DEPARTMENT OF
TRANSPORTATION

Investigating Wastewater Reuse at MnDOT Truck Stations

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16. Abstract (Limit: 250 words)

The University of Minnesota (UMN) and the Minnesota Department of Transportation (MnDOT) conducted a study to determine whether implementing a wastewater reuse program would be a feasible option for MnDOT-owned truck washing stations. MnDOT has 137 truck stations in the state, where trucks are frequently washed to remove road salt build-up. MnDOT recognized an opportunity to potentially reuse the wastewater for appropriate greywater uses and recapture the salt for road use. Sampling was done to assess the wastewater contaminants in truck wash water at 11 truck-washing stations in Minnesota. Then technologies suited to removing organics and total suspended solids (TSS) but not chlorides were reviewed. The recommendation is that either a recirculating sand filter (RSF) or a membrane bioreactor (MBR) would be feasible technologies to use for this purpose. Using the MnDOT truck station in Arden Hills, Minnesota, an economic evaluation was done. Both systems could be used to effectively treat wastewater and produce brine for reuse, but the most economical solution for MnDOT would be to invest in a MBR. Compared with a RSF, an MBR is one-third less expensive over time, primarily due to low material and installation cost as well as a lower annual maintenance costs.

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INVESTIGATING WASTEWATER REUSE AT MNDOT TRUCK STATIONS

FINAL REPORT

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EXECUTIVE SUMMARY

The University of Minnesota (UMN) and the Minnesota Department of Transportation (MnDOT) collaborated to conduct a study to determine whether the implementation of a wastewater reuse program would be a feasible option for MnDOT-owned truck washing stations. MnDOT has 137 truck stations in the state, where trucks are frequently washed to remove road salt build-up. The wastewater from these operations either gets stored for later treatment or goes directly to municipal wastewater treatment plants. An opportunity was recognized here to potentially reuse the wastewater for appropriate greywater uses and recapture salt for road use, especially being that truck station wastewater already has a high potential for reuse because of its more dilute nature.

To understand how MnDOT could implement wastewater reuse, the project began with a review of current wastewater reuse policies in Minnesota, wastewater reuse programs in other states, and some international guidelines for reuse. Three Minnesota case studies were reviewed in which wastewater reuse systems were successfully implemented. Barriers to water reuse were also defined. It was found that to move forward with a project, MnDOT would likely need an individual permit and a variance through the plumbing board for each wastewater reuse system implemented, although with industrial internal reuse, this should be a simple straight-forward process.

The next phase of this project included sampling and data collection from 11 MnDOT truck-washing facilities to determine what common wastewater contaminants exist in the truck washing liquid. The goal for this phase of the project was to gather information to aid in making an accurate recommendation on treatment technologies for these sites. Samples were taken year-round from facilities with holding tanks and facilities that are connected to city sewer systems, with the majority of samples collected in winter. The wastewater was found to contain various levels of biochemical oxygen demand (BOD), suspended solids, heavy metals, chloride, and volatile organic compounds. It was found that the critical parameters to be removed from wastewater prior to reuse were BOD and total suspended solids (TSS). Chloride levels did exceed the allowable discharge standard, but since this project looked at reusing the chloride to make brine for use on roads in winter, this was not of concern.

The next phase of this project was to evaluate treatment technologies best suited to remove organics and TSS from the wastewater but maintain the chloride levels for brine production. Well-established and new treatment methods were reviewed. Case studies where wastewater treatment technologies have been implemented in other states to recycle water and produce brine solution to use for roadway deicing were also reviewed. The recommendation was that either a recirculating sand filter (RSF) or a membrane bioreactor (MBR) would be feasible technologies to use for this purpose. Finally, an economic evaluation was done to compare these two wastewater treatment technologies using system sizes, design projections, and cost estimates based on the MnDOT truck station in Arden Hills, Minnesota, with an averaged flow of 1,000 gallons per day (gpd). Cost estimates for each system were determined assuming a 25-year design life. For each type of system, materials, installation, maintenance, operation and management costs were budgeted. Both systems could be used to effectively treat wastewater and produce brine for reuse, but the most economical solution for MnDOT would be to invest in a MBR at the Arden Hills site. In comparison with a RSF, this type of system was

one-third less expensive over time primarily due to a low material and installation cost as well as a lower annual maintenance cost.

The Onsite Sewage Treatment Program recommends that any future work on this project should include moving forward with bench-scale testing, followed by a full-scale pilot of the recommended system.

CHAPTER 1: INTRODUCTION

Minnesota is rich in water resources, but even so, three-quarters of the state's water is obtained from underground aquifers (Dunbar, 2014). In densely populated areas, the increased demand depletes aquifers at unsustainable rates, strains water supplies and can lead to surface water issues (Fresh Water Society, 2013). Because of naturally occurring high levels of calcium and magnesium, most Minnesota aquifers contain hard water that must be treated and softened through a process that releases salt into wastewater. Once used, this water is discharged to local surface waters causing chloride to build up in the environment creating problems for wildlife and water quality. Reusing wastewater for irrigation and industrial purposes allows groundwater to be reserved for drinking water and can significantly reduce the amount of water pumped and treated by municipalities. By recycling wastewater for other uses, groundwater aquifers could be tapped at more sustainable levels, less water softening would be required, and more of the 65 billion treated gallons of water that currently flow from Minnesota into the Mississippi River could be captured to recharge groundwater (Dunbar, 2014; Freshwater Society, 2013).

Figure 1.1 Salt truck outside Forest Lake Truck Station (L) and the Buffalo Truck Station (R)

The Minnesota Department of Transportation (MnDOT) has 137 truck stations and over 50 Class I rest areas located throughout the state, all of which use water and have the potential for wastewater reuse (MnDOT, 2017a; MnDOT, 2017b). During the winter months, trucks are frequently washed to remove road salt. This wastewater either is stored in tanks for later pumping and treatment or goes directly to municipal wastewater treatment. If captured and treated, this wastewater could be reused for washing or toilet flushing and salt potentially could be recaptured for road use. Rest areas could capture wastewater from sinks or even storm water to reuse for toilet flushing.

CHAPTER 2: EVALUATION OF STATE, FEDERAL AND INTERNATIONAL STANDARDS ON WASTEWATER REUSE

2.1 BACKGROUND

Minnesota's current state and federal regulatory framework regarding wastewater reuse is disjointed and spread out over multiple agencies administering rules that can be contradictory. At this point, wastewater reuse systems require a variance and in some cases permits from local cities or counties. The Interagency Workgroup on Water Reuse (IWWR) was formed in 2013 to bring together all of the agencies that regulate water reuse to study and make recommendations for advancing water reuse policy in Minnesota. The IWWR is a coalition made up of stakeholders and regulators of water and wastewater: the Minnesota Department of Health (MDH), the Board of Soil and Water Resources (BSWR), the Department of Labor and Industry (DLI), the Department of Natural Resources (DNR), the Metropolitan Council, the Minnesota Department of Agriculture (MDA), the Minnesota Pollution Control Agency (MPCA), and the University of Minnesota's Water Resources Center (IWWR, 2017).

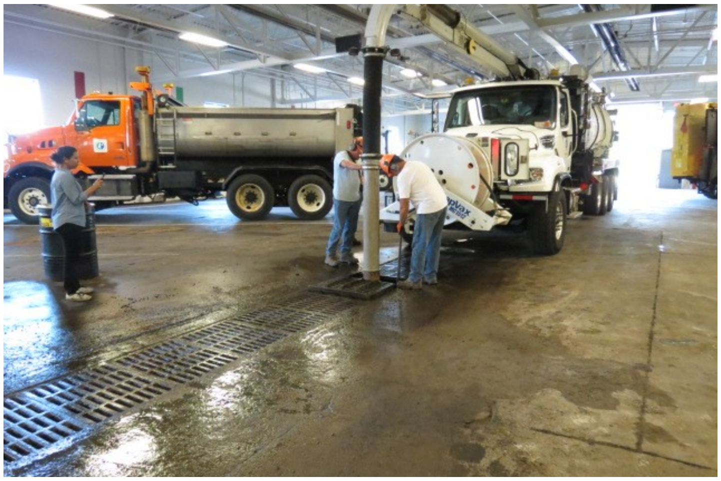

Figure 2.1 Truck washing at Arden Hills facility

According to the IWWR, wastewater can be defined as, "used or discharged water from homes, institutional or public buildings, commercial establishments, farms or industries." For the purpose of regulation, the three general categories of wastewater are (IWWR, 2017):

Domestic Wastewater: Used water from bathing, laundry, toilet, kitchen or similar sources.

Graywater: Wastewater segregated from a domestic wastewater collection system, typically from laundry and bathing water.

Industrial Process Wastewater: Wastewater generated by industrial processes, including backwash water and condensate.

This chapter of the report will specifically look at the regulatory framework surrounding wastewater and graywater reuse as applicable to MnDOT facilities, which includes both typical residential and industrial wastewater.

2.2 OVERVIEW OF MINNESOTA WASTEWATER REUSE REGULATORY BODIES AND THEIR ROLES

This report will look at the role of regulatory bodies specifically overseeing wastewater reuse in Minnesota that would be involved in permitting and regulating reuse at MnDOT facilities. The report will not look at storm water, rainwater capture, or wetland regulation because the scope of the MnDOT Reuse project does not involve discharging wastewater directly to surface waters. The table below lists the agencies involved in the regulation of building and industrial graywater and wastewater reuse.

Table 2.1 Wastewater Reuse Regulatory Agencies and Their Roles

Agency	Role	Rules and Statutes
Minnesota Department of Labor and Industry	The DLI administers the plumbing code which sets the requirements and safety regulations for the design and installation of sanitary drainage and water supply within residential, public, and commercial buildings. The DLI oversees licensing requirements, and issues variances for wastewater reuse on a situational basis.	Minn. Rules 4714
Minnesota Department of Health	The MDH implements the federal Safe Drinking Water Act and has jurisdiction when any reuse activity will result in potable drinking water, or when wastewater will be discharged or injected within proximity of a well.	Minn. Stat. 103H, 103I Minn. Rules 4720.5100-5590
Minnesota Pollution Control Agency	The MPCA implements the federal Clean Water Act and regulates water quality by issuing permits to municipal and industrial sources of wastewater discharge. The MPCA also administers the disposal of graywater and the Subsurface Sewage Treatment Systems Code.	Minn. Stat. 115 Minn. Rules 7001 (NPDES), 7050 (Water Quality Standards), 7052 (Lake Superior Water Standards), 7080 (ISTS), 7090 (Stormwater)
City or County	Issues permits for wastewater volumes less than 10,000 gallons per day based on local regulations.	

The process for obtaining approval for the type of system likely to be used at MnDOT facilities would first require design and installation approval from the DLI Plumbing Board. If approved, the wastewater reuse system would be permitted through a variance to the plumbing code. The process can be lengthy and begins with the completion of a detailed application followed by a 30-day pre-comment period for the applicant. This is followed by an additional 60-day public comment period. Revisions to the wastewater reuse system plan could be necessary, and proof will be required of a certified operator for the wastewater system. After the final permit is issued there will likely be annual fees and monitoring requirements for the system (IWWR, 2017). Minnesota began using the California Title 22 Standards for Water Reuse in 1992 for the MPCA's regulation of municipal and industrial water reuse (MPCA, 2010). Although there are not standardized treatment requirements for wastewater within the plumbing code, Title 22 standards as well as NSF/ANSI 350, 350-1 standards have been used by the Plumbing Board when issuing variances for graywater systems. When wastewater is discharged from a treatment facility, it is subject to the usual rules that are administered by the MPCA (and Met Council if within the Twin Cities) through a National Pollutant Discharge Elimination System (NPDES) permit. If the wastewater is discharged on-site to the surface, subsurface, near a well, or near wetlands the MDA, DNR, BWSR, and MDH could be involved and further permits required (Freshwater Society, 2016). Municipal wastewater reuse has commonly been permitted using California's Title 22 standards, which specify what level of treatment must be achieved for different levels of reuse. Listed below are the four different levels of treatment required by California's Title 22 standards followed by Minnesota's adaptation of the standards for three different types of reuse situations. These standards will be referenced when identifying the level of treatment required for MnDOT graywater and wastewater reuse.

Table 2.2 California Title 22 Water Quality Standards

Water Quality Standards for Various Water Recycling Sites		
Water Type[1,2]	**Parameter**	**Quality Criteria[4,5]**
Disinfected Tertiary[3,6] (recycled water that has been oxidized, filtered and disinfected)	Total Coliform	• Median concentration must not exceed 2.2 MPN/100 mL using the last 7 days analyses were completed
	Turbidity for Filtration Using Natural Undisturbed Soils or a filter bed	• Must not exceed 23 MPN/100 mL in more than one sample in any 30 day period
	Turbidity for Filtration Using Microfiltration, Ultrafiltration, Nanofiltration or Reverse Osmosis	• Must not exceed 240 MPN/100 mL at any time

Disinfected Secondary – 2.2 (recycled water that has been oxidized and disinfected)	Total Coliform	• Median concentration must not exceed 2.2 MPN/100 mL using the last 7 days analyses were completed • Must not exceed 23 MPN/100 mL in more than one sample in any 30 day period
Disinfected Secondary – 23 (recycled water that has been oxidized and disinfected)	Total Coliform	• Median concentration must not exceed 23 MPN/100 mL using the last 7 days analyses were completed • Must not exceed 240 MPN/100 mL in more than one sample in any 30 day period
Un-disinfected Secondary (recycled water that has been oxidized but not disinfected)	---	---

Table taken from the Napa Sanitation District's Wastewater Treatment Master Plan, 2011

Notes:

[1] Water type based on requirements for recycled water as defined by the State of California Department of Public and Title 22 of the California Administrative Code.

[2] "Oxidized" refers to a wastewater in which the organic matter has been stabilized, is nonputrescible and contains dissolved oxygen.

[3] The filtered wastewater must be disinfected using:
a. A process that provided a CT (product of total chlorine residual and modal contact time measured at the same point) or not less than 450 mg-min/L at all times with a modal contact time of at least 90 minutes based on peak dry weather flow; or
b A process that, when combined with filtration, has been demonstrated to inactivate and/or remove 99.999 percent of 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 demonstration.

[4] MPN/100 mL is a bacterial count in most probable number per 100 milliliters.

[5] NTU is Nephelometric turbidity units.

[6] Disinfected Tertiary effluent is sometimes referred to as "Title 22 Unrestricted" or "Title 22 Unrestricted Access."

Table 2.3 MPCA Municipal Wastewater Reuse Standards Adapted from CA Title 22

Types of reuse	**Reuse permit limits**	**Minimum level of treatment**
• Food crops where the recycled water contacts the edible portion of the crop, including root crops • Irrigation of residential landscape, parks, playgrounds, school yards, golf courses • Toilet flushing • Decorative fountains • Artificial snow making, structural fire fighting • Backfill consolidation around potable water pipe • Industrial process water that may come in contact with workers • Industrial or commercial cooling or air conditionin involving cooling towers, evaporative condensers, or spray that creates mist	2.2 MPN/100 ml. Total Coliform 2 NTU daily average; 10 NTU daily maximum turbidity	**Disinfected Tertiary** secondary, filtration, disinfection
• Cemeteries • Roadway landscaping • Ornamental nursery stock and sod farms with restricted access • Pasture for animals producing milk for human consumption • Nonstructural fire fighting	23 MPN/100 ml. Total Coliform	**Disinfected Secondary 23** Secondary, disinfection

• Backfill consolidation around nonpotable water pipe • Soil compaction, mixing concrete, dust control on roads and streets • Cleaning roads, sidewalks, and outdoor work areas • Industrial process water that will not come into contact with workers • Industrial boiler feed • Industrial or commercial cooling or air conditioning not involving cooling towers, evaporative condenser, or spray that creates mist		
• Fodder, fiber, and seed crops • Food crops not for direct human consumption • Orchards and vineyards with no contact between edible portion • Nonfood bearing trees, such as Christmas trees, nursery stock and sod farms not irrigated less than 14 days before harvest • In Minnesota, this is commonly called "spray irrigation"	200 MPN/100 ml. Fecal Coliform	**Disinfected secondary 200** Secondary, disinfection (stabilization pond systems with 210 days of storage do not need a separate disinfection process)

Table taken from MPCA's Municipal Wastewater Reuse Treatment Limits, 2010

The MPCA's adaptation of California's Title 22 standards does not include the highest level of treatment sometimes referred to as "unrestricted access." At this time, Minnesota does approve the treatment of wastewater to potable standards. The level of wastewater treatment and appropriate technology used by MnDOT will be dependent on the intended use of the recycled water. For example, reusing truck washing liquid for any industrial activity where the liquid would come in to contact with workers (such as truck washing or toilet flushing) would need to be treated to within 2.2 MPN/100 ml. Total Coliform.

Other uses such as roadside irrigation or dust control would need to be treated to 23 MPN/100 ml. Total Coliform, slightly lower standards.

2.2.1 NSF International and the American National Standards Institute

NSF International is a non-governmental international organization that identifies as a public health and safety non-profit. NSF develops voluntary consensus standards, provides product certification, system registrations, testing and auditing services, as well as training and education for the health and safety of onsite systems and products related to water and wastewater. NSF International developed the American National Standards Institute in 1970, a program that now provides consistency in evaluating onsite wastewater products for manufacturers, health officials, and customers in the United States. The NSF/ANSI 350 standards specifically apply to onsite residential and commercial water reuse treatment systems, while the NSF/ANSI 350-1 standards cover onsite residential and commercial graywater treatment systems for subsurface discharge. The following two tables are adapted from NSF International's: National Standards for Decentralized Wastewater Treatment: An Overview of Methods and Criteria for Demonstrating Product Performance, 2012. Both standards have been used by the Plumbing Board to evaluate graywater system designs and products when issuing variances.

Table 2.4 Standard 350 and 350-1 Effluent Criteria

Standard 350 Effluent Criteria			Standard 350-1 Effluent Criteria
Parameter	Class R	Class C	
$CBOD_5$	10 mg/L (25)	10 mg/L (25)	25 mg/L
TSS	10 mg/L (30)	10 mg/L (30)	30 mg/L
Turbidity	5 NTU (10)	2 NTU (5)	
E. coli	14 MPN/100 mL (240)	2.2 MPN/100 mL (200)	
pH	6.5-8.5	6.5-8.5	

Table 2.5 Graywater Influent and Characteristics

Graywater Influent Characteristics	
Parameter	**Required Range**
TSS	80-160 mg/L
$CBOD_5$	130-180 mg/L
Temperature	25-35°C
pH	6.5-8.0
Turbidity	50-100 NTU
Total phosphorus	1.0-3.0 mg/L
Total nitrogen	3.0-5.0 mg/L
Total coliforms	10^3-10^4 CFU/100mL
E. coli	10^2-10^3 CFU/100mL

2.3 FEDERAL REGULATORY BODIES

The Safe Drinking Water Act provide federal standards for the quality of potable water while the Clean Water Act regulates wastewater discharged into surface waters. Both are not applicable to residential wastewater reuse or industrial wastewater reuse unless it is going to be used for drinking water or discharged to surface water bodies, both of which are not applicable to the MnDOT Reuse project at this time. In the U.S., water reuse is regulated through states or tribal nations; however, several national agencies and research institutions have released documents to provide technical guidance, standardization, and policy suggestions to support states in water reuse development. The U.S. Environmental Protection Agency (EPA) and the U.S. Agency for International Development (USAID) released the *2012 Guidelines for Water Reuse* to “facilitate further development of water reuse by serving as an authoritative reference on water reuse practices. (USEPA, 2012)” This 600 page document is an excellent resource for policy makers and provides more than 100 case studies to show how reuse systems work in real world applications. While the document is more applicable to policy makers, MnDOT might find the case studies helpful when looking at technology and processes related to their specific types of wastewater reuse.

