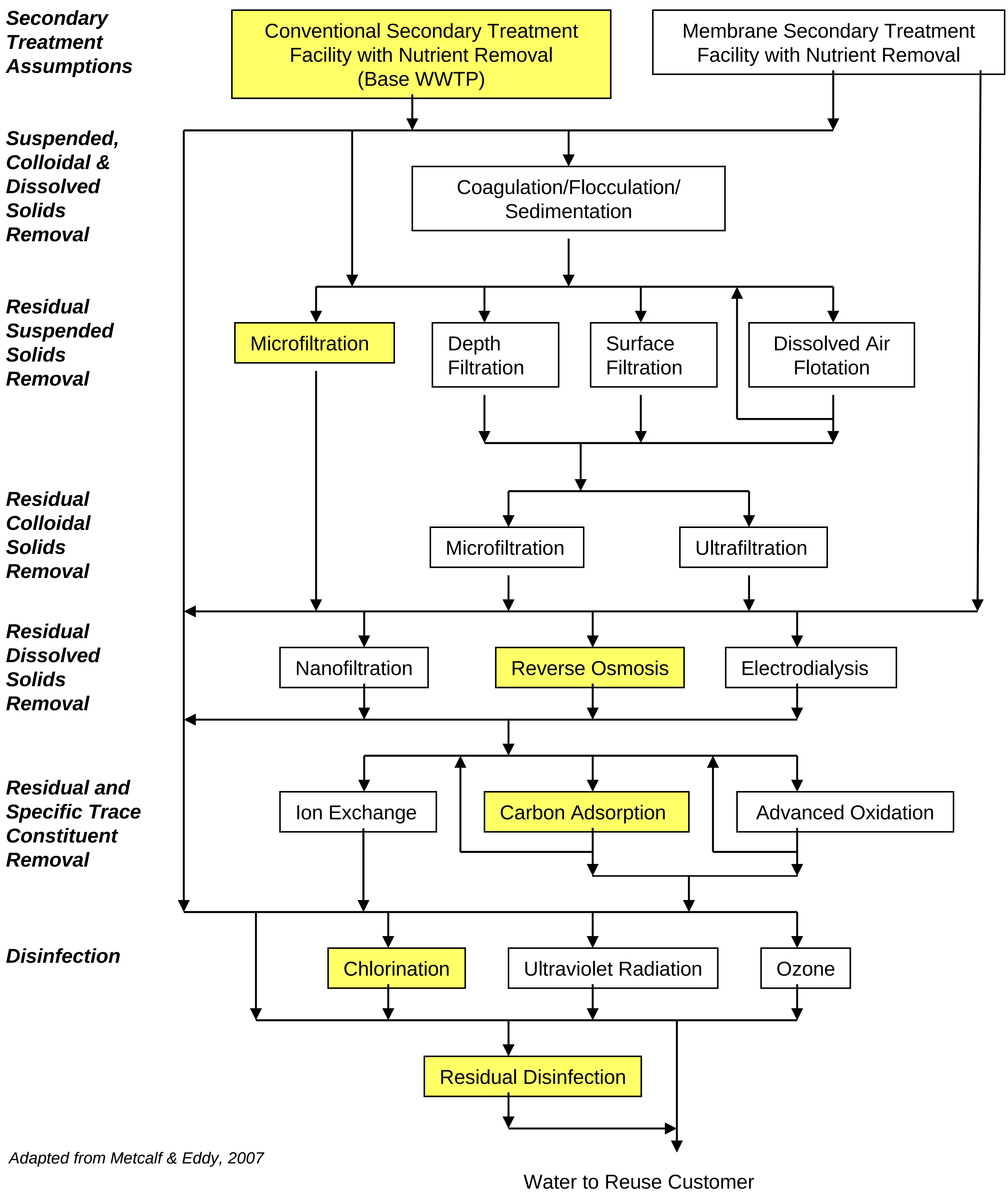
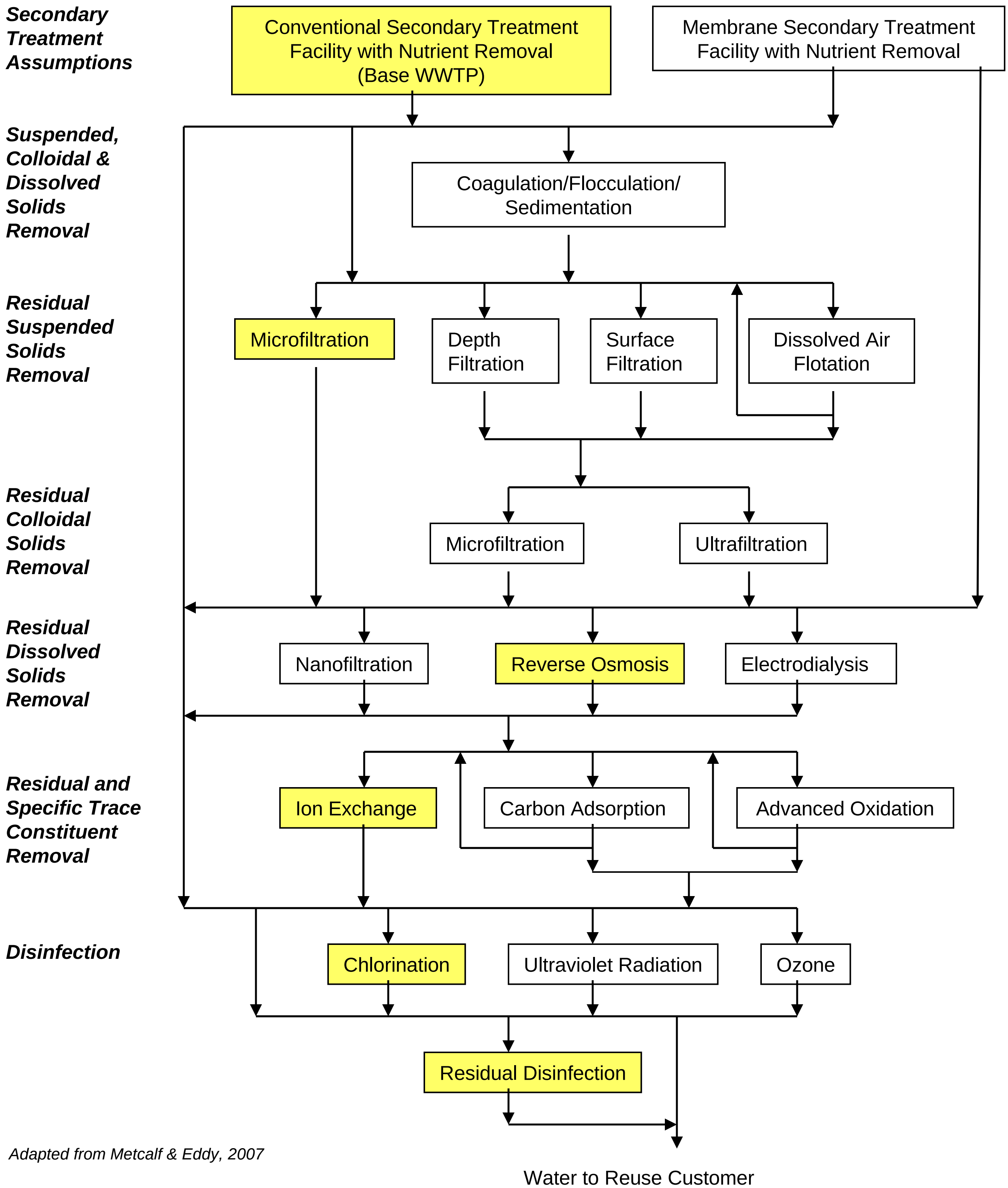


Figure D-7d. Tertiary 3 – Membrane Softening Treatment Train as Basis of Cost



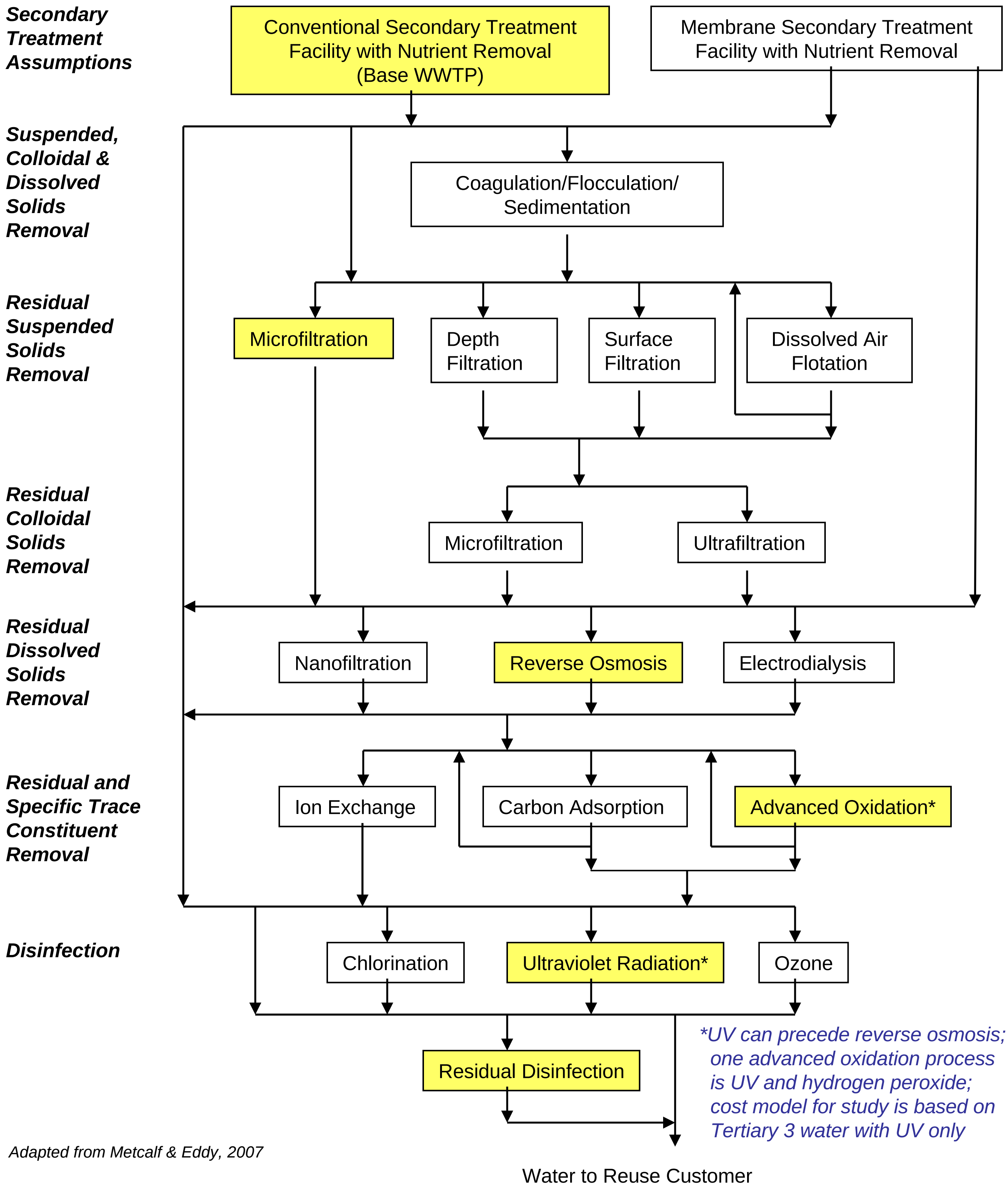
Adapted from Metcalf & Eddy, 2007

Figure D-7e. Tertiary 4 – Advanced with GAC Treatment Train as Basis of Cost



Adapted from Metcalf & Eddy, 2007

Figure D-7f. Tertiary 4 – Advanced with Ion Exchange Treatment Train as Basis of Cost



Adapted from Metcalf & Eddy, 2007

Figure D-7g. Tertiary 4 – Advanced with UV Treatment Train as Basis of Cost

Metropolitan Council

Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR05-07d

MCES Project Number 070186

TECHNICAL MEMORANDUM 4

Wastewater Treatment Plant Effluent Quality

June 30, 2007

Craddock Consulting Engineers

In Association with

CDM and James Crook

1.0 Introduction

This technical memorandum is the fourth in a series of memoranda developed under a Metropolitan Council (Council) project titled "Recycling Treated Municipal Wastewater for Industrial Water Use." Funding for this project was recommended by the Legislative Commission on Minnesota Resources (LCMR) from the Minnesota Environment and Natural Resources Trust Fund. The Met Council is providing additional funding for the project through in-kind contributions of staff time. Other state agencies are participating via stakeholder meetings and technical review and input.

Objective

This memorandum summarizes the effluent quality of wastewater treatment plants (WWTPs) in Minnesota. The purpose of the WWTP effluent quality analysis is to assess the applicability of WWTP effluent as a water source for industries in Minnesota. The constituents evaluated serve as indicators of the level of treatment provided by a WWTP and depending on the industrial use of the water, as specific water quality parameters of concern.

Constituents of Concern

The analysis focuses on the following constituents: 5-day carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), ammonia (NH_3), total phosphorous (TP), and fecal coliforms. Table 1 lists the constituents evaluated and reasons for concern in industrial water reuse. These constituents are routinely measured in WWTP effluent as part of the National Pollutant Discharge Elimination System (NPDES) Permit requirements.

Table 1. Water Quality Concerns for Industrial Applications

Constituent	Reason for Concern
$CBOD_5$ (indicator of organic content)	Biological fouling, foaming, imparts color or odor, interference with disinfection
TSS	Deposition, clogging, interference with disinfection
Ammonia	Corrosion, interference with disinfection
Phosphorous	Scaling, microbial growth
Fecal Coliforms (indicator organism)	Infectious disease

The water quality constituents listed in Table 1 are only a subset of the constituents industries evaluate to select a water source and possibly treat as part of their routine facility operations. Technical Memoranda 1, 2, and 3 produced for this project provide additional information on the water quality parameters of concern for industrial water use. These five constituents are evaluated in detail because they provide a general indicator of the level of treatment at individual WWTPs and there is a well documented database with a high level of quality control and assurance associated with the database.

2.0 Analysis Background and Results

Data Source

All WWTPs are required to submit discharge monitoring reports in accordance with their NPDES permit. Historic records of WWTP influent and effluent quantity and quality are maintained by the Minnesota Pollution Control Agency (MPCA). These data and the corresponding GIS data were provided by MPCA through the Environmental Data Access system and used in this analysis (MPCA, 2005).

The discharge monitoring report data are entered into the Environmental Data Access system as reported by the municipality. Information can be incorrectly listed on the monitoring reports by the municipality (i.e. misplacement of a decimal point is a common error). These "incorrect" values are not identified or changed unless the municipality contacts the MPCA with revised values or if the reported values exceed permitted limits and MPCA takes enforcement action and inquires about the exceedance. For this study, all data are presented as contained in the database.

Data Analysis Methods

Monthly discharge data were summarized as annual average flows and concentration to perform statistical analyses. The 2005 water quality data were linked to the WWTPs location shapefile and maps were generated to characterize the average annual effluent quality of Minnesota's municipal WWTPs. A summary of the data analysis is presented below. Appendix A presents the detailed data analysis methods.

The constituents of concern evaluated in this study are not monitored in the effluent of all facilities. This study identifies a constituent as "not measured" if it is not monitored at these facilities. The term "not measured" is also used to designate missing data for a specific constituent at an individual WWTP, but this is a rare occurrence.

Results

$CBOD_5$

The organic concentration in the water supply needs to be kept at a minimum for most industrial water uses. Organic matter provides a food source for microbial growth which can lead to biological fouling and related scaling problems. Consumption of oxygen and reduced oxygen levels could be a concern for some industries. Also disinfection processes are less stable with higher organic concentrations. Several states with water reuse regulations require reclaimed water to meet a $CBOD_5$ limit of 20 mg/L for various uses. $CBOD_5$, or related parameters such as BOD_5 or TOC, are constituents routinely tested in WWTP effluent, with $CBOD_5$ the most common one for Minnesota's WWTPs. Higher effluent $CBOD_5$ concentrations are often indicative of facilities with lower levels of treatment or possibly facilities that are operating at the capacity limit and are not achieving the performance expected for critical treatment processes.

Figure 1 presents the frequency of occurrence of $CBOD_5$ concentration in the effluent of all Minnesota WWTPs in 2005. Similar information is shown in Figure 2 for facilities with design capacities greater than 1 mgd, defined as larger facilities for this technical memorandum. The variability of effluent $CBOD_5$ is also characterized for the following ranges: < 5 mg/L, 5-10 mg/L, 10-20 mg/L, and >20 mg/L.

The average WWTP effluent $CBOD_5$ concentrations are depicted by location and facility capacity in Figure 3. As shown and further detailed in Figures 4-7, a high percentage of Minnesota facilities produce a high quality effluent in terms of organic concentration. There were 252 facilities with $CBOD_5$ concentrations less than 5 mg/L, accounting for over 600 mgd of the total WWTP design capacity in the state. A similar number of facilities, with a combined design capacity of nearly 140 mgd, produced effluent with $CBOD_5$ in the 5-20 mg/L range. Only 16 facilities in Minnesota produced an effluent with an annual average $CBOD_5$ greater than 20 mg/L. The remaining facilities did not measure $CBOD_5$ in 2005.

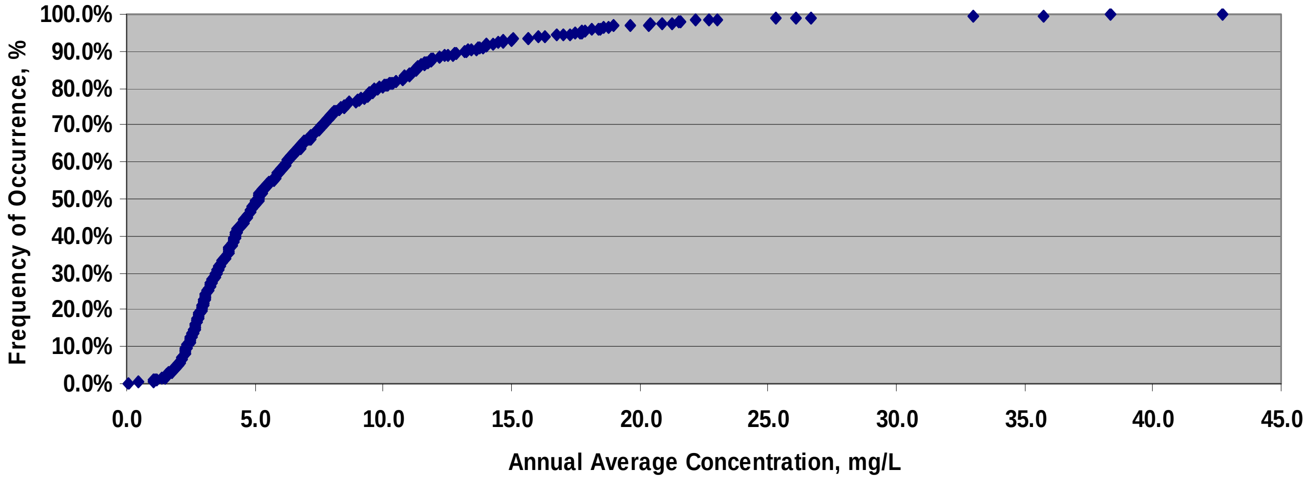


Figure 1. Effluent $CBOD_5$ of Municipal WWTPs in Minnesota

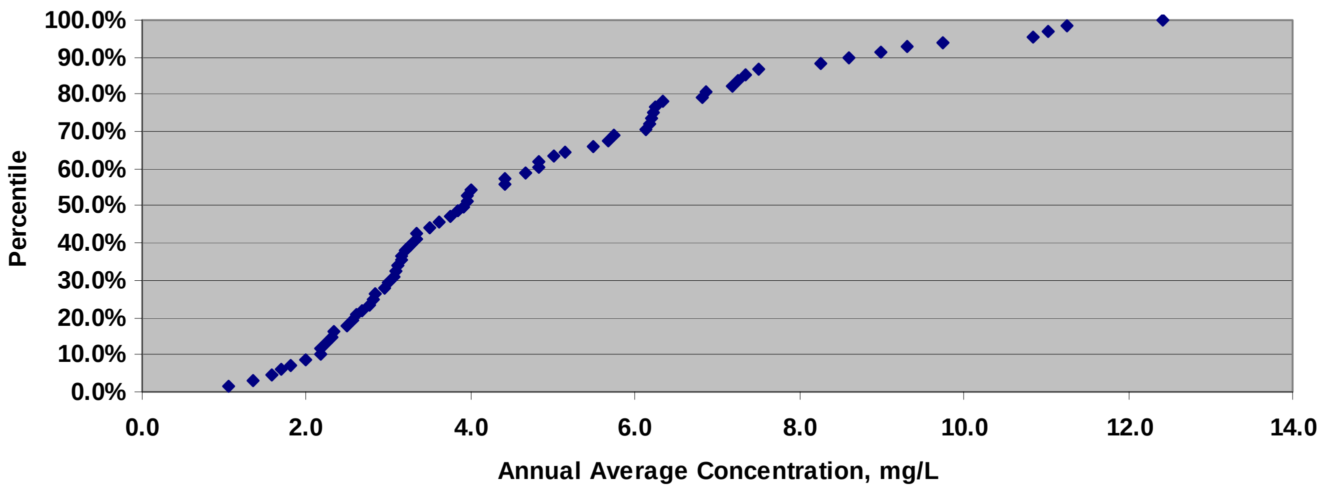
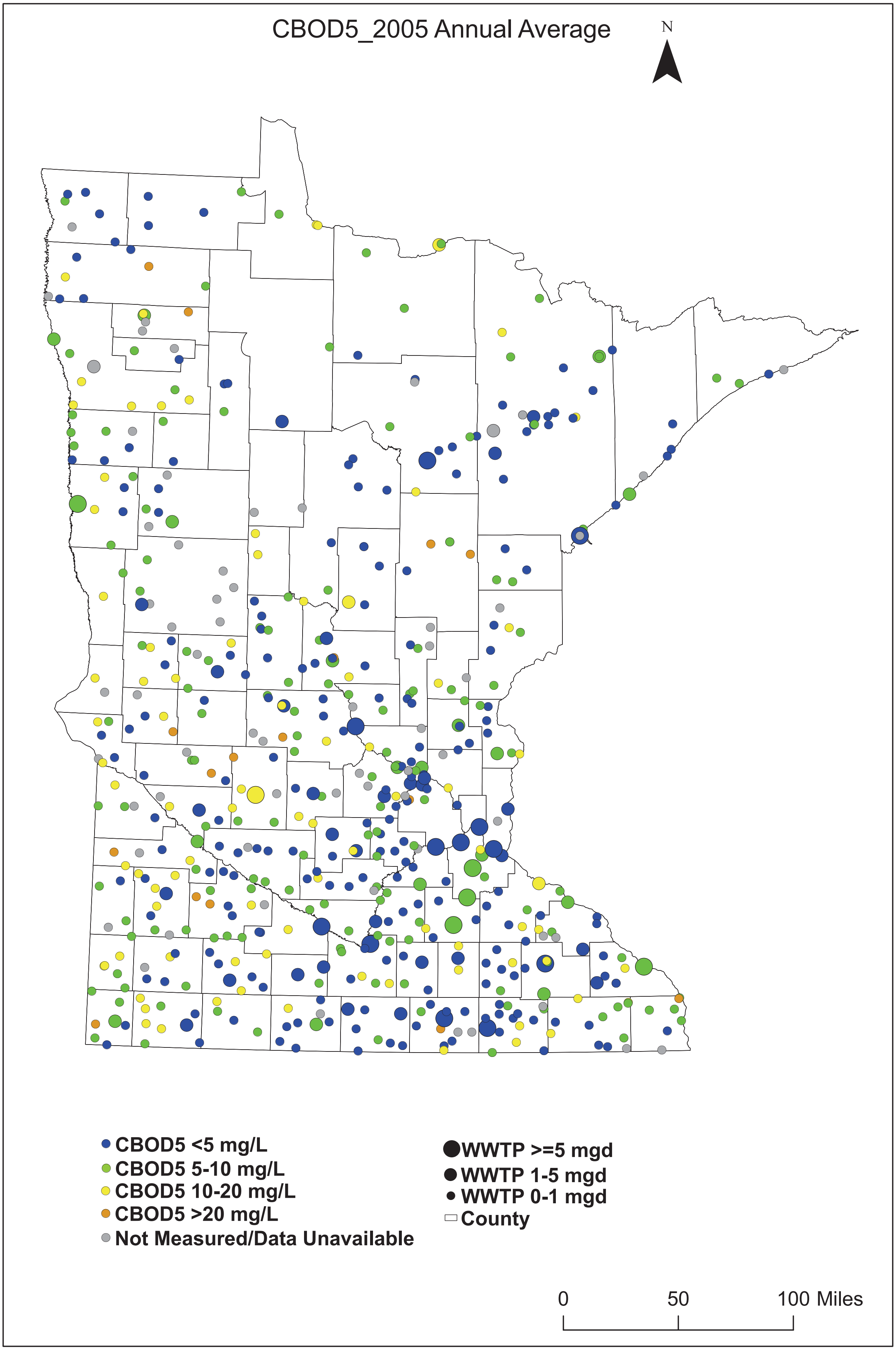


Figure 2. Effluent $CBOD_5$ of Municipal WWTPs Greater than 1 mgd in Minnesota

Figure 3. Effluent CBOD5 of Municipal WWTPs in Minnesota



Source: Discharge Monitoring Reports, MPCA, 2005.

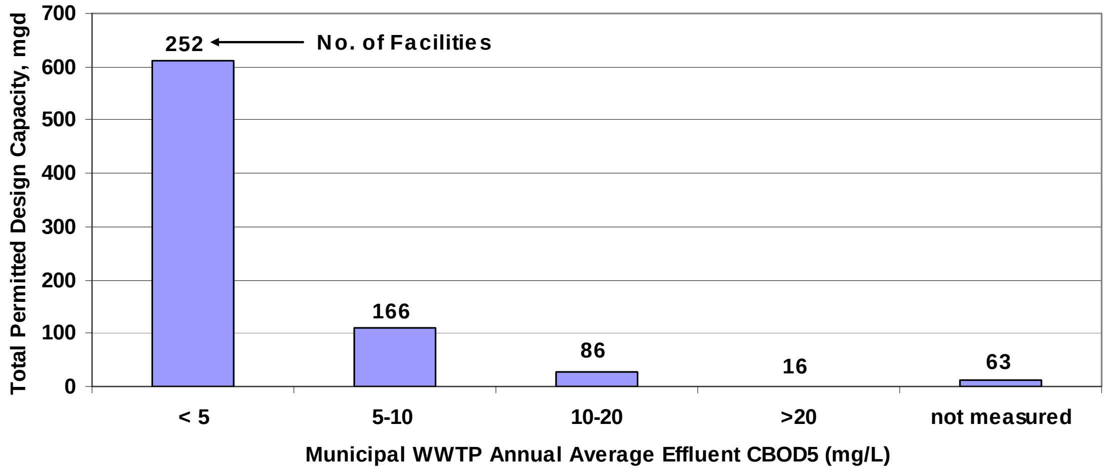


Figure 4. Annual Average Effluent $CBOD_5$, Capacity, and Number of Municipal WWTPs in Minnesota

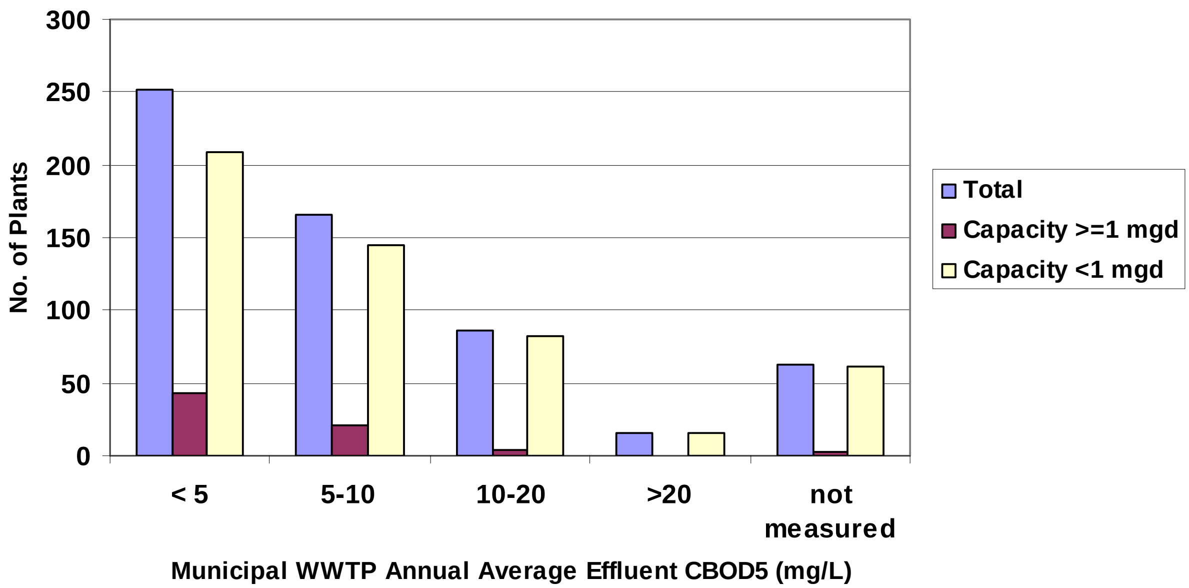


Figure 5. Annual Average Effluent $CBOD_5$ and Number of Municipal WWTPs in Minnesota

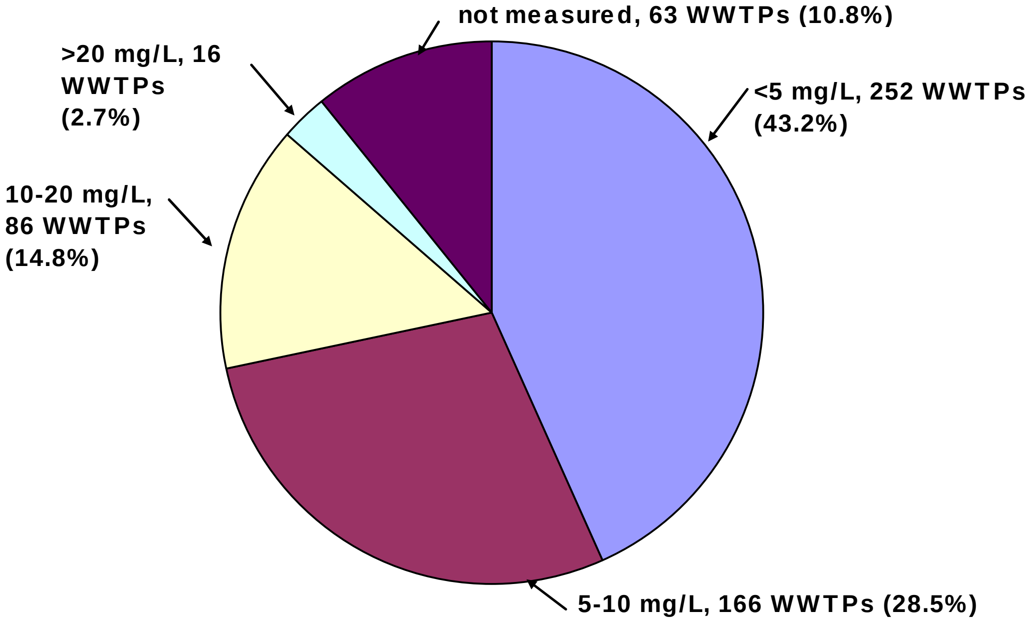


Figure 6. Effluent $CBOD_5$ and Number of Municipal WWTPs in Minnesota

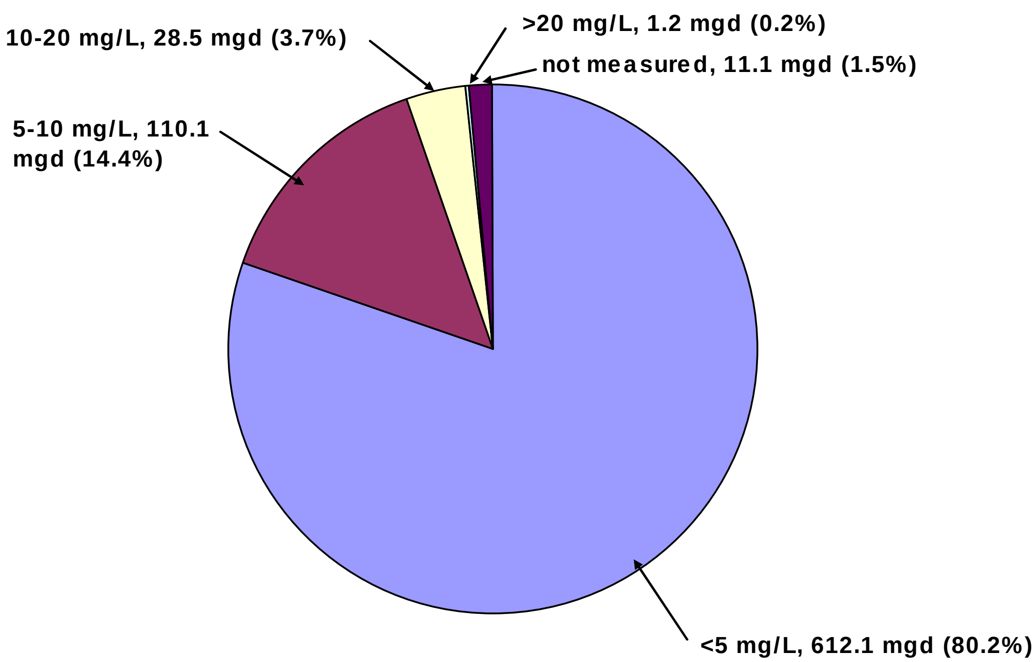


Figure 7. Effluent $CBOD_5$ and Combined Capacity of Municipal WWTPs in Minnesota

TSS

Total suspended solids (TSS) is a gross measure of the amount of particulate in the water. In wastewater, it is typically sand, silt, clay, organic matter, including microorganisms. Elevated TSS levels can create deposition and clogging problems for industrial applications. Particulate matter can also interfere with disinfection and other processes such as reverse osmosis. Several states with water reuse regulations require reclaimed water to meet a TSS limit of 30 mg/L for various uses.

Figure 8 presents the frequency of occurrence of TSS concentration in the effluent of all Minnesota WWTPs in 2005. Similar information is shown in Figure 9 for facilities with design capacities greater than 1 mgd. The variability of effluent TSS is also characterized for the following ranges: < 5 mg/L, 5-10 mg/L, 10-20 mg/L, and >20 mg/L.

The average annual WWTP effluent TSS concentrations are depicted by location and facility capacity in Figure 10 and further detailed in Figures 11-14. There were 100 facilities with less than 5 mg/L of TSS. Those facilities have a combined design capacity of 380 mgd, which is 50% of the total combined capacity of all WWTPs in Minnesota. Over 300 WWTPs, with a combined capacity of nearly 300 mgd, produce an effluent with TSS concentrations in the 5-20 mg/L. Over 100 facilities have effluent TSS concentrations greater than 20 mg/L.