The Water Environment & Reuse Foundation (WERF) collaborated with researchers from the National Water Research Institute (NWRI) to release the 2017 report, *Risk-Based Framework for the Development of Public Health Guidelines for Decentralized Non-Potable Water Systems*. The report defined Decentralized Non-Potable Water (DNW) Systems as those “used to collect, treat, and re-use water from local sources (e.g., roof runoff, stormwater, graywater, and wastewater) for various non-potable applications in individual buildings, neighborhoods, or districts.” The purpose of the report was to provide practical guidelines for regulatory agencies to follow when issuing permits for DNW systems that would protect public health while also weighing the economic costs of such systems (Sharvelle, et al., 2017). The WERF report is a specifically focused on DNW systems while the EPA Guidelines are more broad and comprehensive in scope covering all aspects of water reuse. After the characteristics of MnDOT wastewater was identified, these documents were used to determine which specific reuse technologies were appropriate for the wastewater.

2.4 WASTEWATER REUSE REGULATION IN OTHER STATES

Three states were selected to serve as examples of water reuse regulation because they were early adopters of water reuse and have had decades of regulatory experience: Arizona, California, and Florida. While other states may have water reuse regulations, most were based on either California or Arizona’s standards. Minnesota’s regulatory agencies commonly use California’s Title 22 standards when permitting water reuse systems. Florida is remarkable for how it has consolidated water reuse regulation into a single overseeing body, a challenge that Minnesota is currently facing.

2.4.1 Arizona

Arid regions of the U.S. were early adopters of water reuse as a solution to water supplies issues. Arizona developed water reuse regulations as early as 1972, and in 1999, the Arizona Department of Environmental Quality gained legislative authority to permit water reuse, with an approach, that has been a regulatory model for Texas, New Mexico, and Montana (Fulton, 2014; Cowles, 2015). Arizona uses a three-part approach that allows them to be the comprehensive state administrator on water reuse covering all aspects of permitting through an Aquifer Protection Perm it, Reclaimed Water Permit, and Reclaimed Water Quality Standards (Fulton, 2014). Water reuse systems are evaluated based on performance standards rather than design. Recycled water is categorized into five different classes based on the level of treatment. Each class has allowable uses based on the risk posed to human health and safety and water quality (Rock et al., 2012). By using California's Title 22 Standards, Minnesota has four different levels instead of five. Minnesota also categorizes treatment levels by type of water use, and does not have recycled water classes. However, as Minnesota clarifies its water reuse regulatory framework, it could adopt more stringent classifications modeled on the Arizona standards.

Table 2.6 Recycled Water Quality Standards in Arizona

Recycled Water Class	Treatment Process (Minimum)	Recycled Water Standards							
				Turbidity		Microbial			Total Nitrogen
		BOD5	TSS	24 Hr Avg	Any Time	Fecal Coliform (FC)		Enteric Virus	
		(mg/L)	(mg/L)	(NTU)	(NTU)	Daily conc. (cfu/100ml)	Max conc. (cfu/100ml)	Blended Water	(mg/L)
Class A+	Secondary Treatment + Filtration + Nitrogen Removal + Disinfection	NS	NS	≤ 2	≤ 5	No detectable FC in 4 of last 7 daily samples	≤ 23/100 ml	No detectable enteric virus in 4 of last 7 monthly samples	5-sample geometric mean conc. Less than 10 mg/L
Class A	Secondary Treatment + Filtration + Disinfection	NS	NS	≤ 2	≤ 5	No detectable FC in 4 of last 7 daily samples	≤ 23/100 ml	No detectable enteric virus in 4 of last 7 monthly samples	NS
Class B+	Secondary Treatment + Nitrogen Removal + Disinfection	NS	NS	NS	NS	≤ 200/100 ml in 4 of last 7 daily samples	≤ 800/100 ml	NS	5-sample geometric mean conc. Less than 10 mg/L

Class B	Secondary Treatment + Disinfection	NS	NS	NS	NS	≤ 200/100 ml in 4 of last 7 daily samples	≤ 800/100 ml	NS	NS
Class C	Secondary Treatment (stabilization pond + aeration) + With or w/o disinfection [Retention time in stabilization pond >20 days]	NS	NS	NS	NS	≤ 1000/100 ml in 4 of last 7 daily samples	≤ 4000/100 ml	NS	NS

2.4.2 California

California has been a pioneer in the field of water reuse since 1929 when Los Angeles County's sanitation districts started using recycled wastewater for irrigation in parks and golf courses (Rock et al., 2012). The 1969 Porter-Cologne Water Quality Control Act (PCWQCA) and Title 22 of California's Water Recycling Criteria together set discharge standards for reclaimed water and provide a regulatory framework for water reuse. The California Department of Public Health sets treatments standards for recycled water while nine regional quality control boards administer the regulations and issue permits (Water Education Foundation, 2016). Title 22 has been widely used as a model for other states including Minnesota. The MPCA and the Minnesota Plumbing Board use Title 22 Standards for regulating water reuse.

2.4.3 Florida

Florida is a national leader of water reuse and recycles an average of more than 727 MGD (Martinez & Clark, 2015). This water is used for the following purposes:

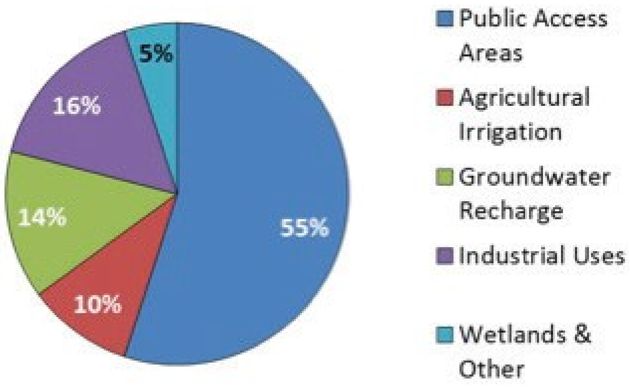

Figure 2.2 Reuse Activities in Florida
Source: IFAS Extension (Martinez & Clark, 2015)

Florida water reuse is regulated by Chapter 62-610, Reuse of Reclaimed Water and Land Application, which is administered by the Department of Environmental Protection through the Division of Water Resource Management. This rule is described as providing “a comprehensive and detailed set of requirements for the design and operational criteria of a wide range of reuse and land application systems consistent with EPA's Guidelines for Water Reuse (FDEP, 2017).” Like Arizona, a single agency oversees the administration of water reuse regulation in the state creating a more streamlined process for permitting. As Minnesota moves forward in developing its own water reuse regulation, states like Florida with a central reuse authority might serve as a model for how to consolidate roles and streamline the regulatory process.

2.5 INTERNATIONAL WASTEWATER REUSE

Most of the countries in the world utilizing wastewater reuse are also countries with arid climates or water scarcity issues. For example, both Australia and South Africa have robust wastewater reuse regulation and practices. Because Minnesota faces reuse conditions that are unique to cold climates, this report will look more broadly at recommendations by organizations such as the United Nations (UN) and the World Health Organization (WHO), and at how other countries with similar climates have tackled wastewater reuse.

According to the UN’s World Water Assessment Program (WWAP), treated wastewater now accounts for 10% of agricultural irrigation water and is used by over 50 countries all over the world (WWAP, 2017). The UN’s Sustainable Development Goal 6 (SDG6) aims at reducing the amount of untreated wastewater by half and significantly increasing water reuse by the year 2030. With this goal in mind, the UN released a comprehensive report, “World Water Development Report 2017: Wastewater, The Untapped Resource” that examines reducing point-source pollution, treating wastewater, reusing reclaimed water and recovering useful by-products in different regions all over the world from social, economic, and environmental perspectives. The report does not recommend specific treatment standards, but references many examples of how different countries are approaching wastewater treatment and reuse all of the world. One the challenges the report identified for North America is a lack of comprehensive risk-based treatment standards for treated wastewater.

The WHO began focusing on wastewater reuse for agricultural purposes and released a series of guidelines in 2006 called, “Guidelines for the Safe Use of Wastewater, Excreta and Greywater” that present a framework for a risk-based approach to reusing wastewater for irrigation. The guidelines look at all of the potential pathogens and harmful substances found in wastewater and discuss how to monitor, treat, and manage them in ways that take social, economic, and environmental considerations into account. The guidelines provide examples of lab test results for contaminated wastewater, discuss the danger to human health for each, and provide examples of treatment standards for each from multiple countries (who, 2006). Recently, the WHO expanded its focus to include potable reuse of wastewater and released another set of guidelines in 2017 called, “Potable Reuse: Guidance for Producing Safe Drinking Water” with the goal of helping drinking-water providers and regulators plan, design, and operate potable reuse schemes. The report uses many different examples from all over the world, but multiple water utilities and treatment plants in California and Texas feature heavily in the report (WHO, 2017). The detailed description of the specific technology used in each case study will be helpful during the next phase of the MnDOT Reuse project when evaluating appropriate wastewater reuse technology for MnDOT facilities.

Many cold climate countries in Northern Europe are not as far along in water reuse implementation as the United States, however Canada operates much like the US in that water reuse regulation is left up to individual provinces and territories. There are national guidelines for certain reuses such as toilet and urinal flushing that provide a recommended range of standards for provinces to use as they adopt their own standards. For example, the total fecal coliform recommended in reuse water used for toilet flushing ranges from 0-200 CFU/100 ml. There are national plumbing code standards that apply to water reuse systems in residential and commercial buildings, and Canada uses NSF 350 performance standards for water reuse systems. Below is an example of reuse standards for Alberta, Canada, but each province has developed their own (Vassos, 2015).

Table 2.7 Alberta Water Reuse Standard

Alberta Water Reuse Standard			
Permitted Uses	**Treatment Requirements**	**Effluent Quality Requirements**	**Monitoring Requirements**
Conventional wastewater irrigation, both unrestricted and restricted	A best practicable treatment approach, providing the required effluent quality (essentially secondary treatment with disinfection)	• CBOD < 100 mg/L • COD < 150 mg/L • TSS < 100 mg/L • EC < 1.0 dS/m for unrestricted use, 1.0-2.5 dS/m for restricted use, > 2.5 unacceptable • SAR < 4 for unrestricted use, 4-9 for restricted use when EC > 1.0 dS/m, > 9 unacceptable • pH = 6.5-8.5 • Total coliform < 1000/10 mL • Fecal coliform < 200/100 mL	Twice annually Twice annually Twice annually Twice annually Twice annually Twice annually Geometric mean of weekly or daily samples in a calendar month, depending on whether or not storage provided

Table taken from Golder Associates, "Water Reuse in Canada," (Vassos, 2015)

2.6 WASTEWATER REUSE CASE STUDIES IN MINNESOTA

2.6.1 Lake Vermillion State Park

Lake Vermillion State Park faced challenges in securing a potable water supply. The onsite-well only pumped two gallons per minute and was high in arsenic while the nearest city water supply was more than five miles away (Minnesota Conservation Volunteer, 2017). Pumping water from Lake Vermillion was the only option, but that water would need to be treated and stored for campground use. In order to conserve lake water and reduce treatment costs, DNR park planners proposed building a graywater system. In April of 2015 the DNR presented this graywater system design to the Plumbing Board who granted a variance and approved the project because it complied with both Title 22 and FSF/ANSI 350, 350-1 standards (MDLI, 2015).

The Lake Vermillion graywater system captures wastewater from 12 sinks and 6 showers, filters it and then treats it with ozone in a tank before using it to flush the 10 toilets. By reusing graywater, the system is estimated to conserve 135,500 gallons of water each season (Minnesota Conservation Volunteer, 2017). Park staff have been trained on the operation and maintenance of the system, but are not required to be certified. The Plumbing Board Meeting Minutes and the DNR's submitted variance application have been included in **Appendix A** in order to provide an example of the application and approval process.

2.6.2 GNP

In 2011, the GNP Company (formerly known as Gold'n Plump Poultry) located in Cold Spring, MN decided to get ahead of upcoming U.S. EPA and MPCA regulations by significantly expanding the wastewater system at its chicken processing facility. The facility uses 1.4 million gallons of water a day, but been able to reuse 300,000 gallons of that water up to five times reducing the overall environmental impact by as much as 80% (Fuhram, 2011; Freshwater Society, 2016). The system filters wastewater through membrane bioreactors that significantly reduce turbidity, biological phosphorus, and ammonia nitrogen to levels well within regulations. The improved water quality of their wastewater discharge could allow the facility to expand production by 20%, and has already resulted in energy savings (Fuhram, 2011). Initially, the facility recycled wastewater for vehicle washing and irrigation, but recently the facility expanded their wastewater infrastructure to treat up to potable standards that can be used for rinsing processed chickens (Freshwater Society, 2016).

2.6.3 Mankato Power Plant

Mankato's wastewater treatment plant (WWTP) needed to be upgraded in order to meet water quality standards at the same time that the power company Calpine Corp was looking for a water source for its cooling towers. In 2006, Calpine agreed to pay $22 million for a new WWTP facility that the city would own and maintain in exchange for a 20-year water supply.

The reuse treatment process is based on California's Title 22 standards, and is more stringent than what is typical for WWTP effluent discharge. The process effectively removes phosphorus and ammonia reducing the amount that is discharged into the Minnesota River. Because the power plant uses less water than the 400 million gallons that are recycled each year, the city can use the excess water for washing trucks, sweeping streets, and irrigating parks (Dunbar, 2014).

2.6.4 Shakopee Mdewakanton Sioux Community

In the 1990's the south metro was placed under pumping restrictions because unsustainable use of the regional groundwater aquifer was affecting surface waters including the ecologically rare Savage Fen. This prompted the Shakopee Mdewakanton Sioux Community (SMSC) to examine their own practices in order to find ways to reduce use and replenish the groundwater aquifer (Dunbar, 2014; Roper, 2017). In 2006, the SMSC built a water reclamation facility (WRF) that reduced the community's water use by 35 million gallons a year, cutting their total groundwater use by a third (SMSC, 2017).

The WRF first filters the wastewater using screens and a vortex grit removal system. Next, the water is treated using Biologically Aerated Filtration (BAF) that utilizes bacteria to consume suspended and dissolved solids in the wastewater. The wastewater is then purified through membrane filtration and disinfected using ultraviolet light. The 136 tons of biosolids removed every year through the water reclamation process are also recycled and transformed into a fertilizer (SMSC, 2017). The reclaimed water is released into a local wetland and an irrigation pond for future use.

The SMSC has spent five years researching and studying the possibility of injecting recycled water back into the groundwater aquifer. The plan is currently under review by state and federal agencies. Despite the high level of water quality, several barriers exist to the use of treated water. Public perception or the "ick" factor regarding recycled drinking water is still an issue for many people. More research is required to match treated water to Minnesota's geology and water chemistry and understand the effects of injecting water back into the aquifer (Roper, 2017). Finally, chemicals of emerging concern are washed down the drain at low levels that build up in our environment. More research is needed to understand which chemicals accumulate in the environment and groundwater and how they can be treated (Dunbar, 2014).

2.7 REGULATORY NEEDS IN MINNESOTA

The regulatory environment in Minnesota is disjointed with overlapping regulatory jurisdictions with contradictory requirements. The regulatory situation causes confusion in the market place and with planning efforts because it is difficult for entities to know what is required to successfully implement a project. The State of Minnesota as directed by the legislature undertook an effort to identify the regulatory opportunities and challenges. The University of Minnesota Technical Assistance program surveyed the interest level in water reuse among stakeholders and asked for their input in identifying barriers to water reuse. A summary of the results is listed below.

2.7.1 MnTAP Survey Results

The University of Minnesota's Minnesota Technical Assistance Program (MnTAP) conducted a survey in 2015 with a stated desire to:

- Get an estimate of the number of reuse applications taking place in Minnesota
- Gauge the level of interest in future applications
- Identify any barriers or gaps that currently limit or prevent water reuse
- Identify any concerns related to water use (WRIW, 2016)

A wide variety of people responded including schools, corporations, wastewater utilities, consultants, golf course managers, and watershed districts, for a total of 588 survey responses. The common barriers to water reuse identified in the survey were:

- Cost
- A lack of technical information and design standards
- Code and regulatory issues
- Public health concerns
- A lack of examples and state-specific guidance (IWWR, 2017)

2.7.2 Barriers to Reuse

The regulatory framework for reuse in Minnesota needs to be simplified and streamlined in order to create a better permitting process. At this point, the MDH has jurisdiction over the water supply until it reaches a residence or business at which point the plumbing code (DLI) assumes authority. As the wastewater leaves the building it comes under the regulatory authority of the MPCA and possibly the DNR or MDH depending on if it's being discharged to surface water or within proximity of a well. A permitting process that clearly defines each agency's roles or creates a single reuse authority is necessary to remove the confusion of contradictory or overlapping rules.

Minnesota does not have a clear authority or agency to conduct inspections, and verify the performance of systems over time. Operation and maintenance of these systems requires training and possibly certification. Which agency would provide these administrative and regulatory functions?

Minnesota is a cold weather climate with vastly different seasonal conditions to take into consideration when designing systems. Irrigation is a common use for recycled water, but this need is only present during summer dry spells. Will reuse water be able to meet high water demands, and will there be a use for recycled water at other times of the year?

The risk or perceived risk to public health is one of the main concerns in using recycled water. Water quality standards vary between states, agencies, and rules. A standardized and clear explanation of water quality requirements is necessary for the state of Minnesota. At the same time, these standards must be balanced with economic realities so that reuse systems do not become impractical.

2.7.3 IWWR Recommendations for the State of Minnesota

MnDOT specific recommendations based on the wastewater are found in Section 5. Current recommendations are based on the need for Minnesota to develop clear and streamlined water reuse policy. The IWWR was tasked by the Minnesota Legislature to “prepare a comprehensive study of and recommendations for regulatory and non-regulatory approaches to water reuse for use in development of state policy for water reuse in Minnesota.” They completed their study this year and came up with a list of eight recommendations (IWWR, 2017):

1. **Define who will do what**
   The plumbing board is not equipped to provide ongoing oversight of reuse systems, which often require additional expertise. Water quality criteria needs to be incorporated into the reuse system approval process, but not necessarily the plumbing code. State standards should be set, and then a single authority should be named or formed to oversee reuse permitting and inspections, or roles should be clearly defined between agencies.

2. **Develop water quality criteria based on the pathogen reduction target approach**
   While drinking water standards are clearly defined, there are no such standards for non-potable water. Instead of treating all water to drink water standards, the IWWR proposes a “fit-for-purpose” concept that allows for different levels of treatment based on the end use and risk of exposure.

3. **Develop a risk-based management system**
   The goal of the management system would be to limit pathogen exposure based on a tiered level of risk. For example, low risk activities such as stormwater use for restricted access irrigation could be managed through education and guidance rather than through regulation. Moderate risk activities such as stormwater reuse for irrigation on housing development lots and public spaces could be handled through a combination of guidance and regulation. High risk examples would include water supply facilities, wastewater treatment facilities, and public pools. These situations would require active regulation and permitting.

4. **Determine standards and guidelines**
   These standards and guidelines should include standardized operation and maintenance plans, design components, recommendations for monitoring and reporting, and labeling and safety feature.

5. **Simplify the process for implementers**

Simplifying the process could mean creating a general permit that could be applied more broadly, streamlining the permitting steps, and educating implementers about the process.

6. **Educate about water reuse**
   A training process should be developed for designers, operators, and maintainers of more complicated or high risk systems.