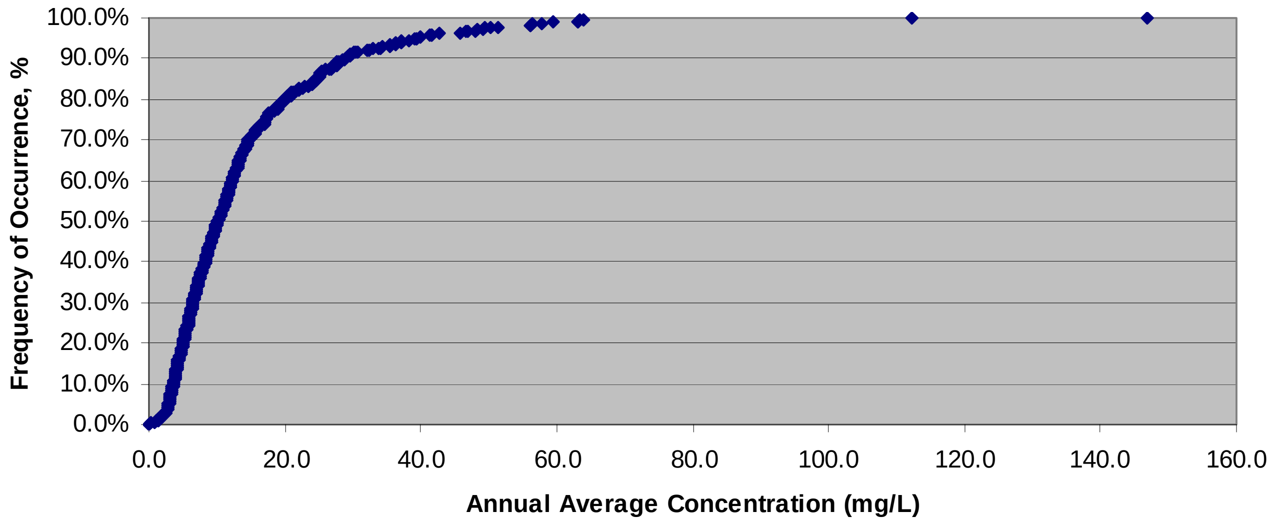


Figure 8. Effluent TSS of Municipal WWTPs in Minnesota

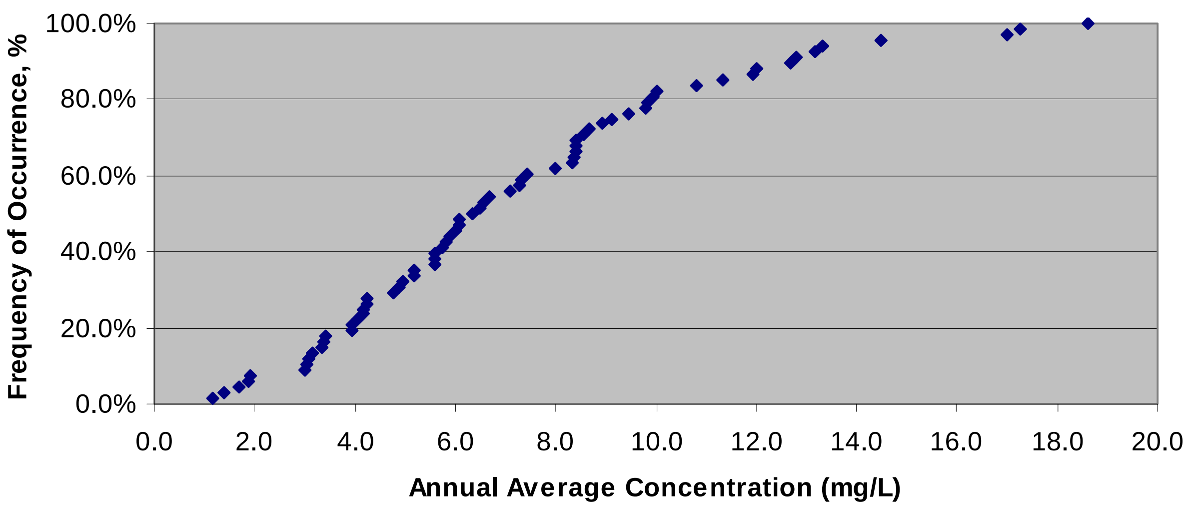
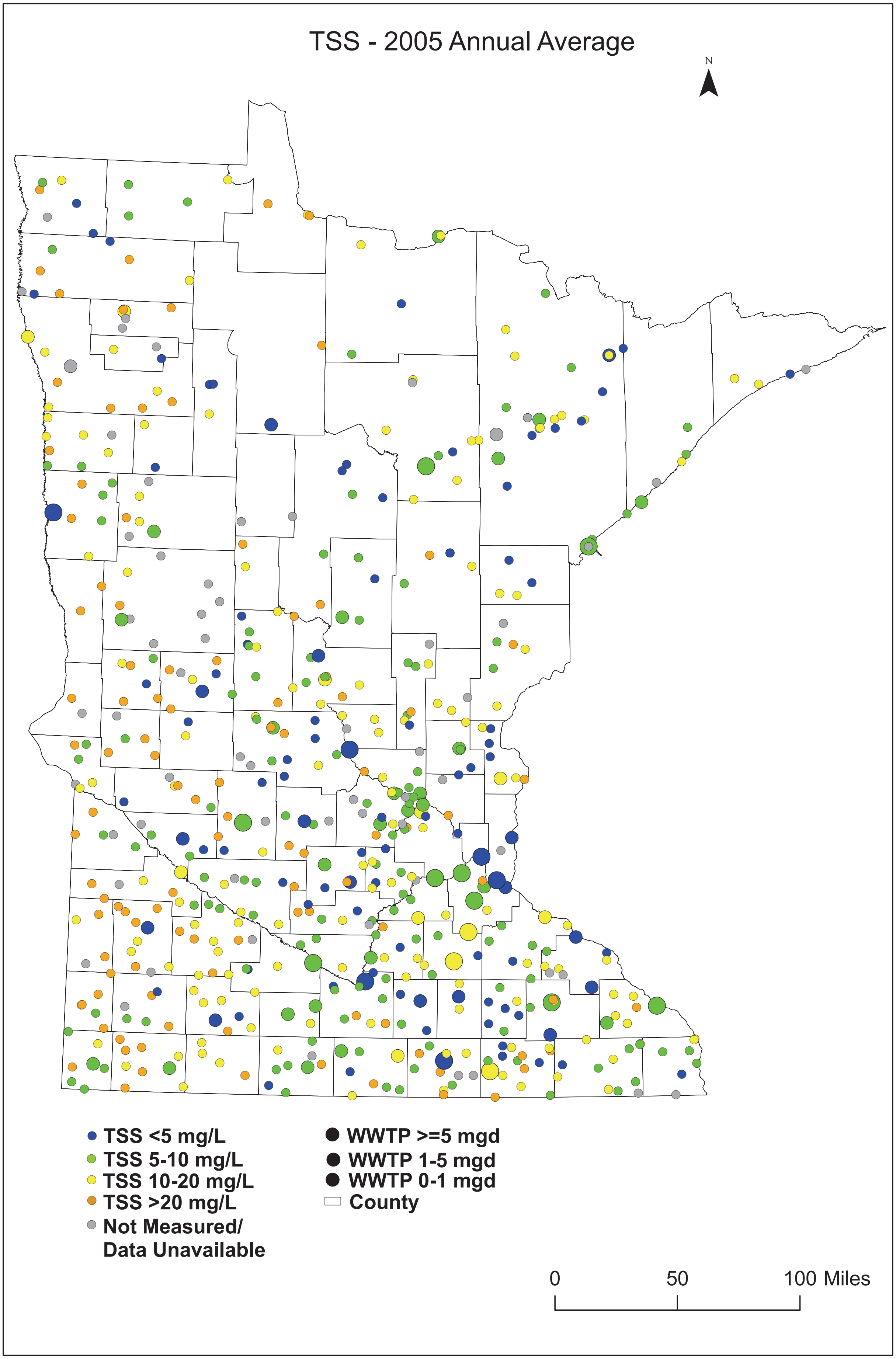


Figure 9. Effluent TSS of Municipal WWTPs Greater than 1 mgd in Minnesota

Figure 10. Effluent TSS of Municipal WWTPs in Minnesota



Source: Discharge Monitoring Reports, MPCA, 2005.

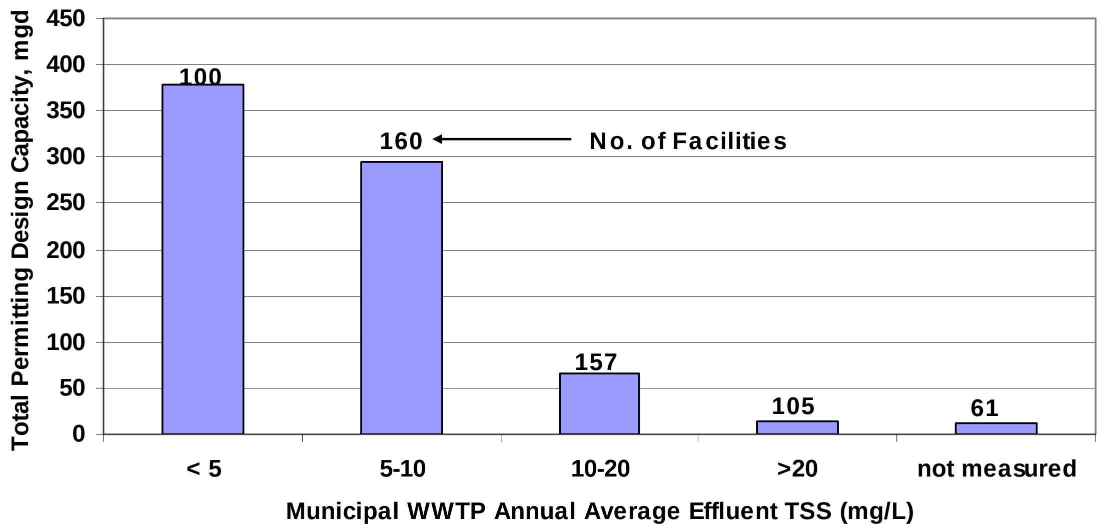


Figure 11. Annual Average Effluent TSS, Capacity, and Number of Municipal WWTPs in Minnesota

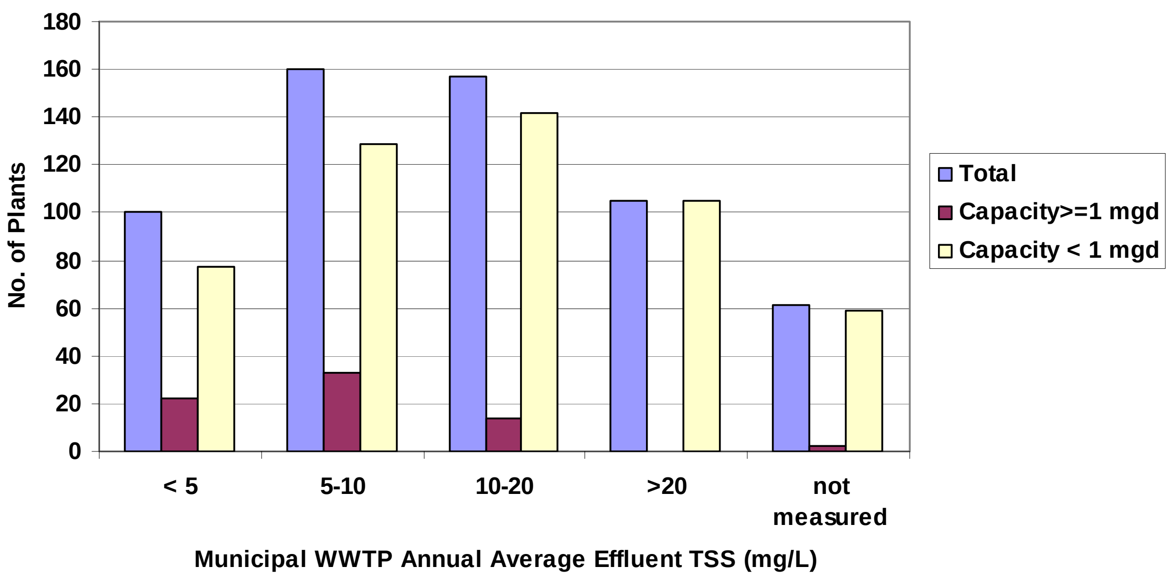


Figure 12. Annual Average Effluent TSS and Number of Municipal WWTPs in Minnesota

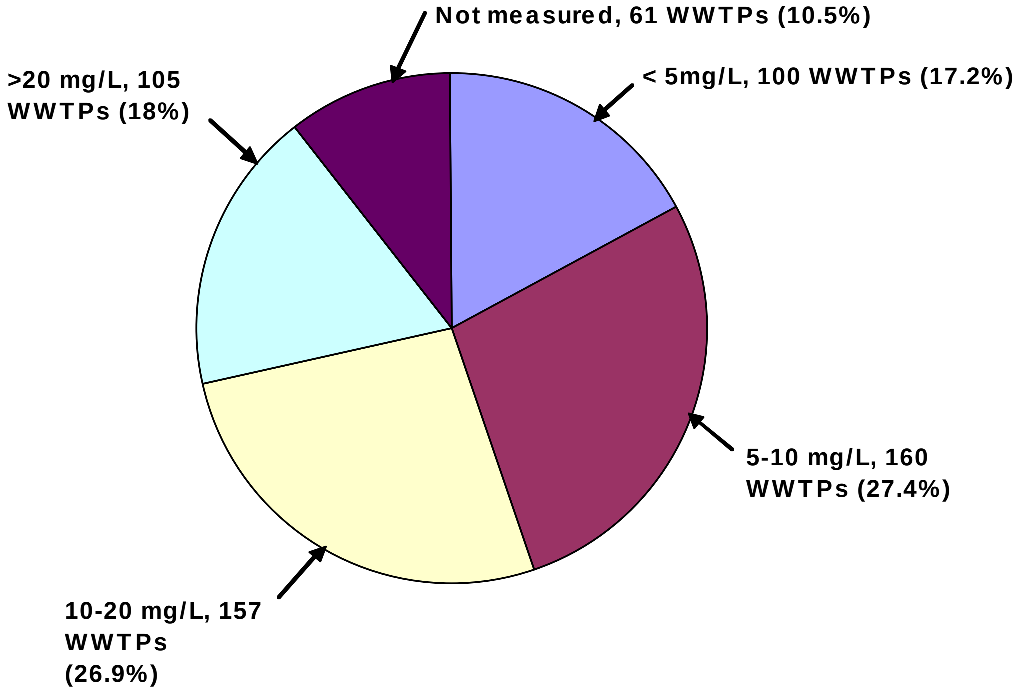


Figure 13. Effluent TSS and Number of Municipal WWTPs in Minnesota

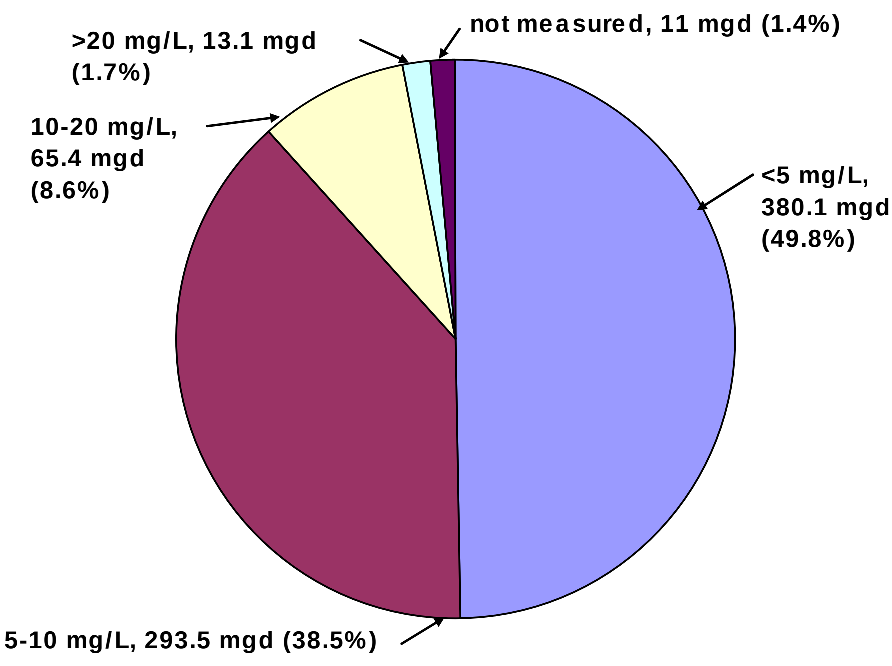


Figure 14. Effluent TSS and Combined Capacity of Municipal WWTPs in Minnesota

Total Phosphorous (TP)

Elevated phosphorus concentrations together with high residual organic constituents in reclaimed water can cause biological fouling and scaling in industrial water systems.

Figure 15 presents the frequency of occurrence of TP concentration in the effluent of all Minnesota WWTPs. Similar information is shown in Figure 16 for WWTPs with design capacities greater than 1 mgd. The variability of effluent TP is also characterized for the following ranges: < 1 mg/L, 1-5 mg/L, and >5 mg/L.

The average WWTP effluent TP concentrations are depicted by location and facility capacity in Figure 17 and further detailed in Figures 18-21. Over 25% of the WWTPs, corresponding to more than 60% of the WWTP capacity, have phosphorus treatment removal processes, indicative of those facilities with effluent concentrations less than 1 mg/L. The majority of the facilities have effluent TP concentrations between 1-5 mg/L. There were 35 facilities with effluent TP greater than 5 mg/L. Those facilities have a combined design capacity of 63 mgd. The remaining facilities did not measure TP in 2005.

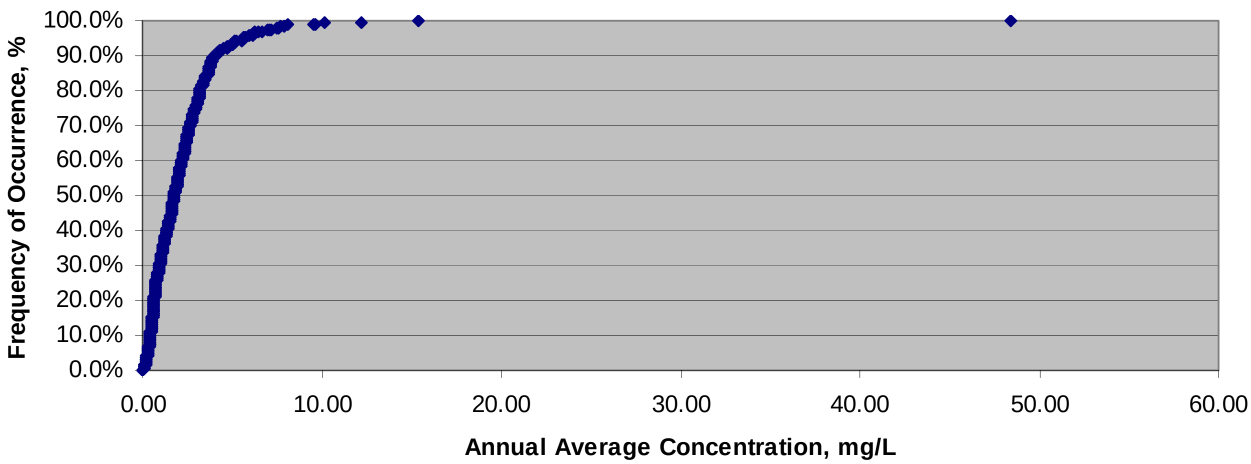


Figure 15. Effluent Total Phosphorous of Municipal WWTPs in Minnesota

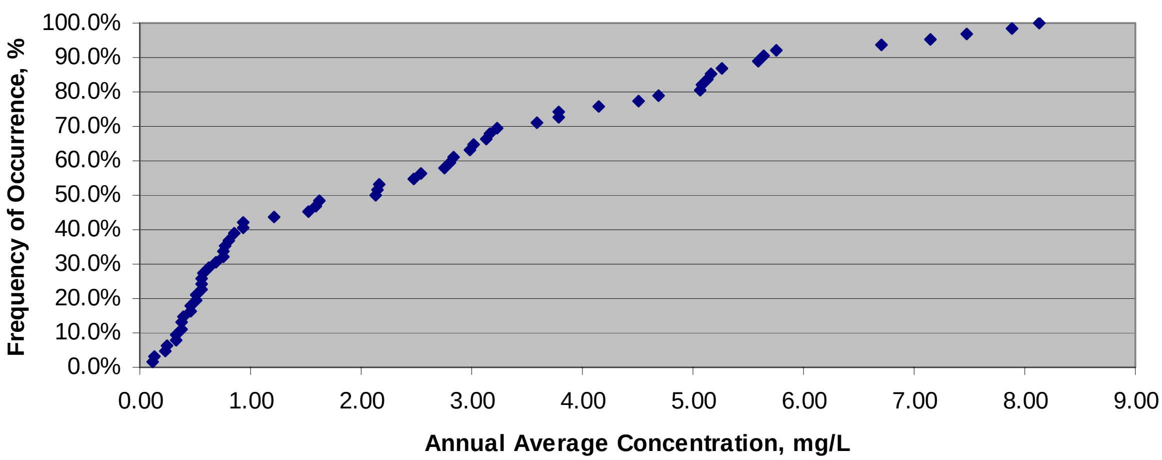
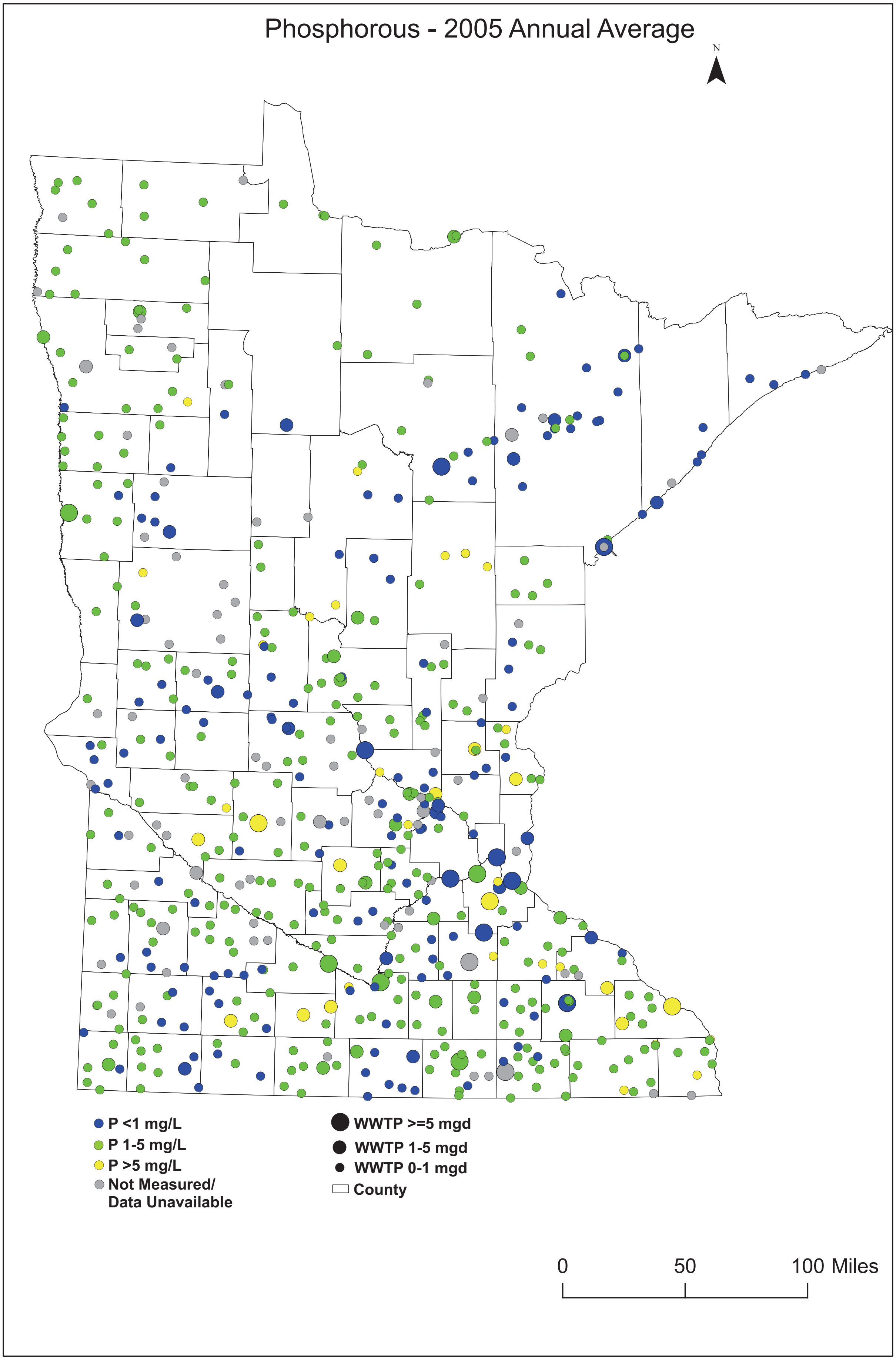