7. **Work to resolve unique issues related to graywater reuse**
   Further work is required to address the unique regulatory needs of graywater reuse. Until all of these issues can be resolved, the plumbing board should continue to issue variances on a case-by-case basis.

8. **Conduct ongoing research**
   Ongoing communication with national agencies and other states is necessary to stay informed of recent research, policies, and practices. Further research is needed on chemicals of emerging concern, microbial pathogens, and cold weather climate concerns in order to create effective rules and guidance.

2.8 SUMMARY

The regulatory framework for wastewater reuse in the State of Minnesota will be a challenge for MnDOT as they explore options for installing these systems in their facilities. Each system will likely need an individual permit and variance through the plumbing board. Reuse technology has widely adopted NSF 350 standards, and Minnesota has been using California Title 22 standards for water reuse since 1992, which means that choosing the right technology will be likely be easier than the permitting process. If MnDOT proceeds in installing reuse technology before Minnesota has developed its own standards there is a chance that these systems could become outdated. The next phase of the reuse project will help determine the type of system MnDOT will need by identifying wastewater characteristics and the type of technology needed to meet CA Title 22 standards.

CHAPTER 3: SAMPLING RESULTS FROM POTENTIAL STREAMS FOR WASTEWATER REUSE

3.1 BACKGROUND

Treating wastewater on-site at commercial sites such as MnDOT facilities is challenging due to many factors. First, a majority of the human-generated wastewater is concentrated blackwater from toilet flushing. Second, when snow removal equipment and vehicles are washed down, there is residue from the roads and petroleum from the equipment. Third, when wastewater is reused for irrigation, toilet flushing or truck washing, the wastewater must be treated for public health and safety and to assure it does not create plumbing or operational issues such as build-up on piping, corrosion of equipment or plugging of nozzles.

Eleven MnDOT truck station were selected and samples taken throughout the 2017-2018 season. Thirty seven winter samples were collected along with additional non-winter samples for comparison. In this part of project, the overall the goal was to identify what common wastewater contaminants are in truck washing liquid. This information was useful in identifying appropriate treatment technologies in the next step.

Figure 3.1 Extracting a non-winter sample from the holding tank at the Shakopee facility.

3.2 METHODS

Sampling locations had an equal number of sites with holding tanks and those connected to municipal wastewater treatment plants (WWTP). Locations were also selected for their proximity to the University of Minnesota – Twin Cities campus. For the eleven sites, a site survey was conducted to determine sampling locations and a follow up site use survey was sent to the facility manager/site supervisor. A non-winter sample was collected at all sites for comparison of winter versus non-winter wastewater characteristics. One third were collected in the fall and the remaining collected in May due to the extended winter. Researchers waited one month from the last snowfall event to assure all the chloride from salt trucks had exited the holding tanks.

The five truck stations with holding tanks were sampled twice during the winter and once in the non-winter for comparison. The Technical Advisory Panel (TAP) determined that due to the composite nature of the holding tanks; fewer samples were needed compared to the sites connected to WWTPs. The two holding tank samples were taken after different events. To assure that variability across the winter occurred, the second holding tank sample was taken after the tank was cleaned following previous events. The five truck stations with holding tanks included Buffalo, Dresbach, McGregor, North Branch, and Shakopee.

Figure 3.2 Wash bay (L) and flammable waste trap sampling (R) at Plymouth facility

Five truck stations connected to city sewer were within the Twin Cities metro area. In order to capture the truck washing liquid before it went to the wastewater treatment plant, sampling had to occur while truck washing was taking place. This required a great deal of coordination after each snow event. Four winter samples and one non-winter sample were taken for comparison. A greater number of winter samples was needed from city sewer sites due to the variability in each washing event. At one truck station, Anoka, wastewater was sampled from the main catchment basin in the middle of the shop. At the remaining four sites: Forest Lake, Maple Grove, Plymouth, and Spring Lake Park, samples were collected from each truck station’s flammable waste trap.

An additional site, Arden Hills, was selected to observe variability over time by collecting ten samples total over the winter and in non-winter months. Arden Hills Truck Station is connected to city sewer and so samples in the winter were taken from the flammable waste trap while truck washing was taking place. A total of seven winter samples, one summer sample, and one fall sample and a May sample were collected.

All sampling used a Masterflex E/S portable sampler with reversible flow with a prime/purge function and a polytetrafluoroethylene hose that extended into the holding tank or flammable waste trap. Any initial grease floating at the top of the tank was flushed through the hose until the layer below was reached. The pump ran for a couple minutes before a sample was collected to flush the hose. After all samples were collected, the hose was flushed for several minutes with soapy water, followed by plain water. The wastewater samples were labeled and placed in a cooler with ice. Samples were delivered to the lab with six hours of collection in order to perform the most time sensitive test for fecal coliform. Pace Analytical ® labs are certified by the Minnesota Department of Health and performed all analysis. All samples were tested for the following parameters using the corresponding approved methods.

Figure 3.3 Sampling the flammable waste trap with the Masterflex E/S Sampler at the Arden Hills Truck Station during a truck washing event.

Table 3.1 Parameters analyzed and the method of analysis

Parameter	**Method**
Biochemical Oxygen Demand (BOD)	Hach 10360 Rev 1.1
Total Suspended Solids (TSS)	SM 2540D
Fecal Coliform	SM 9222D
Metals (Arsenic, Barium, Cadmium, Copper, Lead, Manganese and Zinc)	EPA 6010C
Mercury	EPA 7470A
Volatile Organic Compounds	EPA 82608B
Chloride	SM 4500-Cl E

3.3 RESULTS

3.3.1 Truck Station Data

Table 2 highlights the various site information about the differing truck stations. The full site survey data set can be found in **Appendix B.**

Table 3.2 Facility information.

Facility	Primary Uses	Discharge Location	Flammable Waste Trap	Employees (winter/summer)	Salt Used in 17/18 (tons)
Anoka	Garage, offices, breakroom, bathrooms	WWTP	Yes	13/5	4144
Arden Hills	Garage, offices, bathrooms	WWTP	No	31/70	1800
Buffalo	Garage	Holding tank	Yes	10/?	
Dresbach	Garage, office, breakroom, bathrooms	Holding tank	Yes	9/7	2600
Forest Lake	Garage, office	WWTP	Yes	27/15	4000
Maple Grove	Maintenance garage, mechanic shop and inventory center	WWTP	Yes	48/?	1750
McGregor	Garage, office, breakroom, and bathrooms	Holding tank	No	6/?	2500
North Branch	Garage, ?	Holding tank	Yes	14/6	?
Plymouth	Garage,?				
Shakopee	Garage, ?	Holding tank	Yes	20/?	1500
Spring Lake Park	Garage,?	WWTP	Yes	?	?

3.3.2 Chloride, organics, solids and bacteria data

Table 3 provides of each site’s summary of the data collected on the wastewater during the winter months for chloride, BOD, TSS and Fecal Coliform. Table 4 indicates the average values across all sites for all winter samples. **Appendix C** contains the entire data set.

Table 3.3 Site average data for chloride, BOD, TSS and fecal coliform

Site	Average Chloride (mg/L)	Average BOD (mg/L)	Average TSS (mg/L)	Average Fecal Coliform (CFU/100 ml)
Anoka	46,570	102.1	275	8
Arden Hills	14,572	915.0	236	635
Buffalo	16,683	ND	10	18
Dresbach	23,650	70.1	29	3
Forest Lake	11,361	35.2	236	5
Maple Grove	19,595	151.0	101	TNTC
McGregor	4,333	212.0	59	6
North Branch	15,333	245	114	406
Plymouth	12,052	148.0	231	7
Shakopee	13,040	102.9	52	6
Spring Lake Park	10,638	91.7	239	20

Table 3.4 Summary of the data across all sites for chloride, BOD, TSS and fecal coliform.

	Chloride (mg/L)	BOD (mg/L)	TSS (mg/L)	Fecal Coliform (CFU/100 mL)
MPCA Discharge Limit	*230 mg/L**	*25*	*30*	*200***
Overall Average	17,139	334.2	193	217
Standard Deviation	16,286	521.8	145.46	701
Minimum Value	502	35.2	10	1
Maximum Value	63,900	2140.0	626	3,300

*This is for direct discharge and is dependent upon receiving water body.
** This is enforced during non-winter months when human contact is likely.

3.3.3 Metals

Nine metals were sampled for including arsenic, barium, cadmium, chromium, copper, lead, manganese, zinc and mercury. Of those nine, three were found only at Arden Hills and not with any regularity: Arsenic (1 sample, 9/12), cadmium (4 samples across seasons) and mercury (1 sample 12/6). This data may vary from other sites as during the sampling period paving operations run out of the Arden Hills facility. Some of the data were obtained outside of the paving season, but the flammable waste trap sampled from may have residential material releasing some amounts of these metals into solution over time.

Table 3.5 Average concentrations of six commonly found metals for each site.

Site	Barium (ug/L)*	Chromium (ug/L)	Copper (ug/L)	Lead (ug/L)	Manganese (ug/L)	Zinc (ug/L)
Anoka	611	ND	130.2	ND	984	1,309
Arden Hills	402	118.8	169.7	31.6	690	1275
Buffalo	283	ND	15.8	ND	722	249
Dresbach	374	ND	ND	ND	1042	129
Forest Lake	286	68.0	150.0	36.0	675	701
Maple Grove	374	10.6	312.0	10.6	588	608
McGregor	296	40	62.1	ND	684	69
North Branch	270	ND	86.1	ND	1,030	666
Plymouth	492	66.3	204.0	52.5	682	1,444
Shakopee	115	ND	28.2	ND	683	319
Spring Lake Park	266	27.6	103.7	35.2	346	495

*ug/L = microgram per liter, 1 microgram per liter – 0.001 milligram per liter
ND = not detected

Table 3.6 Summary of the commonly found metals across all sites compared to EPA Chronic Standard for Freshwater.

	Barium (ug/L)*	Chromium (ug/L)	Copper (ug/L)	Lead (ug/L)	Manganese (ug/L)	Zinc (ug/L)
*EPA Chronic Standard for Freshwater**	*NA*	*570*	*NA*	*65*	*NA*	*120*
Overall Average	356.4	74.9	154.8	33.0	709.7	819.6
Standard Deviation	192.8	108.6	105.2	18.1	340.6	615.5
Minimum Value	73.8	10.6	11.2	10.3	133.0	32.1
Maximum Value	887.0	479.0	496.0	60.0	1530.0	2700
Sites with Positive Hits	11	6	10	5	11	11

*These are typically applied to direct discharge to freshwater

When available the aquatic life criteria for toxic chemicals is included. These levels are the highest concentration of specific pollutants in water that are not expected to pose a significant risk to the majority of species in freshwater.

3.3.4 Volatile organic compounds

Seventy different volatile organic compounds (VOC) were sampled for in the wastewater. Of the seventy VOCs only fifteen were found at more than one site, with many not detected at all. Several others were only found at very low concentrations of less than 20 ug/L at a few sites: Chlorobenzene, Chloroform, Dibromochloromethane, Ethylbenzene, 1,3,5-Trimethylbenzene, Xylene. Tables 7 and 8 below summarize the site data compared to the Maximum Contaminant Level (MCL). The MCL is the highest level of a contaminant allowed in drinking water. MCLs are enforceable standards. The MCL of 5 ug/L was exceed for 1,2-Dichloroethan-D4 at all sites The is commonly known as ethylene dichloride (EDC), is a chlorinated hydrocarbon. It is a colorless liquid with a chloroform-like odor. According to EPA (2019), the most common use of 1,2-dichloroethane is in the production of vinyl chloride, which is used to make polyvinyl chloride (PVC) pipes, furniture and automobile upholstery, wall coverings, housewares, and automobile parts. 1,2-Dichloroethane is also used generally as an intermediate for other organic chemical compounds and as a solvent. MnDOT should evaluate their solvent use to determine if there is a product being used containing the contaminant and if its use can be discontinued. It is typically treated by activated carbon or an aerobic process. An aerobic process will be need to treat the organic material in the sample so the concentration will be reduce prior to reuse.

Complete data set for all detected volatile organic compounds can be found in **Appendix D**.

Table 3.7 VOC data for sampled sites (1).

Site	1,2,4-Trimethylbenzene (ug/L)	1,2-Dichloroethane-D4 (ug/L)	2-Butanone (ug/L)	4-Bromofluorobenzene (ug/L)	4-Methyl-2-pentanone (ug/L)
Anoka	2	104	12.6	100.4	14.7
Arden Hills	63.1	98.8	6.1	92.2	12.2
Buffalo	ND	109	40.3	100.1	8.0
Dresbach	ND	96	13.7	96.8	6.6
Forest Lake	ND	102	5.4	101.8	11.8
Maple Grove	4.2	102.5	9.1	99.3	14.2
McGregor	0.5	101	7.0	98.0	ND
North Branch	ND	100	10.4	98.7	10.2
Plymouth	10.0	104	5.8	98.4	8.6
Shakopee	ND	102	7.5	97.2	190.0
Spring Lake Park	8.4	99.2	25.7	97.8	30.8
MCL	***70***	***5***	***NA***	***NA***	***NA***
All Site Average	**38.1**	**101.4**	**13.8**	**97.6**	**27.4**

Table 3.8 VOC data for samples sites (2).

Site	Acetone (ug/L)	p-Isopropyltoluene (ug/L)	Toluene-d8 (ug/L)	Toluene (ug/L)
Anoka	164.4	44.1	99.0	1.1
Arden Hills	593.4	3,224	100	76.9
Buffalo	115.1	43.0	98.9	1.2
Dresbach	46.7	4.6	93.0	1.1
Forest Lake	34.5	14.5	99.0	ND
Maple Grove	83.2	9.0	98.5	ND
McGregor	31.5	164.0	99.0	0.7
North Branch	51.5	2.2	98.0	ND
Plymouth	33.7	35.4	99.0	1.1
Shakopee	68.4	88.0	98.3	ND
Spring Lake Park	39.1	115.7	99.0	2.2
MCL	***NA***	***NA***	***NA***	***1000***
All Site Average	**158.0**	**649.0**	**98.8**	**39.1**

No sites exceed the MCL.

3.3.5 Brine and Cleaner Analysis

In addition to testing the wastewater for potential contaminants, samples of brine and the cleaner used to wash the trucks were tested for metals, volatile organic compounds, BOD, total suspended solids, and chloride. Tables 9 and 10 summarize the results of those tests and what compounds were found in the brine and cleaner.

Table 3.9 Compounds detected in Spring Lake brine.

<table>
<tr><td>Compound</td><td>Zinc</td><td>Acetone</td><td>2-Butanone</td><td>1,2-Dichloro-ethane-d4</td><td>Toluene-d8</td><td>4-Bromo-fluorobenzene</td></tr>
<tr><td>Concentration (ug/L)</td><td>2,930</td><td>50.3</td><td>6.0</td><td>113</td><td>101</td><td>103</td></tr>
<tr><td colspan="4">BOD: ND</td><td colspan="3">Total Suspended Solids: 67.0 mg/L</td></tr>
<tr><td colspan="7">Chloride: 160,000 mg/L</td></tr>
</table>

Table 3.10 Compounds detected in truck cleaner.

<table>
<tr><td>Compound</td><td>Barium</td><td>Copper</td><td>Manganese</td><td>1,2-Dichloro-ethane-d4</td><td>Toluene-d8</td><td>4-Bromo-fluorobenzene</td></tr>
<tr><td>Concentration (ug/L)</td><td>79.3</td><td>72.3</td><td>8.6</td><td>98</td><td>99</td><td>100</td></tr>
<tr><td colspan="4">BOD: 579 mg/L</td><td colspan="3">Total Suspended Solids: 14.0 mg/L</td></tr>
<tr><td colspan="7">Chloride: 80.8 mg/L</td></tr>
</table>

3.4 SUMMARY

The data collected indicates that the critical parameters to be removed from wastewater prior to reuse are organics (BOD) and TSS. The chloride levels do exceed the allowable discharge standard, but because the likely reuse will be to make chloride brine this is not of concern. The fecal coliform levels do occasionally exceed the allowable discharge standard, but the treatment used to remove BOD and TSS will reduce this number below the limit. Zinc is the one metal that was found above the EPA Chronic Standard for Freshwater, but based on the results from the brine the source of zinc is the salt used to make the brine. Zinc often is a secondary constituent of road salt in amounts of 0.02-0.68 ppm (Goldman and Hoffman, 1975). No VOCs of concern were found. The next step will evaluate what treatment process best treats the organics and solids prior to reuse. To lower the zinc levels, source reduction could be achieved by evaluating the zinc levels in the salt used to make the brine solution.

CHAPTER 4: WASTEWATER TREATMENT TECHNOLOGIES

4.1 BACKGROUND

Wastewater treatment technologies were reviewed for potential application to the washout from road salting trucks at Minnesota Department of Transportation truck washing stations. This wastewater contains various levels of BOD, suspended solids, heavy metals, chloride, and volatile organic compounds. Both well-established and more recently developed treatment technologies were tested. Several technologies are available which remove some, if not all of these contaminants. With BOD and TSS exceeding allowable discharge limits at most truck-washing stations, recommended treatment technologies target the removal of those materials, while maintaining chloride levels so that the effluent may be reused to make brine for road application. Multiple case studies are discussed in which similar wastewater reuse projects have been carried out and applicable technologies used.

Washing of trucks at Minnesota Department of Transportation (MnDOT) truck stations following winter road salt application generates high chloride wastewater. This wastewater can be treated on-site and reused for brine application to roads. However, truck-washing stations are small facilities not equipped or staffed to handle multiple wastewater treatment technologies and methods. Regardless, wastewater recycled as brine must be treated to remove contaminants, which pose environmental and public risks.

A wide array of wastewater treatment technologies serve different purposes. Depending on which contaminants must be removed from the wastewater, some technologies may be more useful than others. The wastewater at truck washing stations contains biochemical oxygen demand (BOD), total suspended solids (TSS), heavy metals, and volatile organic compounds. Wastewater sample analysis showed levels of BOD and TSS which must be removed while maintaining chloride levels allowing the water to be reused for brine. We tested well-established and newer treatment technologies for their purposes, methods, and applicability. The goal was to create a comprehensive list of available treatment technologies, as components of on-site wastewater treatment systems at MnDOT truck washing stations, with the end goal of reusing the treated water to make road de-icing brine.

4.2 TREATMENT TECHNOLOGIES

Wastewater treatment processes can involve several steps, depending on how much purification is required. Primary treatments target removal of basic impurities based on size, utilizing sedimentation and filtration methods (this is also considered “pretreatment”). Secondary treatments utilize physicochemical and biological methods to remove suspended solids and BOD. Tertiary treatments are more rigorous in removing pollutants to safe concentrations, if not completely. Both secondary and tertiary treatments serve disinfecting purposes. Wastewater treatment technologies are categorized as physical, chemical, or biological, or some combination of the three. The additive nature of chemical treatments makes such treatment methods unattractive for water reuse, unless the added constituents are readily filtered out of the effluent. Any wastewater being treated for reuse applications requires at least secondary treatment and some level of disinfection (EPA, 2012).

Primary treatment technologies include: screening, sedimentation, precipitation, centrifugation, and filtration. Secondary treatment technologies include: evaporation, distillation, adsorption, ion exchange, coagulation/flocculation, biological processes, and membrane filtration.

All treatment technologies require monitoring of contaminant levels before and after treatment. Different technologies will be employed at different truck washing stations, depending on compound levels present in the washout. Drawbacks of many treatment technologies are that they are expensive, energy intensive and require maintenance. Depending on technologies used, sludge or other waste generated will require disposal.