Figure 16. Effluent Total Phosphorous of Municipal WWTPs Greater than 1 mgd in Minnesota

Figure 17. Effluent Total Phosphorous of Municipal WWTPs in Minnesota



Source: Discharge Monitoring Reports, MPCA, 2005

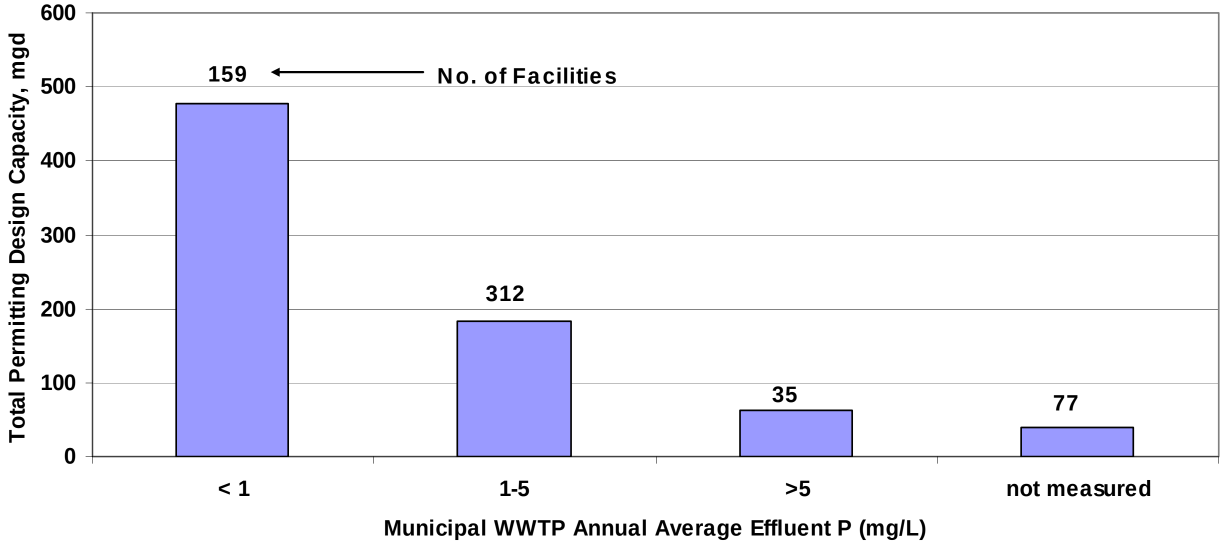


Figure 18. Annual Average Effluent Total P, Capacity, and Number of Municipal WWTPs in Minnesota

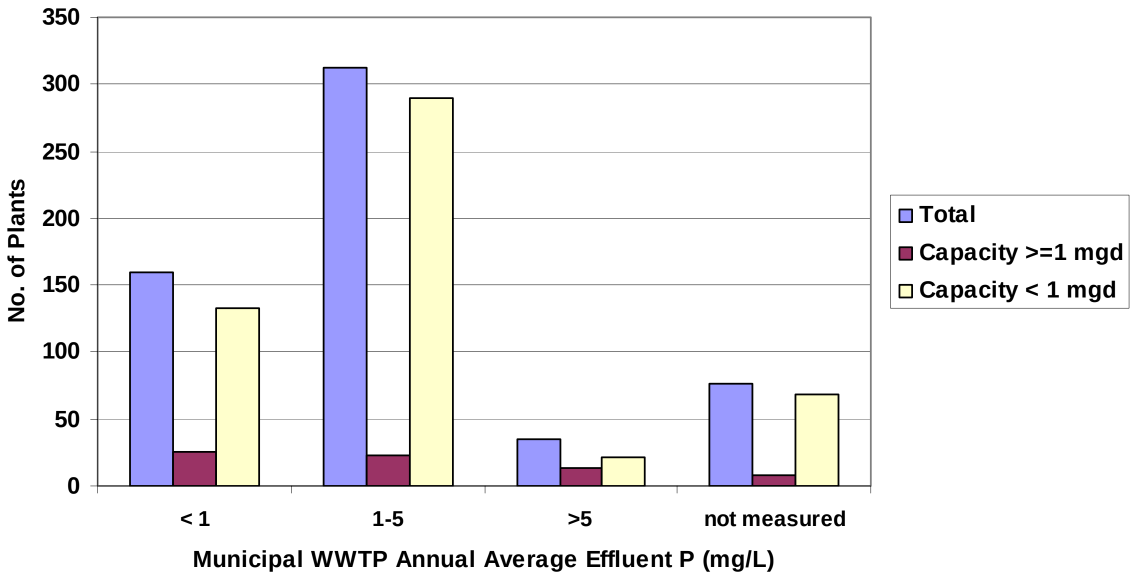


Figure 19. Annual Average Effluent Total P and Number of Municipal WWTPs in Minnesota

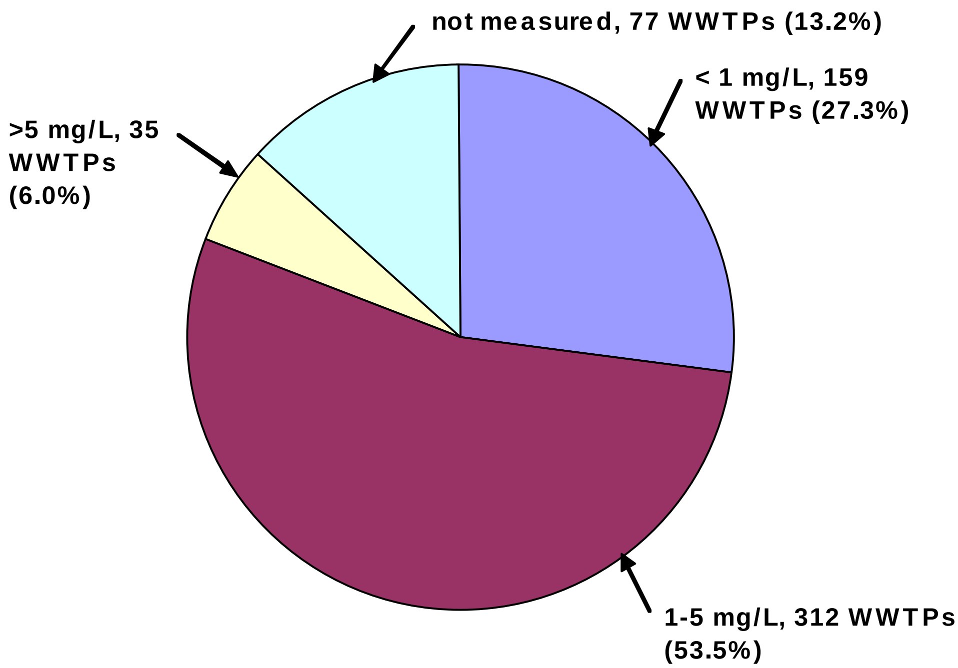


Figure 20. Effluent Total P and Number of Municipal WWTPs in Minnesota

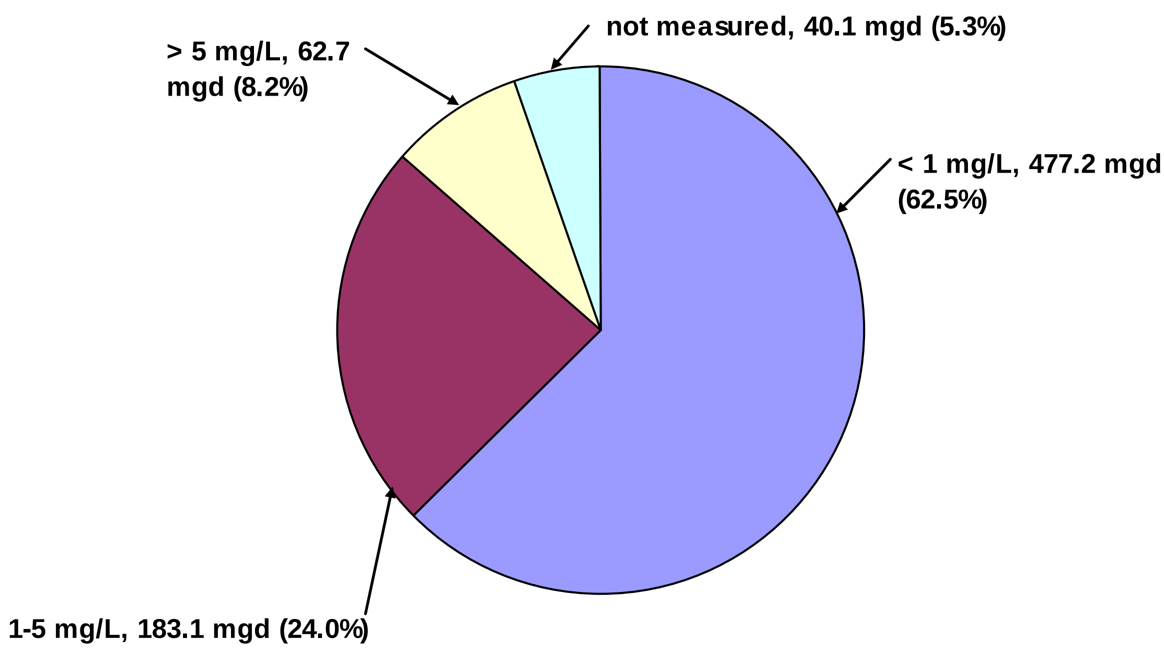


Figure 21. Effluent Total P and Combined Capacity of Municipal WWTPs in Minnesota

Ammonia (NH_3)

Excess ammonia in reclaimed water is a concern for increased corrosion rates, particularly with cooling water applications. Ammonia also promotes biological growth and related biofouling and interferes with disinfection.

Figure 22 presents the frequency of occurrence of NH_3 concentration in the effluent of all Minnesota WWTPs. Similar information is shown in Figure 23 for WWTPs with design capacities greater than 1 mgd. The variability of effluent NH_3 is also characterized for the following ranges: < 1 mg/L, 1-5 mg/L, 5-10 mg/L, and >10 mg/L.

The average WWTP effluent NH_3 concentrations are depicted by location and facility capacity in Figure 24 and further detailed in Figures 25-28. Approximately 15% of Minnesota's WWTPs have nitrogen removal processes, indicated by effluent NH_3 concentrations less than 5 mg/L. This accounts for 600 mgd of the total design capacity in the state. This also assumes that WWTPs that do not monitor for ammonia, do not nitrify. Approximately 80% of Minnesota's WWTPs do not measure ammonia. Of those facilities monitoring for ammonia, 16 produce an effluent with a concentration greater than 5 mg/L.

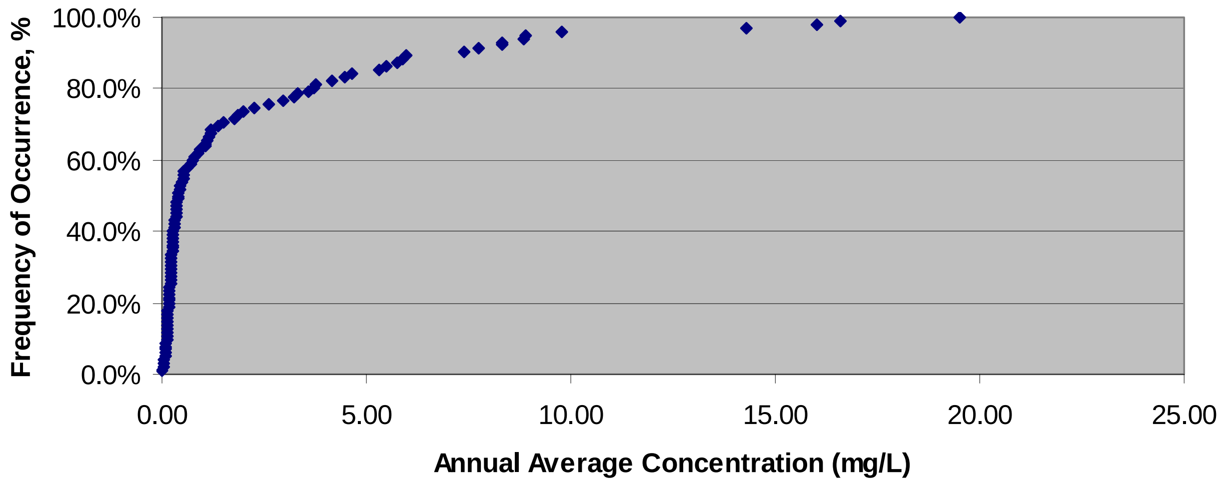


Figure 22. Effluent Ammonia of Municipal WWTPs in Minnesota

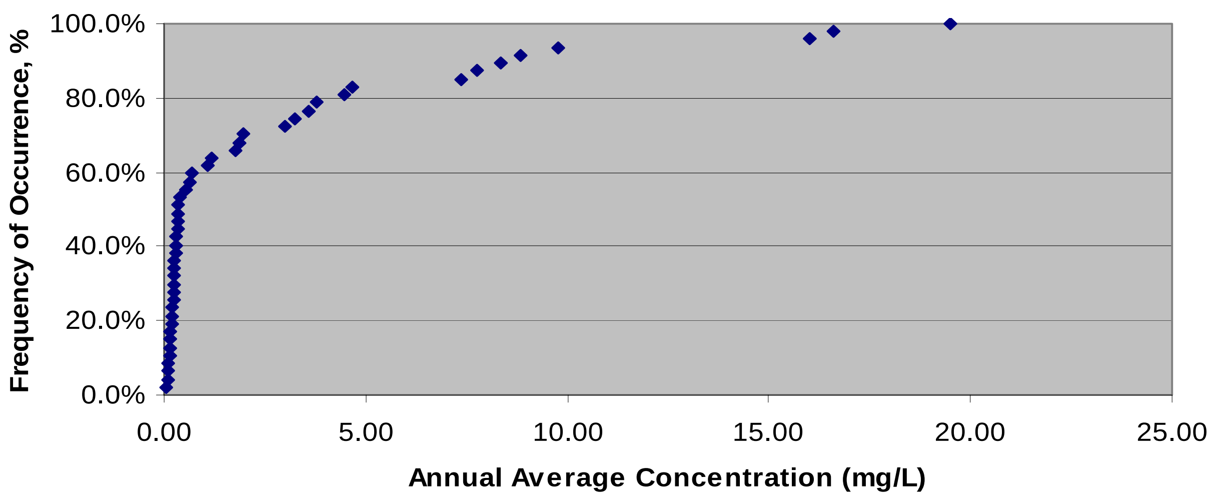
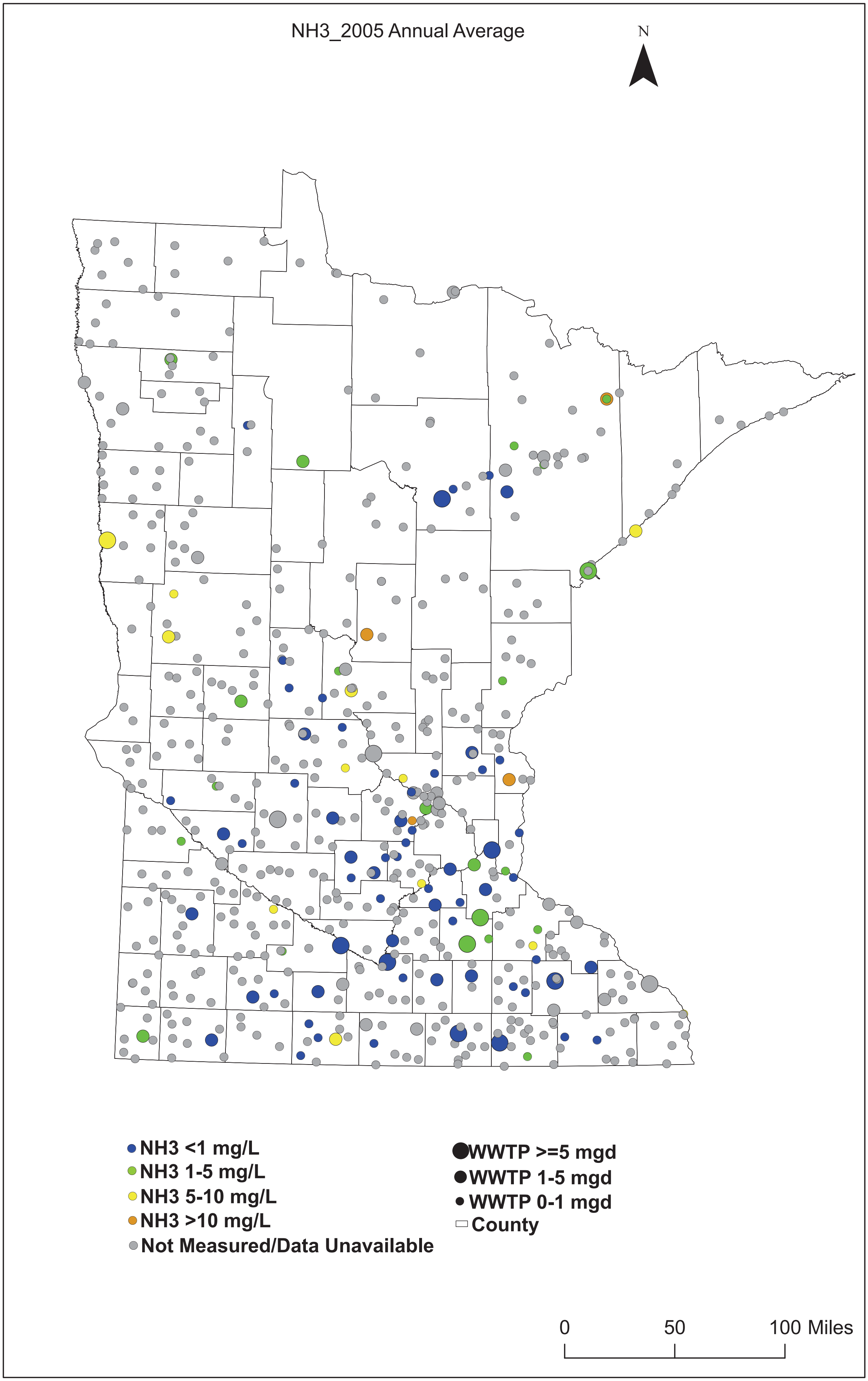


Figure 23. Effluent Ammonia of Municipal WWTPs Greater than 1 mgd in Minnesota

Figure 24. Effluent Ammonia of Municipal WWTPs in Minnesota



Source: Discharge Monitoring Reports, MPCA, 2005.