Due to the high chloride content found in truck wash wastewater, one good option for water reuse would be brine for road application. The purpose in searching for viable wastewater treatment technologies which MnDOT may use at their truck washing stations is to find technologies which may remove contaminants—namely, BOD and TSS—that are present at environmentally hazardous levels, while maintaining chloride levels, allowing the treated water to be reused for making brine.

4.2.1 Well-established treatment technologies

Below are a summary of six proven treatment technologies considered to treat the truck station waste stream as outlined by Ranade and Bhandari (2014).

4.2.1.1 Coagulation/Flocculation

Coagulation separates particles based on charge, as positively charged coagulants are added to reduce electronic repulsion between colloidal particles. Coagulation also has the potential to remove uncharged particles and organic content, which can become trapped in the flocs. Coagulants come in inorganic and organic forms. Inorganic coagulants include: aluminum salts, ferric/ferrous salts, and lime. Inorganic coagulants typically result in a large amount of sludge, which must be disposed of as the use of inorganic coagulants requires a longer settling time of the flocs produced. Additionally, inorganic coagulants are typically only effective in narrow pH ranges. Organic coagulants include: cationic polymers, anionic polymers, and non-ionic polymers. Organic coagulants can significantly reduce the amount of sludge produced, and are thus deemed more efficient. Using coagulants helps to promote sedimentation and would be beneficial in removing suspended solids. BOD and TSS will be removed and chloride will remain in effluent.

4.2.1.2 Adsorption

Organics and inorganics are targeted with adsorption methods. Adsorption is a physicochemical process in which specific molecules are attracted to the adsorbent surface. Adsorption can remove acids, metals, and refractory pollutants. There are many commercially produced adsorbents whose characteristics are dictated by wastewater treatment needs. Temperature and pH must be controlled for maximum efficacy. Like coagulants, adsorbents also come in inorganic and organic forms. Inorganic adsorbents include zeolites and oxides. Organic adsorbents include: activated carbon, polymers, ion exchange resins, and biomass sources. Ion exchange resins remove chloride in some treatment programs, so this adsorbent should not be employed for this project. Rather, activated carbon or biomass sources may prove to be beneficial in removing BOD and TSS while leaving chloride in the resulting effluent.

Activated carbon is the most commonly used adsorbent, and is synthesized from a variety of sources. Not all compounds are readily adsorbed on carbon and may therefore show up as residual BOD. Over time, the carbon needs to either be replaced or regenerated. Powdered carbon is used in conjunction with other treatment methods, with biological treatment methods showing the best BOD removal (EPA 1979). Powdered activated carbon dosages can be easily scaled, and the carbon is removed following adsorption via sedimentation and filtration. Since powdered activated carbon removal is part of the purification process, the activated carbon cannot be regenerated in the system but must be replaced for each treatment. BOD and TSS will be reduced and chloride will remain in effluent.

4.2.1.3 Membrane separation

Membrane separation exploits differences in the abilities of compounds to permeate through a membrane. Compound size, charge, reactivity, and chemical properties determine permeation rate, in addition to that of the membrane. Electrochemical potential gradients create the driving forces of this separation method. Conventional membrane separation processes include: reverse osmosis, nanofiltration, ultra-filtration, and micro-filtration. Newer and more experimental membrane separation processes include: pervaporation, membrane distillation, dialysis, electro-dialysis, emulsion liquid membranes, membrane bioreactors, and hybrid membrane systems. Membrane separation is typically more efficient than other processes, is relatively simple to operate, and can achieve greater purification than other methods. Additionally, membrane separation does not require the use of hazardous chemicals, which require disposal. Drawbacks of membrane separation include the potential need for significant pretreatment, the potential for membranes to break or become fouled, and potential high costs of the membranes and additional pretreatments. Membranes can be made out of polymer, ceramics, or nanomaterials, and complexing agents or adsorbents may be added to the process of membrane separation. Single pass media filters and recirculating media filters filter out solids, bind ions, use bacteria to decompose organics, and may be applied to onsite wastewater treatment as a pretreatment step prior to more rigorous membrane separation (OSTP, 2017).

Microfiltration or ultrafiltration are relevant membrane separation methods for MnDOT’s purposes in treating truck wash water, removing high molecular weight substances while allowing chloride ions to pass through to the effluent. Microfiltration and ultrafiltration systems are the same in concept and construction aside from pore size. With smaller pores, ultrafiltration allows fewer potential contaminants through its pores and is capable of blocking viruses (SAMCO, 2017). Ultrafiltration will not remove ions, so chloride should pass through to the effluent stream. A 2009 Italian study on operating ultrafiltration systems found that ultrafiltration was capable of significantly removing TSS and BOD, producing effluents similar in quality to oxidized and clarified wastewater (Falsanisi et al., 2010).

Reverse osmosis should not be used for this project, as that method is commonly used to desalinate water. BOD and TSS will be removed and chloride will remain in effluent.

4.2.1.4 Biological aerobic treatment

Aerobic treatment involves the use of microorganisms in activated sludge, which oxidize organic compounds and bind organics and heavy metals. A significant amount of sludge is generated in aerobic treatment. The waste sludge must be properly treated before disposal. Appropriate conditions are required nutrient concentration, oxygen supply, bacterial growth rate and retention, pH, and temperature. Aeration is required in aerobic treatment systems—either mechanical or diffused aeration is typically applied. Different methods of activated sludge aerobic treatment include: fixed film, suspended growth, sequencing batch reactors, and membrane bioreactors. The University of Minnesota Onsite Sewage Treatment Program's *Manual for Septic System Professionals in Minnesota* outlines the various types of aerobic treatment units (OSTP 2017).

In fixed film aerobic treatment, bacteria grows on a designated surface. Fixed film is expensive and requires constant aeration and long detention times. Fixed film operates with a low food-tomicroorganism ratio and low biomass accumulation.

In suspended growth aerobic treatment, bacteria float in a main treatment chamber with a constant air supply, and solids settle out in a secondary chamber. Suspended growth systems often have issues with bulking.

In sequencing batch reactor aerobic treatment, the system goes through a series of air bubbling, decomposition, and settling. Sequencing batch reactors settle out more solids than fixed film or suspended growth systems.

Conventionally used bacteria in aerobic treatment systems may be gradually adapted to function in higher salt concentrations. Halotolerant (salt tolerant) bacterial strains have been identified and applied to some wastewater treatment schemes, and halotolerant bacteria have proven more effective in treating saline wastewater than traditionally non-tolerant species (Lefebvre and Moletta, 2006).

Halotolerant bacteria function better in low-salt solutions, while halophilic bacteria will function well in high-salt solutions, and any bacteria in use will function best at relatively consistent salt concentrations once species have had time to adapt. Saccharose addition and aeration stimulate growth of halotolerant bacteria (Karajic et al., 2010). BOD and TSS will be reduced and chloride will remain in effluent.

4.2.1.5 Biological anaerobic treatment

Anaerobic treatment requires the formation of methane, alcohol and ketone groups, and organic acids. Anaerobic treatment can involve a one-stage or two-stage process, with the ability to recycle biomass.

Microorganisms grow and work in an anaerobic environment based on time, temperature, pH, and present nutrients. Compared to aerobic treatment, anaerobic treatment produces about ten times less sludge waste, as waste is converted to combustible gas, and anaerobic treatment requires less energy input. Heavy metals precipitate out of solution as metal-sulfides. Anaerobic treatment done in combination with aerobic treatment results in better water quality based on the initial contaminants present.

Septic tanks are one form of an anaerobic treatment system. A septic tank is capable of removing some BOD and TSS, while promoting settling, flotation, and anaerobic digestion to remove contaminants (OSTP, 2017). Septic tanks are the first step in a wastewater treatment system. The increased buoyant forces of highly saline water reduces the efficiency of sedimentation in a septic tank. As in aerobic treatment, halotolerant anaerobic bacteria will function better in saline wastewater. Additionally, anaerobic treatment in sequence with aerobic treatment will be the most effective for wastewater treatment. BOD and TSS will be reduced and chloride will remain in effluent.

4.2.1.6 Sand filtration

Sand filtration purifies wastewater via straining of particles, adsorption of contaminants to the sand surface and biological growth, and consumption of nutrients by aerobic microorganisms (Lesikar, 2017).

Sand filters can utilize gravity or pressure to pass water through the filtration media. Suspended solids or flocs generated via coagulation are removed with sand filtration. Biological processes occurring in the sand filter unit are the most important mode of wastewater treatment with this method. Slow sand filtration is able to reduce turbidity and bacteria levels, but it is disadvantageous to this project, as slow sand filtration requires a large land area and a significant amount of filter material (National Drinking Water Clearinghouse, 2000). A recirculating sand filter, however, may be a viable alternative for a decentralized wastewater treatment system. A recirculating sand filter system consists of a pretreatment unit, a recirculating tank, and an open sand filter. Recirculating sand filters are excellent for the removal of BOD and TSS, and they require less land area than single-pass sand filters (EPA, 1999). BOD and TSS will be reduced and chloride will remain in effluent.

4.2.2 Newer treatment technologies

4.2.2.1 Membrane bioreactors

Membrane bioreactors are a combination of membrane separation and activated sludge treatment. Several different designs are engineered to meet specific treatment goals. As with other membrane filtration techniques, the membrane may foul or clog channels. Employing ceramic membranes and anaerobic respiration processes can help reduce energy requirements, and membrane bioreactors function as an automated system following installation. Membrane bioreactors use flat sheet or hollow fiber membranes, and air scouring and backwashing are methods used to clean the membranes (OSTP, 2017). Compared to conventional activated sludge treatments, membrane bioreactors are more expensive and consume more energy and resources—pretreatments (if necessary), fouling control, cleansing chemicals—demands made more problematic on decentralized or smaller-scale systems

(Krzeminski et al., 2017). However, membrane bioreactors require less space than conventional activated sludge treatments, and produce a high quality effluent. Membrane bioreactors are great for removing BOD and TSS, and they are able to remove heavy metals as metal adsorbs onto the activated sludge, precipitates, and is filtered out with suspended solids. Membrane bioreactors are effective wastewater treatment methods for small communities (Bernal et al., 2017). BOD and TSS will be reduced and chloride will remain in effluent.

4.2.2.2 Advanced oxidation processes

Advanced oxidation processes involve the formation of hydroxyl radicals and other oxidizing agents, and this method of treatment is used to treat toxic and non-biodegradable waste. Methods of oxidation include: hydrogen peroxide, ozone, cavitation, ultraviolet radiation, photo-catalysis, and electrochemical methods. Ultraviolet radiation and ozone oxidation are methods used for disinfecting purposes, destroying microorganisms, typically of effluent that has been pretreated (OSTP, 2017). Oxidation products may also be treated biologically. Biodegradable compounds treated with oxidizing agents become water, carbon dioxide, and inorganic salts (Mazille and Spuhler, 2018). Oxidation processes have high operating costs requiring expensive materials and high tech equipment.

Due to the chemically reactive nature of advanced oxidation processes, the presence of chloride ions may affect such wastewater treatment processes. Advanced oxidation processes are used for more rigorous wastewater treatment and purification, and thus such technologies are not necessarily applicable to this reuse project.

4.2.2.3 Electrocoagulation

Electrocoagulation treats organic and inorganic pollutants and removes suspended solids and heavy metals from wastewater. Electrocoagulation uses coagulation, flotation, and electrochemical processes. Coagulation is the introduction of an electric current into the wastewater. An electrolytic cell contains a cathode and an anode to serve as the coagulant, with common electrodes being iron and aluminum.

Similar to conventional coagulation, electrocoagulation neutralizes the repulsive forces between particles, encouraging previously suspended particles to bind together and settle. Compared to conventional coagulation, electrocoagulation does not require chemical additives like metal salts, resulting in significantly less sludge. Electrocoagulation has the potential to be a completely automated process. Most research in the area of electrocoagulation treatment used small-scale batch reactors, rather than continuous flow (Moussa et al., 2017). Electrocoagulation is deemed a promising method of treating wastewater to recycle and reuse sludge and/or water, and this method is currently used in lowflow and industrial wastewater streams (Martin, 2014). BOD and TSS will be reduced and chloride will remain in effluent.

4.3 CASE STUDIES

The reuse of wastewater in creating brine for road application is a relatively new and little researched, process. The reuse of truck wash wastewater for brine creation does not have to go through as rigorous of a wastewater treatment process as typical wastewater reuse systems. Most wastewater reuse research and regulations are applicable to greywater, for example, to be treated and reused for irrigation and industry. Research and implementation projects, discussed below, show the potential for onsite wastewater brine reuse.

4.3.1 Colorado

The Colorado Department of Transportation (CDOT) carried out a pilot test with Tasman Geosciences and Epiphany Water Solutions to test greywater treatment and reuse potential. The Epiphany water treatment systems are solar powered, and they used thermal distillation and mechanical vapor recompression to treat wastewater, which came from vehicle cleaning, and plow truck ice melt. Treatment of wastewater produced concentrated brine suitable for reuse and distilled water fit for surface discharge. The treatment unit CDOT implemented in their trial study cost $0.07-$0.12 per gallon to operate (Lindstrom and Joseph, 2017).

4.3.2 Indiana

A research study conducted with the Indiana Department of Transportation (INDOT) assessed the performance of activated sludge treatment of the wastewater generated from washing their de-icing trucks. This study found that salt concentrations of 0-1500 mg/L did not hinder microorganisms used in the activated sludge process. This study also found that salt concentrations above 3000 mg/L aided in flocculation and consequent reduction in turbidity. Higher salt concentrations, however, may inhibit biological treatment (Hashad et al., 2006).

INDOT has successfully reused salt truck wash water in the production of brine solution for road deicing. Equipment need for this recycling process:: an oil and water separator, a sedimentation and retention tank for the wash water, a brine-making tank, storage tanks, reinforced wire mesh strainers, and pumps—with all equipment resistant to corrosion. The salt truck wash water contained measurable levels of BOD (30 mg/L average) and TSS (2000 mg/L average) at the Greenfield, IN, truck-washing location, but other wastewater treatment technologies were not used for this project. INDOT evaluated the implementation of brine production systems using the recycled salt truck wash water at some of their brine manufacturing locations (Alleman et al., 2004).

4.3.3 Minnesota

The GNP Co. facility in Cold Spring, MN, installed membrane bioreactors as part of its onsite wastewater treatment process, showing notable improvements in water turbidity (Fuhrman, 2011). The GNP facility also installed a blower system to improve the activated sludge and membrane processes. They use automated probes to assess water quality throughout their wastewater treatment system, eliminating the need for manual monitoring. Effluent from treated wastewater is reused on site for purposes such as vehicle washing and irrigation (Freshwater Society, 2016).

4.3.4 Virginia

The Virginia Department of Transportation (DOT) researched reuse of storm water runoff from their road-salt storage facilities in the production of brine. After previous attempts at onsite treatment of storm water to remove salts, including the use of reverse osmosis, Virginia DOT decided such treatment options would not be economically viable. This study aimed to find the best conditions for brine production and the various benefits that would result from recycling salt-laden storm water. Laboratory tests found that the levels of TSS present in the storm water did not negatively affect brine quality, and thus the stormwater did not require pretreatment prior to being reused for brine production (Fitch et al, 2008).

4.4 SUMMARY

The treatment of salt truck washing wastewater for brine reuse requires a multiple-step wastewater treatment system, targeting the removal of BOD and TSS. The onsite system could include a septic tank for initial wastewater collection, sedimentation, and anaerobic biological treatment processes followed by aerobic biological treatment and filtration, which could be combined in a membrane bioreactor. The high salinity of this wastewater may inhibit activated sludge, dependent on the present bacteria’s tolerance. Because chloride cannot be removed by bacteria, biological treatments are a viable option for reducing BOD and TSS in the wastewater while maintaining chloride levels for water reuse as brine.

The discussed treatment technologies all have the ability to remove BOD and TSS to varying degrees, while leaving chloride in the water. Before fully implementing any onsite wastewater treatment system at the MNDOT truck washing stations, it is recommended that lab tests assess the efficacy of a proposed treatment system. Maintenance and regular monitoring are required for any wastewater treatment system installed.

Although the reuse of salt truck washing wastewater to create brine is not categorized with other reuse applications, like greywater reuse whose regulations and permits do not apply to this project, some regulations do exist. Plumbing code regulations may apply with the installation of wastewater treatment systems.

Other wastewater reuse applications may be explored, such as onsite reuse for toilet flushing, but such applications would require significantly more treatment to remove chloride, which are energy intensive and costly processes. Compliance with regulations on allowable discharge concentrations of detected compounds would be required for other wastewater reuse applications.

Although only wastewater treatment technologies were explored for the removal of BOD and TSS, significant levels of zinc were detected in the salt truck washing wastewater. Because zinc was detected in the original brine, it is advised that the source of salt be reassessed to avoid discharging zinc in such high levels.

Overall, the onsite treatment and reuse of salt truck wash wastewater from MNDOT truck washing stations to create brine seems feasible, and this reuse can help reduce chloride loads to municipal wastewater treatment plants as well as lessen the demand on water resources.

CHAPTER 5: COST ANALYSIS OF WASTEWATER TREATMENT TECHNOLOGIES

5.1 BACKGROUND

The Minnesota Department of Transportation (MnDOT) generates a significant amount of wastewater containing high chloride levels as a result of washing vehicles and trucks used for road salt application. One option for managing this wastewater is to treat it on-site and reuse the effluent to make brine for road application, rather than routing the water to a municipal wastewater treatment facility. Based on sampling performed over the winter of 2017/2018, biochemical oxygen demand (BOD) and total suspended solids (TSS) need to be removed from the wastewater prior to use in brine production (UMNa, 2018). Following a review of available wastewater, two viable treatment technologies which could potentially be applied to a high-chloride reuse system were chosen for a cost analysis (UMNb, 2018). A recirculating sand filter (RSF) and a membrane bioreactor (MBR) are the two wastewater treatment systems analyzed in this report. Both systems were chosen because they are effective at reducing BOD and TSS in a truck wash water waste stream. The basic difference between these systems is how the dissolved oxygen is provided. RSFs use passive aeration while MBRs use mechanical methods to transfer oxygen. In either case, high rates of BOD removal can be achieved but with different economic and managerial requirements.

5.2 WASTEWATER TREATMENT SYSTEM TECHNOLOGY OVERVIEW

Whether a RSF or a MBR is chosen for this project, a 2,000-gallon flow equalization with dual pumps is recommended to be installed due to the variable flow rates from truck washing. Both of the proposed systems use aerobic treatment to remove BOD and TSS. The primary function of aerobic treatment is to remove oxygen demand by providing naturally occurring organisms with sufficient oxygen to process organic and other compounds present in wastewater.