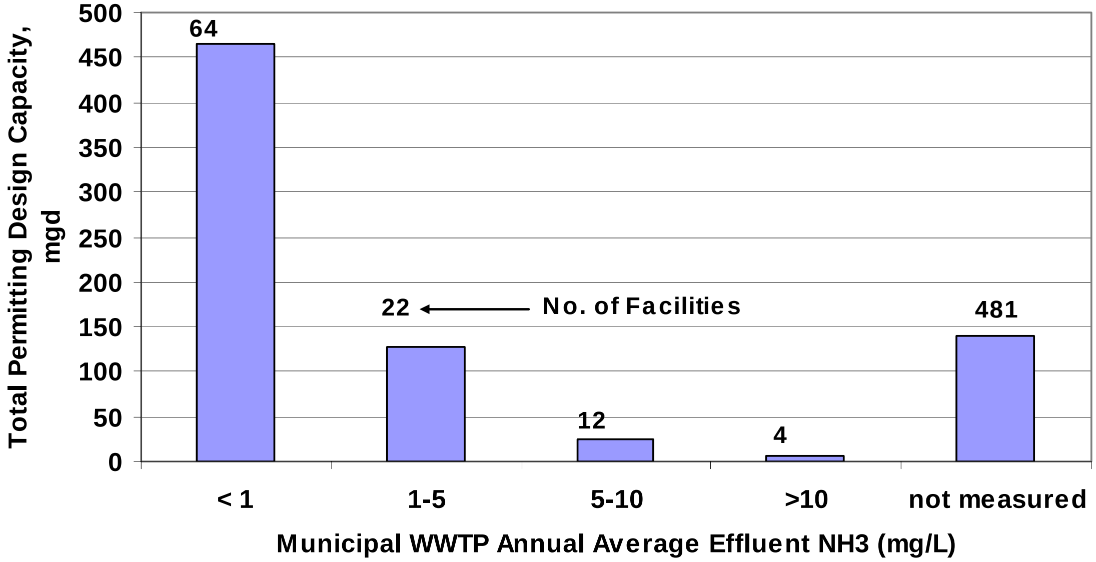


Figure 25. Annual Average Effluent Ammonia, Capacity, and Number of Municipal WWTPs in Minnesota

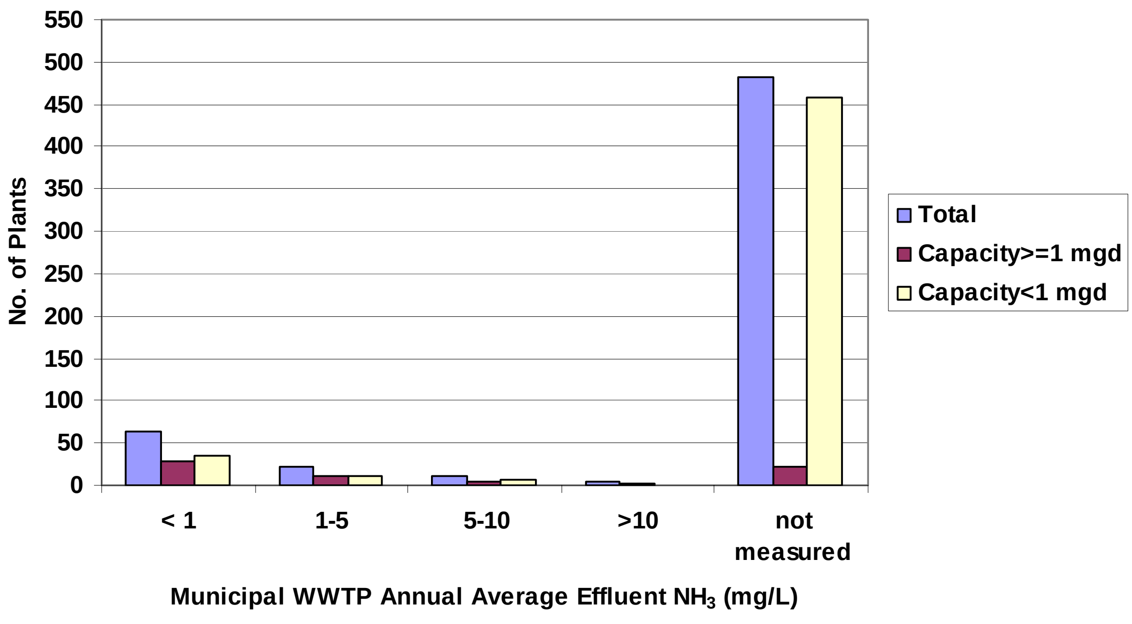


Figure 26. Annual Average Effluent Ammonia and Number of Municipal WWTPs in Minnesota

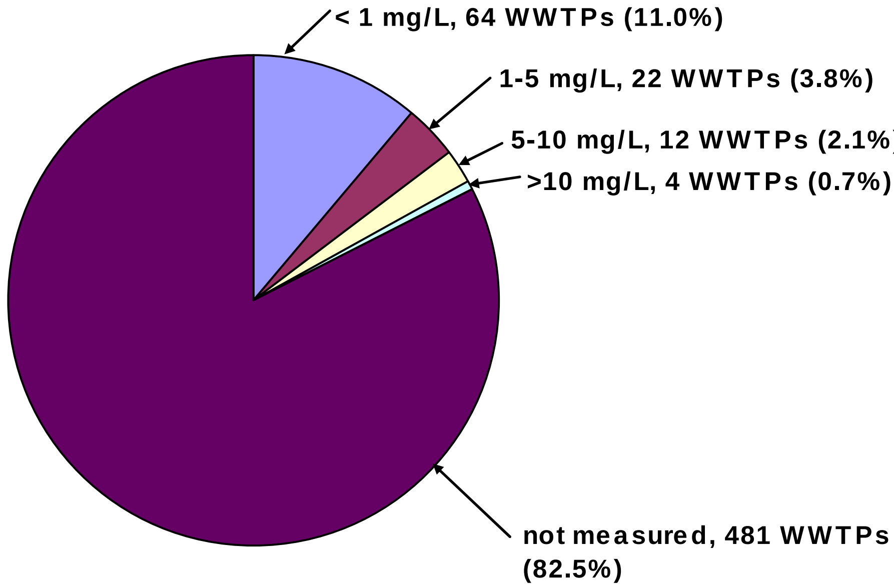


Figure 27. Effluent Ammonia and Number of Municipal WWTPs in Minnesota

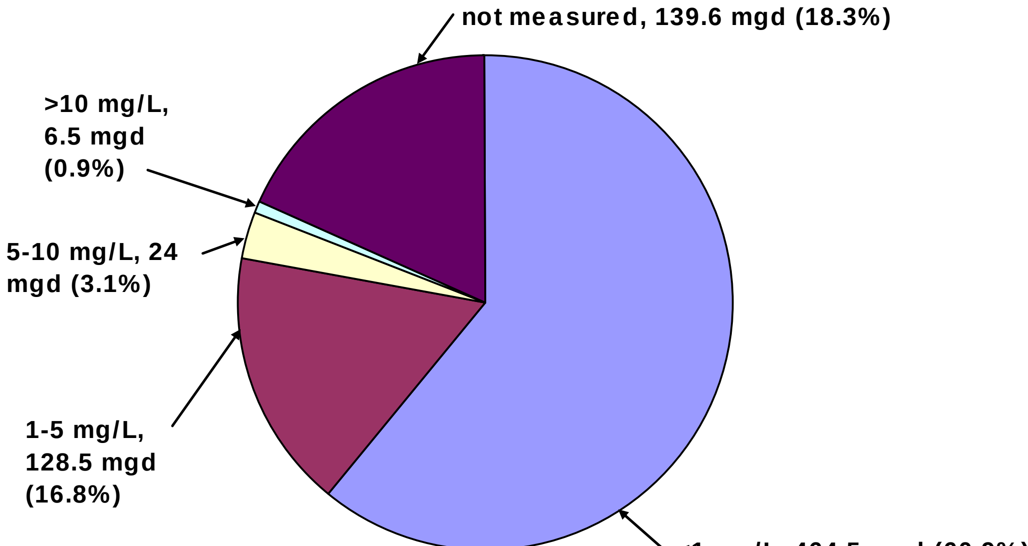


Figure 28. Effluent Ammonia and Combined Capacity of Municipal WWTPs in Minnesota

Fecal Coliforms

Fecal coliforms are commonly used as indicator organisms of pathogenic organisms found in treated wastewater. The presence of coliform organisms is taken as an indication that pathogenic organisms may also be present, and the absence of coliform organisms is taken as an indication that the water is free from disease-producing organisms. The only constituent regulated by the California Water Recycling Criteria (the regulations Minnesota uses for administering permits for water reuse) for industrial water uses is an indicator organism, total coliforms. For uses that are not likely to contact humans, the total coliform limit is 23/100 ml. For uses with potential for human contact, the total coliform limit is 2.2/100 ml. Most WWTPs in Minnesota are permitted to meet a fecal coliform limit of 200. Fecal coliforms are a subset of total coliforms.

Figure 29 presents the frequency of occurrence of fecal coliforms in the effluent of all Minnesota WWTPs. Similar information is shown in Figure 30 for WWTPs with design capacities greater than 1 mgd. The variability of effluent fecal coliforms is also characterized for the following ranges: <10/100 mL, 10-100/100 mL, and >100/100 mL.

The average WWTP effluent fecal coliform concentrations are depicted by location and facility capacity in Figure 31 and further detailed in Figures 32-35. Minnesota facilities produce a high quality effluent in terms of fecal coliforms. There were 170 facilities with fecal coliform counts less than 10/100 mL, accounting for 150 mgd of the WWTP capacity in the state. Nearly 300 facilities with a design capacity totaling 535 mgd have effluent fecal coliform concentrations in the 10-100/100 mL range. Over 40 WWTPs, with a combined capacity of 70 mgd, produce an effluent with a fecal coliform count greater than 100/100 mL.

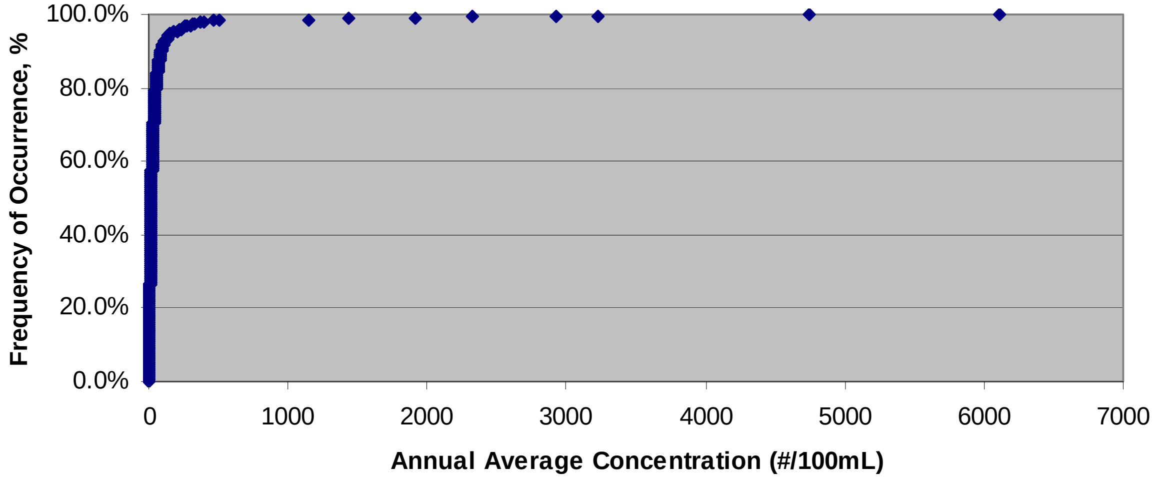


Figure 29. Effluent Fecal Coliform of Municipal WWTPs in Minnesota

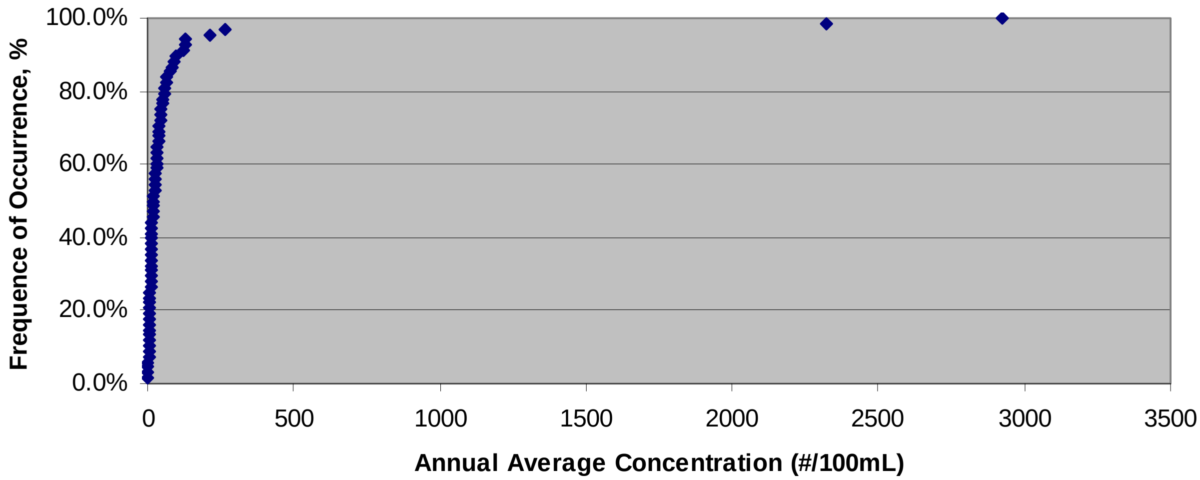
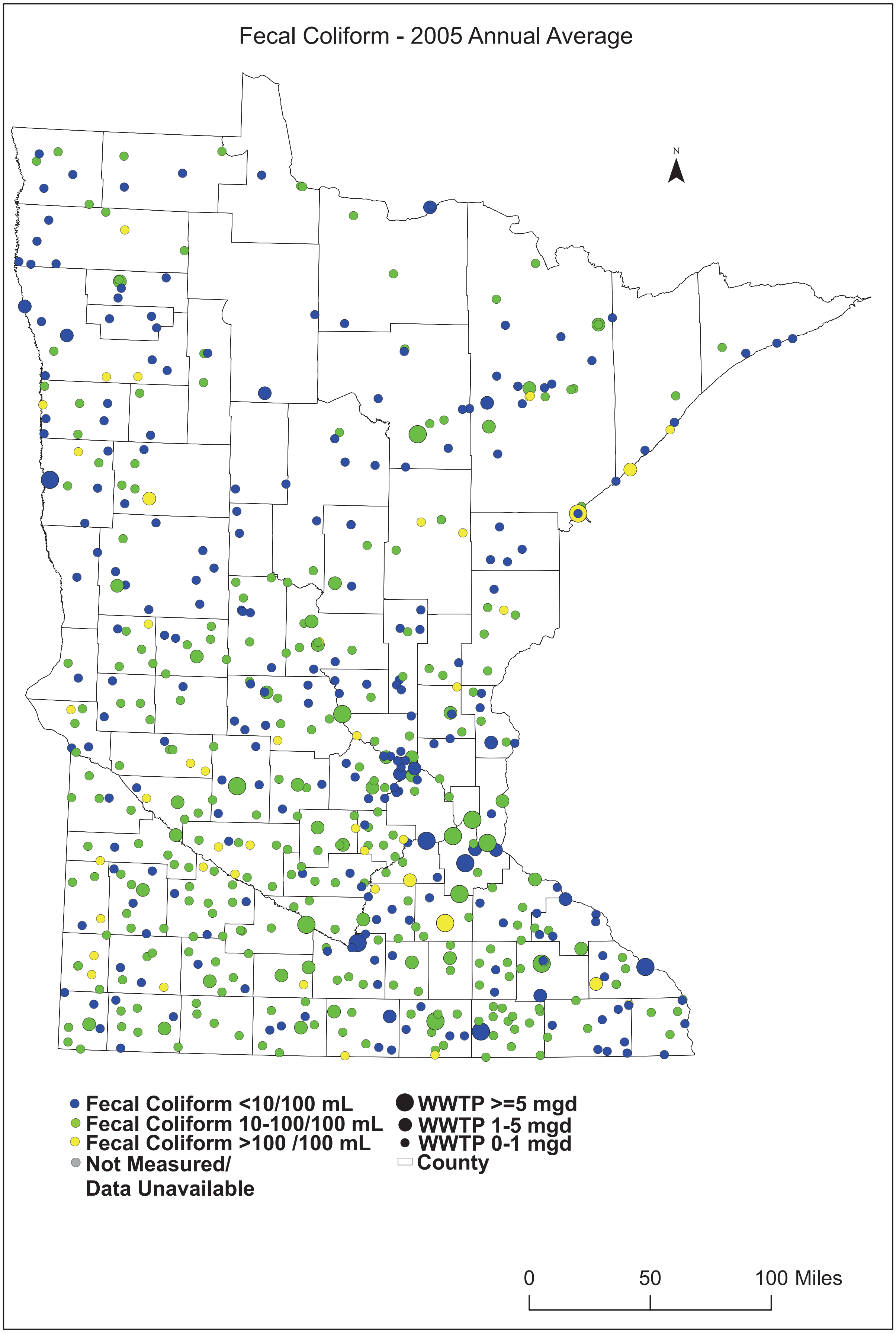


Figure 30. Effluent Fecal Coliform of Municipal WWTPs Greater than 1 mgd in Minnesota

Figure 31. Effluent Fecal Coliform of Municipal WWTPs in Minnesota



Source: Discharge Monitoring Reports, MPCA, 2005

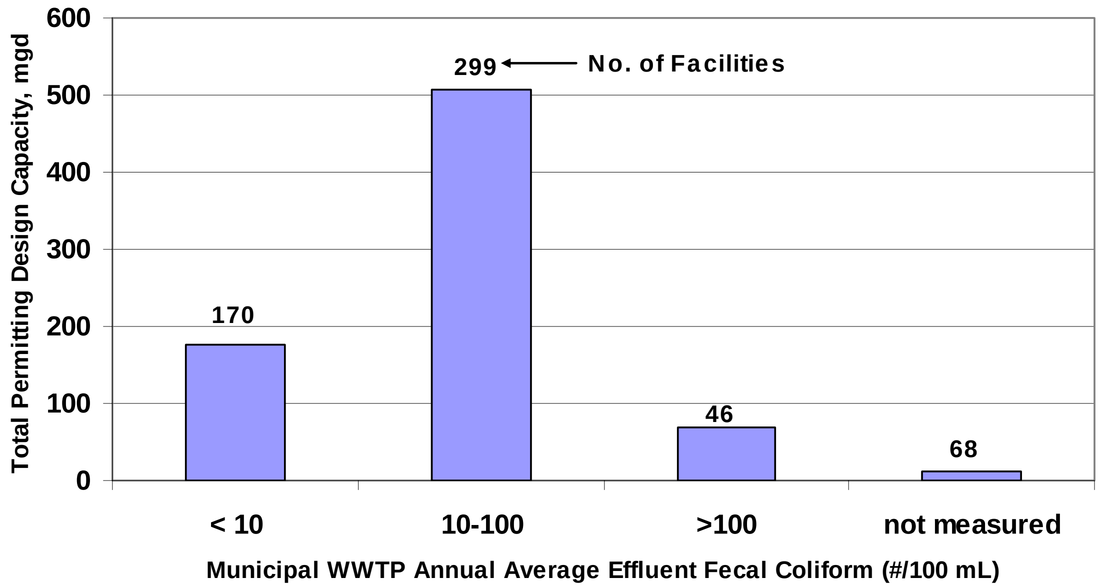


Figure 32. Annual Average Effluent Fecal Coliform, Capacity, and Number of Municipal WWTPs

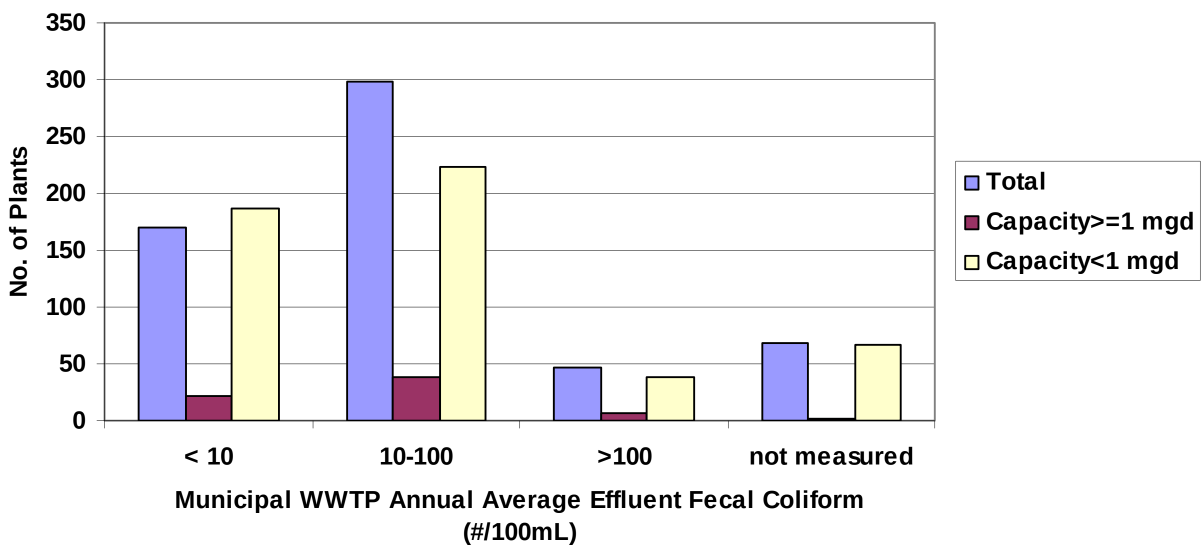


Figure 33. Annual Average Effluent Fecal Coliform and Number of Municipal WWTPs in Minnesota