5.2.1 RSF

RSFs are a fixed growth aerobic treatment system. In fixed growth systems, wastewater is applied to a fixed surface (typically using a pump), microorganisms become established and break down the constituents. Microorganism production is slower during colder temperatures. The filter could be located indoors to or placed in an insulated container outdoors to promote production. This action provides tremendous surface area for oxygen transfer, effectively reducing BOD and TSS. In addition to a septic tank and flow equalization tank, this system has a watertight container to encapsulate the media, an effluent distribution network, coarse sand and gravel media, an underdrain, a control system, a recirculation tank, a distribution line and a return line. For this evaluation, it was assumed the RSF will be built below grade but it could also be constructed in a watertight container inside a building. Wastewater will be loaded onto the sand treatment media at a rate of approximately five gallons per day per square foot (forward flow). To reduce the amount of solids in the wastewater applied to the sand filter, a septic tank capacity of four times the design flow was included in the design. The flow equalization tank will dose into a 2,000-gallon recirculation tank with dual filtered pumps to dose the sand filter. With a design flow of 1000 gallons per day, the RSF system requires approximately 300 square feet of land in addition to spatial requirements for all the tanks and piping (Buchanan et al. (a), 2010). After the wastewater passes through the media, the flow is split. About 20-25% of the effluent flows to the next treatment component or to a dispersal component. The rest of the flow is directed to a recirculation tank and blended with wastewater that has received only primary treatment (liquid-solid separation). Many different recirculation regimes are possible depending upon the wastewater characteristics and treatment goals. RSF systems are easily scalable if the design flow varies from 1,000 gpd. Due to the higher organic load of the wastewater, the RSF will be similar to a trickling filter. Usually, trickling filters have far greater void space and porosity within their media, which allows for higher organic loading. The higher loading rate and increased void volume with the proposed RSF promotes a heavier biological growth on the media. This growth will periodically "slough" off and travel with the effluent to a recirculation tank where it settles out.

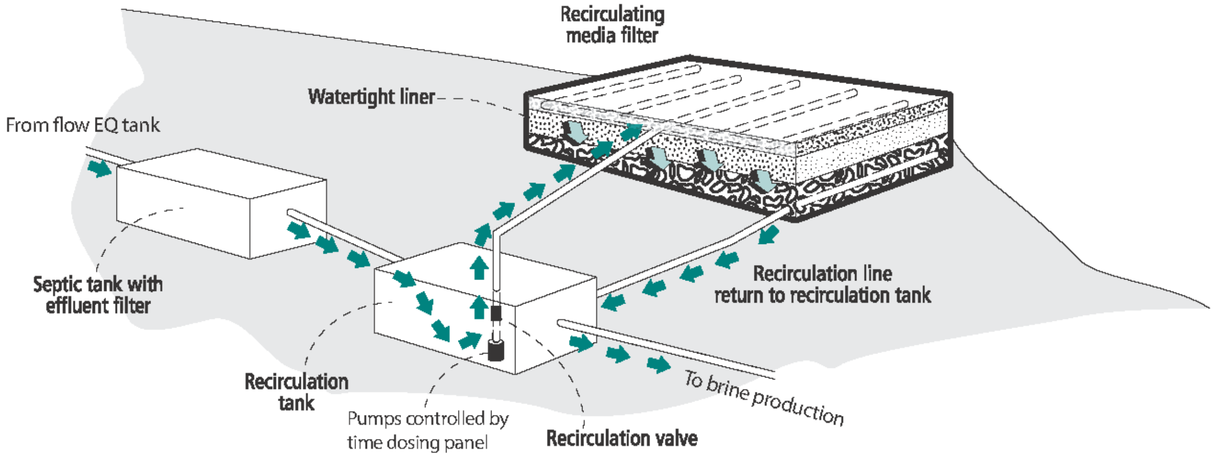

Figure 5.1 Recirculating Sand Filter Flow Path

The largest advantage of a fixed growth aerobic treatment system may be flexibility in siting. The ability of the system to transfer oxygen to the microbes that facilitate treatment is critical. The site must be graded to prevent stormwater runoff from entering the system and inhibiting this transfer of oxygen. Sand or sand/gravel filters are generally constructed on site with a PVC watertight liner using two feet of sand with a particle size 3.0 to 5.0 millimeters. An additional two feet of gravel ¾" to 1" in diameter is placed beneath the sand as an underdrain. These specifications are designed to provide the recommended surface area for bacterial attachment, adequate void space for passive air flow to provide oxygen to aerobic organisms and prevent rapid clogging (in media filters) by the combination of filtered solids and biological growth.

5.2.2 MBR

An MBR is a suspended growth aerobic treatment system. In suspended growth systems microorganisms and wastewater are continuously mixed in a well-aerated tank. Aeration is often provided mechanically by compressors or blowers that introduce air into the water. MBRs are also effective at reducing BOD and TSS. MBRs include activated sludge components but use membrane filtration units to separate biomass from effluent. First developed in the 1960s, MBRs have undergone significant modifications since the late 1990s that have resulted in a more robust and practical membrane filtration unit. Unlike the suspended growth configurations previously mentioned, MBRs do not depend on gravity (settling) to separate the biomass and effluent. With membrane filtration, time and space required for biomass separation is significantly reduced. As a result, MBR systems can treat a greater volume of water and occupy less space than conventional suspended growth systems. However, the increased treatment capacity is accompanied by increased electrical cost because greater aeration capacity and pressurization is needed to operate a MBR at its full potential.

In addition to a septic tank, a flow equalization tank, and a pump to time-dose the recirculation tank, this system has an aerated bioreactor tank, blowers, filtration membranes, and a control system. The design flow of this system will be 1000 gallons per day. Space requirements for a membrane bioreactor are less than that of a recirculating sand filter, as space is only needed for each of the tanks and their associated equipment and piping. A membrane bioreactor system is easily scalable as tank sizes are adjusted for a site’s expected daily wastewater flows (Buchanan (a) et al, 2010). MBR systems have evolved over the last 10 years to be easier to maintain and operate. If MBRs are installed it will be critical for MnDOT to either train staff in house or contract out maintenance of the filters.

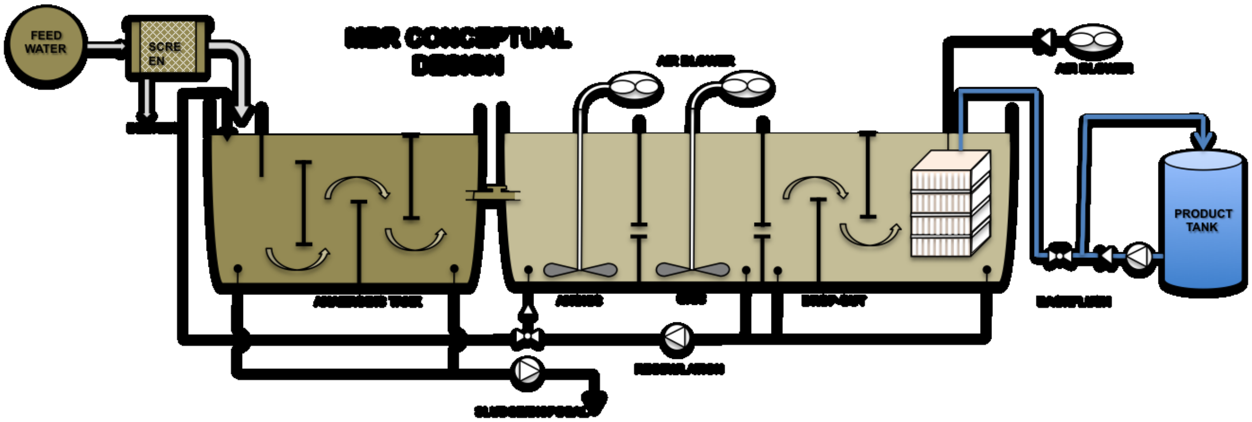

Figure 5.2 Example MBR Treatment Train

http://ceraflo.com/MBR_tech.html

5.3 WASTEWATER TREATMENT SYSTEM COST ANALYSIS

A cost analysis tool created by the Water Research Foundation was used to estimate total and itemized costs of the RSF and MBR wastewater treatment systems (**Appendix E**). This tool, updated in 2018, is a workable spreadsheet that takes into consideration site-specific data, incorporating local sales tax, electricity rates, contractor charges, daily wastewater volume, and onsite soil conditions (Buchanan et al, (b), 2018). The truck station in Arden Hills, MN, was used as the site location for both wastewater treatment systems analyzed. The expected electricity rate, priced per kilowatt-hour, was based on the Xcel Energy Minnesota business rate for on-peak services from October through May (Xcel Energy, 2018). It was estimated that the equipment would only be operating six months per year.

These cost estimates do not include routing the treated effluent to the brine production site. The zip code for the facility was used to determine the location factors that indicate the local cost of labor, materials, and overhead as compared to the national average. Location factors are published each year by the R.S. Means Company, Inc. The data used by this model are from the RSMeans Building Construction Cost Data, 67th Annual Edition (2017).

It is likely that MnDOT's cost will be higher due to labor compliance requirements—the labor rate was adjusted by a factor of 1.3 to estimate this difference. It was estimated that the operation and maintenance costs for the MBR would be double that of the RSF due to the cleaning requirements of the membrane. The assumptions in Table 1 were used to determine maintenance costs (Buchanan et al, 2018).

Table 5.1 Maintenance frequencies over 25 year design life

Item	Frequency	Occurrence
Septic tank cleaning	3 years	8
Recirculating tank, flow equalization and MBR tank cleaning	5 years	4
Pump replacement	7 years	2
Blower replacement	5 years	4

5.3.1 RSF

The system may be designed to function for 25 years and would be scheduled for full replacement after that time. The upper portion of the sand media will needed to be replaced periodically due to plugging. It is estimated that this replacement will need to occur every five years—more frequent than traditional sand filter systems due to the high organic and chloride contents in this waste stream. This means the sand media would need to be replaced four times throughout the system's lifespan prior to full-system replacement. It is estimated that the septic tank will need to be cleaned every three years and the recirculation and flow equalization every five years. These costs were averaged out over 25 years to determine the annual costs.

5.3.2 MBR

The system may be designed to function for 25 years and would be scheduled for full replacement after that time. Energy requirements and their associated costs will be higher for an MBR than for an RSF system due to the continual operation of a blower. The upfront and electrical cost of the MBR was adjusted by a factor of 1.3 due to the addition of a membrane, compared to a typical suspended growth reactor.

Table 5.2 Summary of Cost Analysis

Technology	Capital Cost for Installation	Annual Energy Costs	Annual Maintenance Costs	Annualized Cost to Rebuild System in 25 years	Life Cycle Present Value Based on 25 year Design Life
RSF	$92,100	$9	$2036	$3,684	$445,579
MBR	$56,824	$293	$1567	$2,273	$297,396

5.4 MANAGEMENT REQUIREMENTS

Regular service is important for all systems to ensure long-term performance, the system's ability to protect public health and the environment and to protect MnDOT's investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of the components used.

The management associated with these two treatment systems could be performed by MnDOT staff or contracted out to third party service provider. Our evaluation included hiring an external service provider due to concerns with the additional workload this system will add to truck station staff. With both systems, there are some common management activities:

1. Managing truck bay areas to prevent excess organic material into the system
2. Tracking water usage into the system
3. Periodically verifying and adjusting the control setting as needed
4. Monitoring septic and flow equalization tanks for sludge and scum and arranging for pumping as needed
5. Verifying effluent quality from the treatment unit is meeting requirements for brine production

In the sections below management requirements specific to each technology are discussed.

5.4.1 RSF

The recirculation tank effluent filters will need periodic cleaning and tank monitoring for sludge and scum. Pumps, distribution elements, and the control system will need to be checked and serviced. Media filter must be regularly inspected to ensure that effluent is not ponding on the surface. If it becomes clogged and rejuvenation methods are unsuccessful, media must be removed and replaced. The upper sand layer is estimated to need removal and replacement every five years.

5.4.2 MBR

The aeration system and blowers must be checked regularly for proper functioning. Biomass accumulation must be checked and occasionally removed. Filtration membranes will need to be cleaned especially with the potential for increased clogging due to this waste stream’s high organic and chloride contents.

5.5 TREATMENT TECHNOLOGY RECOMMENDATION WITH COST ANALYSIS

A RSF or MBR system could be used to effectively treat the winter effluent from washing down trucks and other equipment used for salt and brine application. The requirements and costs of materials, installation, operation, and maintenance were estimated and compared between the two wastewater treatment systems. System sizes, design projections, and cost estimates were based on the MnDOT truck station in Arden Hills, MN with an averaged flow of 1,000 gallons per day (gpd). Cost estimates for each system were determined assuming a 25-year design life. Based on this analysis, the most economical solution for MnDOT would be to invest in a MBR at this site. In comparison with a RSF, this type of system is one third less expensive over time primarily due to a low material and installation cost as well as a lower annual maintenance cost.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This research evaluated the reuse potential of truck washdown water and identified the operational and maintenance implementation barriers. There are several MnDOT facilities where it might make sense to pilot reuse due to the current set-up of the building or planned updates. The implementation steps are outlined below:

1. Identify one or two potential locations for reuse, evaluating the changes in plumbing needed and the risk of wastewater stream being affected by different users. After discussions with MnDOT, reuse at Arden Hills was tabled and Granite Falls was determined to be a more appropriate pilot location because the facility is already plumbed to separate and collect the washdown water, and the Granite Falls facility has a relatively small brine production (particularly compared to the Arden Hills facility).
2. Currently, wastewater has been collected and is being tested at a bench scale to determine whether chemical or biological treatment will be effective.
3. Due to concerns with contamination risks at Arden Hills, another truck station was identified to be a pilot location. Granite Falls makes sense as it is already plumbed for reuse and does not have a contamination risk. It is currently unknown how much of the washdown water for Granite Falls will be needed to make brine. This information will be essential not only for the design of the treatment used but also for the amount of storage. It would be ideal to reuse 100% of the washdown water to limit any chloride-rich water being taken to a wastewater treatment plant.
4. After installation, evaluation of treatment effectiveness and management requirements will be essential information. This information can then be used to determine whether broader scale implementation of reuse is appropriate for MnDOT.

Concerns were brought up after data collection about cyanide levels. It is recommended that this contaminate be evaluated and that further information be obtained from MnDOT’s salt providers about the levels and potential reduction of both cyanide and zinc. If a MBR is installed, research indicates that both zinc and cyanide would be reduced and/or removed (Moslehi et al., 2008; Fatone et al.; 2009).

If this pilot is successful, it is advised that MnDOT evaluate the current discharge locations for its truck stations across Minnesota. Since 2009, the MPCA has identified more than 100 Minnesota WWTPs that have the potential to contribute levels of chloride higher than allowed by the standard, which is 230 mg/L for chronic levels and 860 mg/L for acute levels (2019). Truck stations discharging or hauling their washdown water to these facilities would be good candidates for future projects.

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APPENDIX A: LAKE VERMILLION STATE PARK VARIANCE APPLICATION

Plumbing Board
Meeting Minutes
April 21, 2015 at 9:30 a.m.

Minnesota Room – Department of Labor and Industry
443 Lafayette Road North, St. Paul, MN 55155

Members

John Parizek (Chair)
Scott Eggen
Jim Kittelson
Larry Justin
John Flagg
Ron Thompson
Phillip Sterner (Secretary)
Jim Lungstrom
Grant Edwards
Joe Beckel
Pete Moulton

Members Absent

Mike McGown
Jeff Brown

DLI Staff & Visitors

Wendy Legge (Chief Gen. Counsel, DLI)
Suzanne Todnem (DLI)
Cathy Tran (DLI)
Jim Peterson (DLI)
Lyndy Lutz (DLI)
Charles Olson (DLI)
Brad Jensen (DLI)
Gary Thaden (MMCA)
Matt Marciniak (IAPMO)
Richard Hauffe (ICC)
Gary Ford (Metro Testing)
Brian Noma (MDH)
Tim Power (MNLA)
Andrew Paulsen (Water Control Corp)
Chad Filek (J-Berd Mech)
Michael Hogenson (Standard Water Control Sys.)
Noah Rouen (Standard Water Control Sys.)
Chris Nelson (Karges-Faulconbridge, Inc.)
Jami Sehm (City of Blaine)
Mike Ritter (MWQA)
Jim Gander (Superior Mechanical)
Charlie Pickard (Aladdin Solar)
Tim Power (MNLA)
Betsy Vohs (Gensler Architecture)
Elizabeth Borer (Marg. A-Cargill Philanthropies)
Shawn Kinniry (Marg. A-Cargill Philanthropies)
James Manning (Gausman & Moore)
Phil Raines (ABC)
Jim Gander (Superior Mechanical)
Scott Thompson (MN Plumbing Training)
Patrick Litchy (DNR)
Peter Paulson (DNR)

The Special Meeting was scheduled for 1:30 p.m. on April 27, 2015 in the Minnesota Room at DLI. The board may want to consider additional changes based on comments at the hearing. The Minnesota Room is being held on May 12, 2015 for this purpose. (This could be a meeting by telephone.) Legge clarified that if the Board wanted to make any additional rule changes these would need to be proposed by May 20, 2015. Parizek noted that all comments would be responded to.

The meeting broke until 10:45 a.m.

B) Petition for Variance – Margaret A. Cargill Philanthropies (Attachment C)

Parizek noted the Variance was reviewed previously and additional information was requested by the Board. Chris Nelson, Karges Falconbridge, Inc. (KFI) addressed the Board in regards to installation of a Gray Water Drip Irrigation System and he referred to their response sent to the Board dated April 7, 2015, questions 1 through 5 (Attachment C).

Nelson said the system is not in place right now – they are waiting on approval. He added that the owner contracts with reputable contractors to perform maintenance services and he noted this information is located in Attachment C. The Owner researched this, KFI helped design it, the training and maintenance is part of the closeout O&M manuals and these will be given to the contractor to make sure the system works correctly. The Board discussed continuing maintenance, log sheets, piping, plumbing code requirements, water safety (contaminants) and administrative authority. Nelson noted that the permanent variance is for only the one property, no others.

A motion was made by Justin, seconded by Eggen, to approve Margaret A. Cargill's petition for a permanent variance within the scope of the information submitted (Attachment C). The majority vote ruled with 9 votes for and 3 opposed; the motion carried.

A motion was made by Justin, seconded by Sterner, to authorize John Parizek to issue the written order required by Minnesota Statutes 14.056, Subdivision 5, in connection with granting the Margaret A. Cargill variance. The majority vote ruled with 9 for and 3 opposed; the motion carried.

C) Petition for Variance – Graywater Systems at the Lake Vermillion-Soudan Underground Mine State Park Campground Project (Attachment D)

Peter Paulson, AIA, CSI, LEED Green Assoc., Minnesota Department of Natural Resources, stated they are seeking a variance to use a gray water system at the new Lake Vermillion campground. Jim Manning, Gausman & Moore and Andrew Paulsen, Water Control Corporation introduced themselves to the Board.

Peter Paulson referred to Attachment D and said they are experiencing a hardship in getting potable water at the (Lake Vermillion) campground. There is very little opportunity to acquire well water and city water is more than 5 miles away. Potable water would only be obtained by taking water from Lake Vermillion, treating it, bringing it to the campground, storing it, and then using it. Because of this, and the Department of Natural Resource's (DNR) conservation mission, they think a gray water system as a pilot (project) is a good fit.

Peter Paulson said technical questions should be directed to Jim Manning or Andrew Paulsen and that he would answer questions regarding the overall development and timelines of the new state park. Edwards noted that he reviewed the blue prints and said the gray water portion is capturing waste water from lavatories only and then treating it and flushing toilets and urinals. There is make-up water with an RPZ protection.

Jim Manning said there are showers within the building as well, and that the waste water from showers would be included in the water captured. The system that is designed is a continual monitoring type of system that monitors water quality with an internal pumping arrangement that circulates water within the treatment system to maintain it to appropriate water quality levels. They are trying to maintain NSF 350 effluent criteria which would fall under the class C commercial range of water effluent. This water effluent would only be piped to the water closets. Currently the urinals are waterless so the piping would be capped at the urinal location for possible future use. The effluent then flows to the septic sewer system onsite; therefore, instead of sending all of the effluent into the septic system it is trying to intercept the gray water portion, treating it, and then using it in the toilets before it is discharged out to the septic system.