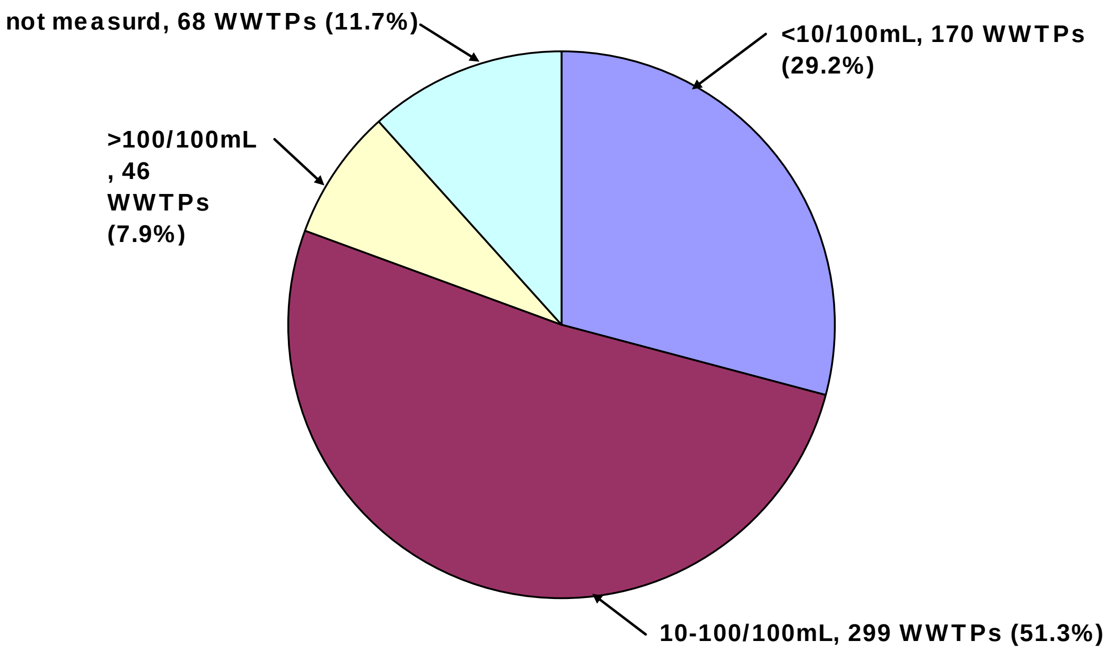


Figure 34. Effluent Fecal Coliform and Number of Municipal WWTPs in Minnesota

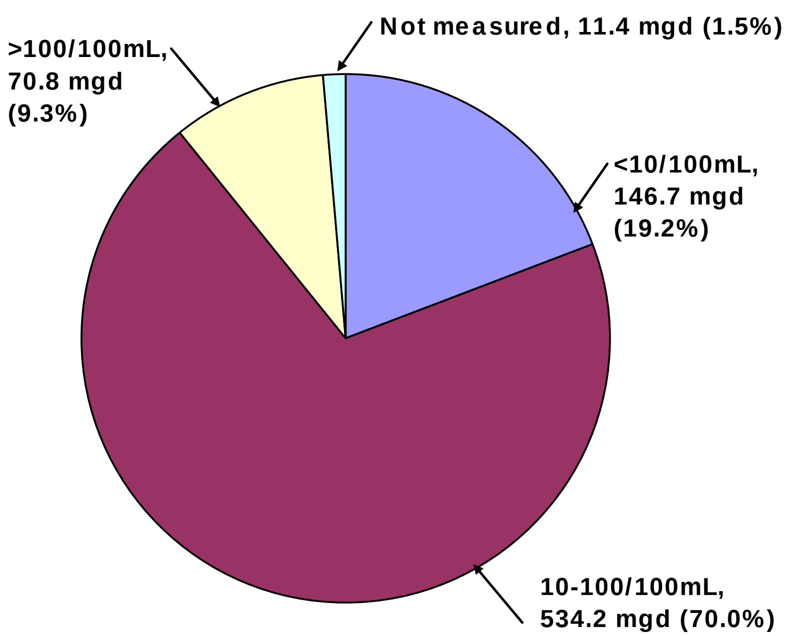


Figure 35. Effluent Fecal Coliform and Combined Capacity of Municipal WWTPs in Minnesota

3.0 Summary

The majority of the municipal WWTPs in Minnesota produce a good quality secondary effluent with low nutrient levels ($CBOD_5$ < 5 mg/L, TSS < 5 mg/L, TP < 1 mg/L, NH_3 < 5 mg/L, and fecal coliform < 10/100 mL). This provides a good "base level" water quality for supplying reclaimed wastewater from municipalities to industries. Specific industry water quality requirements will determine if additional treatment processes will be required. It is most likely that additional disinfection treatment will be required to meet the total coliform limits required by Minnesota permitting practices. The majority of plants, particularly the larger WWTPs, will not need further reduction of organics, particulate solids, and nutrients for industrial uses requiring lower levels of quality or little concern for dissolved solid concentrations. If hardness, dissolved salts, or trace constituents need to be removed, then additional reduction of organic, suspended solids and nutrients will be required for optimum treatment process performance.

4.0 References

Minnesota Pollution Control Agency (MPCA). 2005. Minnesota Discharge Monitoring Report data obtained through the Environmental Data Access system, April 2006. Refer to: http://www.pca.state.mn.us/data/edaWater/index.cfm.

Appendix A Data Analysis Methods

Database Used: MPCA Discharge Monitoring Reports (2003-2005; 2005 focus)
Filenames (as received from MPCA): Water Quality Data
(http://www.pca.state.mn.us/data/edaWater/index.cfm)
Date data received from MPCA: April 19, 2006

Analysis Approach

Step 1: Import the original MPCA water quality data (in text file format) into Microsoft Access.

Step 2: Create queries in the Access database to extract annual maximum, minimum, and average value of the calendar month average water quality data in 2005 for each municipal wastewater treatment facility, discharging to a water body, in Minnesota. Water quality parameters evaluated include $CBOD_5$, TSS, NH_3, P, and fecal coliform.

Step 3: Display average values of effluent quality spatially for the state. This required linking the 2005 water quality data generated from the MS Access query analysis to the shapefile for the wastewater treatment facilities (WWTPs).

Step 4: Generate maps and graphics to characterize average effluent quality of Minnesota's municipal WWTPs.

- Evaluate the variability of effluent quality through general statistics and percentile plots for each water quality parameter.
- Determine appropriate ranges to characterize each constituent.
- Create GIS maps that show WWTPs and range of effluent quality.
- Generate bar charts and pie charts to summarize the number of WWTPs and permitted capacity based on the effluent quality ranges.

Metropolitan Council

Recycling Treated Municipal Wastewater for Industrial Water Use

LCMR05-07d

MCES Project Number 070186

TECHNICAL MEMORANDUM 5

Stakeholder Input

June 30, 2007

Craddock Consulting Engineers

In Association with

CDM and James Crook

1.0 Introduction

This technical memorandum is the fifth in a series of memoranda developed under a Metropolitan Council (Council) project titled "Recycling Treated Municipal Wastewater for Industrial Water Use." Funding for this project was recommended by the Legislative Commission on Minnesota Resources (LCMR) from the Minnesota Environment and Natural Resources Trust Fund. The Met Council is providing additional funding for the project through in-kind contributions of staff time. Other state agencies are participating via stakeholder meetings and technical review and input.

In addition to technical issues, there are regulatory, legal, and institutional issues such as funding and fees, agency jurisdictions, ordinances, and public involvement that must be addressed to successfully implement wastewater recycling programs. To begin to address the many facets of implementing wastewater recycled projects in Minnesota, a series of stakeholder meetings were held in conjunction with this study.

There were three stakeholder forums held:

- Regulatory
- Industrial
- Broader base

This memorandum provides a summary of the meetings and serves to record the meeting agenda, meeting notes, and relevant handouts.

2.0 Regulatory Meetings

There were two regulatory meetings held early in the project and included representatives of the MPCA, MDNR, MDH, Dakota County, and Met Council staff from environmental services. These meetings were used to gain input on the state agency setting for wastewater recycling and how these practices are handled now and any plans for the future. Exhibit A provides the regulatory meeting agendas, meeting summary notes, and attendance lists.

3.0 Industry Meetings

There were two meetings held with industrial representatives. A total of 11 industries participated in the workshops with 15 representatives attending. A range of industry sectors and business sizes were represented. Table 1 lists the industries attending the two workshops.

The main question addressed was: What issues/concerns does your industry have with using a recycled wastewater supply? Followup discussions focused on project elements for demonstration projects and any issues the industry might have if looking to site a new facility. The discussion of issues was segmented into technical issues and institutional issues. In some cases, issues overlapped these general categories.

Table 1. Industry Workshop Attendees

March 8, 2007	March 15, 2007
Great River Energy	ADC Telecommunications Inc
Kraemer Mining & Materials, Inc	CertainTeed Corporation
Marathon Petroleum Company LLC	Fagen Engineering LLC
Rock-Tenn Company	Flint Hills Resources LP
Twin City Tanning Co/SB Foot Tanning Co	Gopher Resources Corporation
	Xcel Energy

Exhibit B provides the industry meeting agendas, meeting summary notes, and attendance lists.

4.0 Broader Base Meeting

The third forum brought together a broader spectrum of stakeholders: the same regulatory agencies, two industries from the previous meetings (CertainTeed Corporation and Marathon Petroleum Company), a cross-sector group (Minnesota Environmental Initiative), wastewater utilities (Mankato and Met Council), and a representative from the Water Utility Council, Minnesota Section, American Water Works Association. This group reviewed the outcomes of the previous stakeholder meetings and discussed next steps to promote wastewater recycling on a broader scale in Minnesota.

Exhibit C provides the broader base meeting agenda, meeting summary notes, and attendance list.

4.0 Summary

The general outlook carried from the workshops is that the institutional issues need to be solved or in the evaluation process before significant consideration is given to a recycled wastewater project. While there are certainly some technical issues that must be resolved and better understood, the meeting participants were confident that technical solutions could be found. It would be a matter of cost and related benefits that would dictate the feasibility - if the institutional issues are first addressed.

All participants were encouraged by the interest expressed in the topic of wastewater recycling. The broader base stakeholder workshop was an important step in bringing various parties together.

Exhibit A
Regulatory Stakeholder Meetings

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Agenda

Meeting: Informational Meeting-Planning/Regulatory Focus
Meeting No.: ME01 Date: 3/30/06
Location: Mears Park Centre, Rm 1A Time: 1:00 – 3:00 pm
230 E 5th St. St. Paul

Participants

Claude Anderson	MCES	Sheila Grow	MDH	Patti Craddock	CCE Team
Bill Cook	MCES	Bruce Henningsgaard	MPCA	Jim Crook	CCE Team
Chris Elvrum	MCES	Laurel Reeves	MDNR	Bob Molzahn	CCE Team
Melba Hensel	MCES	David Sahli	MPCA	Jen Packer	CCE Team
Deborah Manning	MCES	David Swenson	Dakota Co	Li Zhang	CCE Team
Bryce Pickart	MCES				

1:00 pm Introductions – Deborah Manning, MCES

1:10 pm Meeting Objectives – Deborah Manning

1:15 pm MCES Direction – Bryce Pickart, MCES

1:25 pm Project Overview & Initial Inquiry – Patti Craddock, Craddock Consulting Engineers

1:40 pm Overview of Water Reuse – Jim Crook, Ph.D., P.E.
- Current Uses
- Water Quality Criteria
- Regulations and Guidelines
- Attributes of a Successful Reuse Program
- Trends in Water Reuse

2:15 pm Dialog on Reuse Topics Pertinent to Minnesota – Patti Craddock

2:55 pm Summary – Deborah Manning
- Recap
- Action Items

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Summary

Meeting: Informational Meeting-Planning/Regulatory Focus
Meeting No.: ME01 Date: 3/30/06
Location: Mears Park Center, Rm 1A Time: 1:00 – 3:00 PM

Attendees:

Name	Organization	Phone	Email
Bryce Pickart	MCES	651-602-1091	bryce.pickart@metc.state.mn.us
Deborah Manning	MCES	651-602-1114	Deborah.Manning@metc.state.mn.us
Claude Anderson	MCES	651-602-8291	claude.anderson@metc.state.mn.us
Bill Cook	MCES	651-602-1811	Bill.Cook@metc.state.mn.us
Melba Hensel	MCES	651-602-1072	melba.hensel@metc.state.mn.us
Chris Elvrum	MCES	651-602-1000	christopher.elvrum@metc.state.mn.us
Shelia Grow	MDH	651-201-4692	sheila.grow@health.state.mn.us.
Bruce Henningsgaard	MPCA	651-296-6300	bruce.henningsgaard@pca.state.mn.us
Laurel Reeves	MDNR	651-296-6157	Laurel.Reeves@dnr.state.mn.us
David Sahli	MPCA	651-296-6300	david.sahli@pca.state.mn.us
David Swenson	Dakota Co	651-438-4418	David.Swenson@co.dakota.mn.us
Patti Craddock	CCE	651-690-0400	pcraddock@craddockconsulting.com
Jim Crook	Consultant	781-659-0414	jimcrook@msn.com
Jen Packer	CDM	651-772-1313	packerjl@cdm.com
Li Zhang	CDM	651-772-1313	zhangl@cdm.com
Bob Molzahn	Consultant	651-772-1313	molzahnre@cdm.com

Summary:

1. Introductions – Deborah Manning opened

2. Meeting Objectives – Deborah Manning
   - Gain broad MCES participation and other stakeholder input in the project.

3. MCES Direction – Bryce Pickart
   - The project will focus on industrial reuse of reclaimed wastewater on a statewide basis, with more specific focus given to the metro area. The project will identify potential industrial customers, evaluate treatment processes required and estimate the costs associated with providing reclaimed water to industrial users. The project will also evaluate regulations/ordinances and identify institutional barriers related to implementation of wastewater reuse.
   - Project requested by legislator and is funded through the Legislative Commission on Minnesota Resources (LCMR).

4. Project Overview & Initial Inquiry – Patti Craddock
   - Refer to presentation slides.
   - Industrial reuse of reclaimed wastewater will be evaluated on three levels (state, metro area, individual wastewater treatment plants (WWTPs)). Empire will be one case study of an individual WWTP.

- Drivers for Reuse in MN:
  - Potable water supply availability is becoming an issue in some areas, notably with planning for the next 20-50 years.
  - Receiving stream load limitations, under evaluation in the ongoing TMDL process, may restrict the discharges of some WWTPs.
- Initial Industrial Cusomer Inventory Results
  - Presented bar and pie charts showing 2004 Minnesota general water use and industrial (9 categories) water use
  - Presented state, metro area, and Empire WWTP area maps showing location of industries, volume of water used (by size of icon), source of water as surface or ground water, and proximity to WWTPs with capacities greater than 5 mgd.

5. Overview of Water Reuse – James Crook
- Refer to presentation slides
- The major types of wastewater reuse applications can be categorized as urban, industrial, agricultural, recreational, habitat restoration/enhancement, ground water recharge and augmentation of potable supplies.
- Treatment technology is dependent on the industrial need and the quality of the source water. Treatment processes for reclaimed wastewater include coagulation/flocculation, sand filtration, carbon adsorption, membrane processes, and disinfection. Most recent trend in technologies for reuse are with membranes and UV.
- Industrial water quality requirements shown for several industries including cooling water and boiler feed water.
- Regulations vs. Guidelines – reviewed other states and their reuse regulations.
- Water Reuse Criteria – reviewed different levels and applications by various states
  - Water quality requirements
  - Treatment process requirements
  - Treatment reliability requirements
  - Monitoring requirements
  - Operational requirements
  - Cross-connection control provisions
  - Use area controls
- Trends in Reuse

6. Dialog on Reuse Topics Pertinent to Minnesota – Deborah Manning
- Reuse Involvement
  - MPCA:
    - Main involvement has been for golf course irrigation in MN: no place to discharge water.

    - Involved with Mankato NPDES permit, also one for the Shakopee Mdewakanton Sioux Community (issued by EPA, not MPCA)
    - Hennepin Co. Public Works Facility – had no place to discharge
    - TMDLS – see reuse as an important option
  - MDNR: Previous interaction: to determine if a water appropriation permit is needed for reclaimed water. Possible issues related to funding with the appropriations.
  - MDH: Source water protection is one driver for water reuse.
  - Dakota County: Interested in reuse of reclaimed water to replenish aquifers by agricultural irrigation. This is a way to keep water used in the watershed.
  - MCES:
    - Metro area water sources are being evaluated under another MCES project: Regional Assessment of Water Supply Systems, Water Demand, and Availability and Management Needs. It will provide some additional data/results to this project for metro area water supplies and future demands.
    - Performed literature search on reuse and wrote a white paper.
    - Recognize the benefits to municipal wastewater agencies – but need to keep the focus of the project on industrial reuse. How can reclaimed water benefit industries, where perhaps location of an industry or growth of an industry is restricted by water supply.
  - Bob Molzahn:
    - No water supply issue historically to require a state-perspective on reuse.
    - Water supply could be an issue in the future. Establishing regulations for water reuse now will benefit the implementation of water reuse in the future.
    - In looking at industrial reuse: look to the future and scenarios to promote industry location and growth with an available water supply nearby.

- Sources of Data/Target Areas
  - Focus on ethanol plants in the southwestern part of Minnesota where there is a water supply shortage. Also a high-profile industry right now.
  - Mining areas in the north have competing water needs.
  - Areas in northwest and southwest of metro area.

- Regulations vs. case-by-case
  - Threshold to write regulations is uncertain.
  - California & Florida water reuse guideline are good water reuse standards.
  - Public involvement is an important factor in the preparation of water reuse regulation/guidelines.

- Minnesota Department of Health will have input in regulations when water reuse involves public health issue (e.g., affecting public drinking water supply, aerosols in spray mists).
- Need to consider notice to solicit, public review periods, etc.
- Issues with large ISTSs occurring now.
- Will come to the forefront by legislators – if an issue they'll be the ones to get the word out and a call for action.

- Regional Assessment of Metro Area Water Supply Systems: Chris Elvrum provided a brief overview and schedule for the project.

7. Summary

- Input from the MCES advisory team and other stakeholders is valuable.
- As the project moves on, the project team will be contacting the stakeholders for data and comments on the technical memos and the final report.
- Next scheduled meeting with stakeholders will be in early 2007. Interim meetings with the planning/regulatory stakeholders at this meeting may be held, with one possible in mid-summer.

Decisions:
No major decisions reached. This was an informational meeting.

Municipal Wastewater Reuse Regulatory Stakeholder Group
June 12, 2006 2:00 – 3:30 PM
Metropolitan Council
Lower Level Room B, 390 N. Robert Street, St. Paul, MN
Agenda

Introductions, Meeting Purpose, and Agenda Review

Recap of Treated Municipal Wastewater Reuse in MN

- Drivers
- Existing Applications/Projects
- Existing Regulations
    - Resources from federal government and other states
    - MN guidelines
- Agencies/Institutions with Oversight or Role in Reuse
    - Mission/goals/roles/jurisdictions
    - Experience/history with reuse
    - Approach to dealing with reuse cases and opportunities
    - Institutional policies/supports/barriers

Is the Regulatory Table Set for Fostering Wastewater Reuse in MN?

- Is the status quo sufficient? What issues need to be addressed that currently aren't?
- Triggers for changing status quo (e.g., moving from guidance to regulations)
- Other groups, initiatives, etc. already addressing the issue
- Other groups that need to be included or consulted
- Examples from other states
- What, if anything, additional is required?

Other Issues

- Water rights
- Policies
- Local ordinances
- Environmental assessment and impact
- Public perception/education/involvement
- Fee structures

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Summary

Meeting: Municipal Wastewater Reuse Regulatory Stakeholder Group
Meeting No.: ME02 Date: 6/12/06
Location: 390 Robert Street, Rm B Lower Level Time: 2:00 – 3:30 PM

Attendees:

Name	Organization	Phone	Email
Bryce Pickart	MCES	651-602-1091	bryce.pickart@metc.state.mn.us
Deborah Manning	MCES	651-602-1114	Deborah.Manning@metc.state.mn.us
Claude Anderson	MCES	651-602-8291	claude.anderson@metc.state.mn.us
Bill Cook	MCES	651-602-1811	Bill.Cook@metc.state.mn.us
Melba Hensel	MCES	651-602-1072	melba.hensel@metc.state.mn.us
Sara Bertelsen	MCES	651-602-1035	sara.bertelsen@metc.state.mn.us
Shelia Grow	MDH	651-201-4692	sheila.grow@health.state.mn.us.
Bruce Henningsgaard	MPCA	651-296-9289	bruce.henningsgaard@pca.state.mn.us
Laurel Reeves	MDNR	651-259-5692	Laurel.Reeves@dnr.state.mn.us
David Sahli	MPCA	651-296-8722	david.sahli@pca.state.mn.us
David Swenson	Dakota Co	651-438-4418	David.Swenson@co.dakota.mn.us
Patti Craddock	CCE	651-690-0400	pcraddock@craddockconsulting.com

Summary:

1. Introductions – Deborah Manning opened

2. Meeting Focus – Deborah Manning
   - General reuse of treated wastewater effluent.
   - Broaden the topic from the kickoff meeting which had a focus toward industrial reuse applications.
   - Also need to consider reuse in terms of 'water supply', not just as a wastewater discharge option.

3. Recap of Treated Municipal Wastewater Reuse Applications in Minnesota
   - List of 7 facilities (handout)
     - To add: the EPA permitted facility for the Shakopee Mdewakanton Sioux Community,
       - 0.639 mgd
       - Membrane filtration with UV disinfection
       - Discharge permitted to a wetland that is used to irrigate the community's golf course
     - Noted that the list does not include agricultural irrigation practices; these facilities all have a beneficial end use other than as a discharge for treated wastewater (there are facilities in MN that land discharge, such as with rapid infiltration basins (RIBs) or to wetlands, which can be considered reuse applications).

- Drivers – main driver for those on list was to find a suitable discharge for the wastewater; only the Mankato facility had 'water supply' as the primary driver, where Calpine Corporation needed cooling water for their new energy facility.
- Agency/Institution Roles
    - Draft Table – Handout
        - Lists Agency, Mission/Goals, Role with Wastewater Reuse, Jurisdiction, Approach to Reuse, Issues
        - Reviewed list and noted other items, such as:
            - MPCA: Under Approach to Reuse – note that MN uses the California Recycling Criteria as basis of water quality criteria used in NPDES permit; also require under MN Rules that planning (facility plans) for all treatment facilities must evaluate reuse alternatives.
            - MDNR: Noted that there would not be an appropriation fee to 'reuse' water for most applications. Gray area is with aquifer recharge applications, where water is reused later by multiple users.
            - MDH: noted that MDH would be involved for issues related to human exposure.

4. Fostering Wastewater Reuse in Minnesota
- Open discussion on this issue.
- Miscellaneous comments provided below.
- Groundwater recharge/irrigation
    - Groundwater recharge, whether by irrigation or more direct practices, will benefit local aquifers
    - MDH must balance recharge need with source protection; issues arisen historically in the state
        - Concern with stormwater basins in wellhead areas
    - Issues with agricultural irrigation – wells high in nitrates
    - Mechanism to reduce transfer of water outside of local watershed.
- Reuse topic has come up at the Metro Area Water Supply meetings (MCES Regional Water Supply Assessment Project).
    - Some stakeholders are knowledgeable in this area.
    - See as a water supply solution.
    - Also discussed as a 'redundant' supply option.

5. Public Perception
- No public comments related to health concerns or water quality issues with existing reuse projects (through permit process).

- Not a well-known topic in Minnesota.
- Industrial sector may need some education in this area. Industries are use to internally using water, but not 'reuse' of water from another supply, like municipal WWTPs.

6. Other Stakeholders to Involve
   - Minnesota Environmental Initiative
   - Minnesota Environmental Partnership
     - Over 90 groups
     - Help organize groups for specific issues
   - Concurrent project: MCES Regional Water Supply Assessment
   - Southwest and Northwest Metro Area Ground Water Groups
   - Clean Water Cabinet
   - Industrial
     - Mining (iron range)
     - Red River Basin Committee (well organized group that had addressed ground water supply and surface water for the watershed)
     - Corn Growers (ethanol)
     - MEP
     - Chamber of Commerce – talk with Mike Robertson

7. Summary
   - Plan to look to the Water Supply Advisory group for involvement and tie in the water supply driver.
   - Additional meetings with the planning/regulatory stakeholders at this meeting and an expanded list of stakeholders will be held, with the timing of the meeting(s) dependent on the other stakeholders that are brought into the project.

Decisions:
No major decisions reached. The intent of this meeting was discussion and information-sharing.

Exhibit B
Industry Stakeholder Meetings

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Agenda

Meeting: Industrial Stakeholders
Meeting No.: MP03 Date: 3/08/07
Location: Metro 94, Rm 32 South Time: 1:00 – 4:00 pm
455 Etna St Suite 32, St. Paul

1:00 pm Introductions – Deborah Manning, MCES

1:10 pm Meeting Objectives – Deborah Manning

1:15 pm Project Overview – Patti Craddock, Craddock Consulting Engineers

1:25 pm Water Use Survey – Patti Craddock

1:30 pm Discussion – Bob Matthews, CDM
- Format and Roles
- Questions to Address
  - What issues/concerns do you have with using a reclaimed water supply?
  - If you site a new facility, what features would encourage you to use a reclaimed water supply?

2:30 pm Break

2:40 pm Discussion (Continued)

3:30 pm Q&A – Patti Craddock

3:45 pm Summary – Patti Craddock
- Recap
- Action Items

Adjourn

Technical Issues

Topic	Discussion
Reliability	• Most industries will require a backup supply; assume can keep existing supply as a backup. • Envision reclaimed supply for a portion of the facility's water uses; want the flexibility of multiple supplies. • Reclaimed water may provide a water supply to areas with groundwater contamination. It is possible that pumping could be restricted in some areas with contamination and an industry may not be able to meet their water supply needs with their well system. Reclaimed water would provide a constant source (emphasizes need for multiple supplies or interconnections between water supply systems in times of emergency).
Pressure	• Many industries would want some type of storage facility to provide them the flexibility to meet various pressure requirements. • Many have this in their system now and would expect to keep this for flexibility. • There were no specific pressure requirements of concern noted – industries handle this issue now.

Water Quantity	• Need detailed information on supply availability to understand diurnal, weekly, and seasonal patterns; previous inquiries with a WWTP by an industry indicated this data was lacking.
	• Will there be reservoirs in the system? (depends on demand/supply of specific application; other states have storage for seasonal use [irrigation] and diurnal flow variability)
	• Issue: Who owns the water?
	  o Is it the municipality or the state?
	  o Who does industry go to for appropriation?
	  o This issue surfaced at the regulatory meeting in Mar06
	  o Comment from DNR: if water is piped to another entity, there would be no additional permit process; if the water is put back into the ground or surface water, then a DNR appropriations permit would be required.
	  o Need further discussion on this with DNR.
	• Industries can also provide a water supply:
	  o Kraemer Mining quarry reservoirs are currently under evaluation as a municipal water supply. Looking to provide a water treatment plant.
	  o Rock Tenn Co discharges good water source as cooling water and is a potential supply.

Technical Issues

Topic	Discussion
	- Have industrial discharges been a potential supply source evaluated in the Metro Area Water Supply Master Plan? - Many industries have reduced water use with internal process changes or with reuse of their facility’s wastewater effluent. - In most cases, these internal reuse practices are most cost-effective and should be evaluated before looking at a municipal supply. - The survey and related project inquiry identified industries recycling treated wastewater from their WWTP as a water supply for other uses at their facility.
Water Quality	- Need better information on water quality for constituents not sampled for NPDES permit. - Found data lacking on chlorides in evaluating a supply for cooling water. - Need a year of data to evaluate seasonal changes; recommend at least 5 years of data. - Need to have adequate sample size to characterize the variability in constituents within and in different seasons. - Need to know fluctuations in quality to adequately adjust industrial process. - Prefer a source with consistency or at least enough information about variability and when to expect changes, to adjust industrial processes. Need a warning system for abrupt quality changes. - Concern with pathogens and public perception. “Water is water” – know how to treat it, just need to have adequate information to know what treatment is needed and make the right business decision. - Industries already pretreating water had no problems continuing this practice; those not pretreating the water might consider it, but some may not have the facility space or staff to handle new treatment requirements. Reclaimed water is a less desirable water supply option if it adds to the process needs of a facility.

Institutional Issues

Topic	Discussion
Agreement Terms	• Term (years) of appropriation can be longer for water reuse than existing water supplies to make it a more attractive source. • Provide automatic permit renewal for DNR appropriation permit if using reclaimed water (one less permitting task). • Multiple purposes of reclaimed water could be brought into the agreement process. Discussed added benefits of nutrients for agricultural irrigation practices.
Price and Fees	• Cost to treat must be justifiable; need facility planning studies. • See water reuse as “the right thing to do” – environmental stewardship should factor into the financial analysis. • Financial incentives – will encourage industries to investigate water reuse options. • Consider a pollution tax credit – no sales tax on effluent reuse project equipment. Similar to previous program in MN. • Need more information to demonstrate that water reuse is economically viable. • Who invests in the pipeline and treatment facilities? • Does it make business sense? Is it economically viable? • Cost-sharing: Who, how, what jurisdictional structures? • Environmental stewardship should be factored into economics – do not want industries punished for doing their part in water conservation.
Regulations	• The regulatory requirements for water reuse should reward the environmental stewardship of participating entities and not excessively add to the permitting process. o Regulations should not be a ‘disincentive’ to using reclaimed water. • Initial inquiries into using reclaimed water indicate that many permit requirements are added to the industry’s NPDES permit – for constituents that are currently met by the WWTP. • The case-by-case basis used by MN: o Provides uncertainty at the planning level stages on what will be required. o Limits/requirements could change once planning and design have started.

Institutional Issues

Topic	Discussion
Liability/ Indemnification	• If a quality issue causes a health problem – who is liable? • Industry concerned with taking responsibility for a contaminant measured in their effluent that is from the reclaimed supply – who is at fault for a possible violation or health risk? • Have other states seen problems with contaminants in the reclaimed supply that are discharged by the industry? (No – just a public perception)
Environmental Stewardship	• Water reuse is the "right thing to do" • Consider an award category for water reuse to acknowledge industries. • Need a consistent message from the regulatory community. o Water conservation/resource protection versus public perceptions related to health. • Need to link environmental stewardship to the regulatory policy and structure – "don't make it hard to do the right thing"
Public Education	• Public education seen as critical to success of reuse projects. • Need a public education program which includes data about a specific reuse application (appropriate sampling and measurement to show an application is meeting all regs and environmental indices). • See the need for education up-front to support the concept so when it is time to implement there are no obstacles. • Do not want to begin a capital planning process if public outcry is going to kill it.

Demonstration Project	• What is a demonstration project? Is this to demonstrate technology, regulatory process, public education element? (Answer: any or all of the above).
	• The implementation issues of a reuse project would be an important focus of a demonstration project.
	    o Document and explore the regulatory aspects, public education efforts and results, data needs at various levels of project planning through construction.
	    o Several participants thought the institutional issue inquiry is more important than the technical or treatment technologies – since the technology-related projects would be a very site specific applications.
	• Better wastewater effluent characterization could be an element of a demonstration project or a separate project to document characteristics for various areas or select WWTPs.
	• Demonstration project would be a partnership of various entities to 'walk hand-in-hand' through the planning and implementation process.

Institutional Issues

Topic	Discussion
Summary/Misc Comments	• If we can address the issues identified in this meeting, then water reuse is a viable water supply option for some industries. • The larger hurdles are the institutional issues not the technical ones.

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Agenda

Meeting: Industrial Stakeholders
Meeting No.: MP04 Date: 3/15/07
Location: 390 North Robert St Time: 1:00 – 4:00 pm
St. Paul, MN 55101 RM LLB

1:00 pm Introductions – Deborah Manning, MCES

1:10 pm Meeting Objectives – Deborah Manning

1:15 pm Project Overview – Patti Craddock, Craddock Consulting Engineers

1:25 pm Water Use Survey – Patti Craddock

1:30 pm Discussion – Patti Craddock
- Format and Roles
- Questions to Address
    - What issues/concerns do you have with using a reclaimed water supply?
    - What issues should be the focus of a demonstration project?

2:30 pm Break

2:40 pm Discussion (Continued)

3:30 pm Q&A

3:45 pm Summary
- Recap
- Action Items

Adjourn

Technical Issues

Topic	Discussion

Reliability	• Concerned about control of water quality and quantity
	    o Industries perceive they have that control now
	    o Relates to their performance
	• How will seasonal quantity requirements be addressed?
	• Expect to have some source as a backup
	    o Maintaining a backup supply has a cost
	        ▪ Need to exercise equipment and maintain pipes
	        ▪ Maintain intakes and other features
	        ▪ Need to account for this in a facility analysis
	    o Will there be permit changes for the backup supply?
	        ▪ Could affect both NPDES and Appropriations permits
	        ▪ Ex: some permits have flow-based restrictions that will trigger requirements.
	            • If a reclaimed supply is not available and a backup supply must be used and the amount/quality exceeds a permit limit or requirement – who pays the penalty or the extra costs to meet the permit limit (which would not have been incurred if the reclaimed supply had been available)?
	    o If backup supply is used – need to handle two different source waters and the quality differences
	    o Could reduce the storage requirements if another supply is used to augment rather than just backup a reclaimed supply
	        ▪ Need to assess the quality issues with a blended supply
	        ▪ Need to assess the infrastructure requirements (piping, valving, painting and signage) and costs for a specific application
	• Reclaimed supply can also be a backup to the main supply (emergency source if the ground or surface water supply has a contamination – comment brought in from March 8 meeting)
	• Who handles the maintenance, particularly of the transmission mains? Will the municipality have access?

Technical Issues

<table>
<tr><th>Topic</th><th>Discussion</th></tr>
<tr><td>Pressure</td><td>No specific issues identified. Recognize the need to have infrastructure and industry facilities to meet pressure needs for a specific facility.</td></tr>
<tr><td>Water Quantity</td><td>Relationships of water demand and reclaimed supply in Minnesota.
Location of larger water users not often near a WWTP or a municipality large enough to produce a reclaimed supply.
Proximity of industries and WWTPs not a good fit for large facilities (NIMBY).
In some areas, low flow periods for WWTP may be when there is greater demand. For example, during dry summers, when urban water uses are higher, the wastewater flows are lower (less influence from storm events).
Question to Industry: Would you accept an agreement to use a certain amount of water?
No – for industries with production dependent on economic cycles
Yes – for those with very consistent water uses; but would weigh any economic benefits to a base amount vs the risk of not using the agreed amount</td></tr>
<tr><td>Water Quality</td><td>Will reuse water bring in metals/other constituents that will cause the industry to exceed pretreatment or NPDES permit limits?
Need sampling on influent to industry for all parameters in the pretreatment permit
Likewise for any NPDES permits
This could be done at the exit to the WWTP to alleviate industry from burden of sampling; however, need assurance to protocol, etc.
Noted that the federal pretreatment standards apply to the process stream of an industry, so may not be an issue for the discharge stream to the sewer
Could there be some type of waiver if an industry uses reclaimed water?
Want to know how uniform the water quality is and will there be a warning if quality changes.
Need analytical consistency: understand timing of sampling between WWTP and industry. Need information to make process decisions in a timely manner and not affect quality of product and effluent limits.
As part of the permitting process, need to evaluate if an industry can move or with a new industry, discharge back to the WWTP versus having own discharge (NPDES permit)
Provides more control in permitting process if agency supplying reclaimed water is receiving industry discharge</td></tr>
</table>

Technical Issues

Topic	Discussion
	o Mankato-Calpine discussed as an example • Using a reclaimed supply can result in transfer of pollutants to other watersheds or to different stream segments of a watershed o What are the implications of this transfer on the TMDL process? o What impact will this have on NPDES permits? o While there are multiple pollutants that could be involved, mercury is one example that was discussed. • Source water quality can affect some facilities from meeting their NPDES permits. For example, during low-flow periods there are TDS requirements. If the TDS of the source water coming in is too high, it may not be a concern for the industry's process, but could be a problem for the discharge permit. • Temperature and cooling water: if reclaimed water is warmer than an existing supply, then it could result in warmer water being discharged and negatively impact the receiving water. • Need to prepare for situation where a WWTP has a process upset – results in catastrophic failure of the industry's equipment and service o How are damages handled? o How is lost production handled?

Institutional Issues

Topic	Discussion
Agreement Terms	• Key item is liability
Price and Fees	• Initial project/task is needed to evaluate funding sources and incentives for both industry and municipality o need capital to make changes in a facility to have new water system piping and related appurtenances o while municipalities can bond for capital projects, need to plan now and without assurances that implementation hurdles can be overcome, it may delay or keep a water reuse project from occurring • Recognized that cost is a factor, but at this point need to handle other issues. • Incentives and funding for initial projects were seen as an important feature in getting reuse applications going in Minnesota.
Regulations	• Case-by-case permitting process was viewed by some industries as preferable. o The flexibility provided the ability to handle specific quantity and quality issues for each industry. o Better to build a knowledge base using a case-by-case approach prior to setting overall standards. • What agencies will be involved in the permitting process? • Who will decide whether an industrial water use is contact on non-contact (human)? o Likely MDH will be involved in this determination • Issue of pollutant transfer in the watershed(s) is one discussed under water quality and also a topic for overall environmental protection. • See water quality discussion for link to regulatory considerations
Liability/ Indemnification	• Need to evaluate if legislation is necessary to address the issue of liability for a municipal entity supplying reclaimed water. o Can a government agency accept the liability? o The liability issue was considered to be above an agreement level and applicable to state liability laws.

Institutional Issues

Topic	Discussion
	o Would be difficult for private sector to enter an agreement without liability being addressed. o Main issues: ▪ If there is a public health problem that is related to the reclaimed water – who is at fault? ▪ If the industry has damage or loss of production because of the water quality or quantity – how is lost revenue to be paid? ▪ If a discharge or pretreatment permit is violated and it is related to the reclaimed water – who pays penalty, how is fault decided? o How do different states handle the liability laws? • Are there liability issues with the transmission mains? Who's right-of-way?
Environmental Stewardship	• Interest in a reclaimed water supply at this stage is motivated by the environmental benefits and not for technical and cost reasons. While costs and institutional factors may drive a decision to use a reclaimed supply, the initial interest is the 'bigger picture' view of water resource protection.
Public Education	• Recognize the need to educate public; also employees at facilities using reclaimed water.
Demonstration Project	• Evaluate specific processes to demonstrate human health safety for workers and local community residents. • Evaluate the implementation process of a water reuse project to identify hurdles and participation requirements of various state, municipal, and private entities, including the general public. Envision a team of participants that walks through the process together. • Evaluate industries where water supply is an issue. This will provide focus to technologies for specific source water in areas with most benefit to water supply conservation. • Further definition of institutional issues that must be addressed in a water reuse project. o Range of institutional issues including regulatory permitting process, public education, liability, user agreements. o Specifically address role of agencies and industry in determining regulatory limits and which category specific water uses fall under.