Andrew Paulsen said they would be treating the tank with ozone and using this for the fixture flushing. The fixture flushing load has different capacities for incoming and outgoing. The incoming would be approximately 1,900 gallons (based on onsite sewage capacity of 50 gallons per campsite) and the fixture flushing with a seasonable building, depending upon how many campers are at the facility, would be difficult to gauge; however, they typically say 5 flushes per person per day.

Peter Paulson said the campground incorporates 28 campsites that includes 3 group sites (20-30 individuals per group site), and two buildings.

Andrew Paulsen replied to Tran regarding NSF350 saying this was the target. Ultimately testing is going to be necessary to determine that it is within that NSF350 class C requirement; however, with the system properly maintained, and the expected effluent, it's a reasonable expectation. Tran asked if there were any requirements or certifications that would need to be done. Paulson said there would be the necessary amount of training to ensure that onsite staff understood the operation of the equipment and the overall maintenance requirements as well but that there were no certification requirements.

Jim Manning said the documents (Attachment D) include testing and owner training for the operation and maintenance of the system. Edwards asked how the system would be identified. Manning said their intent is to use schedule 80 PVC and have it the correct color. All of the piping would be maintained within the mechanical space and piped to the water closets as opposed to being distributed throughout the building. None of it would be used for irrigation. It is only going to be discharged to the toilets and the urinal locations. Edwards asked how much fresh water per year using a gray water system would save. Manning said a substantial amount. He added that it would be approximately 50-75% due to the water closet usage relative to the lavatory and other shower usage.

Tran asked where the intention of *backwash water* from the filters was going. Manning said it would be discharged into the sanitary. Tran noted that plans would need to be reviewed by the Department of Labor and Industry and inspections would follow if the variance petition is approved.

Filtering at 25 microns and the possibility of having the water coming out of the system dyed was discussed by the Board. Brian Noma stated that adding a dye to water could be detrimental.

A motion by Edwards, seconded by Moulton, to grant the permanent variance within the scope as described by the Minnesota Department of Natural Resources (Attachment D). *Parizek proposed a friendly amendment that the discharge requirements meet rainwater discharge and inspections per guidelines in 1702.9.4 and 1702.12 as it applies to rain water, modified for gray water systems. The friendly amendment was accepted by Edwards but not by Moulton. The chair asked for another second; the friendly amendment failed due to lack of a second. The original motion was voted on.* The majority vote ruled with 8 for and 2 opposed; the motion carried.

A motion was made by Sterner, seconded by Eggen, to authorize John Parizek to issue the written order required by Minnesota Statutes 14.056, Subdivision 5, in connection with granting the Minnesota Department of Natural Resources variance. The vote was unanimous; the motion carried.

D) Petition for Variance – Manitou Ridge Golf Course (Attachment E)

There were no representatives at the meeting. The Board reviewed the Petition for Variance for completeness. Legge noted that once the board receives a complete Petition for Variance the Board must act within 60 days. In her opinion, the petition was not complete. The Board could ask for more information or decide to grant or deny the variance, either one. Legge stated that the Board should state exactly what is needed for the Petition for Variance to be "complete".

Attachment D -

MNDNR

Minnesota Department of Natural Resources
Operations Services Division
Peter K. Paulson
500 Lafayette Road
St. Paul, Minnesota 55155-4029
651.259.5486 TTY: 651.296.5484 Fax: 651.297.5818
Peter.Paulson@state.mn.us

March 10, 2015

To:

John Parizek, Exec/Board Chair
Minnesota Plumbing Board
5646 Cedarwood Trail
Prior Lake, MN 55372
jparizek@dunwoody.edu

Grant Edwards, Board Vice Chair
Minnesota Plumbing Board
5872 Jefferson St NE
Fridley, MN 55432
grantandsarah@live.com

From:

Peter Paulson
DNR Principal Architect

Subject: Variance Petition for use of Graywater Systems at the Lake Vermilion-Soudan Underground Mine State Park Campground Project

DNR Project No.: *8P107*

I am sending this variance request (attached) as a follow-up to my 12/29/14 letter. As mentioned, DNR has a strong interest in pursuing and implementing innovative water efficiency strategies in our new buildings; and specifically, non-potable graywater reuse systems for toilet flushing at the new Lake Vermilion-Soudan Underground Mine State Park Campground project.

The new campground is scheduled to begin construction in 2015 and will include two campground sanitation buildings, an RV dumpstation, and onsite septic systems; however, providing well water of sufficient quantity and quality at this site poses a considerable hardship as noted in the attached variance request.

In addition to graywater systems, it's our intention to implement typical and/or available water efficiency strategies at the new campground, including low-flow/'WaterSense' fixtures and devices such as toilets, faucets and shower heads; and also waterless urinals.

Also attached to this request: graywater system plans and specifications; cutsheets of proposed system equipment; a description of onsite septic system capabilities; and a system maintenance/operational description. Please feel free to contact me if you have questions or require additional information.

Sincerely,

Peter Paulson, ALA, CSI, LEED Green Assoc

cc: Deb Boyd, Kath Ouska, Trent Luger, Dave Sobania, Patrick Litchy, Licia Oligmueller, Cathy Tran, Jim Peterson

VARIANCE PETITION
Non-potable graywater reuse systems for toilet flushing
Lake Vermilion-Soudan Underground Mine State Park Campground Project

14.056 RULE VARIANCES

Subdivision 1: Contents of variance petition

A petition for a variance under section 14.055 must include the following information:

1. **The name and address of the person or entity for whom a variance is being requested:**

   Minnesota Department of Natural Resources
   Operations Services Division
   500 Lafayette Road
   St. Paul, MN 55155

2. **A description of and, if known, a citation to the specific rule for which a variance is requested:**

   4715.0200 Item U

   "If water closets or other plumbing fixtures are installed in a building where there is no public sewer available as determined by the authority having jurisdiction, suitable provision must be made for treatment of the building sewage by methods which meet the design criteria of the Minnesota Pollution Control Agency."

   (Item U, requires plumbing fixtures be discharged onto an approved treatment system by methods which meet the design criteria of the MPCA. On-site gray water system and treatment as proposed is not yet a recognized treatment method by MPCA per plumbing code.)

   4715.0310

   "If a public sewer is accessible in a street or alley to a building or premises and the connection is feasible, liquid wastes from any plumbing system in that building must be discharged into the public sewer unless otherwise prohibited by this code or a local ordinance.

   If a public water supply system is accessible, the water distribution system must be connected to it unless otherwise permitted by the administrative authority. A water well taken out of service because a person is connecting to a public water supply must either be maintained for a use such as irrigation, or sealed and abandoned in accordance with the Minnesota Water Well Construction Code. (Minnesota Rules, chapter 4725)

   If either a public sewer or water supply system or both are not available, an individual water supply or sewage disposal system, or both, conforming to the published standards of the administrative authority must be provided.

   Every building must have its own independent connection with a public or private sewer, except that a group of buildings may be connected to one or more manholes which are constructed on the premises, and connected to a public or private sewer. These manholes must conform to the standards set by the local sewer authority."

   (Rule language requires liquid waste from any plumbing system discharged into a sewage disposal system (SSTS system) administered by MPCA.)

4715.1200

"All plumbing fixtures and drains used to receive or discharge liquid wastes or sewage shall be connected to the drainage system of the building in accordance with the requirements of the code."

(Rule language requires all fixtures to connect to the building drainage system. The definition of "drainage system" requires all sewage and liquid wastes be connected to a legal point of disposal and therefore design and installation must meet part 4715.0200, U for legal disposal.)

3. **The variance requested, including the scope and duration of the variance:**

   Scope: Installation of non-potable graywater reuse systems for toilet flushing in two campground sanitation buildings at the new Lake Vermilion-Soudan Underground Mine State Park Campground project.

   Duration: This is a permanent installation, so duration is for the lifetime of the two buildings.

4. **The reasons that the petitioner believes justify a variance, including a signed statement attesting to the accuracy of the facts asserted in the petition:**

   Our request for this variance is due to a considerable hardship we are experiencing at this site. Well water of sufficient quantity and quality is not available to fulfill our operational needs due to the unique geology/hydrology of the site (mostly bedrock and wetlands), and sourcing potable water from the town of Soudan (4-5 miles of force main) is not at all practical or cost effective. Hardship issues include:

   a. Potable water for the new campground and subsequent project phases must be sourced directly from Lake Vermilion, with treatment and storage facilities installed as part of the phase-one development.

   b. For this project, we are specifying the graywater systems as a bid alternate, and are therefore pursuing the variance process to gain approval for final use. Graywater construction documents (plans and specifications) were prepared by Gausman & Moore Engineers based on systems and equipment information supplied by Soderholm & Associates and Water Control Inc.

   c. The DNR conservation mission coupled with an increasing focus on water efficiency as required by Governor Dayton's Executive Order 11-13 (paragraph 1.d) and sustainable building guidelines such as B3 and LEED are all compelling us to pursue water efficiency innovation.

   d. Many DNR facilities and worksites (especially state park campgrounds) are located in areas where municipal services are not available, and use of well water and onsite septic systems in our buildings is common. Use of well water can deplete aquifers, and aquifer depletion can cause unintended negative consequences.

   e. Reductions in potable (well) water use can reduce the size, impact and cost of onsite septic systems, many of which are located by necessity within highly sensitive DNR sites (ex. state park campgrounds such as this) where natural and cultural resource protection is an imperative.

   f. Suitable terrain for onsite septic systems at Lake vermilion-Soudan Underground Mine State Park is extremely limited.

   The signed cover letter (attached to this variance request) constitutes our statement that the facts asserted in this petition are accurate.

5. **A history of the agency's action relative to the petitioner, as relates to the variance request:**

   This is our first request to the Plumbing Board regarding graywater systems. Previous DNR variance requests to DLI were regarding other (non-graywater) topics.

6. **Information regarding the agency's treatment of similar cases, if known:**

   We are not aware of any similar cases at this time.

7. **The name, address, and telephone number of any person the petitioner knows would be adversely affected by the grant of the petition:**

   The new campground project is geographically isolated and entirely within Lake Vermilion-Soudan Underground Mine State Park. The town of Soudan is approximately 5+ miles from the campground; Ely, approximately 20 miles. The nearest residences and cabin sites (9 – 10 total) are located to the east of the park on Armstrong Bay Road, approximately ½ mile from the campground to the closest residence.

   In our estimation, no persons will be adversely affected if this petition is granted.

Subdivision 2: Fees
An agency may charge a petitioner a variance fee. The fee is:

1. $10, which must be submitted with the petition, and is not refundable; or

2. The estimated cost for the agency to process the variance petition, if the agency estimates that the cost will be more than $20.

   If an agency intends to charge costs to the petitioner under paragraph clause 2, the agency and the petitioner must agree on the costs and the timing and manner of payment.

The DNR is willing to pay a reasonable fee to the Plumbing Board to process this variance request.

Onsite Septic System Capabilities:

Lake Vermilion-Soudan Underground Mine Campground

Using graywater treated from sinks and showers to flush toilets in the sanitation buildings: Due to less water from showers and sinks, the waste concentrations will likely be stronger. The septic system design is based on MN Chapter 7080 with residential waste strengths of 170 mg/l BOD and 60 mg/l TSS. Due to limited areas for final soil distribution, Advantex AX 100 filter media was incorporated into the design as a pretreatment unit.

The exact waste strengths will not be known until system is in full operation. However Sara Heger (University of Minnesota Water Resource Center) has completed research on MNDOT Hwy Rest Areas which we believe to be very similar to DNR sanitation buildings utilizing graywater systems. She suggested a (conservative) waste strength of 400 mg/l BOD and 100 mg/l TSS leaving the septic tank.

Jesten Brenner with Orenco Systems, Inc. provided the following information on how the Advantex AX 100 would perform on the larger system 1900 gpd with an assumed 30% and 50% fresh water reduction due to grey water system.

Influent parameters:

- BOD: 400 mg/L
- TSS: 100 mg/L
- For the Design flow of 1900 gpd (30% reduction):
- 0.00133 MGD*400 mg/L BOD*8.34= 4.44 lb/day
- 4.44 lb/day / 0.08 lbs BOD/ sqft/ day = 55.5 sqft of textile required
- For the Design flow of 1900 gpd (50% reduction):
- .00095 MGD*400 mg/L BOD*8.34= 3.17 lb/day
- 3.17 lb/day / 0.08 lbs BOD/sqft/day = 39.6 sqft of textile required
- An AX100 has a nominal square footage of 100 sqft, so it will be adequate for this portion of the onsite WWTP.

Waste strengths can be tested to determine if pumping the septic tank more often is necessary. Note: Sara Heger suggested installing two smaller septic tanks instead of one large one. The first tank could be pumped more often at a cheaper cost than one large tank, with the same waste strength reduction.

System Maintenance/Operational Description:

Lake Vermilion-Soudan Underground Mine Campground

DNR Park staff currently operating the Soudan Underground mine dewatering and treatment system will *also* operate the proposed campground sanitation building graywater systems; and will perform daily monitoring and all necessary maintenance of the graywater systems after installation.

Current staff include (4) millwright level maintenance staff and two master electricians. The millwrights maintain the mine's dewatering and treatment system. The electricians have experience with PLC controlling. Plumbing and repair duties are performed daily at the mine. Dawn Voges, (assistant park manager) holds a Class D Wastewater Treatment Licensure.

> The existing mine dewatering and treatment facility is a high pressure system that includes multiple sumps, each with its own float and pump system. Most of the pumps underground in the mine are 50hp 480 volt 3 phase pumps. In the above-ground facility, water is treated using smaller Variable Frequency Drive (VFD's) pumps that are controlled by monitoring pressure and flow rate. The treatment at this time is relatively straightforward with pre-filter followed by Ion Exchange Tanks.

DNR staff is on duty 7 days per week, 365 days per year.

The campground graywater systems will not be used during the winter months (sanitation buildings are seasonal use only and are drained down and winterized every fall).

APPENDIX B: SITE SUMMARY DATA

MnDOT Truck Station Reuse Sampling Data

Facility	Brief Description of Facility	# of Washing Stations	Flammable Trap	Flam Trap Cleaning Interval	Employees	Flow Measurements	Holding tank or WWTP
Anoka	Garage with 3 offices and 2 breakrooms, bathrooms	1	1	Bi-annual	Winter 13, Summer 5	No, city possibly	WWTP
Arden Hills	Garage, 5 offices	1	1	Bi-annual	Winter 31, Summer 70	Yes	WWTP
Buffalo		1	1	Annual	Winter 10, Summer NA	Pumping records	Holding Tank
Drescbach	Office, lunchroom, 2 bathrooms, truck storage and mechanical bay.	1	1	Bi-annual	Winter 9, Summer 7	Water meter newly installed	Holding Tank
Forest Lake	3 mechanic bays, 1 office/ equipment building and 1 warm storage building with wash bay	1	2	Annual	Winter 27 , Summer 15	No holding tank, maybe the city has info	WWTP
Maple Grove	Maintenance garage, mechanic shop and inventory center	2	2	Annual	24 maintenance, 16 mechanics, 8 inventory	NA	WWTP
McGregor	Garage, office, breakroom, and bathrooms	1	1	Annual	Winter 6, Summer NA	NA	Holding Tank
North Branch	NA	1	1	Monthly	Winter 14, Summer 6	NA	Holding Tank
Plymouth	NA	2	1	Annual	NA	NA	WWTP
Shakopee	NA	1	1	Bi-annual	Winter 20, Summer NA	Pumping records	Holding Tank
Spring Lake Park	NA	1	1	Annual	NA	NA	WWTP

MnDOT Truck Station Reuse Sampling Data

Facility	Describe the facility truck washing practices	Cleaning Products for Washing	Trucks & Other Equipment	Other Equipment Washed	Tons of salt use for 2017/2018 Season
Anoka	When the snow storm is over we do a quick rinse of all the trucks at the end of each shift and a day or 2 later we do a real good washing of the trucks.	Truck washing soap	3 tandem and 6 single axle gravel trucks, 1 flat rack truck, 4 pickup trucks and 2 one ton trucks	Tractors and lawn mowers, truck hauling dirt, loader	2685
Arden Hills	Following Metro District truck washing procedure.	Cortec truck soap VpCI-406 MN, Big Orange-E	12	Mowers, tractors, brooms, pick up, skid steer, loaders.	3985
Buffalo	After every snow event we do a thorough wash and wash pickups one time a week.	Truck washing soap	5 tandems and 3 pickups	Tractors skid loaders loaders	1882
Drescbach	We clean as much off the truck before washing. Wash above designated drain using power washer	NA	4 plow truck, loader, 2 pick-ups and crew cab	NA	1828
Forest Lake	During the storm and in between shifts we do a quick rinse with the fire hose. After the storm, soap, brushes, fire hose and the pressure washer are used to thoroughly clean the trucks.	Ripper Cleaner, Big Orange Cleaner & Blue Glo Cleaner. Soap in the pressure washer is VpCI-406 MN Cortec	9 plow trucks, 2 loaders, 2 1-tons and 5 pickups	Tractors/mowers, loaders, dump trucks, pickups and 1 ton	3960
Maple Grove	NA	NA	14	Mowers, pickups and 1 ton trucks	4347
McGregor	Pressure washer, both quick rinse and complete washings	Hotsy truck and equipment wash	3 Trucks, 1 grader, 1 loader, 2 pickups	Trucks, mowers, loader	934
North Branch	After every snow and ice event all equipment is washed	Mars VpCI-406MN	8	Tractors, trucks and skid steer	2223
Plymouth	Quick rinse of windows, mirrors, lights and steps in between shifts with fire hose. Thorough washing with pressure washer after the event is over.	Soap VPCI-406 MN VPCI-406 Dilution	NA	Pick-up trucks, skid steers, lawn mowers, and random truck and equipment.	6165
Shakopee	Quick rinse to remove dirt/ salt pressure washer	Dawn dish soap	7 plow trucks	Pickups/mowers	2167
Spring Lake Park	NA	NA	NA	NA	7004

APPENDIX C: COMPLETE DATA FILE FOR CHLORIDE, BOD, TSS, FECAL COLIFORM AND METALS

MnDOT Truck Station Reuse Sampling Data

		Chlorides, Organics & Bacteria				Metals								
Site	**Parameter**	**Chloride**	**BOD**	**TSS**	**Fecal Coliform**	**Arsenic**	**Barium**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Manganese**	**Zinc**	**Mercury**
Units		mg/L	mg/L	mg/L	CFU/100 mL	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Anoka, flammable waste trap	12/6/2017	51400	ND	522	17	ND	651	ND	ND	126.0	ND	1420	884	ND
	1/2/2018	57400	ND	300	1	ND	482	ND	ND	96.7	ND	820	838	ND
	1/17/2018	53700	133.0	260	5	ND	759	ND	ND	146.0	ND	811	2700	ND
	1/25/2018	63900	71.1	225	NA	ND	659	ND	ND	152.0	ND	778	1520	ND
	5/17/2108	6450	ND	70	TNTC	ND	505	ND	ND	ND	ND	1090	605	ND
	Average	**46570**	**102.1**	**275**	**8**	**ND**	**611**	**ND**	**ND**	**130.2**	**ND**	**984**	**1309**	**ND**
	Median	**53700**	**102.1**	**260**	**5**	**ND**	**651**	**ND**	**ND**	**136.0**	**ND**	**820**	**884**	**ND**
Arden Hills, flammable waste trap	9/12/2017	502	2140.0	380	3300	35.3	256	3.5	24.4	171.0	44.0	1040	804	ND
	11/9/2017	2170	855.0	132	230	ND	162	6.4	479	295.0	21.4	513	1820	ND
	12/6/2017	15000	ND	144	51	ND	422	ND	ND	91.6	ND	429	733	629
	12/29/2017	25000	352.0	136	<2	ND	419	ND	ND	102.0	ND	434	852	ND
	1/29/2018	7830	237.0	296	189	ND	424	10.4	46.3	165.0	38.8	654	1070	ND
	2/5/2018	25700	296.0	400	3	ND	474	ND	81.6	175.0	ND	864	2030	ND
	2/28/2018	7770	ND	206	TNTC	ND	256	4.6	36.4	146.0	26.0	500	793	ND
	3/7/2018	4950	ND	275	34	ND	477	ND	45	112.0	27.9	486	1130	ND
	3/21/2018	10600	1610.0	251	<1	ND	337	ND	ND	270.0	ND	618	1540	ND
	5/17/2018	46200	ND	139	<1	ND	788	ND	ND	ND	ND	1360	1980	ND
	Average	**14572**	**915.0**	**236**	**635**	**35.3**	**402**	**6.2**	**118.8**	**169.7**	**31.6**	**690**	**1275**	**629**
	Median	**9215**	**603.5**	**229**	**120**	**35.3**	**420.5**	**5.5**	**45.7**	**165.0**	**27.9**	**565.5**	**1100**	**629**
Buffalo, holding tank	1/2/2018	19900	ND	ND	<2	ND	325	ND	ND	ND	ND	804	244	ND
	3/22/2018	7050	ND	ND	31	ND	172	ND	ND	15.8	ND	527	253	ND
	5/18/2018	23100	ND	10	5	ND	351	ND	ND	ND	ND	836	ND	ND
	Average	**16683**	**ND**	**10**	**18**	**ND**	**283**	**ND**	**ND**	**15.8**	**ND**	**722**	**249**	**ND**
Dresbach, holding tank	9/19/2017	NA	70.1	ND	<1.0	ND	246	ND	ND	ND	ND	651	ND	ND
	2/26/2018	26500	ND	29	NA	ND	561	ND	ND	ND	ND	1530	135	ND
	3/23/2018	20800	ND	ND	6	ND	314	ND	ND	ND	ND	946	122	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**23650**	**70.1**	**29**	**3**	**ND**	**374**	**ND**	**ND**	**ND**	**ND**	**1042**	**129**	**ND**
Forest Lake, flammable waste trap	12/14/2017	9390	ND	273	8	ND	312	ND	ND	160.0	ND	660	802	ND
	1/2/2018	24300	ND	286	<1	ND	251	ND	54.6	164.0	ND	604	599	ND
	1/17/2018	10900	ND	180	1	ND	265	ND	ND	83.2	ND	353	401	ND
	3/7/2018	11400	ND	333	<10	ND	501	ND	124	266.0	55.6	1390	1180	ND
	5/17/218	817	35.2	106	TNTC	ND	99.7	ND	25.3	76.6	16.3	367	524	ND
	Average	**11361**	**35.2**	**236**	**5**	**ND**	**286**	**ND**	**68**	**150.0**	**36.0**	**675**	**701**	**ND**
	Median	**10900**	**35.2**	**273**	**5**	**ND**	**265**	**ND**	**54.6**	**160.0**	**36.0**	**604**	**599**	**ND**
Maple Grove, flammable waste trap	12/6/2017	15900	ND	78	TNTC	ND	382	ND	ND	496.0	ND	615	561	ND
	1/2/2018	51300	ND	151	TNTC	ND	639	ND	ND	139.0	ND	1120	411	ND
	1/18/2018	7210	ND	87	TNTC	ND	231	ND	ND	272.0	ND	277	605	ND
	1/29/2018	3970	151.0	86	TNTC	ND	244	ND	10.6	341.0	10.6	341	855	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**19595**	**151.0**	**101**	**TNTC**	**ND**	**374**	**ND**	**10.6**	**312.0**	**10.6**	**588**	**608**	**ND**
	Median	**11555**	**151.0**	**87**	**TNTC**	**ND**	**313**	**ND**	**10.6**	**306.5**	**10.6**	**478**	**583**	**ND**

MnDOT Truck Station Reuse Sampling Data

		Chlorides, Organics & Bacteria				Metals								
Site	**Parameter**	**Chloride**	**BOD**	**TSS**	**Fecal Coliform**	**Arsenic**	**Barium**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Manganese**	**Zinc**	**Mercury**
Units		mg/L	mg/L	mg/L	CFU/100 mL	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
McGregor, holding tank	1/24/2018	5110	247.0	20	TNTC	ND	286	ND	53.3	41.9	ND	805	48.7	ND
	3/22/2018	3530	177.0	114	6	ND	241	ND	43	119.0	ND	553	100	ND
	5/17/2018	4360	ND	42	<1	ND	360	ND	22.7	25.5	ND	693	57.3	ND
	Average	**4333**	**212.0**	**59**	**6**	**ND**	**296**	**ND**	**40**	**62.1**	**ND**	**684**	**69**	**ND**
North Branch, holding tank	9/20/2018	NA	164.0	14	15	ND	205	ND	ND	11.2	ND	1180	148	ND
	3/7/2018	15500	ND	61	1200	ND	230	ND	ND	ND	ND	609	489	ND
	4/4/2018	20200	326.0	267	2	ND	376	ND	ND	161.0	ND	1300	1360	ND
	5/17/2018	10300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**15333**	**245.0**	**114**	**406**	**ND**	**270**	**ND**	**ND**	**86.1**	**ND**	**1030**	**666**	**ND**
Plymouth, flammable waste trap	12/6/2017	4470	ND	34	27	ND	136	ND	17.7	122.0	ND	280	1190	ND
	1/2/2018	19800	ND	122	<1	ND	490	ND	ND	141.0	ND	618	1110	ND
	1/12/2018	22900	ND	434	<1	ND	887	ND	83.8	359.0	52.5	895	1980	ND
	1/17/2018	9250	148.0	445	<1	ND	554	ND	97.4	302.0	ND	800	1720	ND
	5/18/2018	3840	ND	118	TNTC	ND	391	ND	ND	96.0	ND	816	1220	ND
	Average	**12052**	**148.0**	**231**	**7**	**ND**	**492**	**ND**	**66.3**	**204.0**	**52.5**	**682**	**1444**	**ND**
	Median	**9250**	**148.0**	**122**	**27**	**ND**	**490**	**ND**	**83.8**	**141.0**	**52.5**	**800**	**1220**	**ND**
Shakopee, holding tank	9/13/2017	NA	40.6	ND	<10	ND	97.6	ND	ND	ND	ND	1300	ND	ND
	2/27/2018	12700	ND	52	6	ND	193	ND	ND	ND	ND	532	465	ND
	3/27/2018	3020	156.0	ND	<1	ND	97.2	ND	ND	28.2	ND	367	354	ND
	5/18/2018	23400	112.0	ND	6	ND	73.8	ND	ND	ND	ND	533	139	ND
	Average	**13040**	**102.9**	**52**	**6**	**ND**	**115**	**ND**	**ND**	**28.2**	**ND**	**683**	**319**	**ND**
Spring Lake Park, flammable waste trap	9/13/2017	NA	49.5	117	<10	ND	596	ND	ND	ND	ND	356	32.1	ND
	1/17/2018	7970	ND	282	30	ND	269	ND	ND	162.0	ND	451	640	ND
	1/24/2018	2730	ND	49	1	ND	103	ND	ND	33.0	10.3	133	280	ND
	4/4/2018	31400	68.1	228	<1	ND	249	ND	ND	ND	ND	400	651	ND
	4/9/2018	9600	204.0	133	29	ND	145	ND	ND	99.8	ND	291	666	ND
	5/17/2018	1490	45.1	626	TNTC	ND	234	ND	27.6	120.0	60.0	443	702	ND
	Average	**10638**	**91.7**	**239**	**20**	**ND**	**266**	**ND**	**27.6**	**103.7**	**35.2**	**346**	**495**	**ND**
	Median	**7970**	**58.8**	**181**	**29**	**ND**	**241.5**	**ND**	**27.6**	**109.9**	**35.2**	**378**	**645.5**	**ND**

ND = non-detect
NA = not available
TNTC = too numerous to count

Summary Data

Overall Average	17139	334.2	193	217	35.3	356.4	6.2	74.9	154.8	33.0	709.7	819.6	629
Standard Deviation	16286	521.8	145.46	701	0	192.8	3.0	108.6	105.2	18.1	340.6	615.5	0
Minimum Value	502	35.2	10	1	35.3	73.8	3.5	10.6	11.2	10.3	133.0	32.1	629
Maximum Value	63900	2140.0	626	3300	35.3	887.0	10.4	479.0	496.0	60.0	1530.0	2700.0	629
Sites with Positive Hits	11	10	11	11	1	11	1	6	10	5	11	11	1

APPENDIX D: COMPLETE DATA SET FOR ALL DETECTED VOLATILE ORGANIC COMPOUNDS

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	Acetone	Allyl chloride	Benzene	Bromobenzene	Bromochloromethane	Bromodichloromethane	Bromoform	Bromomethane	2-Butanone	n-Butylbenzene	sec-Butylbenzene	tert-Butylbenzene	Carbon tetrachloride	Chlorobenzene	Chloroethane	Chloroform	Chloromethane	2-Chlorotoluene	4-Chlorotoluene	1,2-Dibromo-3-chloropropane	Dibromochloromethane	1,2-Dibromoethane	Dibromomethane
	Units	ug/L																						
Anoka, flammable waste trap	12/6/2017	69.3	ND	ND	ND	ND	ND	ND	ND	7.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/2/2018	427.0	ND	ND	ND	ND	1.1	ND	ND	9.4	ND	ND	ND	ND	1.5	ND	ND	ND	ND	ND	ND	1.7	ND	ND
	1/17/2018	115.0	ND	ND	ND	ND	ND	ND	ND	7.0	ND	ND	ND	ND	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/25/2018	46.8	ND	ND	ND	ND	ND	ND	ND	5.4	ND	ND	ND	ND	2.0	ND	ND	ND	ND	ND	ND	1.2	ND	ND
	5/17/2018	164.0	ND	ND	ND	ND	ND	ND	ND	33.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**164.4**	**ND**	**ND**	**ND**	**ND**	**1**	**ND**	**ND**	**12.6**	**ND**	**ND**	**ND**	**ND**	**1.8**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.5**	**ND**	**ND**
Arden Hills, flammable waste trap	9/12/2017	2350.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	4320	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	11/9/2017	504.0	ND	ND	ND	ND	ND	ND	ND	ND	15.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12/29/2017	598.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/29/2018	181.0	ND	ND	ND	ND	ND	ND	ND	5.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2/5/2018	117.0	ND	ND	ND	ND	ND	ND	ND	7.5	ND	6.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2/28/2018	164.0	ND	ND	ND	ND	3.5	ND	ND	5.3	1.3	ND	ND	ND	ND	ND	20.4	ND	ND	ND	ND	1.7	ND	ND
	3/7/2018	240.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5	ND	ND	ND	ND	ND	ND	ND
	3/21/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**593.4**	**ND**	**ND**	**ND**	**ND**	**3.5**	**ND**	**ND**	**6.1**	**7.5**	**2163**	**ND**	**ND**	**ND**	**ND**	**11.0**	**ND**	**ND**	**ND**	**ND**	**1.7**	**ND**	**ND**
Buffalo, holding tank	1/2/2018	257.0	ND	ND	ND	ND	ND	ND	ND	13.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3/22/2018	58.8	ND	ND	ND	ND	ND	ND	ND	97.7	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5/18/2018	29.5	ND	ND	ND	ND	ND	ND	ND	9.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**115.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**40.3**	**ND**	**ND**	**ND**	**ND**	**0.5**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Dresbach, holding tank	9/19/2017	52.2	ND	ND	ND	ND	ND	ND	ND	16.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2/26/2018	58.3	ND	ND	ND	ND	ND	ND	ND	13.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3/23/2018	29.7	ND	ND	ND	ND	ND	ND	ND	11.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**46.7**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**13.7**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Forest Lake, flammable waste trap	12/14/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7	ND	ND	ND	ND	ND	ND	ND
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	1.8	ND	ND	ND	ND	ND	ND	ND
	1/17/2018	30.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	ND	ND
	3/7/2018	50.0	ND	ND	ND	ND	ND	ND	ND	5.4	ND	ND	ND	ND	ND	ND	2.7	ND	ND	ND	ND	1.2	ND	ND
	5/17/2018	22.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.8	ND	ND	ND	ND	ND	ND	ND
	Average	**34.5**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**5.4**	**ND**	**ND**	**ND**	**ND**	**1.1**	**ND**	**2.5**	**ND**	**ND**	**ND**	**ND**	**1.2**	**ND**	**ND**

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	Acetone	Allyl chloride	Benzene	Bromobenzene	Bromochloromethane	Bromodichloromethane	Bromoform	Bromomethane	2-Butanone	n-Butylbenzene	sec-Butylbenzene	tert-Butylbenzene	Carbon tetrachloride	Chlorobenzene	Chloroethane	Chloroform	Chloromethane	2-Chlorotoluene	4-Chlorotoluene	1,2-Dibromo-3-chloropropane	Dibromochloromethane	1,2-Dibromoethane	Dibromomethane
	Units	ug/L																						
Maple Grove, flammable waste trap	12/6/2017	62.7	ND	ND	ND	ND	ND	ND	ND	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND
	1/2/2018	159.0	ND	ND	ND	ND	ND	ND	ND	16.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND
	1/29/2018	28.0	ND	ND	ND	ND	ND	ND	ND	5.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**83.2**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**9.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.2**	**ND**	**ND**
McGregor, holding tank	1/24/2018	ND	ND	ND	ND	ND	ND	ND	ND	7.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3/22/2018	36.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5/17/2018	26.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**31.5**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**7.0**	**ND**	**ND**	**ND**	**ND**	**0.6**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
North Branch, holding tank	9/20/2018	45.3	ND	ND	ND	ND	ND	ND	ND	14.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3/7/2018	67.3	ND	ND	ND	ND	ND	ND	ND	9.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	4/4/2018	41.8	ND	ND	ND	ND	ND	ND	ND	7.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**51.5**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**10.4**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Plymouth, flammable waste trap	12/6/2017	45.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.3	ND	ND	ND	ND	ND	ND	ND
	1/2/2018	48.1	ND	ND	ND	ND	ND	ND	ND	5.8	ND	1.1	ND	ND	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/12/2018	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.2	ND	ND	ND	ND	ND	ND	ND
	1/17/2018	21.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.1	ND	ND	ND	ND	ND	ND	ND
	5/18/2018	20.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND
	Average	**33.7**	**ND**	**ND**	**ND**	**ND**	**1**	**ND**	**ND**	**5.8**	**ND**	**1.1**	**ND**	**ND**	**1.4**	**ND**	**2.9**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Shakopee, holding tank	9/13/2017	118.0	ND	ND	ND	ND	ND	ND	ND	10.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2/27/2018	35.4	ND	ND	ND	ND	ND	ND	ND	5.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3/27/2018	21.0	ND	ND	ND	ND	ND	ND	ND	5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5/18/2018	99.1	ND	ND	ND	ND	ND	ND	ND	8.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**68.4**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**7.5**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Spring Lake Park, flammable waste trap	9/13/2017	54.1	ND	ND	ND	ND	ND	ND	ND	45.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/17/2018	37.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/24/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	4/4/2018	24.6	ND	ND	ND	ND	ND	ND	ND	5.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	4/9/2018	44.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5/17/2018	35.2	ND	ND	ND	ND	ND	ND	ND	ND	1.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Average	**39.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**25.7**	**1.8**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**

ND = non-detect

NA = not available

TNTC = too numerous to count

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	1,2-Dichloro benzene	1,3-Dichloro benzene	1,4-Dichloro benzene	Dichloro difluoro methane ND	1,1-Dichloroe thane	1,2-Dichloroe thane	1,1-Dichloroe thene	cis-1,2-Dichloroe thene	trans-1,2-Dichloroe thene	Dichlorof luoromet hane	1,2-Dichloro propane	1,3-Dichloro propane	2,2-Dichloro propane	1,1-Dichloro propene	cis-1,3-Dichloro propene	trans-1,3-Dichloro propene	Diethyl ether	Ethylben zene	Hexachloro-1,3-butadiene	Isopropyl benzene	p-Isopropyl toluene	Methylene Chloride	4-Methyl-2-pentanone	Methyl-tert-butyl ether
	Units	ug/L																							
Anoka, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	45.8	ND	10.9	ND
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	13.9	ND
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	14.4	ND
	1/25/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.9	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	128	ND	22.2	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**44.1**	**ND**	**14.7**	**ND**
Arden Hills, flammable waste trap	9/12/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24300	ND	ND	ND
	11/9/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2240	ND	ND	ND
	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	139	ND	12.6	ND
	12/29/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	349	ND	ND	ND
	1/29/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	91.3	ND	10.7	ND
	2/5/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26.7	ND	14.5	ND
	2/28/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	53.9	ND	10.3	ND
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	154	ND	13.0	ND
	3/21/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1660	ND	ND	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	701	ND	ND	ND	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**701**	**3224**	**ND**	**12.2**	**ND**
Buffalo, holding tank	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.6	ND	ND	61.4	ND	11.3	ND
	3/22/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.4	ND	5.56	ND
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	55.7	ND	ND	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**9.6**	**ND**	**ND**	**43**	**ND**	**8**	**ND**
Dresbach, holding tank	9/19/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.0	ND	5.7	ND
	2/26/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.8	ND	7.1	ND
	3/23/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.95	ND	6.94	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**4.6**	**ND**	**6.6**	**ND**
Forest Lake, flammable waste trap	12/14/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.8	ND	9.6	ND
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5	ND	14.4	ND
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17.8	ND	10.4	ND
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.1	ND	14.3	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	44.5	ND	10.5	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**14.5**	**ND**	**11.8**	**ND**

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	1,2-Dichlorobenzene	1,3-Dichlorobenzene	1,4-Dichlorobenzene	Dichlorodifluoromethane ND	1,1-Dichloroethane	1,2-Dichloroethane	1,1-Dichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Dichlorofluoromethane	1,2-Dichloropropane	1,3-Dichloropropane	2,2-Dichloropropane	1,1-Dichloropropene	cis-1,3-Dichloropropene	trans-1,3-Dichloropropene	Diethyl ether	Ethylbenzene	Hexachloro-1,3-butadiene	Isopropyl benzene	p-Isopropyl toluene	Methylene Chloride	4-Methyl-2-pentanone	Methyl-tert-butyl ether
	Units	ug/L																							
Maple Grove, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.2	ND	ND	ND
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.5	ND	17.0	ND
	1/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1/29/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20.3	ND	11.3	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**9.00**	**ND**	**14.2**	**ND**
McGregor, holding tank	1/24/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	256	ND	ND	ND
	3/22/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	47.3	ND	ND	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	ND	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**164**	**ND**	**ND**	**ND**
North Branch, holding tank	9/20/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	6.4	ND
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.4	ND	9.1	ND
	4/4/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.1	4.6	15.1	ND
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**2.2**	**4.6**	**10.2**	**ND**
Plymouth, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	67.5	ND	6.7	ND
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	28.6	ND	16.5	ND
	1/12/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	22.9	ND	7.6	ND
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.9	ND	6.1	ND
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	48.3	ND	5.9	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**35.4**	**ND**	**8.6**	**ND**
Shakopee, holding tank	9/13/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	316	ND	ND	ND
	2/27/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.3	ND	8.4	ND
	3/27/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13.7	ND	10.7	ND
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.9	ND	550	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**88**	**ND**	**190**	**ND**
Spring Lake Park, flammable waste trap	9/13/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	402	ND	30.8	ND
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	256	ND	ND	ND
	1/24/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14.9	ND	ND	ND
	4/4/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND
	4/9/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.3	ND	ND	5.9	ND	ND	ND
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.5	ND	ND	ND
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.3**	**ND**	**ND**	**115.7**	**ND**	**30.8**	**ND**