Institutional Issues

<table>
<tr><th>Topic</th><th>Discussion</th></tr>
<tr><td></td><td>

<li style="list-style:none">
Specifically address the risks/unknowns
How to set up an agreement to handle risks?
What happens if the water reuse system does not perform as agreed?
Establish a multi-agency group to foster water reuse projects.
This group could promote demonstration projects and be affiliated with the review of demonstration projects.
Review and identify funding sources and incentives for reuse projects.
This group could have a liason associated with related groups in the state such as the Metropolitan Area Water Supply Advisory Committee, Ethanol team established by MPCA, and others
Evaluate specific facility modifications required to retrofit an existing supply (potable, well, or surface water source) to a reclaimed supply.
One component of a project should include education of facility personnel on water reuse.
Need to understand processes in place to minimize health risks.
Educate employees on a reclaimed water source at their facility, the piping design requirements, operational considerations, and maintenance to keep it a safe supply.
Recognize that there are a multitude of industries with potential uses – could target one case study that would handle issues common to all (such as the institutional) and technical issues that would benefit a cross-section of industries.
Possible funding source for demonstration projects or studies to evaluate reuse applications is a SEP, supplemental environmental project. Most permittees would rather put penalty money to a good use, with added benefit to their watershed.
</td></tr>
<tr><td>Miscellaneous</td><td>

Water discharge versus energy use – this is a topic for areas with limited receiving waters that require zero discharge.
Some facilities must evaporate and use energy to do this. See tradeoff to the environment for more energy use and related pollutants to those discharged to a water body.
Water reclamation could offer options to facilities on a specific receiving stream with no discharge allowed and look to minimize energy use.
</td></tr>
</table>

Institutional Issues

Topic	Discussion

	• Question: Why is MCES evaluating water reuse?
	  o Protection of water resources
	    ▪ To sustain water supplies - keep potable supplies available for potable uses.
	    ▪ To meet water quality goals established for Minnesota's waters – reduced discharges is one option to meet more stringent discharge limits in the future.
	  o Requested by the legislature
	    ▪ State-wide evaluation
	    ▪ Metro area focus particularly with access to resources and data for metro area facilities and industries.
	• This question promoted discussion of industries using a reclaimed supply – extent of the benefit.
	  o Need a consumption of a water supply by an industry to provide benefit to a receiving stream in terms of reduced pollutant loadings
	    ▪ For facilities using once-through cooling, taking river water and discharging it back to the river – there is limited benefit to the receiving stream.
	    ▪ However, if the surface water source has limited withdrawals, then replacing the surface water supply with a reclaimed supply can benefit the waterway with sustained flows/lake or reservoir levels.
	  o Replacing a ground water supply with reclaimed water conserves the potable supply, regardless if the water is consumed by industry operations.
	• Reclaimed water can be a competitor to water utilities, particularly those with excess capacity.

Industry Stakeholder Workshop Attendance

MCES Recycling Treated Wastewater for Industrial Water Use

March 8, 2007 Meeting

Person	Organization
Sara Wilson	Kraemer Mining & Materials, Inc
Dennis Taylor	Great River Energy
Herbie Owen	Marathon Ashland Petroleum LLC
Joe Strukel	Rock-Tenn Company
Travis Richins	Rock-Tenn Company
Brian West	Rock-Tenn Company
John Smith	Twin City Tanning Co/SB Foot Tanning Co
Deborah Manning	MCES
Bill Cook	MCES
Melba Hensel	MCES
Claude Anderson	MCES
Bob Pohlman	MCES
Patti Craddock	CCE
Bob Matthews	CDM
Li Zhang	CDM

March 15, 2007 Meeting

Person	Organization
Sue Newton	ADC Telecommunications Inc
John Kimble	Certainteed Corporation
Pete Anderson	Certainteed Corporation
Mike Rutledge	Fagen Engineering LLC
Mike Falk	Flint Hills Resources LP
Wayne Duerfeldt	Gopher Resources Corporation
Patrick Flowers	Xcel Energy
Jeff Berrington	Xcel Energy
Deborah Manning	MCES
Melba Hensel	MCES
Claude Anderson	MCES
Bob Pohlman	MCES
Patti Craddock	CCE

Exhibit C
Broader Base Stakeholder Meeting

MCES Recycling Treated Wastewater for Industrial Reuse Project
Meeting Agenda

Meeting: Water Reuse Stakeholder
Meeting No.: MP05 Date: 4/24/07
Location: Metro 94, Rm 32 Time: 1:00 – 3:30 pm
455 Etna St Suite 32, St. Paul

1:00 pm Introductions – Deborah Manning, MCES

1:05 pm Meeting Objectives – Deborah Manning

1:10 pm Project Overview – Patti Craddock, Craddock Consulting Engineers

1:15 pm Discussion: Water Reuse Implementation Considerations – Patti Craddock

- Environmental Stewardship (*complete by 1:30 pm)*
- Regulatory Leadership (*complete by 1:55 pm)*
- Liability (*complete by 2:10 pm)*
- Partnered Project (*complete by 2:25 pm)*

2:25 pm *Break – 10 minutes*

- Economic Incentives (*complete by 2:50 pm)*
- Supply Issues (*complete by 3:15 pm)*

3:15 pm Q&A – Patti Craddock

3:25 pm Summary – Deborah Manning
- Recap
- Action Items

3:30 pm Adjourn

Water Reuse for Minnesota Industries – Implementation Considerations Discussion with Stakeholders, April 24, 2007

Topic	Key Points	Potential Actions
Environmental Stewardship	• Water reuse for many industries will be driven by their commitment to sustainable resources.	• Establish an award program for water reuse. • Evaluate existing award programs and how water reuse practices would fit under these programs. • Support a public education/outreach effort linking water reuse to environmental stewardship and sustainability.
Regulatory Leadership	• **Approval and Permitting Process:** The regulatory requirements and permitting process should encourage industries and municipalities to pursue water reuse. • **Water Reuse Image:** Recognition that this is a practice the state encourages for water resource protection. • **Watershed Transfer of Pollutants:** Address pollutant transfer in the TMDL process and NPDES permitting. • **Appropriations Permit:** Clarify the need for a DNR Appropriations Permit.	• Establish a regulatory 'water reuse group' with individuals as the key point of contact for each agency involved in establishing a permit to provide and use a reclaimed water supply. • The water reuse group or a subcommittee will engage in a partnered project that recommends regulatory topics for further evaluation. • Provide fact sheets and other guidance documents for municipalities and industries to reference as they consider water reuse applications, to include: o Related permits required o State agency approvals required • Other information as deemed necessary
Liability	• Industries need to be assured they are not taking on undue liability with the use of a reclaimed supply. There is concern for facility damages/loss of production, permit violations, and health problems associated with using a reclaimed supply.	• Establish a group or fund a project to resolve the liability and indemnification issues of water reuse applications.

Water Reuse for Minnesota Industries – Implementation Considerations Discussion with Stakeholders, April 24, 2007

Topic	Key Points	Potential Actions
Partnered Project	• Projects initiated, reviewed and documented by the various stakeholders will provide a resource that will encourage water reuse practices.	• Identify regulatory, industry, municipal wastewater utility, water utility, local community groups, and other partners to form a working group that is involved with the project(s). This group would walk “hand-in-hand” through the project and provide review and assessment of the project upon completion. • Projects can be case studies of the complete project process or focus on key features of water reuse projects, such as: public information programs, specific technologies, or regulatory guidelines.
Economic Incentives	• Incentives are needed to attract industries to use a reclaimed supply and municipalities to incorporate reuse in their WWTP practices. • Water reuse systems can be funded and operated by a variety of management structures – different options should be considered to provide the best incentives and optimize system costs.	• Evaluate and promote the use of the Supplemental Environmental Project (SEP) program as a source of money for water reuse projects. • Recommend state grants (LCMR) for initiation projects with in-kind contributions by partnering entities. • Evaluate SRF project selection process to identify features that would encourage water reuse projects. • Consider a pollution tax credit for equipment used in a water reuse project.

Water Reuse for Minnesota Industries – Implementation Considerations Discussion with Stakeholders, April 24, 2007

Topic	Key Points	Potential Actions
Supply Issues	• **Reliability:** A reclaimed supply can be the primary supply, backup supply or supplemental supply for an industry. The management of multiple water supplies must be considered in the facility infrastructure and processes, the storage requirements to meet variable demand patterns, and related permit requirements. • **Dual Systems:** Future development should consider dual water systems (potable and reclaimed supplies). • **Water Quality Data:** There are insufficient data available on the WWTP effluent from most municipalities. This makes it difficult to assess the treatment requirements and associated costs that would be needed to use a reclaimed supply. • **Water Sampling to Assure Permit Compliance and Acceptability for Intended Use:** The potential unknown contaminants that could occur in a municipal WWTP effluent and the concern for industry process problems and discharge permit compliance will require additional sampling to assure established water quality goals are met.	• Establish a funded program for analysis of municipal WWTP effluent for parameters of concern for water reuse applications. This program could target WWTP with highest benefits for reuse and establish a historic data base for water quality that can be referenced in the planning for water reuse projects. • Incorporate reliability, water sampling, and other supply consideration issues as key elements of study in a 'partnered project'.

Water Reuse Stakeholder Meeting
April 24, 2007
Discussion Summary

Overview

The Water Reuse Stakeholder Meeting, held April 24, 2007 from 1-3:30 pm at Metropolitan Council Environmental Services (MCES) Metro 94 Complex Meeting Rm 32, brought together regulatory, industrial, water utility, wastewater utility, and community representatives. This document summarizes the questions and comments made during the meeting. The discussion documentation follows the table of Implementation Topics and Initial Recommendations handed out at the meeting and provided in Exhibit 1. The topics summarize issues and practices identified through earlier workshops with regulators and industries and the recommendations listed served as an initial list to generate discussion with this group of stakeholders, as presented below. Exhibit 2 contains the meeting participant list and agenda.

Discussion Summary

Environmental Stewardship

1. How or are we going to incorporate goals for water reuse?
   a. Have we established any benchmarks?
   b. MCES still needs to discuss this with Council members.

2. One goal could be to implement a project (demonstration or partnered project).

3. Rewards program could be fostered after community programs similar to solid waste recycling programs. These are ongoing programs that acknowledge industry's commitment to using recycled materials/products and recycling their byproducts.

4. MnTap Award – could qualify for one based on industry's commitment to reducing water use.

5. Important that the award program is an ongoing program, this fosters competition and more recognition.

6. Industry supports these award programs, but there is an economic threshold.

7. Responsible Care – American Chemistry Council sponsored award program. Acknowledges reductions in green house gas emissions and other air and water quality pollutant reductions.

8. Brewing company in Colorado – took on the corporate culture for environmental stewardship and conservation. This affected the construction, materials selection, etc for their facility and daily operations.

9. Reuse of water will offset use of ground and surface waters = protect natural resources.

Regulatory

1. One industry had difficulty in early discussions with a municipality and regulators on a potential water reuse project. The extra monitoring and hoops to jump through were too many and the industry did not make much progress on evaluating reuse.

2. Industry would like direction on pre-approved processes to know if their water uses would qualify.
   a. It would be helpful to know options before they get too far in the planning process.
   b. Want clarification on uses that qualify as 'non-contact' water uses.

3. The CA Recycling Criteria specify water quality criteria for specific uses and can be referenced as a source.

4. Current regulations: MN handles on a case-by-case basis using the California Water Recycling Criteria.
   a. How do we begin the process to decide if regulations, guidelines, or case-by-case approach is best for Minnesota?
      - One method is to set up a Technical Advisory Committee (TAC)
        - TAC consists of experts from other states and within the state, regulators, industries, and community groups.
        - Who leads this effort for a TAC? In other states it is lead by the regulatory agency that permits water reuse.

   b. Can we just adopt the California criteria given the differences in climate? For example the influence of humidity and more significant seasonal temperature changes.
      - In Texas, they first adopted tougher turbidity criteria than the CA criteria for turbidity and then went back and revised this because they could not technically justify it.

5. MN has prepared case-by-case water reuse permits for the following applications:
   a. Golf course irrigation

   b. Agricultural irrigation, mostly alfalfa and corn for animal feed
   c. Toilet flush water
   d. Power plant cooling water with mist spray from towers

6. Invest in a pilot study to demonstrate that a process meets the public health and other water quality criteria.
   a. Example provided for industry that made cardboard boxes that were in contact with fruits and vegetables.
   b. Documented process parameters such as temperature and water quality parameters, plus final product use
   c. No health issues noted; met water quality criteria

7. Water reuse information can be provided on the MPCA website (given followup with other MPCA departments).

8. Is there a demand for reclaimed water that requires investment in water regulation development?
   a. How do we forecast this demand and plan for it?
   b. Regulatory community would support setting criteria if there was a demand.

9. Questions were raised by municipalities on whether their NPDES limits would be changed given the changes in their discharge from the receiving stream to reuse applications.
   a. There are some cases where the reduced quantity could affect a municipality from meeting a concentration limit. For example, for plants with ammonia limits that handle ammonia recycle from their digesters – often need the volume to meet the concentration limit, but are fine with the mass limit.
   b. Will the NPDES limits be changed to correspond to the reduced flow and mass to the receiving stream that is directed to reuse?
   c. For reclaimed water that is used by an entity and a portion discharged back to a receiving stream located in a different watershed or stream segment – how will this affect the TMDL for the associated streams?
   d. Concern expressed that in the TMDL process, the existing allocation for the WWTP will be reallocated because of the reduction in discharge for reuse. However, the reuse customer may go out of business or change practices and then the municipality would need to go back to the receiving stream. The WWTP would then be in violation of their permit.
   e. How the TMDL process affects a permit will depend on the timing of the NPDES permit revisions for water reuse with the TMDL process for the associated receiving stream.

10. How did the TMDL process fit with existing reuse applications in MN?
    a. For the golf course irrigation projects, land application was required for WWTP effluent because there was no discharge to waterways available/allowed.
    b. Mankato is in an area with an existing TMDL. In this case it was unique, because the reclaimed flow was directed back to the WWTP and was discharged with their effluent.

11. Is a DNR Appropriations Permit required? In most cases no. As with Mankato/Calpine Corporation, Calpine did not need one. It is possible if the reclaimed supply passes a watershed divide or other circumstances, then an appropriations permit may be required.

12. Seasonal nutrient removal limits for receiving streams promote reuse for agricultural or urban irrigation.

Liability

1. In other states, compliance with permit limits provides the assurance of a safe supply for public health. Agreements are used to list specific requirements for quality and quantity for a given industry. Monitoring assesses compliance with limits and serves as a record to determine if the supply causes a problem in the industry's production process

2. If a problem arises from use of a potable supply, an industry would not make a claim against a public water utility for resulting damages.

3. Liability related caps:
   - Environmental damage - $250,000
   - Product damage - $1M

4. Wastewater quality is more variable and there is limited control over illegal dumping into the system. A wastewater utility could track a problem to an industrial discharge – putting fault on another entity.

5. Use reservoirs/storage to dampen spikes or other variability in wastewater quality.

6. Concern expressed on cross-connections to the potable supply.
   a. Need an ongoing inspection program to ensure infrastructure is performing adequately to prevent backflow of reclaimed system into potable system.
   b. Need standards for back-flow prevention devices.
   c. Place as a requirement of the user.

Water Reuse Stakeholder Meeting
April 24, 2007
Discussion Summary

Partnered Project

1. Goal: to implement a project with the supplier, user, and regulators that documents the steps, obstacles, and decisions made from planning through operation.
   a. Purpose would be more for the institutional issues vs. the technical ones
   b. Multiple options or points of focus

2. MPCA would be interested in working with a wastewater utility and industry on this project. There was a good working team with Calpine and Mankato in developing that project.

3. How would a project be funded?
   a. There are national funding sources from WateReuse Foundation, AWWARF, WERF. Not many on industrial projects from these sources.

4. There is not a widespread understanding that there are water supply issues in MN. Education is required to show reuse is important for MN's water resources.

5. There are different issues or considerations for adding reuse to existing infrastructure than for future facilities. Future WWTPs could be sited to incorporate industry, agricultural land, transportation, etc. around the beneficial reuse of water.

6. What criteria will be used to determine if reuse is necessary? If we look 50 years down the road, what will push the state to reuse? Will the TMDL process bring us there? Will our visionary approach to the metro area water supply indicate it is water supply? How about other MN communities?

7. Who would be in the project group? MPCA, MN OSHA, MDH with industry and wastewater utility.

8. Lead organization:
   a. Some participants felt it was too early to state this.
   b. Others thought it should be those that want to make it happen – the municipality or the industry.
   c. See regulator as the protector of citizen's interests.
   d. Ex. Mankato/Calpine Corporation.

9. DNR supported working with a group with multiple agencies to look at opportunities for reuse or ways to promote reuse.

10. TMDL process is not an issue for a partnering project.

11. Conservation. Our discussion today has not focused on this. It is important to ensure the project notes that all conservation practices should continue to be pursued and that water reuse presents an additional conservation practice. We should continue to reduce water use and what water we use we should recycle.

Economic Incentives/Funding

1. What type of financial plan has been considered for a reuse system? Answer: none yet.

2. Proximity of a reuse customer to the WWTP would be important given transmission costs.

3. Funding and financing depends on the driver. In the case of MCES, if it is water quality driven then funding could follow the same method as done for treatment and discharge to our waterways – cost is shared in the metro area.

4. Priority List for PFA funding:
   a. Get more points or higher on list if discharge is to land treatment vs. receiving stream. This will help projects with irrigation reuse, but not reuse to industries.
   b. Need a rule change to get higher points for water reuse.

5. Concern expressed by industry if looking at reuse to offset costs required to treat wastewater based on revised water quality limits – and cost is transferred to the industry.

6. Industrial facility near a WWTP – why pay for the water if industry pays for pipe to get it there and provides any additional treatment for their water supply requirements?

7. Could the water utility structure the rates to provide more incentive for industry to consider reuse?
   a. Concern expressed that for those with few options and that have already reduced water use this would not be fair.
   b. Idea is to consider linking water utility and reclaimed rates. This is easier to do with a community that has same entity for both the water and wastewater utilities.

8. Need incentives to look ahead and be prepared – drivers may not be here now, but expect reuse will have a role in the future.

Water Reuse Stakeholder Meeting
April 24, 2007
Discussion Summary

Technical Supply Issues/Public Perception

1. Technical issues are site specific and variable.

2. Example provided of the SMSC plant
   a. 2 trains with different treatment to meet different end quality requirements
   b. Aquifer recharge is an ongoing discussion

3. All points noted in the Implementation Considerations table need to be considered.

Public Education – not addressed earlier

4. The topic of public awareness is critical to address in the implementation of water reuse practices in Minnesota.

5. The Minnesota public needs to be aware that reuse is for the good of the environment and that health concerns are addressed.

6. Reuse is an opportunity to be of benefit to the environment.

7. Public involvement process must begin early – up-front in the planning process need to involve community.

8. Issue for some – is this going into the tap water?

9. Consider TCAAP and Riley Tar – contaminated supplies are being treated and used by the communities. Community was educated on the treatment process and accepting of technology to use the supply. Cost was covered by federal funds for site cleanup and remediation.

10. Similar public perception issue seen with biosolids. Some communities are not allowing biosolids applications on their fields.

11. California regulations are based on significant studies. These can serve as sources to show the public the extent of scientific research that has been done in the development of regulations and related risk assessments.

12. Reuse can be part of our environmental ethic.

13. In other similar efforts to promote an environmental issue or treatment technology – it took one person or agency to take the lead. A similar model could work for water

reuse. Also, implementation could target one industry sector and gain acceptance from that type industry and type of water uses.

14. The Office of Environmental Assistance and their mission appear to align with the conservation basis of water reuse. Can they become involved?

Water Reuse Stakeholder Meeting - April 24, 2007
Participant List
MCES Recycling Treated Wastewater for Industrial Water Use

First Name	Last Name	Organization
Lih-in	Rezania	MN Dept of Health
Jim	Japs	MN Dept of Natural Resources
Lisa	Thorvig	MN Pollution Control Agency
David	Sahli	MN Pollution Control Agency
Katrina	Kessler	MN Pollution Control Agency
Bradley	Nordberg	MN Pollution Control Agency
Mary	Fralish	City of Mankato
Bob	Cockriel	City of Bloomington/WUC Representative
Shelley	Shreffler	Minnesota Environmental Initiative
Herbie	Owen	Marathon Petroleum
John	Kimble	CertainTeed Corporation
Bryce	Pickart	MCES
Bill	Cook	MCES
Deborah	Manning	MCES
Melba	Hensel	MCES
Claude	Anderson	MCES
Bob	Pohlman	MCES
Chris	Elvrum	MCES
Patti	Craddock	Craddock Consulting Engineers
Bob	Molzahn	CDM
Bob	Matthews	CDM