ND = non-detect

NA = not available

TNTC = too numerous to count

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	Naphthalene	n-Propylbenzene	Styrene	1,1,1,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane ND	Tetrachloroethene	Tetrahydrofuran	Toluene	1,2,3-Trichlorobenzene	1,2,4-Trichlorobenzene	1,1,1-Trichloroethane	1,1,2-Trichloroethane	Trichloroethene	Trichlorofluoromethane	1,2,3-Trichloropropane	1,1,2-Trichlorotrifluoroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Vinyl chloride	Xylene (Total)	1,2-Dichloroethane-d4 (S)	Toluene-d8 (S)	4-Bromofluorobenzene (S)
	Units	ug/L																						
Anoka, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	107	104	98.0
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	116	100	105.0
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	93	97	100.0
	1/25/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	105	98	97.0
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7	ND	ND	ND	99	98	102.0
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**2**	**ND**	**ND**	**ND**	**104**	**99**	**100.4**
Arden Hills, flammable waste trap	9/12/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	410	ND	ND	ND	100	100	100.0
	11/9/2017	51.4	ND	ND	ND	ND	ND	ND	66.0	ND	ND	ND	ND	ND	ND	ND	ND	87.7	18.6	ND	33	100	98	90.0
	12/6/2017	ND	ND	ND	ND	ND	ND	ND	10.2	ND	ND	ND	ND	ND	ND	ND	ND	5.9	1.3	ND	3.9	103	103	97.0
	12/29/2017	ND	ND	ND	ND	ND	ND	ND	115.0	ND	ND	ND	ND	ND	ND	ND	ND	11.4	ND	ND	ND	97	98	86.0
	1/29/2018	ND	ND	ND	ND	ND	ND	ND	6.4	ND	ND	ND	ND	ND	ND	ND	ND	5.1	1	ND	ND	89	99	96.0
	2/5/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7	ND	ND	ND	97	97	100.0
	2/28/2018	ND	ND	ND	ND	ND	ND	ND	4.4	ND	ND	ND	ND	ND	ND	ND	ND	8	1.9	ND	5.4	102	99	94.0
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	74.5	ND	ND	ND	ND	ND	ND	ND	ND	3.9	ND	ND	ND	100	101	83.0
	3/21/2018	ND	ND	ND	ND	ND	ND	ND	262.0	ND	ND	ND	ND	ND	ND	ND	ND	34.3	ND	ND	ND	NA	107	77.4
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	101	99	99.0
	Average	**51.4**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**76.9**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**63.1**	**5.7**	**ND**	**14.1**	**99**	**100**	**92.2**
Buffalo, holding tank	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	117	97	100.0
	3/22/2018	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	98.2
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	101	100	102.0
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.16**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**109**	**98.9**	**100.1**
Dresbach, holding tank	9/19/2017	ND	ND	ND	ND	ND	ND	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	93	102.0
	2/26/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	91	90	99.0
	3/23/2018	ND	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	96	89.4
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**96**	**93**	**96.8**
Forest Lake, flammable waste trap	12/14/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	104	99	102.0
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	115	100	106.0
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	92	98	98.0
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	103	99	102.0
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	98	99	101.0
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**102**	**99**	**101.8**

MnDOT Truck Station Reuse Sampling Data

Detectable VOCS

Site	Parameter	Naphthalene	n-Propylbenzene	Styrene	1,1,1,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane ND	Tetrachloroethene	Tetrahydrofuran	Toluene	1,2,3-Trichlorobenzene	1,2,4-Trichlorobenzene	1,1,1-Trichloroethane	1,1,2-Trichloroethane	Trichloroethene	Trichlorofluoromethane	1,2,3-Trichloropropane	1,1,2-Trichlorotrifluoroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Vinyl chloride	Xylene (Total)	1,2-Dichloroethane-d4 (S)	Toluene-d8 (S)	4-Bromofluorobenzene (S)
	Units	ug/L																						
Maple Grove, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	110	102	99.0
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	119	100	104.0
	1/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	93	95	96.0
	1/29/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.2	ND	ND	ND	88	97	98.0
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**4.2**	**ND**	**ND**	**ND**	**102.5**	**98.5**	**99.3**
McGregor, holding tank	1/24/2018	ND	ND	ND	ND	ND	ND	21.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	104	100	90.0
	3/22/2018	ND	ND	0.3	ND	ND	ND	9.0	0.7	ND	ND	ND	ND	ND	ND	ND	ND	0.5	0.3	ND	ND	NA	98	101.0
	5/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	98	99	103.0
	Average	**ND**	**ND**	**0.3**	**ND**	**ND**	**ND**	**15.1**	**0.7**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**0**	**0**	**ND**	**ND**	**101**	**99**	**98.0**
North Branch, holding tank	9/20/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	97	97	100.0
	3/7/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	106	96	97.0
	4/4/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	98	101	99.0
	non-winter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**100**	**98**	**98.7**
Plymouth, flammable waste trap	12/6/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	105	103	98.0
	1/2/2018	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	10.0	2.1	ND	6.7	113	101	103.0
	1/12/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	111	94	88.0
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	92	97	99.0
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	99	101	104.0
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**10.0**	**2.1**	**ND**	**6.7**	**104**	**99**	**98.4**
Shakopee, holding tank	9/13/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	105	97	98.0
	2/27/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	101	96	102.0
	3/27/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	103	89.7
	5/18/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	97	99.0
	Average	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**102**	**98.25**	**97.2**
Spring Lake Park, flammable waste trap	9/13/2017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	106	100	100.0
	1/17/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.2	ND	ND	ND	92	97	99.0
	1/24/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	99	95.0
	4/4/2018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	101	100	98.0
	4/9/2018	4.7	ND	ND	ND	ND	ND	ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	5.0	2.1	ND	7.4	96	100	97.0
	5/17/2018	4.2	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18.1	3.2	ND	ND	100	98	98.0
	Average	**4.45**	**1.3**	**ND**	**ND**	**ND**	**ND**	**ND**	**2.2**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**8.4**	**2.7**	**ND**	**7.4**	**99.2**	**99**	**97.8**

ND = non-detect

NA = not available

TNTC = too numerous to count

APPENDIX E: RSF AND MBR COST SPREADSHEETS

Suspended Growth Costing Information

Item	Default Unit Cost	Location Factor Unit Cost	User Provided Unit Cost
Actual Cost (per Gallon per Day) for Suspended Growth Aerobic Treatment Unit - including delivery	$15.00	$14.79	$19.95
Actual Cost to Install Treatment Device (per gpd of capacity)	$3.58	$4.25	$5.65
Actual Cost of one Blower	$653.00	$643.86	

Technology: Suspended Growth Aerobic Treatment

Assumptions:

Daily Wastewater Volume	1,000	gpd	Assumed Cost per Gallon for ATU	$ 19.95
Cost of Suspended Growth Device:	$ 19,950			
Installation Cost of Suspended Growth Device:	$ 5,652			
Cost of Septic and Flow Equalization Tank:	$5,758			
Installation Cost of Septic and Flow Equalizatoin Tank	$ 10,246			
Lbs of BOD5 & TKN Removed per day	4.42	lb/d		
Required Oxygen Transfer Rate:	7.41	lb/d		
Standard cfm of Air Flow:	10.15	scfm		
Power Requirement of Device:	0.56	hp		
Hours of Operation per Day:	24	hr		

Materials:

Cost of Materials:		$ 25,708
P&O for Materials:	20%	$ 5,142
Sales Tax on Materials:	7.38%	$ 1,896
Total Materials:		$ 32,746

Labor & Equipment:

Cost of Labor & Equipment:		$ 15,898
P&O Labor & Equipment:	20%	$ 3,180
Total Labor & Equipment:		$ 19,078

Professional Services Fees:		$ 5,000
Capital Costs:		$ 56,824

Energy Costs:

Electrical Cost	$ 0.12	$/kW·h	Inflation Rate (%)	3%
Aeration Power	0.557	kW	Discount Rate (%):	
Aeration Run Time	24	hr/d	Salvage Value:	None
Panel Power:	0.0010	kW	Depreciation:	None
Annual Electric Cost:	$ 293			

Life Cycle Costs:

Annual Maintenance Contract:	$ 1,000	$1/gpd		
Tank cleaning of septic tank/3 yrs	$ 192	$300/1000 gallons		
Tank cleaning of flow eq and ATU /5 years	$ 192	$300/1000 gallons		
5-yr replacement on blower	$ 103	per year		
Pump replacement/7 years (2 pumps)	$ 80	per year	Annual maintenance costs	$ 1,567
Anualized cost to rebuild system in 25 yrs	$ 2,273			
Sum Annualized Cost:	$ 3,840			

System Life (years)	25	yrs
Life Cycle Present Value:	$ 297,396	

System Life (years)	25
Construction and Installation Costs	$ 56,823.59
Annual Energy Costs	$ 293.29
Annual Maintenance Cost	$ 3,839.96
Discount Factor (as percent)	0.0%
Inflation Rate (as percent)	3.0%
Present Value of System Life Cycle Cost	$ 297,395.73

	Annualized Costs								
Year	**Energy**	**Maintenance**	**Periodic Costs**	**Total Cost in Year Zero**	**Sum Cost of Year**	**Sum Cost of Year Adjusted for Inflation**	**Present Value of Cost of Year**	**Inflation Factor**	**Discount Factor**
0				$ 56,823.59	$ 56,823.59	$ 56,823.59	$ 56,823.59	1.000	1.000
1	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 6,598.38	$ 6,598.38	1.030	1.000
2	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 6,796.33	$ 6,796.33	1.061	1.000
3	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 7,000.22	$ 7,000.22	1.093	1.000
4	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 7,210.23	$ 7,210.23	1.126	1.000
5	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 7,426.54	$ 7,426.54	1.159	1.000
6	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 7,649.33	$ 7,649.33	1.194	1.000
7	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 7,878.81	$ 7,878.81	1.230	1.000
8	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 8,115.18	$ 8,115.18	1.267	1.000
9	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 8,358.63	$ 8,358.63	1.305	1.000
10	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 8,609.39	$ 8,609.39	1.344	1.000
11	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 8,867.67	$ 8,867.67	1.384	1.000
12	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 9,133.70	$ 9,133.70	1.426	1.000
13	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 9,407.71	$ 9,407.71	1.469	1.000
14	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 9,689.95	$ 9,689.95	1.513	1.000
15	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 9,980.64	$ 9,980.64	1.558	1.000
16	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 10,280.06	$ 10,280.06	1.605	1.000
17	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 10,588.47	$ 10,588.47	1.653	1.000
18	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 10,906.12	$ 10,906.12	1.702	1.000
19	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 11,233.30	$ 11,233.30	1.754	1.000
20	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 11,570.30	$ 11,570.30	1.806	1.000
21	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 11,917.41	$ 11,917.41	1.860	1.000
22	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 12,274.93	$ 12,274.93	1.916	1.000
23	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 12,643.18	$ 12,643.18	1.974	1.000
24	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 13,022.48	$ 13,022.48	2.033	1.000
25	$ 293.29	$ 3,839.96	$ 2,272.94		$ 6,406.20	$ 13,413.15	$ 13,413.15	2.094	1.000

Technology: Attached Growth Recirculating Media Filter

Assumptions:

Daily Wastewater Volume	1,000	gpd	Surface Area	250	ft^2
Cost of Materials:	$ 29,833				
Installation Cost:	$ 40,917				
Number of Pumps:	4				
Pump Flow Rate:	65	gpm			
Pump Design TDH:	18	ft of water			
Pump Power:	0.49	hp			
Flow Rate into Single Pass Zone:	65	gpm			
Hours of Operation per Day:	0.26	hr/d			

Materials:

Cost of Materials:		$ 29,833
P&O for Materials:	20%	$ 5,967
Sales Tax on Materials:	7.38%	$ 2,200
Total Materials:		$ 37,999

Labor & Equipment:

Cost of Labor & Equipment:		$ 40,917
P&O Labor & Equipment:	20%	$ 8,183
Total Labor & Equipment:		$ 49,101

Professional Services Fees:	$ 5,000.00
Capital Costs:	$ 92,100.1

Energy Costs:

Electrical Cost	$ 0.12	$/kW·h	
Recirculation Power	1.469	kW	
Recirculation Time:	0.26	hr/d	
Panel Power:	0.0010	kW	(assumes continuous power draw)
Annual Electric Cost:	$ 8.78		

Life Cycle Costs:

Annual Maintenance Contract:	$ 500	$0.50/gpd	Inflation Rate (%):	3%
Tank cleaning of septic tank/3 yrs	$ 384	$300/1000 gallons	Discount Rate (%):	
Tank cleaning of recir. & flow eq/5 years	$ 192		Salvage Value:	None
Cost of Sand Filter Repair/ 5 years	$ 800		Depreciation:	None
Pump replacement/ 7 years (4 pumps)	$ 160		Annual maintenance costs	$ 2,036
Annualized cost to rebuild system in 25 yr	$ 3,684			
Sum of Annualized Maintenance Costs:	$ 5,720			

System Life (years)	25	yrs
Life Cycle Present Value:	$ 445,579	

System Life (years)	25
Construction and Installation Costs	$ 92,100.13
Annual Energy Costs	$ 8.78
Annual Maintenance Cost	$ 5,720.01
Annual Replacement Budget:	$ 3,684
Discount Factor (as percent)	0.0%
Inflation Rate (as percent)	3.0%
Present Value of System Life Cycle Cost	$ 445,578.95

Year	Annualized Costs		Periodic Costs	Total Cost in Year Zero	Sum Cost of Year	Sum Cost of Year Adjusted for Inflation	Present Value of Cost of Year	Inflation Factor	Discount Factor
	Energy	Maintenance							
0				$ 92,100.13	$ 92,100.13	$ 92,100.13	$ 92,100.13	1.000	1.000
1	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 9,695.17	$ 9,695.17	1.030	1.000
2	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 9,986.03	$ 9,986.03	1.061	1.000
3	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 10,285.61	$ 10,285.61	1.093	1.000
4	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 10,594.18	$ 10,594.18	1.126	1.000
5	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 10,912.00	$ 10,912.00	1.159	1.000
6	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 11,239.36	$ 11,239.36	1.194	1.000
7	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 11,576.54	$ 11,576.54	1.230	1.000
8	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 11,923.84	$ 11,923.84	1.267	1.000
9	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 12,281.55	$ 12,281.55	1.305	1.000
10	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 12,650.00	$ 12,650.00	1.344	1.000
11	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 13,029.50	$ 13,029.50	1.384	1.000
12	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 13,420.38	$ 13,420.38	1.426	1.000
13	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 13,823.00	$ 13,823.00	1.469	1.000
14	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 14,237.69	$ 14,237.69	1.513	1.000
15	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 14,664.82	$ 14,664.82	1.558	1.000
16	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 15,104.76	$ 15,104.76	1.605	1.000
17	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 15,557.90	$ 15,557.90	1.653	1.000
18	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 16,024.64	$ 16,024.64	1.702	1.000
19	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 16,505.38	$ 16,505.38	1.754	1.000
20	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 17,000.54	$ 17,000.54	1.806	1.000
21	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 17,510.56	$ 17,510.56	1.860	1.000
22	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 18,035.87	$ 18,035.87	1.916	1.000
23	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 18,576.95	$ 18,576.95	1.974	1.000
24	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 19,134.26	$ 19,134.26	2.033	1.000
25	$ 8.78	$ 5,720.01	$ 3,684.01		$ 9,412.79	$ 19,708.29	$ 19,708.29	2.094	1.000

RSF Costing Information

Item	**Unit**	**Default Unit Cost**	**Location Factor Unit Cost**
Materials			
Septic Tank	per gallon	1.46	$1.44
Flow equalization Tank	per gallon	1.46	$1.44
Recirculation Tank	per gallon	1.46	$1.44
4' x 8' x ½" sheets of OSB or particle board	per sheet	$18.90	$18.64
treated 4" x 4" (per foot)	per foot	$2.10	$2.07
treated 2" x 4"	per foot	$1.05	$1.04
untreated 2" x 4"	per foot	$1.05	$1.04
treated 2" x 6"	per foot	$1.58	$1.55
treated 2" x 12"	per foot	$2.63	$2.59
30 mil PVC liner	per sq ft	$0.53	$0.52
coarse rock that supports media	per ton	$31.50	$31.06
bedding sand for under liner	per ton	$21.00	$20.71
#57 washed rock	per ton	$15.75	$15.53
RSF sand (media)	per ton	$42.00	$41.41
30" x 48" riser with lid	each	$315.00	$310.59
1" dia. Sch. 40 PVC	per foot	$1.96	$1.93
1-1/4" dia. Sch. 40 PVC	per foot	$2.49	$2.46
1-1/2" dia. Sch. 40 PVC	per foot	$2.73	$2.69
2" dia. Sch. 40 PVC	per foot	$3.33	$3.28
2-1/2" dia. Sch. 40 PVC	per foot	$5.18	$5.10
3" dia. Sch. 40 PVC	per foot	$6.60	$6.51
4" dia. Sch. 40 PVC	per foot	$9.61	$9.47
6" dia. Sch. 40 PVC	per foot	$17.80	$17.55
Recirculation Pump, screened vault & controls	unit	$1,008.00	$993.89
Pump Control Panel	each	$575.00	$566.95
2" PVC end cap	each	$2.10	$2.07
6" PVC end cap	each	$36.75	$36.24
6" PVC threaded end plug	each	$57.75	$56.94
6" bulkhead connector	each	$577.50	$569.42
4" bulkhead connector	each	$315.00	$310.59
3" bulkhead connector	each	$157.50	$155.30
2" bulkhead connector	each	$94.50	$93.18
6" schedule 40 elbow	each	$75.60	$74.54
4" PVC Sch 40 els	each	$26.25	$25.88
2" Sch 40 PVC els	each	$4.20	$4.14
1 ½" Sch 40 PVC els	each	$3.15	$3.11
1½ x 2" Sch 40 PVC reducer els	each	$9.45	$9.32
2" x 1 ½" Sch 40 PVC reducer Tees	each	$6.30	$6.21
2" Sch 40 PVC Tee	each	$5.25	$5.18
1 ½" Sch 40 PVC Tees	each	$3.15	$3.11
2" Sch 40 PVC crosses	each	$10.50	$10.35
1 ½" Sch 40 crosses	each	$7.35	$7.25
2" to 1" Sch 40 PVC slip bushings	each	$1.05	$1.04
1 ½" x 1" Sch 40 PVC slip bushings	each	$0.68	$0.67
1 ½" Sch 40 PVC threaded male bushings	each	$5.25	$5.18
1 ½" Sch 40 PVC female threaded adapters	each	$5.25	$5.18
2" x 1 ½" Sch 40 PVC reducer bushing	each	$1.05	$1.04

3" PVC Sch 40 swing check valve	each	$105.00	$103.53
1 ½" long sweep, PVC	each	$26.25	$25.88
1 ½" Sch 40 PVC swing check valves	each	$52.50	$51.77
1" orifice shields	each	$1.58	$1.55
2" Sch 40 PVC ball valve	each	$105.00	$103.53
V 6606 Hydro Tec	each	$178.50	$176.00
12" meter boxes with lids	each	$36.75	$36.24
Labor			
Labor & Equipment to Construct Sand Filter ($ per square foot of sand filter area)		$57.41	$61.43
Tank Excavation and Installation (based on $ per gallon)		$1.80	$1.93